

Helpful Websites

ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing)

<http://www.impacttest.com/>

Center for Disease Control – United States

http://www.cdc.gov/concussion/HeadsUp/sports_specific.html

NHS – United Kingdom

<http://www.nhs.uk/conditions/head-injury-minor/Pages/Introduction.aspx>



Computerised cognitive assessment of athletes with sports related head injury

A Collie, D Darby and P Maruff

Br. J. Sports Med. 2001;35;297-302
doi:10.1136/bjasm.35.5.297

Updated information and services can be found at:
<http://bjsm.bmj.com/cgi/content/full/35/5/297>

These include:

References

This article cites 23 articles, 6 of which can be accessed free at:
<http://bjsm.bmj.com/cgi/content/full/35/5/297#BIBL>

19 online articles that cite this article can be accessed at:
<http://bjsm.bmj.com/cgi/content/full/35/5/297#otherarticles>

Rapid responses

You can respond to this article at:
<http://bjsm.bmj.com/cgi/eletter-submit/35/5/297>

Email alerting service

Receive free email alerts when new articles cite this article - sign up in the box at the top right corner of the article

Notes

To order reprints of this article go to:
<http://journals.bmj.com/cgi/reprintform>

To subscribe to *British Journal of Sports Medicine* go to:
<http://journals.bmj.com/subscriptions/>

Review

Computerised cognitive assessment of athletes with sports related head injury

A Collie, D Darby, P Maruff

Abstract

Professional and amateur participants in many sports are at risk of brain injury caused by impact with other players or objects. In many cases, mild cognitive deficits may persist after the common neurological signs of brain injury have passed. In recent years, the athlete's cognitive status after concussion has been measured with conventional "paper and pencil" neuropsychological tests. However, such tests are not ideal for sporting settings, as they are designed for the detection of gross cognitive impairments at a single assessment, not for the identification of mild cognitive deficits on repeated assessment. A number of computerised cognitive assessment tests and test batteries have been developed over the past two decades. These batteries offer major scientific and practical advantages over conventional neuropsychological tests which make them ideal for the assessment of cognitive function in sportspeople. This review first describes the problems associated with cognitive assessment of people with sports related cognitive deficits, and then critically examines the utility of conventional neuropsychological and computerised cognitive tests in sporting settings.

(*Br J Sports Med* 2001;35:297–302)

Keywords: cognitive assessment; head; injury; concussion; computerised; neuropsychology

may be difficult to diagnose with certainty using on field or subjective medical assessment techniques.³ This, in turn, complicates decisions about real time return to play, as well as decisions about the longer term health consequences of the injury, including risk of further injury. Sports in which repeated TBIs are common, such as boxing,⁴ also raise the problem of cumulative cognitive damage,¹ the assessment and management of which is currently poorly codified. In addition, people who participate in sports such as scuba diving or high altitude climbing are at risk of brain injury through other mechanisms of brain damage (ischaemia, nitrogen narcosis,⁵ hypoxia⁶) that may also contribute to persistent cognitive deficits. These problems are not limited to professional sportspeople. Amateur and recreational participants in boxing,⁴ some martial arts, and varieties of football including soccer,⁷ rugby,⁸ American football,⁹ and Australian Rules football,¹⁰ may exhibit cognitive deficits following head injury incurred in the sporting arena. Although many sports have modified their rules to reduce the incidence of TBI, such injuries still occur regularly.

Conventional neurological and neuropsychological techniques have significant limitations for the accurate evaluation of these conditions during field play.¹¹ For example, neuropsychological tests are expensive in both time and skilled labour requirements. Even if sufficient resources are available to baseline test an entire team or training squad before a season, the measurement properties of most neuropsychological tests are not ideal for repeated testing. New approaches using shorter "paper and pencil" test batteries, as well as computerised tests, have emerged to overcome these problems and facilitate both on field and subsequent decisions about fitness to play. Computerised testing offers the theoretical advantages of infinite randomised forms, standardised self administration, rapid testing, internet based delivery, and centralised data storage, analysis, and reporting. These approaches are relatively new and not yet widely adopted, in part because of continuing evolution. Although computerised testing has definite advantages over conventional neuropsychological testing, there are also a number of limitations that must be considered before they can be applied to identify subtle TBI in sporting contexts. This review will describe the problems associated with cognitive assessment

Centre for Neuroscience,
University of Melbourne, Parkville,
Victoria, Australia
A Collie
D Darby

Neuropsychology Laboratory, Mental Health Research Institute of Victoria, Parkville, Victoria, Australia
A Collie
P Maruff

Behavioural Neurology Laboratory, Mental Health Research Institute of Victoria
D Darby

School of Psychology, La Trobe University, Bundoora, Victoria, Australia
P Maruff

Correspondence to:
Dr Collie, Neuropsychology Laboratory, Mental Health Research Institute of Victoria, Locked Bag 11, Parkville, Victoria, Australia 3052
alex@neuro.mhri.edu.au

Accepted 4 May 2001

Modern sport is highly competitive, with the health of elite sports men and women regarded as major assets by themselves, their sporting associations, and the community. Their cognitive health in particular is one of the most important factors in their continuing success, as measured by performance statistics. Head injury is a significant risk whenever athletes perform competitively in sports entailing physical contact with other players or objects. Traumatic brain injury (TBI) can lead to overt problems such as acute headache, nausea, vomiting, dizziness, syncope, confusion, and coma.¹ However, in many cases the signs of TBI are covert, manifesting as mild cognitive deficits that may be detected only through careful neuropsychological testing.² Such subclinical impairment

of people with sports related cognitive deficits, and then critically examine the utility of conventional neuropsychological and computerised cognitive tests in sporting settings. As most reports describe athletes with sports related head injury, our discussion will be restricted to the use of cognitive tests in concussed and head injured athletes. This information should form a basis for the wider development and implementation of computerised testing in all sporting arenas.

Research and review articles were considered for discussion in this review if they had been published in international peer reviewed scientific journals in sports medicine, neurology, or neuropsychology and had in our opinion met one or more of the following criteria: (a) the article reported the results of computerised cognitive or conventional neuropsychological assessment of athletes with a sports related brain injury; (b) the article had made an inference about the neurological and/or cognitive consequences of sports related brain injury; (c) the article provided adequate description of a computerised cognitive test or test battery; or (d) the article discussed the limitations of conventional neuropsychological or computerised cognitive tests.

Assessment of cognitive function in sportspeople with head injury

Conventionally, athletes who have received a head injury through sports related incidents are deemed fit to resume participation on the basis of clinical judgment. Such judgments are often made with reference to the athlete's subjective rating of his/her symptoms or other non-standardised assessments of recovery.³ For example, a football player may be allowed to resume competition after a good performance at training. In people who have sustained a head injury, there are potentially serious neurological and cognitive consequences of early re-entry into the sporting arena that judgments made in this way fail to adequately consider. For example, a second concussive episode may exacerbate the effects of an initial concussion disproportionate with its severity, and cause serious and long term neurological and behavioural consequences ("second impact syndrome"¹²). The effects of concussion have also been shown to be cumulative,^{1 13} and repeated exposure to head injury may therefore result in progressively deteriorating cognitive function.⁴

These findings led to the adoption approximately two decades ago of neuropsychological tests to measure an athlete's cognitive abilities after a concussion. Performance on such tests has since been used to guide decisions about recovery from concussion and resumption of participation. Also, a number of studies have used neuropsychological tests to investigate cognitive function in head injured athletes.^{2 8 10}

These studies generally compare the individual athlete's neuropsychological test scores after concussion with those before concussion (baseline test scores collected before the beginning of the sporting season). This approach controls for interindividual differences in performance, including differences occurring

as a result of prior head injury, learning difficulties in young athletes, and other sources of individual variability. However, this approach presents a number of methodological and practical problems that are difficult to overcome when conventional neuropsychological tests are used. For example, a typical neuropsychological assessment battery may require two to three hours to administer and requires that a neuropsychologist or trained technician be present to supervise the athlete. These requirements make the baseline assessment of an entire sporting team or squad an unreasonably time consuming and expensive exercise. To overcome this problem, recent studies have used shortened test batteries comprising five or six neuropsychological tests that require about 20–30 minutes to administer.⁹ These "screening" batteries provide an adequate guide to the athlete's baseline cognitive status, while still allowing comparisons with the status after concussion in a number of cognitive domains. However, this approach still fails to overcome many of the methodological and practical problems that occur when repeated neuropsychological assessments are required (discussed below).

Computerised cognitive tests offer a solution to many of these methodological and practical problems. Computerised tests were designed initially to detect quite severe impairments in patients with neurological and psychiatric illness, in patients with brain lesions, and in people exposed to neurotoxic substances. As such, early computerised batteries comprised neuropsychological tests modified for computer presentation and response recording—for example, Cambridge Neuropsychological Test Automated Battery (CANTAB)¹⁴. More recent computerised batteries have used the unique properties of computing hardware to develop tests that are sensitive to very mild changes in cognition, such as those expected to occur in sports related TBI (table 1). To be interpretable according to conventional psychological principles, computerised tests have retained the structure of standard neuropsychological tests. However, the properties of the test may be enhanced such that many of the limitations of neuropsychological tests are minimised. For example, stimulus presentations can be randomised between participants, creating many alternative and equivalent forms of the test and resulting in a reduction in practice effects.

In the following sections, we summarise the major limitations of conventional neuropsychological tests when used in sporting settings, and describe how these may be overcome through the use of computerised cognitive tests. As an adjunct to this discussion, table 2 describes some of the properties of some current computerised cognitive test batteries.

Detection of mild cognitive dysfunction

Most neuropsychological tests are designed for the assessment of cognitive dysfunction caused by neurological or psychiatric illness or brain lesions, not for the assessment of mild changes in cognitive function over time.¹⁵ As a consequence, many conventional neuropsychological

tests have poor psychometric properties for serial study, including a limited range of possible scores, floor and ceiling effects, and poor test-retest reliability. We have proposed recently that mild cognitive impairments may only be accurately detected with neuropsychological tests that possess good psychometric properties.¹⁶ Thus, although impairments in many cognitive domains may be a consequence of sports related TBI, these impairments will only be observed when reliable, valid, and sensitive neuropsychological tests are used. Analysis of previous sports related concussion studies supports this proposal. The most commonly observed impairments in these studies are on tests of information processing and psychomotor control.^{9 10} As a general rule, such measures—for example, Trail Making Test, Digit Symbol Substitution Test—have better psychometric properties for serial testing than neuropsychological tests of more complex cognitive functions.¹⁷

One of the consequences of recording response time (RT) as a dependent variable with computerised cognitive tests is that many of these psychometric limitations are

overcome—that is, RTs are typically recorded in milliseconds, ensuring that there are thousands of possible levels of performance. Tests of simple RT are also repeatable, as they do not suffer greatly from practice effects,¹⁸ which also ensures that they have better test-retest reliability than many neuropsychological tests.¹⁷ These advantages were highlighted recently in an article by Bleiberg and colleagues,¹⁸ who recorded the performance of six patients with mild TBI on RT measures of psychomotor speed, memory, mathematical, and spatial processing, as well as on a conventional neuropsychological battery. Patients were impaired significantly relative to matched controls on four of the five computerised RT measures encompassing multiple cognitive domains. In contrast, analysis of group performance on conventional neuropsychological tests indicated that the TBI group performed worse than the control group on only two of 12 tests, and actually performed significantly better than controls on another. A number of other studies also show the utility of computerised RT measures in detecting cognitive changes associated with mild TBI.^{19–21}

Table 1 Properties of conventional neuropsychological and computerised cognitive tests

| | Conventional neuropsychological tests | Computerised cognitive tests |
|-----------------------------|--|---|
| Psychometric considerations | | |
| Alternative forms | None—few | Many—infinite |
| Stimulus randomisation | Within test only | Within test, between test and between subjects |
| Test-retest reliability | Wide range | Generally high for RT measures |
| Normative data | Mainly cross sectional | Very little for most tests |
| Practice effects | Large for most tests because of lack of alternative forms | Small because of many alternative forms and randomisation of stimulus presentation |
| Output | Level of performance | Level of performance and variability in performance |
| Practical considerations | | |
| Administration time | 1 min–4 h | 1 min–2 h |
| Support required | Neuropsychologist or trained technician for administration, scoring and interpretation | Some tests may be self administered and automatically scored. Interpretation still required |
| Accessibility | Poor. Requires trained personnel | High. May be internet delivered |
| Data storage and analysis | Time consuming and costly | Automated |

RT, Response time.

Table 2 Analysis of the suitability of some existing computerised cognitive test batteries for use in sporting settings

| Test battery | Reference | Psychometric considerations | Practical considerations |
|--|--------------------------------------|---|---|
| Cambridge Neuropsychological Test Automated Battery (CANTAB) | Sahakian <i>et al</i> ¹⁴ | Few alternative forms Low reliability on some tests Stimulus randomisation Provides cognitive profile Lots of normative data | Long administration time (1–2 h) Additional hardware requirements Expensive (requires trained tester) Automated analysis |
| Automated Neuropsychological Assessment Metrics (ANAM) | Bleiberg <i>et al</i> ²⁹ | Infinite alternative forms Stimulus randomisation Provides cognitive profile Little normative data | Short administration time No additional hardware requirements Requires trained tester Automated analysis |
| Cognitive Drug Research (CDR) test battery | Wesnes <i>et al</i> ²⁷ | Many alternative forms Acceptable to high reliability Stimulus randomisation Provides cognitive profile Lots of normative data | Short administration time (20 min) Additional hardware requirements Expensive (requires trained tester) Automated analysis |
| CogState | Westerman <i>et al</i> ²⁶ | Infinite alternative forms Acceptable to high reliability Stimulus randomisation Provides cognitive profile Little normative data | Short administration time (15–20 min) No additional hardware requirements Inexpensive (self administered) Internet delivered Automated analysis |
| CogScreen | Kane & Kay ²⁸ | Many (8) alternative forms Acceptable reliability Stimulus randomisation Provides cognitive profile Some normative data | Short administration time (30 min) Additional hardware requirements Expensive (requires tester) Automated analysis |

Detection of performance variability

Computerised cognitive tests are also ideal for measuring variability in performance. Previous studies of people with TBI suggest that performance variability may be a better indicator of cognitive dysfunction associated with a concussive episode than level of performance. For example, Stuss and colleagues^{19 20} observed inconsistent performance on tests of RT in patients in hospital with head injury. Similarly, in the study by Bleiberg and colleagues¹⁸ described above, patients with TBI displayed erratic performance on computerised cognitive tests both within a day and across four consecutive days of assessment. Conventional neuropsychological tests are unable to give an indication of performance variability because responses on most of these tasks are recorded in a binary fashion—that is, correct or incorrect—or as a single integer. In contrast, computerised tests allow collection of RTs to stimuli, and, if enough responses are collected, the variability in these RTs can be calculated accurately, as in the studies described above.

Sensitivity and specificity

Although it is crucial for a cognitive test or test battery to be relevant to a particular target group—for example, sportspeople—restriction of development to that group raises the potential for the test to lack sensitivity to all potential forms of impairment. Cognitive tests should be developed and then also tested in groups of patients with well defined clinical conditions that are known to interfere with cognitive function. For example, the performance of patients with anxiety disorders or depression can define cognitive profiles or patterns of performance that could indicate a potential reason for poor performance in athletes. Furthermore, an understanding of the nature and severity of cognitive impairments in these serious conditions can provide important clues to the presentation in athletes of the cognitive consequences of more mild conditions that may arise directly or indirectly from head injury such as fatigue and stress. The effect of common medications, such as benzodiazepines and alcohol, on cognitive function can also be determined by such computerised studies.^{22 23} These results can then be used to infer differential diagnostic causes in athletes in whom similar patterns of deficiency are found. Cognitive tests should aim to do more than just detect deviation from normal. They should limit the diagnostic possibilities by defining recognisable patterns of abnormal performance.

Alternative forms, practice effects, and test-retest reliability

Practice effects are a particularly important methodological problem for sports related TBI, as the magnitude of these effects may vary depending on the test-retest interval.²⁴ For example, if an athlete is concussed two weeks after a baseline assessment, then practice is likely to have a substantial effect on test performance. In contrast, if an athlete is concussed in the last game of a long season, practice effects will be reduced. Practice effects

are assumed to operate only between the first and second administration of a neuropsychological test battery,²⁵ but recent reports suggest that, at least for some tests, they may influence performance on up to four serial assessments.¹⁷ When the athlete is assessed at 24 hours, five days, and 14 days after concussion, as is standard, practice effects may be operating at none or all of these assessments. A resolution to this problem is therefore important for accurate decision making.

One method of reducing the magnitude of practice effects is to use alternate forms of the test or test battery. However, many conventional neuropsychological tests do not have alternate forms.¹⁷ This means that interpretation of data obtained from a recently concussed athlete will be influenced by the effects of practice and also by the reliability of the test. Also, when a neuropsychological test does have alternate forms, these are not always equivalent, which introduces another systematic source of measurement error. A second method advocated to control for practice effects is to record serial data from an appropriate control group—for example, a non-concussed athlete. This allows the estimation of practice effects and measurement error, which can then be considered jointly with the athlete's performance before and after concussion. However, very few serially recorded data have been published,¹⁷ and an adequate control participant may be difficult to recruit. Computerised cognitive tests allow the randomisation of stimulus presentation within a test, between tests, and between subjects if appropriate, and multidimensional stimuli can be used. This may result in the production of many, or indeed infinite, alternate forms of the test. In turn, having many alternate forms will result in reduction of the effects of practice on test performance when the test is administered serially and a consequent reduction in measurement error. This will increase the test-retest reliability of the test.

Practical matters

Perhaps the most attractive properties of computerised cognitive tests to sports administrators and sports physicians is that they offer major practical advantages over conventional neuropsychological assessment techniques. For example, data can be stored and scored automatically by the computer in milliseconds, allowing immediate interpretation by the physician or trainer at the time of assessment. Of particular importance to multicentre research studies is the possibility that data may be transferred between sites, or to a central database, electronically in a matter of seconds. This raises the possibility that an office bound neuropsychologist could collate and interpret the test results of a recently injured athlete and send their interpretation back to the trainer or physician at the sporting arena in a matter of minutes. If enough computing resources are available, baseline assessments may be conducted on an entire sporting team in a single testing session. If the computerised test is internet deliverable and self administered, baseline assessments can be conducted by the athlete in

their home environment, removing the need for teams of assessors to visit sporting clubs and interrupt training sessions. Finally, computerised assessment allows standardisation of administration protocols between subjects and between multiple sites. In turn, this results in minimisation of measurement error introduced by the assessor, especially where the test is self administered.

Another problem associated with using paper and pencil neuropsychological tests in sporting settings is that the athlete's test results need to be generated and interpreted by a neuropsychologist. Again, this can be an expensive and time consuming exercise, as most neuropsychologists attached to sporting teams have other professional interests that may take precedence. Finally, and perhaps more importantly, computerised cognitive tests may require less than 30 minutes to complete, while still providing a profile of cognitive performance.^{26 27}

Limitations of computerised cognitive assessment

There are three major limitations of most computerised cognitive assessment tools. The first is the hardware required to administer the tests. For example, the CANTAB battery requires not only a PC and keyboard, but also a touch sensitive screen.¹⁴ Similarly, CogScreen requires a PC, keyboard, mouse, and a stylus to indicate responses.²⁸ This means that the tests are not as portable as conventional neuropsychological tests. The second limitation is the cost involved in setting up a computerised assessment system, which may include purchasing expensive software and hardware—for example, a touch sensitive screen—as well as training neuropsychologists and technicians in administration protocols, data storage, and analysis. In contrast, many paper and pencil neuropsychological tests are available freely in the scientific literature and require no computer expertise to administer or score. Furthermore, many computerised cognitive tests do not have sufficient normative and test-retest reliability data, and have not been validated against conventional neuropsychological measures or for use in different disorders and settings. These limitations may all be overcome by further test development and validation. For example, we have recently developed an internet deliverable cognitive test that runs on any platform and can therefore be administered on any PC, with results returned through an existing internet connection.²⁶ This, and cognitive tests developed by other groups,²⁹ are now being validated for use in many settings.

Despite the many advantages of computerised cognitive assessment, the results from such assessments should not be considered in isolation. In fact, computerised testing should be used mainly to inform decisions on fitness to resume participation when the sports physician or trainer is uncertain of the athlete's status after a conventional neurological and physical examination has been conducted. The cardinal signs of concussive episodes should be considered before the athlete's cognitive status—for

example, nausea, headache, retrograde and anterograde amnesia. Further, it may be appropriate to conduct a more detailed neuropsychological examination of the athlete after a concussive episode, in order to gain a greater understanding of the domains of cognition persistently affected by the brain injury.

Summary and conclusions

An increasing awareness of the effects of sports related head injury on cognition has led sports physicians to seek fast and accurate assessments of cognitive function, to facilitate management decisions about time of recovery and resumption of participation. Over the past two decades, this has been accomplished through the use of clinical judgment or conventional paper and pencil neuropsychological tests. However, there are limitations associated with using such tests in repeated measures designs. This has led to the development of computerised cognitive test batteries, which are often specifically designed for the serial assessment of cognitive function in the individual. Such computerised batteries offer both scientific and practical advantages over conventional neuropsychological measures. These include high sensitivity and specificity to mild impairments in cognition as occurs in many athletes with sports related head injuries, and the ability to conduct baseline assessments before the season on entire sporting teams in a matter of hours. Recent work suggests that computerised tests of RT allow the detection of very subtle cognitive changes, return to baseline performance, and also the detection of performance variability. The widespread use of many computerised tests and test batteries is limited currently by their high cost and low accessibility; however, some very recently developed test batteries are designed to be internet deliverable and inexpensive. Another limitation of most computerised test batteries is the lack of normative data; however, this is rapidly being overcome as these test batteries become more commonly used.

It is likely that, in the near future, cognitive testing programs will be more widely implemented using one or other computerised screening test. Such programs would perform baseline testing before the season to establish optimum non-impaired performance. The tool used would preferably be self instructing and brief (10–15 minutes). It should be readily available for athletes to practice before supervised testing by sporting associations or teams. Results would then be stored safely and available for comparison with repeat tests after head injury at appropriate medically based intervals. For example, a mild concussion may be judged during play to be insignificant, which, if backed up by an unchanged computerised test at the time, would allow the player to resume play immediately. A more significant concussion may require testing only when the medical attendant felt the athlete was back to normal. Subtle decrements would indicate persisting impairment, and retesting could continue until return to baseline performance had occurred. If no such return to baseline was

achieved, then further neuropsychological and medical assessments would be indicated. Such testing programs are predicted to be available inexpensively via the internet for all levels of sports men and women including amateurs.

In conclusion, physicians and athletes in sports in which there is a risk of concussive head injury may benefit greatly from the use of computerised tests of cognitive function. For the sports physician, this benefit may come in the form of more accurate and informed decision making with regard to the athlete's resumption of participation, and a reduction in time to conduct and interpret baseline assessments of athletes and those made after concussion. For the athlete, dual benefits arise, with a reduced risk of long term deficits in cognitive function caused by early re-entry into the sporting arena, and return to baseline test performance predictive of continued optimal on field accomplishment.

- 1 McCrory PR, Berkovic SF. Second impact syndrome. *Neurology* 1998;50:677-83.
- 2 Hinton-Bayre AD, Geffen GM, Geffen LB, et al. Concussion in contact sports: Reliable change indices of impairment and recovery. *J Clin Exp Neuropsychol* 1999;21:70-86.
- 3 Dicker G, Maddocks D. Clinical management of concussion. *Aust Fam Physician* 1993;22:750-3.
- 4 Butler R. Neuropsychological investigation of amateur boxers. *Br J Sports Med* 1994;28:187-90.
- 5 Fothergill DM, Hedges D, Morrison JB. Effect of CO₂ and N₂ partial pressures on cognitive and psychomotor performance. *Undersea Biomed Res* 1991;18:1-19.
- 6 Regard M, Oelz O, Brugger P, et al. Persistent cognitive impairment in climbers after repeated exposure to extreme altitude. *Neurology* 1989;39:210-13.
- 7 Matser JT, Kessels AG, Jordan BD, et al. Chronic traumatic brain injury in professional soccer players. *Neurology* 1998;51:791-6.
- 8 Hinton-Bayre AD, Geffen GM, McFarland KA. Mild head injury and speed of information processing: a prospective study of professional rugby league players. *J Clin Exp Neuropsychol* 1997;19:275-89.
- 9 Macciocchi SN, Barth JT, Alves W, et al. Neuropsychological functioning and recovery after mild head injury in collegiate athletes. *Neurosurgery* 1996;39:510-14.
- 10 Maddocks D, Saling M. Neuropsychological deficits following concussion. *Brain Injury* 1996;10:99-103.
- 11 Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clinical Journal of Sports Medicine* 1995;5:32-5.
- 12 Cantu RC. Second-impact syndrome. *Clin Sports Med* 1998;17:37-44.
- 13 Gronwall D, Wrightson P. Cumulative effect of concussion. *Lancet* 1975;ii:995-7.
- 14 Sahakian BJ, Morris RG, Evenden JL, et al. A comparative study of visuospatial memory and learning in Alzheimer-type dementia and Parkinson's disease. *Brain* 1988;111:695-718.
- 15 McSweeney AJ, Naugle RI, Chelune GJ, et al. "T Scores for Change": an illustration of a regression approach to depicting change in clinical neuropsychology. *The Clinical Neuropsychologist* 1993;7:300-12.
- 16 Collie A, Maruff P, Shafiq-Antonacci R, et al. Memory decline in healthy older people: implications for identifying mild cognitive impairment. *Neurology* 2001;56:1533-8.
- 17 McCaffrey RJ, Duff K, Westervelt HJ. *Practitioner's guide to evaluating change with neuropsychological assessment instruments*. New York: Kluwer Academic/Plenum Publishers, 2000.
- 18 Bleiberg J, Garmoe WS, Halpern EL, et al. Consistency of within-day and across-day performance after mild brain injury. *Neuropsychiatry, Neuropsychology and Behavioural Neurology* 1997;10:247-53.
- 19 Stuss DT, Stethem LL, Hugenholtz H, et al. Reaction time after head injury: fatigue, divided and focused attention, and consistency of performance. *J Neurol Neurosurg Psychiatry* 1989;52:742-8.
- 20 Stuss DT, Pogue J, Buckle L, et al. Characterization of stability of performance in patients with traumatic brain injury: variability and consistency on reaction time tests. *Neuropsychology* 1994;8:316-24.
- 21 Hugenholtz H, Stuss DT, Stethem LL, et al. How long does it take to recover from a mild concussion? *Neurosurgery* 1988;22:853-8.
- 22 Hartly LR. Prescribed psychotropic drugs. The major and the minor tranquilisers. In: Smith DM, Jones AP, eds. *Handbook of human performance*; vol 2. London: Academic Press, 1992.
- 23 Finnegan F, Hammersley R. The effects of alcohol on performance. In: Smith DM, Jones AP, eds. *Handbook of human performance*; vol 2. London: Academic Press, 1992.
- 24 Mitrushina M, Satz P. Effect of repeated administration of a neuropsychological battery in the elderly. *J Clin Psychol* 1991;47:790-800.
- 25 McCaffrey RJ, Ortega A, Orsillo SM, et al. Practice effects in repeated neuropsychological assessments. *The Clinical Neuropsychologist* 1992;6:32-42.
- 26 Westerman R, Darby D, Maruff P, et al. Cognitive testing of pilots: How and why? *Australian Defence Force Health* 2001;2:29-36.
- 27 Wesnes KA, Garratt C, Wickens M, et al. Effects of sibutramine alone and with alcohol on cognitive function in healthy volunteers. *Br J Clin Pharmacol* 2000;49:110-17.
- 28 Kane RL, Kay GG. Computerized assessment in neuropsychology: a review of tests and test batteries. *Neuropsychol Rev* 1992;3:1-17.
- 29 Bleiberg J, Halpern EL, Reeves D, et al. Future directions for the neuropsychological assessment of sports concussion. *J Head Trauma Rehabil* 1998;13:36-44.

Take home message

Careful assessment of cognitive function in athletes with sports related head injury will facilitate clinical strategies for the athletes' recovery and return to play. Computerised cognitive tests and test batteries are designed specifically for the detection of very mild cognitive dysfunction, and offer both practical and scientific advantages over conventional neuropsychological tests.

Commentary

Neuropsychological testing to determine return to play strategies after sport related concussion has received increasing interest in the past few years. Initially simultaneously developed in America and Australia in the mid-1980s, it has been given added impetus by work in both American professional football and ice hockey. At present, most groups use "pencil and paper" tests as the mainstay of this assessment. This review presents an interesting window into the future of this approach by introducing the idea of computerised testing. Once validated, such strategies will open the possibility of neuropsychological testing to be much more widely available at relatively low cost to athletes at all levels of performance. There is also the possibility in the future that selected tests will be available on "palm" computers for immediate sideline assessment. This may sound far fetched but at least one company at present has a palm version of their computerised neuropsychological testing program. The wider use of such testing and the increasing expertise of team doctors assessing such injuries can only improve the safety of athletes.

P MCCRORY

31 Grosvenor Parade, Balwyn, Victoria 3103, Australia
pmccrory@compuserve.com

Current Trends in Athletic Training Practice for Concussion Assessment and Management

Andrew J. Notebaert; Kevin M. Guskiewicz

The University of North Carolina at Chapel Hill, Chapel Hill, NC

Andrew J. Notebaert, MS, ATC, and Kevin M. Guskiewicz, PhD, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to Kevin M. Guskiewicz, PhD, ATC, Department of Exercise and Sport Science, The University of North Carolina at Chapel Hill, Fetzer Gym CB#8700, Chapel Hill, NC 27599. Address e-mail to gus@email.unc.edu.

Context: Athletic trainers surveyed in 1999 demonstrated little consensus on the use of concussion grading scales and return-to-play criteria. Most relied on clinical examination or symptom checklists to evaluate athletes with concussion.

Objective: To investigate the current trends of certified athletic trainers in concussion assessment and management.

Design: Subjects were invited to participate in a 32-question Internet survey.

Setting: An Internet link to the survey was e-mailed to the subjects.

Patients or Other Participants: A total of 2750 certified athletic trainers and members of the National Athletic Trainers' Association were randomly e-mailed and invited to participate.

Main Outcome Measure(s): Survey questions addressed topics including years of certification, number of concussions evaluated each year, methods of assessing concussion, and guidelines used for return to play. Compliance with the recent position statement of the National Athletic Trainers' Association on sport-related concussion was also evaluated.

Results: Certified athletic trainers averaged 9.9 ± 7.3 years of certification and evaluated an average of 8.2 ± 6.5 concussions per year. To assess concussion, 95% reported using the clinical examination, 85% used symptom checklists, 48% used

the Standardized Assessment of Concussion, 18% used neuropsychological testing, and 16% used the Balance Error Scoring System. The most frequently used concussion grading scale and return-to-play guideline belonged to the American Academy of Neurology (30%). When deciding whether to return an athlete to play, certified athletic trainers most often used the clinical examination (95%), return-to-play guidelines (88%), symptom checklists (80%), and player self-report (62%). The most important tools for making a return-to-play decision were the clinical examination (59%), symptom checklists (13%), and return-to-play guidelines (12%). Only 3% of certified athletic trainers surveyed complied with the recent position statement, which advocated using symptom checklists, neuropsychological testing, and balance testing for managing sport-related concussion.

Conclusions: Our findings suggest that only a small percentage of certified athletic trainers currently follow the guidelines proposed by the National Athletic Trainers' Association. Various assessment methods and tools are currently being used, but clinicians must continue to implement a combination of methods and tools in order to comply with the position statement.

Key Words: mild traumatic brain injury, mild brain injury, evaluation

Sports medicine clinicians and researchers have access to a variety of tools for evaluating and rehabilitating athletic injuries. These tools, for the most part, offer clinicians information about the presence and severity of injury. Additionally, they may suggest a timeframe for rehabilitation and return to play. However, this is not the case with sport-related concussion. No simple tests can be performed on the brain to determine the severity of a closed head injury and help clinicians establish goals for rehabilitation and return to play. The complexity of concussion injuries requires clinicians to use a variety of tools for information, but the current tendency is to base the return-to-play decision on the athlete's self-reporting of symptoms and ability to perform sport-specific tasks without a recurrence of concussion symptoms.^{1–4} Relying solely on this information can be dangerous because it creates an incomplete picture of the injury.

A multifaceted protocol has been proposed by several authors in the literature.^{1,2,5–9} The recent position statement of

the National Athletic Trainers' Association (NATA) recommends the use of symptom checklists, neuropsychological testing, and postural stability assessment.⁵ Baseline testing on these measures is important for athletes participating in sports with a high concussion risk; however, if resources allow, then all athletes should receive baseline assessment. Follow-up testing should be conducted to aid in the decision process for return to play. Using all the available information may be the best approach to safely returning an athlete to play after a concussion.

Research on sport-related concussion has increased tremendously in the modern era. A literature search on PubMed revealed large increases in the amount of published material in scientific journals each decade since the 1960s (Table 1). This increase in research has expanded the information available to certified athletic trainers (ATCs) and led to a greater understanding of sport-related concussion. However, the literature has also raised more questions and

Table 1. Number of Published Materials on Concussion in Sport in PubMed*

| Decade | Number |
|-----------|--------|
| 1960–1969 | 5 |
| 1970–1979 | 23 |
| 1980–1989 | 34 |
| 1990–1999 | 143 |
| 2000–2004 | 172 |

*Search terms were *concussion*, *mild head injury*, *mild traumatic brain injury*, and *sport*.

forced clinicians to rethink their approach to concussion management.

Our study is based on a survey similar to one administered at the 1999 NATA Annual Meeting and Clinical Symposia.¹⁰ The authors analyzed trends in concussion assessment and management by ATCs. Little consensus was found on concussion grading scales and return-to-play criteria, and most ATCs relied on clinical examination or symptom checklists as evaluative tools for concussion assessment. The ATCs evaluated an average of 7 concussions per year and, along with team physicians, were primarily responsible for making return-to-play decisions. The majority of ATCs also indicated that standardized methods of concussion assessment (SMCA) would help provide more information for concussion management.¹⁰

In recent years, several journal special issues and position statements have been devoted solely to concussion in sport.^{5,7,8,11,12} Given the increase in published research findings in recent years, our purposes were to (1) investigate and update the current trends in athletic training practice for concussion assessment and management, (2) determine whether the trends have changed over the past 5 years, and (3) evaluate whether ATCs were compliant with the recent NATA position statement on sport-related concussion.

METHODS

A list of approximately 2750 ATCs was randomly generated from all regular certified members of the NATA. These members were contacted by e-mail, which included a link to the survey. The ATCs agreeing to participate in this study took approximately 20 minutes to complete the survey. The Academic Affairs Institutional Review Board approved the survey, and consent to participate in the study was implied by the subjects' submission of the online survey.

We adapted a 32-question survey (Table 2) from a 21-item survey used by Ferrara et al.¹⁰ Our intent was to evaluate the clinical practice habits and decision-making skills of ATCs in relation to sport concussion. The survey first gathered demographic data, the number of years certified, employment position and setting, and the sports covered by the clinician. It

Table 2. Sample Questions from Athletic Trainer Concussion Questionnaire—2004

● Indicate your current primary position:

☐ Clinical ☐ Academic ☐ Research ☐ Administrative ☐ Student ☐ Other

● Indicate your current primary employment/position setting:

☐ College athletics ☐ Professional athletics ☐ High school athletics
☐ Sports medicine clinic ☐ General hospital setting ☐ Academic department
☐ Fitness center ☐ Personal trainer ☐ Corporate health

● What methods do you typically utilize to assess and diagnose concussion? (check all that apply)

☐ Clinical examination ☐ Standardized Assessment of Concussion (SAC)
☐ Symptom checklists ☐ Neuropsychological testing (paper/pencil)
☐ Balance Error Scoring System (BESS) ☐ Neuropsychological testing (computerized)
☐ Concussion grading scales ☐ Other (specify) _____

● What methods do you typically utilize to make decisions about return to play after concussion? (check all that apply)

☐ Clinical examination ☐ Concussion grading scales
☐ Physician recommendations ☐ Return-to-play guidelines
☐ Neuropsychological testing (computerized) ☐ Symptom checklist
☐ Neuropsychological testing (traditional) ☐ Player self-report
☐ Balance Error Scoring System (BESS) ☐ Standardized Assessment of Concussion (SAC)
☐ Head CT/brain MRI ☐ Other (specify) _____

● What is the single method you rely on the most in making decisions about return to play after concussion? (select one)

☐ Clinical examination ☐ Concussion grading scales
☐ Physician recommendations ☐ Return-to-play guidelines
☐ Neuropsychological testing (computerized) ☐ Symptom checklist
☐ Neuropsychological testing (traditional) ☐ Player self-report
☐ Balance Error Scoring System (BESS) ☐ Standardized Assessment of Concussion (SAC)
☐ Head CT/brain MRI ☐ Other (specify) _____

Please answer the following questions on the following scenario: Your athlete had no loss of consciousness but had posttraumatic amnesia for <1 minute. Your evaluation the next day found:

● Your clinical examination revealed abnormalities but the player appeared normal on standardized methods of concussion assessment (eg, SAC, BESS, neuropsychological testing). Would you return this player to competition?

☐ Yes ☐ No

● A player was reporting postconcussion symptoms but appeared normal on standardized methods of concussion (eg, SAC, BESS, neuropsychological testing). Would you return this player to competition?

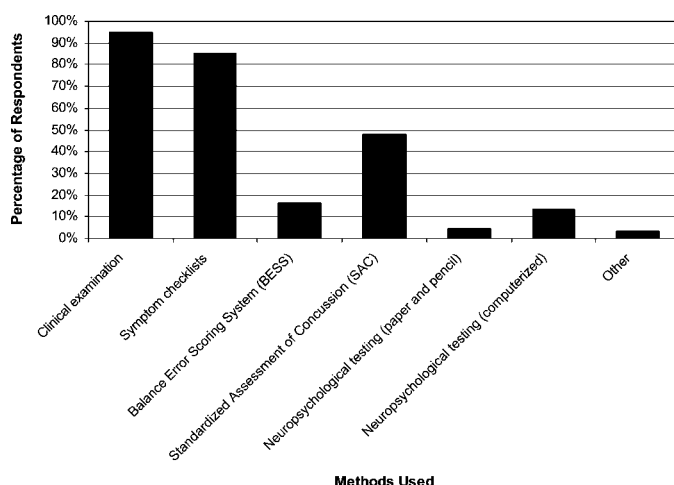
☐ Yes ☐ No

Table 3. Concussions Evaluated Per Year by Athletic Trainers' Primary Employment Settings (Number, Percentage)

| Number of Concussions Evaluated | Professional Setting (n = 25) | College (n = 305) | High School (n = 308) | Sports Medicine Clinic (n = 101) | Other (n = 110) | Total (n = 849) |
|---------------------------------|-------------------------------|-------------------|-----------------------|----------------------------------|-----------------|-----------------|
| 0 to 2 | 10 (40.00) | 38 (12.50) | 9 (2.92) | 22 (21.78) | 41 (37.96) | 120 (14.18) |
| 3 to 5 | 5 (20.00) | 103 (33.88) | 77 (25.00) | 33 (32.67) | 35 (32.41) | 253 (29.91) |
| 6 to 10 | 8 (32.00) | 109 (35.86) | 129 (41.88) | 31 (30.69) | 25 (23.15) | 302 (35.70) |
| More than 10 | 2 (8.00) | 54 (17.76) | 93 (30.19) | 15 (14.85) | 7 (6.48) | 171 (20.21) |

Table 4. Athletic Trainers' Witnessing of Selected Concussion Symptoms (Number, Percentage)

| Percent-age of Evaluated Concussions | Loss of Consciousness (n = 837) | Retrograde Amnesia (n = 832) | Post-traumatic Amnesia (n = 829) | Post-concussion Syndrome (n = 822) |
|--------------------------------------|---------------------------------|------------------------------|----------------------------------|------------------------------------|
| 100% | 2 (0.24) | 3 (0.36) | 2 (0.24) | 9 (1.09) |
| 75–99% | 1 (0.12) | 9 (1.08) | 9 (1.09) | 26 (3.16) |
| 50–74% | 13 (1.55) | 41 (4.93) | 32 (3.86) | 43 (5.23) |
| 25–49% | 19 (2.27) | 88 (10.58) | 53 (6.39) | 42 (5.11) |
| 10–24% | 80 (9.56) | 177 (21.27) | 140 (16.89) | 110 (13.38) |
| 1–9% | 442 (52.81) | 356 (42.79) | 328 (39.57) | 321 (39.05) |
| 0% | 280 (33.45) | 158 (18.99) | 265 (31.97) | 271 (32.97) |

**Figure 1. Frequency of methods used to evaluate and diagnose concussion. Subjects were asked to check all that apply.**

then asked for an average number of concussions seen by the clinician per year and selected symptoms observed with these injuries. The survey asked the subject to identify the clinical tools used and the individuals responsible for return-to-play decisions. Several questions asked about the use of SMCA, and ATCs were given examples such as the Standardized Assessment of Concussion (SAC),¹³ the Balance Error Scoring System (BESS),⁹ and neuropsychological testing. For our purposes, we further defined SMCA retrospectively as tools and methods described in the literature that are objective in nature and use standard scoring. Questions asked clinicians what decisions would be made for return to play given hypothetical information. Subjects were also asked if they consulted with neuropsychologists or thought that ATCs should be trained to administer neuropsychological examinations.

The survey was posted on the Internet and hosted by SurveyMonkey.com. Questions were grouped in blocks of 3

to 5 for the ease of the respondents and were presented in mainly multiple choice and fill-in-the-blank formats. Respondents were not required to answer all questions and were free to pass over any questions or sections. The survey was free to all respondents and did not collect any personal information. The response data were available only to the researchers and were downloaded as a Microsoft Excel (version 2000; Microsoft Corp, Redmond, WA) spreadsheet.

Descriptive statistics were calculated on the data, followed by chi-square tests of association using SPSS (version 11.5; SPSS Inc, Chicago, IL). Alpha level was set a priori at .05 for all tests.

RESULTS

A total of 927 ATCs responded to the 2750 e-mails sent out, for a response rate of 33.7%. Surveyed ATCs averaged 9.94 ± 7.3 years of certification. All respondents were current ATCs except for 1 who had recently retired. More than 85% ($n = 676/779$ [86.78%]) reported being licensed if their state had athletic trainer licensure available. More than half (568/926 [61.34%]) of those surveyed had earned a master's degree or PhD.

The most common responses for primary employment position were the high school (323/911 [35.46%]), collegiate (314/911 [34.47%]), and sports medicine (109/911 [11.96%]) clinical settings. Subjects were most often responsible for covering women's basketball, men's basketball, football, baseball, and women's soccer. More than 30% (232/769) reported using the American Academy of Neurology¹⁴ recommendations as their primary return-to-play guidelines. The Colorado Medical Society¹⁵ and the 2001 Cantu evidence-based³ guidelines followed, with 20.7% (159/769) and 19.9% (153/769), respectively, whereas 13.1% (101/769) used some combination of guidelines or a site-specific guideline, and 8.6% (66/769) reported not using any return-to-play guidelines.

The average number of concussions diagnosed per year was 8.2 ± 6.5 (Table 3). Only 20% of ATCs reported evaluating more than 10 concussions per year, with more than 50% of those being in the high school setting.

More than 80% of ATCs surveyed reported evaluating relatively few concussions (less than 25% of the total) that involved loss of consciousness, retrograde amnesia, or posttraumatic amnesia (Table 4). Of the ATCs who had evaluated cases of postconcussion syndrome, approximately 68% (465/686) said a physician had diagnosed the condition.

Respondents reported using a variety of methods to assess and evaluate concussion and make return-to-play decisions. The clinical examination and symptom checklists are used consistently for concussion evaluation (>85% of the time) among ATCs (Figure 1). Clinical examinations, physician recommendations, return-to-play guidelines, and symptom checklists are the most common return-to-play methods used ($\geq 80\%$

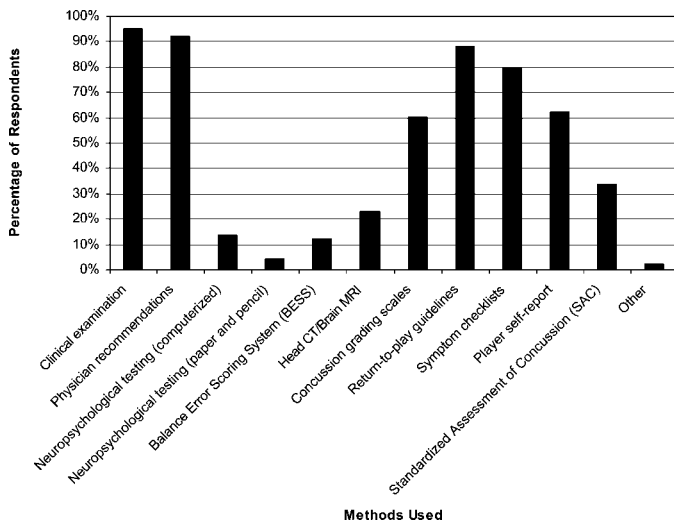


Figure 2. Frequency of methods used to guide return-to-play decisions. Subjects were asked to check all that apply.

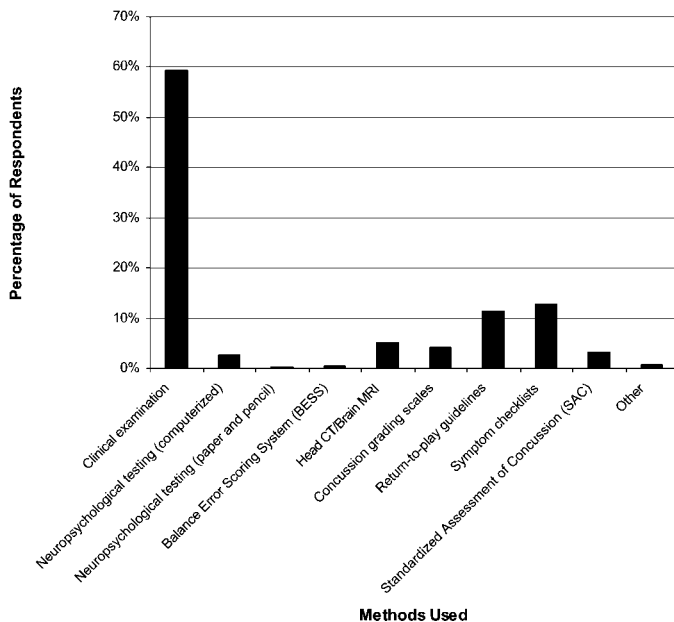


Figure 3. Frequency of primary method/tools used to guide return-to-play decisions. Subjects were asked to select the primary method guiding return-to-play decisions.

of the time), and the clinical examination was the most frequently reported primary method (Figures 2 and 3).

The team physician was reported to be the most responsible person in making return-to-play decisions, with the ATC as the second most responsible (Table 5).

Approximately 68% (518/762) reported that using SMCA would be more helpful than relying on the clinical examination alone. Just over 32% (244/762) stated that using SMCA would not add anything to the clinical examination. Thirty-five percent (266/752) stated that SMCA would have no effect on the return-to-play decisions, whereas 17.0% (128/752) declared that an athlete would likely return sooner if SMCA were used. Almost 48% (358/752) reported that, in their opinion, SMCA would prolong the amount of time an athlete would remain out of competition after a concussion. More than 62% (470/

Table 5. Caregivers Responsible for Making Return-to-Play Decisions (Number, Percentage)*

| Caregiver | 1st Caregiver (n = 814) | 2nd Caregiver (n = 805) | 3rd Caregiver (n = 716) |
|------------------------|----------------------------|----------------------------|----------------------------|
| Athletic trainer | 212 (26.04) | 461 (57.27) | 126 (17.60) |
| Team physician | 422 (51.84) | 165 (20.50) | 45 (6.28) |
| Primary care physician | 169 (20.76) | 136 (16.89) | 164 (22.91) |
| Coach | 0 (0.00) | 11 (1.37) | 74 (10.20) |
| Player | 1 (0.12) | 9 (1.12) | 136 (18.99) |
| Parents | 2 (0.25) | 17 (2.11) | 134 (18.72) |
| Other | 8 (0.98) | 6 (0.75) | 38 (5.31) |

*Subjects were asked to indicate who was most responsible (1st), followed by the next most important (2nd and 3rd) in making return-to-play decisions.

Table 6. Athletic Trainers' Return-to-Play Decisions Based on Hypothetical Situations

| Clinical Findings | Standard Methods of Concussion Assessment | Return-to-Play Decision | |
|--|---|-------------------------|-----|
| | | Yes | No |
| Clinical examination abnormal | Normal | 14 | 770 |
| Postconcussion symptoms present | Normal | 4 | 783 |
| Clinical examination normal, no symptoms | Abnormal | 98 | 678 |

758) did not believe that SMCA could be misused to return an athlete to play sooner than usual.

Subjects were asked about a scenario in which an athlete sustained a mild head injury and had no loss of consciousness but posttraumatic amnesia for less than 1 minute. Three sets of hypothetical findings on follow-up examination were given and the ATCs asked if they would return the athlete to play (Table 6). Approximately 15% reported that they would return an athlete to play if the only abnormal findings were noted on SMCA.

Of the ATCs surveyed, 135 reported using computerized neuropsychological testing. Seventy-five percent (100/135) used ImPACT (University of Pittsburgh Medical Center, Pittsburgh, PA) as their primary computerized neuropsychological test. Almost 10% (13/135) used ANAM (National Rehabilitation Hospital Assistive Technology and Neuroscience Center, Washington, DC), 4.5% (6/135) used CogState (CogState Ltd, Victoria, Australia), and 4.5% (6/135) used HeadMinder (HeadMinder Inc, New York, NY). Just over 25% (193/767) reported having access to a neuropsychologist for consultation after a concussion, but only about one fourth of those (48/198) said they routinely consult the neuropsychologist. Seventy-eight percent (593/757) stated that athletic trainers should be trained to administer neuropsychological tests to assess concussion.

Chi-square tests of association were performed to assess for trends between the number of years certified and the clinical tools used, the number of years certified and the primary position, the primary position and the clinical tools used, and the employment setting and the clinical tools used. A significant relationship was found between ATCs with more years of certification and increased use of computerized neuropsychological testing ($\chi^2_4 = 14.12$, $P = .007$). High school ATCs more frequently used symptom checklists ($\chi^2_4 = 14.11$, $P = .007$), and college and professional ATCs more frequently used computerized neuropsychological testing.

logical tests ($\chi^2_4 = 27.92$, $P \leq .001$) compared with ATCs in different employment settings.

DISCUSSION

Our purpose was to examine the current trends in concussion assessment and management, to compare those trends with a comparable survey conducted 5 years earlier, and to investigate practice patterns of ATCs in relation to the NATA position statement on sport-related concussion. Currently, ATCs assess an average of 8.2 concussions per year, up from an average of 7.0 concussions per year reported 5 years ago.¹⁰ We were unable to determine whether this is a significant difference because we did not have access to the data from the original survey. Whether these findings reflect an increase in concussion incidence or better identification of concussions that may have previously gone undetected is unclear.

Scientific publications on sport-related concussion have increased by 17% during the last 4 years (172 from 2000 through 2004) over the prior decade (143 from 1990 through 1999) (see Table 1). Given the large increase in concussion research, ATCs have more information available on this topic and likely a higher level of awareness than 5 years ago.

Our survey data show that more ATCs are using tools available to them than 5 years ago. More than 95% of ATCs used the clinical examination, 85% used a symptom checklist, 48% used the SAC,¹³ 16% used the BESS,⁹ and 18% used neuropsychological testing. These results help to describe the current trends in concussion management when compared with the findings of Ferrara et al¹⁰ that 33% used the clinical examination, 35% used symptom checklists, 10% used the SAC,¹³ 5% used the BESS,⁹ and 15% used neuropsychological testing. With the reported increases in the use of these methods and tools, it seems that ATCs are now in better position to assess and manage concussions.

The suggestion that more concussions are occurring in sport, however, has not yet been substantiated, primarily because of the challenges faced in collecting both exposure and injury data. The Centers for Disease Control and Prevention estimated 300 000 sport-related concussions annually in the United States.¹⁶ The actual incidence per exposure to concussion could be decreasing, because participation in sports with concussion risks continues to grow every year while the number of injuries has remained fairly constant.¹⁷ Concussion incidence has primarily been reported in football. In 1983, Gerberich et al¹⁸ reported that 20% of high school football players sustained a concussion in a given season; however, this study has been widely criticized because of the retrospective collection of data by players and coaches. Collegiate football had an estimated 10% incidence rate in the 1980s,¹⁹ but a more recent investigation has indicated a lower incidence rate for both high school (5.6%) and collegiate football (4.4 to 5.5%).²⁰ However, the number of concussions occurring may actually be higher than those evaluated and reported by ATCs, based on results of a recent study by McCrea et al²¹ that nearly 50% of all concussions during a high school football season were unreported. With advances in concussion research and the availability of more sophisticated assessment tools, clinicians may have become better at both identifying and assessing concussion.

There is still no consensus on concussion grading scales and return-to-play guidelines. Although the number of clinicians not using a grading system is less than previously reported,

one grading scale does not appear to be overwhelmingly preferred over another. Most concussion guidelines rely on loss of consciousness and amnesia to help grade the severity of concussion. However, loss of consciousness and amnesia are seen in relatively few cases of concussion.^{20,22} Results from our study concur, as the clinicians reported evaluating few athletes with loss of consciousness and amnesia. Previous authors^{20,22,23} noted that concussed athletes present most often with headache, poor balance and dizziness, confusion, or feeling "slowed down." The majority of concussion guidelines focus solely on loss of consciousness and posttraumatic amnesia, ignoring other signs and symptoms, as well as their duration and severity.

A discrepancy appears to exist between the current expectations that clinicians should regularly use SMCA and what occurs on the playing fields and in athletic training rooms across America. A smaller percentage of respondents in this study (68%) than in the previous study (86%)¹⁰ reported that using SMCA would be more effective than using the clinical examination alone. In both studies, ATCs reported (47% in both) that using SMCA would prolong the amount of time an athlete would be withheld from competition. Because more clinicians in our study reported that SMCA could be misused (38% versus 24%) or could prolong the amount of time an athlete would remain out of competition, it would seem that SMCA is not gaining popularity as might be expected given the abundance of published research on sport-related concussion in recent years. Also, when asked a hypothetical question (see Table 2) about a concussed athlete, more respondents in our study (12.6% versus 1.2% in the previous study) indicated they would allow an athlete to return to play who had a normal clinical examination but an abnormal SMCA. Clinicians should understand that SMCA gives reliable information about a player's status; an abnormal SMCA should caution the clinician against allowing the athlete to return to competition. As a follow-up to help explain our main findings, we conducted post hoc analyses (chi-square tests of association), which revealed no association between clinicians using SMCA and their responses to our hypothetical questions.

Although neuropsychological assessment is recommended for athletes both before participation and in guiding return to play,²⁴ our survey shows that relatively few ATCs use this tool. Accessibility may be one barrier. Neuropsychological testing is relatively new to the sports medicine community, and ATCs often do not have the time or the resources to obtain baseline tests and perform follow-up assessments after concussion. Computerized neuropsychological testing is probably the most convenient protocol, but testing multiple subjects at one time requires multiple computers. If computer availability is limited, only a few athletes can be evaluated in 15 to 35 minutes, which may not be practical for many institutions. In the event of an injury, ATCs and physicians still need to involve a neuropsychologist to assist in interpreting the results before making a return-to-play decision. Paper-and-pencil testing is more available but typically requires a trained person to administer and interpret the test results. The problem of being able to test only a limited number of athletes at one time also restricts the use of paper-and-pencil testing.

We observed an association between an ATC's experience and the likelihood of using neuropsychological testing for managing concussion. The more years of experience an ATC reported, the more likely he or she was to use neuropsychological testing. This finding could suggest that entry-level ath-

letic trainers are not being exposed to this tool in their athletic training experience. Experience in the field and exposure to neuropsychological testing through research may lead clinicians to incorporate this tool into their concussion management protocols.

The NATA position statement on concussion management recommends that all athletes, especially those playing sports with high concussion risks, be enrolled in a program involving cognitive and postural stability testing. These tests should be performed before the athlete engages in activity to establish a baseline for the individual and then after a concussion is diagnosed to identify any deficits that cannot be determined by self-reported symptoms.⁵ Our data indicate that only about 3% of those surveyed currently cover all 3 areas recommended by the NATA by using symptom checklists, neuropsychological testing, and the BESS for concussion assessment or return-to-play decisions. About 24% used at least 2 methods, and 80% used at least 1 method. The actual percentage is potentially higher because the only postural stability measure we inquired about was the BESS. Clinicians may use an alternate form of postural stability testing, such as forceplate measures. However, even if our survey included other forms of postural stability testing, we would not expect compliance with the NATA recommendations to improve.

Our study is restricted by the inherent limitations of survey research. We assume that the subjects answered the questions truthfully and honestly. We also assume that all subjects read and interpreted the questions in the same way. For example, although no return-to-play decision should be based on an individual tool, we did not provide specifics as to which tools were used in the hypothetical situations. Thus, this lack of information could have led to variable responses by the participants. Our response rate (34%) appeared low; however, we believe the response rate was actually higher than calculated because about 150 e-mail addresses returned mail server errors and were determined undeliverable. We estimated that another 10% of the e-mail addresses were no longer in use, because e-mail addresses tend to change frequently. We expect that our adjusted response rate would approach 40%, which is within the range (36% to 52%) for similarly administered Web-based surveys reviewed in the literature.²⁵⁻²⁷ Another potential limitation was that some of the surveys were not fully completed. We chose to include information on any question submitted, but this led to a variation in the number of responses for each survey item and to the number of responses we used in analysis.

In conclusion, our findings suggest that, in general, ATCs have made moderate progress in concussion assessment and management during the past 5 years. However, clinicians need to continue to incorporate and improve concussion protocols at their individual sites. Further research and education are important in evaluating and managing concussions. Clinicians should make a concerted effort to incorporate as many tools and methods as possible in order to obtain a complete picture of each individual's concussion. This will allow clinicians to make well-informed return-to-play decisions and will ultimately allow for safer participation for athletes. Future prospective studies involving interventions should allow us to more clearly investigate the role of SMCA in making safe return-to-play decisions after concussion.

REFERENCES

1. Guskiewicz KM, Cantu RC. The concussion puzzle: evaluation of sport-related concussion. *Am J Med Sports*. 2004;6:13-21.

2. Oliaro S, Anderson S, Hooker D. Management of cerebral concussion in sports: the athletic trainer's perspective. *J Athl Train*. 2001;36:257-262.
3. Cantu RC. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *J Athl Train*. 2001;36:244-248.
4. Durand P Jr, Adamson GJ. On-the-field management of athletic head injuries. *J Am Acad Orthop Surg*. 2004;12:191-195.
5. Guskiewicz KM, Bruce SL, Cantu RC, et al. National Athletic Trainers' Association position statement: management of sport-related concussion. *J Athl Train*. 2004;39:280-297.
6. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Clin J Sport Med*. 2005;15:48-55.
7. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001: recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med*. 2002;36:6-10.
8. Wojtyls EM, Hovda D, Landry G, et al. Current concepts: concussion in sports. *Am J Sports Med*. 1999;27:676-687.
9. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train*. 2001;36:263-273.
10. Ferrara MS, McCrea M, Peterson CL, Guskiewicz KM. A survey of practice patterns in concussion assessment and management. *J Athl Train*. 2001;36:145-149.
11. Special issue: concussion in sports. *Clin J Sport Med*. 2000;11(3).
12. Special issue: concussion in athletes. *J Athl Train*. 2001;36(3).
13. McCrea M, Randolph C, Kelly JP. *Standardized Assessment of Concussion (SAC): Manual for Administration, Scoring and Interpretation*. 2nd ed. Waukesha, WI: CNS Inc; 2000.
14. Practice parameter: the management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee. *Neurology*. 1997;48:581-585.
15. Colorado Medical Society Sports Medicine Committee. Guidelines for the management of concussion in sports. *Proceedings of the Mild Brain Injury in Sports Summit*. Dallas, TX: National Athletic Trainers' Association; 1994: 106-109.
16. Centers for Disease Control and Prevention. Sports-related recurrent brain injuries: United States. *MMWR Morbid Mortal Wkly Rep*. 1997;46:224-227.
17. Bray C. *1982-2003 Sports Sponsorship and Participation Report*. Indianapolis, IN: National Collegiate Athletic Association; 2004.
18. Gerberich SG, Priest JD, Boen JR, Straub CP, Maxwell RE. Concussion incidences and severity in secondary school varsity football players. *Am J Public Health*. 1983;73:1370-1375.
19. Barth JT, Alves W, Ryan T, et al. Mild head injury in sports: neuropsychological sequela and recovery of function. In: Levin H, Eisenberg H, Denton A, eds. *Mild Head Injury*. New York, NY: Oxford University Press; 1989:257-275.
20. Guskiewicz KM, Weaver NL, Padua DA, Garrett WE Jr. Epidemiology of concussion in collegiate and high school football players. *Am J Sports Med*. 2000;28:643-650.
21. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med*. 2004;14:13-17.
22. Guskiewicz KM, McCrea M, Marshall SW, et al. Cumulative effects of recurrent concussion in collegiate football players: the NCAA Concussion Study. *JAMA*. 2003;290:2549-2555.
23. Collins MW, Field M, Lovell MR, et al. Relationship between postconcussion headache and neuropsychological test performance in high school athletes. *Am J Sports Med*. 2003;31:168-173.
24. McCrory P. Preparticipation assessment for head injury. *Clin J Sport Med*. 2004;14:139-144.
25. Umefjord G, Petersson G, Hamberg K. Reasons for consulting a doctor on the Internet: Web survey of users of an Ask the Doctor service. *J Med Internet Res*. 2003;5:e26.
26. Romanelli F, Ryan M, Smith KM. Board of Pharmaceutical Specialties-certified faculty: a survey of United States colleges of pharmacy. *Pharmacotherapy*. 2004;24:395-400.
27. Braithwaite D, Emery J, De Lusignan S, Sutton S. Using the Internet to conduct surveys of health professionals: a valid alternative? *Fam Pract*. 2003;20:545-551.

SUPPLEMENT

Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004

P McCrory, K Johnston, W Meeuwisse, M Aubry, R Cantu, J Dvorak, T Graf-Baumann, J Kelly, M Lovell, P Schamasch

See end of article for authors' affiliations

Br J Sports Med 2005;39(Suppl 1):i78-i86. doi: 10.1136/bjism.2005.018614

Correspondence to:
Associate Professor
McCrory, PO Box 93,
Shoreham, Victoria 3916,
Australia; paulmccr@
bigpond.net.au

Accepted 7 February 2005

In November 2001, the 1st International Symposium on Concussion in Sport was held in Vienna, Austria to provide recommendations for the improvement of safety and health of athletes who suffer concussive injuries in ice hockey, football (soccer), and other sports. The 2nd International Symposium on Concussion in Sport was organised by the same group and held in Prague, Czech Republic in November 2004. It resulted in a revision and update of the Vienna consensus recommendations, which are presented here.

This paper is a revision and update of the Vienna consensus recommendations developed after the 1st International Symposium on Concussion in Sport.¹ The Prague agreement statement is designed to build on the principles outlined in the original Vienna document and to develop further conceptual understanding of this problem. This document is developed for use by doctors, therapists, health professionals, coaches, and other people involved in the care of injured athletes, whether at the recreational, elite, or professional level.

BACKGROUND PERSPECTIVE

In November 2001, the 1st International Symposium on Concussion in Sport was held in Vienna, Austria. This meeting was organised by the International Ice Hockey Federation (IIHF) in partnership with the Federation Internationale de Football (FIFA) and the International Olympic Committee Medical Commission (IOC). As part of the resulting mandate for the future, the need for leadership and updates was identified. To meet that mandate, the 2nd International Symposium on Concussion in Sport was organised by the same group and held in Prague, Czech Republic in November 2004.

The original aims of the symposia were to provide recommendations for the improvement of safety and health of athletes who suffer concussive injuries in ice hockey, football (soccer), and other sports. To this end a range of experts were invited to both meetings in order to address specific issues of epidemiology, basic and clinical science, injury grading systems, cognitive assessment, new research methods, protective equipment, management, prevention, and long term outcome. At the conclusion of the initial conference, a small group of experts were given a mandate by the conference delegates and organising bodies to draft a document describing the agreement position reached by those in attendance at that meeting. That document was co-published in the *British Journal of Sports Medicine*, *Clinical Journal of Sport Medicine*, and *Physician and Sportsmedicine*.¹

The wider interest base resulting from the first meeting and document was reflected by the expanded representation. New groups at the second meeting included trauma surgeons, sport psychologists, and others. This same group

has produced the current document as an update of the original Vienna consensus document and includes a sideline assessment form with a pocket sized summary card for use by clinicians.

This protocol represents a work in progress, and, as with all other recommendations or proposals, it must be updated as new information is added to the current state of the literature and understanding of this injury.

BACKGROUND ISSUES

Definition of concussion

Over 35 years ago, the Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons proposed a "consensus" definition of concussion.^{2,3} This definition was recognised as having a number of limitations in accounting for the common symptoms of concussion. In the Vienna document, a revised consensus definition was proposed as follows: "Sports concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces". Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be used in defining the nature of a concussive head injury include the following.

- (1) Concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an "impulsive" force transmitted to the head.
- (2) Concussion typically results in the rapid onset of short lived impairment of neurological function that resolves spontaneously.
- (3) Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.
- (4) Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.
- (5) Concussion is typically associated with grossly normal structural neuroimaging studies.

No changes were made to the definition by the Prague Group beyond noting that in some cases post-concussive symptoms may be prolonged or persistent.

First published in the main issue of *BJSM* in April (*Br J Sports Med* 2005;39:196-204).

Pathophysiological basis of concussion

At this time, there is no existing animal or other experimental model that accurately reflects a sporting concussive injury. It is noted that, in experimental models, of more severe injury a complex cascade of biochemical, metabolic, and gene expression changes occur.⁴ Whether similar metabolic changes occur in sports concussion, however, remains speculative at this time.⁵

Concussion grading scales

The Vienna recommendation that injury grading scales be abandoned in favour of combined measures of recovery in order to determine injury severity (and/or prognosis) and hence individually guide return to play decisions received continued support.

It was also noted that concussion severity can only be determined in retrospect after all concussion symptoms have cleared, the neurological examination is normal, and cognitive function has returned to baseline.⁶ There is limited published evidence that concussion injury severity correlates with the number and duration of acute concussion signs and symptoms and/or degree of impairment on neuropsychological testing.^{7–12} The development of validated injury severity scales continues in the published literature.¹³

Subtypes of concussion

One of the issues speculated on at the Vienna conference was whether concussion represents a unitary phenomenon with a linear spectrum of injury severity or whether different concussion subtypes exist. These subtypes may represent differences in clinical manifestations (confusion, memory problems, loss of consciousness), anatomical localisation (such as cerebral versus brainstem), biomechanical impact (rotational versus linear force), genetic phenotype (apolipoprotein epsilon 4 (ApoE4) positive versus ApoE4 negative), neuropathological change (structural injury versus no structural injury), or an as yet undefined difference. These factors may operate independently or interact with each other. It is clear that the variations in clinical outcome with the same impact force require a more sophisticated approach to the understanding of this phenomenon than currently available.¹⁴

Significance of loss of consciousness

The traditional approach to severe traumatic brain injury using loss of consciousness as the primary measure of injury severity has acknowledged limitations in assessing the severity of sporting concussive injury. Findings in this field describe association of loss of consciousness with specific early deficits but does not necessarily imply severity.^{13 15} As such the presence of loss of consciousness as a symptom would not necessarily classify the concussion as complex (see below).

Significance of amnesia

There is renewed interest in the role of post-traumatic amnesia and its role as a surrogate measure of injury severity.^{13 16} Published evidence suggests that the nature, burden, and duration of the clinical post-concussive symptoms may be more important than the presence or duration of amnesia alone.^{8 15 17} Further it must be noted that retrograde amnesia varies with the time of measurement after the injury and hence is poorly reflective of injury severity.^{18 19}

Paediatric concussive injury

The general recommendations outlined in the Vienna document were originally designed for the management of adult sporting concussion. Agreement was reached, however,

that identified those recommendations as relevant and useful to management of children as well. In broad terms it was felt that the recommendations should be applicable to children (defined as 5–18 years of age) whereby children should not be allowed to return to play or training until clinically completely symptom free. In addition, the concept of “cognitive rest” was introduced with special reference to a child’s need to limit exertion with activities of daily living and to limit scholastic activities while symptomatic. There was also a recognition by the group that additional research is needed to better clarify the potential differences between adults and children with regard to recovery from injury and to develop cognitive assessment tools that better evaluate the younger athlete.

Formal cognitive assessment is currently problematic until late teen years because of the continuing cognitive maturation that occurs during this period, which, in turn, makes the utility of comparison with either the person’s own baseline performance or population norms limited.²⁰

Because of the different physiological response during childhood to head trauma, a conservative return to play approach is recommended. It may be appropriate to extend the amount of time of asymptomatic rest and/or the length of the graded exertion in children and adolescents. Future research is needed in this area.

A NEW CLASSIFICATION OF CONCUSSION IN SPORT

Historically, concussions have been classified with a number of different grading systems. In the Vienna Statement, this approach was abandoned. One of the key developments by the Prague Group is the understanding that concussion may be categorised for management purposes as either simple or complex.

Simple concussion

In simple concussion, an athlete suffers an injury that progressively resolves without complication over 7–10 days. In such cases, apart from limiting playing or training while symptomatic, no further intervention is required during the period of recovery, and the athlete typically resumes sport without further problem. Formal neuropsychological screening does not play a role in these circumstances, although mental status screening should be a part of the assessment of all concussed athletes. Simple concussion represents the most common form of this injury and can be appropriately managed by primary care physicians or by certified athletic trainers working under medical supervision.²¹ The cornerstone of management is rest until all symptoms resolve and then a graded programme of exertion before return to sport. All concussions mandate evaluation by a medical doctor.

Complex concussion

Complex concussion encompasses cases where athletes suffer persistent symptoms (including persistent symptom recurrence with exertion), specific sequelae (such as concussive convulsions), prolonged loss of consciousness (more than one minute), or prolonged cognitive impairment after the injury. This group may also include athletes who suffer multiple concussions over time or where repeated concussions occur with progressively less impact force. In this group, there may be additional management considerations beyond simple return to play advice. Formal neuropsychological testing and other investigations should be considered in complex concussions. It is envisaged that such athletes would be managed in a multidisciplinary manner by doctors with specific expertise in the management of concussive injury such as a sport medicine doctor with experience in concussion, sports neurologist, or neurosurgeon.

CLINICAL ISSUES

Pre-participation physical examination

Recognising the importance of concussion history, and appreciating the fact that many athletes will not recognise all the concussions they may have suffered in the past, a detailed concussion history is of value.^{22–25} Such a history may identify athletes that fit into the “complex” category outlined above and provides an opportunity for the doctor to educate the athlete about the significance of concussive injury.

A structured concussion history should include specific questions as to previous symptoms of a concussion, not just perceived number of past concussions. It is also worth noting that dependence on the recall of concussive injuries by team mates or coaches has been shown to be unreliable.²² The clinical history should also include information about all previous head, face, or neck injuries, as these may have clinical relevance to the present injury. It is worth emphasising that, with maxillofacial and neck injuries, co-existent concussive injuries may be missed unless specifically assessed. Specific questions pertaining to disproportionate impact versus symptom severity matching may alert the clinician to a progressively increasing vulnerability to injury.

As part of the clinical history, it is advised that details on protective equipment used at the time of injury be sought, both for recent and remote injuries. The benefit of this approach allows modification and optimisation of protective behaviour and an opportunity for education.

It is specifically recommended that:

- (1) both a baseline cognitive assessment (such as the Prague SCAT test in the absence of computerised neuropsychological testing) and symptom score is performed as part of the pre-participation evaluation;
- (2) although formal baseline neuropsychological screening may be beyond the resources of many sports or individual athletes, it is recommended that, in organised high risk sports, consideration be given to having cognitive evaluation regardless of the age or level of performance.

Signs and symptoms of acute concussion

The suspected diagnosis of sports concussion made on the sideline is applicable to both medical and non-medical personnel and can include clinical symptoms, physical signs, cognitive impairment, and/or loss of consciousness.

If any one of the following symptoms or problems is present, a head injury should be suspected and appropriate management instituted. These will be summarised on the sideline concussion assessment tool (SCAT) that accompanies this document (fig 1).

- (a) Cognitive features (see below)
 - Unaware of period, opposition, score of game
 - Confusion
 - Amnesia
 - Loss of consciousness
- (b) Typical symptoms (see SCAT (fig 1) for standard symptom scale); other symptoms such as a subjective feeling of slowness and fatigue after an impact may indicate that a concussion has occurred or has not fully resolved.²⁶
 - Headache or pressure in the head
 - Balance problems or dizziness
 - Nausea

- Feeling “dinged”, “foggy”, stunned, or “dazed”
- Visual problems—for example, seeing stars or flashing lights, double vision
- Hearing problems—for example, ringing in the ears
- Irritability or emotional changes

(c) Physical signs

- Loss of consciousness/impaired conscious state
- Poor coordination or balance
- Concussive convulsion/impact seizure
- Gait unsteadiness/loss of balance
- Slow to answer questions or follow directions
- Easily distracted, poor concentration
- Displaying inappropriate emotions—for example, laughing, crying
- Vomiting
- Vacant stare/glassy eyed
- Slurred speech
- Personality changes
- Inappropriate playing behaviour—for example, running in the wrong direction
- Significantly decreased playing ability

Sideline evaluation of cognitive function is an essential component in the assessment of this injury. Brief neuropsychological test batteries that assess attention and memory function have been shown to be practical and effective. Such tests include the Maddocks questions²⁷ and the Standardised assessment of concussion.²⁸ It is worth noting that standard orientation questions—for example, time, place, person—have been shown to be unreliable in the sporting situation when compared with memory assessment.^{27–29}

It is recognised, however, that abbreviated testing paradigms are designed for rapid concussion evaluation on the sidelines and are not meant to replace comprehensive neuropsychological testing, which is sensitive enough to detect subtle deficits that may exist beyond the acute episode, nor should they be used as a stand alone tool for the ongoing management of sports concussions. It should also be recognised that the appearance of symptoms may be delayed several hours after a concussive episode.

Convulsive and motor phenomena

A variety of acute motor phenomena—for example, tonic posturing—or convulsive movements may accompany a concussion.^{30–31} Although dramatic, these clinical features are generally benign and require no specific management beyond the standard treatment for the underlying concussive injury.

Development of the sport concussion assessment tool (SCAT)

Figure 1 outlines the SCAT. The intent was to create a standardised tool that could be used for patient education as well as for physician assessment of sports concussion. The SCAT was developed by combining the following existing tools into a new standardised tool:

- (1) Sideline evaluation for concussion.^{28–29}
- (2) Management of concussion sports palm card; American Academy of Neurology and the Brain Injury Association.³²
- (3) Standardised assessment of concussion.³³
- (4) Sideline concussion check; UPMC, Thinksafe, Sports Medicine New Zealand Inc and the Brain Injury Association.

A

This tool represents a standardized method of evaluating people after concussion in sport. This Tool has been produced as part of the Summary and Agreement Statement of the Second International Symposium on Concussion in Sport, Prague 2004

Sports concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an 'impulsive' force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.
3. Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.
4. Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.
5. Concussion is typically associated with grossly normal structural neuroimaging studies.

Post Concussion Symptoms

Ask the athlete to score themselves based on how they feel now. It is recognized that a low score may be normal for some athletes, but clinical judgment should be exercised to determine if a change in symptoms has occurred following the suspected concussion event.

It should be recognized that the reporting of symptoms may not be entirely reliable. This may be due to the effects of a concussion or because the athlete's passionate desire to return to competition outweighs their natural inclination to give an honest response.

If possible, ask someone who knows the athlete well about changes in affect, personality, behavior, etc.

Remember, concussion should be suspected in the presence of ANY ONE or more of the following:

- Symptoms (such as headache), or
- Signs (such as loss of consciousness), or
- Memory problems

Any athlete with a suspected concussion should be monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

For more information see the "Summary and Agreement Statement of the Second International Symposium on Concussion in Sport" in the: Clinical Journal of Sport Medicine 2005; xx(xx): xxx-x British Journal of Sports Medicine 2005; xx(xx): xxx-x Neurosurgery 2005; ; xx(xx): xxx-x Physician and Sportsmedicine 2005; xx(xx): xxx-x This tool may be copied for distribution to teams, groups and organizations.



The SCAT Card (Sport Concussion Assessment Tool) Athlete Information

What is a concussion? A concussion is a disturbance in the function of the brain caused by a direct or indirect force to the head. It results in a variety of symptoms (like those listed below) and may, or may not, involve memory problems or loss of consciousness.

How do you feel? You should score yourself on the following symptoms, based on how you feel now.

Post Concussion Symptom Scale

| | None | | Moderate | | Severe | |
|-----------------------------|------|---|----------|---|--------|---|
| Headache | 0 | 1 | 2 | 3 | 4 | 5 |
| "Pressure in head" | 0 | 1 | 2 | 3 | 4 | 5 |
| Neck Pain | 0 | 1 | 2 | 3 | 4 | 5 |
| Balance problems or dizzy | 0 | 1 | 2 | 3 | 4 | 5 |
| Nausea or vomiting | 0 | 1 | 2 | 3 | 4 | 5 |
| Vision problems | 0 | 1 | 2 | 3 | 4 | 5 |
| Hearing problems / ringing | 0 | 1 | 2 | 3 | 4 | 5 |
| "Don't feel right" | 0 | 1 | 2 | 3 | 4 | 5 |
| Feeling "dinged" or "dazed" | 0 | 1 | 2 | 3 | 4 | 5 |
| Confusion | 0 | 1 | 2 | 3 | 4 | 5 |
| Feeling slowed down | 0 | 1 | 2 | 3 | 4 | 5 |
| Feeling like "in a fog" | 0 | 1 | 2 | 3 | 4 | 5 |
| Drowsiness | 0 | 1 | 2 | 3 | 4 | 5 |
| Fatigue or low energy | 0 | 1 | 2 | 3 | 4 | 5 |
| More emotional than usual | 0 | 1 | 2 | 3 | 4 | 5 |
| Irritability | 0 | 1 | 2 | 3 | 4 | 5 |
| Difficulty concentrating | 0 | 1 | 2 | 3 | 4 | 5 |
| Difficulty remembering | 0 | 1 | 2 | 3 | 4 | 5 |

(follow up symptoms only)

| | | | | | | |
|--------------------------|---|---|---|---|---|---|
| Sadness | 0 | 1 | 2 | 3 | 4 | 5 |
| Nervous or Anxious | 0 | 1 | 2 | 3 | 4 | 5 |
| Trouble falling asleep | 0 | 1 | 2 | 3 | 4 | 5 |
| Sleeping more than usual | 0 | 1 | 2 | 3 | 4 | 5 |
| Sensitivity to light | 0 | 1 | 2 | 3 | 4 | 5 |
| Sensitivity to noise | 0 | 1 | 2 | 3 | 4 | 5 |
| Other: _____ | 0 | 1 | 2 | 3 | 4 | 5 |

What should I do?

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

Signs to watch for:

Problems could arise over the first 24-48 hours. You should not be left alone and must go to a hospital at once if you:

- Have a headache that gets worse
- Are very drowsy or can't be awakened (woken up)
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused; are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on your feet; have slurred speech




Remember, it is better to be safe. Consult your doctor after a suspected concussion.

What can I expect?

Concussion typically results in the rapid onset of short-lived impairment that resolves spontaneously over time. You can expect that you will be told to rest until you are fully recovered (that means resting your body and your mind). Then, your doctor will likely advise that you go through a gradual increase in exercise over several days (or longer) before returning to sport.

Figure 1 Sport concussion assessment tool (SCAT).

B

The SCAT Card

(Sport Concussion Assessment Tool)
Medical Evaluation

Name: _____ Date: _____

Sport/Team: _____ Mouth guard? Y N

1) SIGNS

Was there loss of consciousness or unresponsiveness? Y N
 Was there seizure or convulsive activity? Y N
 Was there a balance problem / unsteadiness? Y N

2) MEMORY

Modified Maddocks questions (check correct)

At what venue are we? ____; Which half is it? ____; Who scored last? ____
 What team did we play last? ____; Did we win last game? ____?

3) SYMPTOM SCORE

Total number of positive symptoms (from reverse side of the card) = _____

4) COGNITIVE ASSESSMENT

5 word recall

| | (Examples) | Immediate | Delayed |
|--------|------------|-----------|-----------------------------|
| | | | (after concentration tasks) |
| Word 1 | cat | _____ | _____ |
| Word 2 | pen | _____ | _____ |
| Word 3 | shoe | _____ | _____ |
| Word 4 | book | _____ | _____ |
| Word 5 | car | _____ | _____ |

Months in reverse order:
 Jun-May-Apr-Mar-Feb-Jan-Dec-Nov-Oct-Sep-Aug-Jul (circle incorrect)
or

Digits backwards (check correct)

| | | |
|-------------|-------------|-------|
| 5-2-8 | 3-9-1 | _____ |
| 6-2-9-4 | 4-3-7-1 | _____ |
| 8-3-2-7-9 | 1-4-9-3-6 | _____ |
| 7-3-9-1-4-2 | 5-1-8-4-6-8 | _____ |

Ask delayed 5-word recall now

5) NEUROLOGIC SCREENING

| | Pass | Fail |
|-----------------------|-------|-------|
| Speech | _____ | _____ |
| Eye Motion and Pupils | _____ | _____ |
| Pronator Drift | _____ | _____ |
| Gait Assessment | _____ | _____ |

Any neurologic screening abnormality necessitates formal neurologic or hospital assessment

6) RETURN TO PLAY

Athletes should not be returned to play the same day of injury. When returning athletes to play, they should follow a stepwise symptom-limited program, with stages of progression. For example:

1. rest until asymptomatic (physical and mental rest)
2. light aerobic exercise (e.g. stationary cycle)
3. sport-specific training
4. non-contact training drills (start light resistance training)
5. full contact training after medical clearance
6. return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur. Resistance training should only be added in the later stages. Medical clearance should be given before return to play.

Instructions:
 This side of the card is for the use of medical doctors, physiotherapists or athletic therapists. In order to maximize the information gathered from the card, it is strongly suggested that all athletes participating in contact sports complete a baseline evaluation prior to the beginning of their competitive season. This card is a suggested guide only for sports concussion and is not meant to assess more severe forms of brain injury. **Please give a COPY of this card to the athlete for their information and to guide follow-up assessment.**

Signs:
 Assess for each of these items and circle Y (yes) or N (no).

Memory:
 Select any 5 words (an example is given). Avoid choosing related words such as "dark" and "moon" which can be recalled by means of word association. Read each word at a rate of one word per second. The athlete should not be informed of the delayed testing of memory (to be done after the reverse months and/or digits). Choose a different set of words each time you perform a follow-up exam with the same candidate.

Concentration / Attention:
 Ask the athlete to recite the months of the year in reverse order, starting with a random month. Do not start with December or January. Circle any months not recited in the correct sequence.

 For digits backwards, if correct, go to the next string length. If incorrect, read trial 2. Stop after incorrect on both trials.

Neurologic Screening:
 Trained medical personnel must administer this examination. These individuals might include medical doctors, physiotherapists or athletic therapists. Speech should be assessed for fluency and lack of slurring. Eye motion should reveal no diplopia in any of the 4 planes of movement (vertical, horizontal and both diagonal planes). The pronator drift is performed by asking the patient to hold both arms in front of them, palms up, with eyes closed. A positive test is pronating the forearm, dropping the arm, or drift away from midline. For gait assessment, ask the patient to walk away from you, turn and walk back.

Return to Play:
 A structured, graded exertion protocol should be developed; individualized on the basis of sport, age and the concussion history of the athlete. Exercise or training should be commenced only after the athlete is clearly asymptomatic with physical and cognitive rest. Final decision for clearance to return to competition should ideally be made by a medical doctor.

For more information see the "Summary and Agreement Statement of the Second International Symposium on Concussion in Sport" in the:
Clinical Journal of Sport Medicine 2005; in press
British Journal of Sports Medicine 2005; **39**:196-204
Neurosurgery 2005; in press
Physician and Sportsmedicine 2005; in press

Figure 1 Continued.

- (5) McGill abbreviated concussion evaluation (ACE) (unpublished).
- (6) National Hockey League physician evaluation form (unpublished).
- (7) The UK Jockey Club assessment of concussion.³⁴
- (8) Maddocks questions.²⁷

The authors gave input through a process of collaboration and iterative review. The SCAT was evaluated for face and content validity on the basis of scientific literature³⁵ and clinical experience of the authors. The memory questions, specifically, were modified from the validated Maddocks questions to make these questions less football-specific.²⁷

INVESTIGATIONAL ISSUES

Neuropsychological assessment after concussion

The application of neuropsychological testing in concussion has been shown to be of value and continues to contribute significant information in concussion evaluation.^{10 11 36 37} It has been shown that cognitive recovery may precede or follow clinical symptom resolution, suggesting that the assessment of cognitive function should be an important component in any return to play protocol.¹² It must be emphasised, however, that neuropsychological assessment should not be the sole basis of a return to play decision but rather be seen as an aid to the clinical decision making. Although neuropsychological screening may be performed or interpreted by other healthcare professionals, the final return to play decision should remain a medical one in which a multidisciplinary approach has been taken.

Neuropsychological testing should not be performed while the athlete is symptomatic because it adds nothing to return to play decisions, and it may contaminate the testing process by allowing practice effects to confound the results. In certain cases, however, serial follow up after the injury is valuable, both as a means to encourage athlete compliance and for comparison purposes.

Over-riding principles common to all neuropsychological test batteries is the need for and benefit of baseline testing before injury and serial follow up. Recent work with computerised platforms, however, suggests that performance variability may be a key measure for acute concussion diagnosis even in the absence of a baseline test. This strategy is currently the subject of research. Inherent problems with most neuropsychological tests include the normal ranges, sensitivity and specificity of tests, and practice or learning effect, as well as the observation that players may return to baseline while still symptomatic.³⁶ Computerised testing using infinitely variable test paradigms may overcome some of these concerns. Computerised testing also has the logistical advantage that the tests may be administered by the team doctor (or be web based) rather than requiring a neuropsychologist for a formal assessment. The strengths and weaknesses of such testing have been reviewed.³⁷

It is recommended that neuropsychological testing remain one of the cornerstones of concussion evaluation in complex concussion. It is not currently regarded as important in the evaluation of simple concussion. Although this modality contributes significantly to both the understanding of the injury and management of the individual athlete, neuropsychological testing should not be the sole basis of management decisions, either for continued time out or return to play decisions.

Objective balance assessment

Balance testing, either with computerised platforms or clinical assessment, may offer additional information in concussed athletes and may be used as a part of the overall

concussion management strategy, particularly where symptoms or signs indicate a balance component.³⁸

Neuroimaging

It was recognised in the Vienna agreement document that conventional structural neuroimaging is usually normal in concussive injury. Given that caveat, the following suggestions are made. Computed tomography (or, where available, magnetic resonance imaging) of the brain contributes little to concussion evaluation, but should be used whenever suspicion of an intracerebral structural lesion exists. Examples of such situations may include prolonged disturbance of conscious state, focal neurological deficit, or worsening symptoms.

Newer structural magnetic resonance imaging modalities, including gradient echo, perfusion, and diffusion weighted imaging, have greater sensitivity for structural abnormalities, but the lack of published studies as well as the absence of pre-injury neuroimaging data limits the usefulness of this approach in clinical management at the present time.

In addition, the predictive value of various magnetic resonance imaging abnormalities that may be incidentally discovered is not established. Although there have been some compelling findings with promising new functional imaging technologies—for example, positron emission tomography (PET), single photon emission computed tomography (SPECT), and functional magnetic resonance imaging (fMRI)—they are still at early stages of development.^{39–41}

Although neuroimaging may play a part in the assessment of complex sports concussions or more severe brain injury, it is not essential for simple concussive injury.

Genetic testing

Genotyping has been shown to be of benefit in traumatic brain injury. Published studies have shown that ApoE4 is a risk factor for adverse outcome after all levels of brain injury.^{42–48} Similarly ApoE4 has been shown to be a risk factor for the development of chronic traumatic encephalopathy in boxers.⁴⁹ The significance of ApoE4 in sports concussion risk or injury outcome is unclear. Other published studies have noted the association of a particular calcium subunit gene abnormality with brain swelling after minor head trauma.⁵⁰ Although still in the early stages of understanding, routine genetic screening cannot be recommended at the present time. Furthermore, doctors are urged to be mindful of the ethical implications of such testing.

Experimental concussion assessment modalities

Different electrophysiological recording techniques such as evoked response potential and electroencephalogram have shown reproducible abnormalities in the post-concussive state.^{51–53} However, not all studies reliably differentiated concussed athletes from controls.^{54–57} The clinical significance of these changes remains to be established.

In addition, biochemical serum markers of brain injury (including S-100b, NSE, MBP, GFAP) have been proposed as means by which cellular damage may be detected if present.^{58 59} However, there is currently not sufficient evidence to justify the use of these markers clinically.

CONCUSSION MANAGEMENT

Acute injury

When a player shows any symptoms or signs of a concussion, the following should be applied.

- (1) The player should not be allowed to return to play in the current game or practice.

- (2) The player should not be left alone, and regular monitoring for deterioration is essential over the initial few hours after injury.
- (3) The player should be medically evaluated after the injury.
- (4) Return to play must follow a medically supervised stepwise process.

A player should never return to play while symptomatic. "When in doubt, sit them out!"

Return to play protocol

As described above, most injuries will be simple concussions, and such injuries recover spontaneously over several days. In these situations, it is expected that an athlete will proceed rapidly through the stepwise return to play strategy.⁶⁰

During this period of recovery in the first few days after an injury, it is important to emphasise to the athlete that physical and cognitive rest is required. Activities that require concentration and attention may exacerbate the symptoms and as a result delay recovery.

The return to play after a concussion follows a stepwise process:

- (1) No activity, complete rest. Once asymptomatic, proceed to level 2.
- (2) Light aerobic exercise such as walking or stationary cycling, no resistance training.
- (3) Sport specific exercise—for example, skating in hockey, running in soccer; progressive addition of resistance training at steps 3 or 4.
- (4) Non-contact training drills.
- (5) Full contact training after medical clearance.
- (6) Game play.

With this stepwise progression, the athlete should continue to proceed to the next level if asymptomatic at the current level. If any post-concussion symptoms occur, the patient should drop back to the previous asymptomatic level and try to progress again after 24 hours.

In cases of complex concussion, the rehabilitation will be more prolonged, and return to play advice will be more circumspect. It is envisaged that complex cases should be managed by doctors with a specific expertise in the management of such injuries.

An additional consideration in return to play is that concussed athletes should not only be symptom-free but also should not be taking any pharmacological agents/drugs that may affect or modify the symptoms of concussion. If antidepressant treatment is started during the management of a complex concussion, the decision to return to play while still receiving such medication must be considered carefully by the clinician concerned (see below).

In professional sport, where there are team doctors experienced in concussion management as well as access to immediate—that is, sideline—neurocognitive assessment, return to play management is often more rapid, but it must still follow the same basic principles, namely full clinical and cognitive recovery before consideration of return to play.

Role of pharmacological treatment

Pharmacological treatment in sports concussion may be applied in two distinct situations: (a) management of specific symptoms—for example, sleep disturbance, anxiety—in complex concussion; (b) to modify the underlying pathophysiology of the condition with the aim of shortening the duration of the concussion symptomatology.⁶¹

In broad terms, this approach to management should be only considered in complex sports concussions and by clinicians experienced in concussion management.

Sports psychology

In addition, sport psychology approaches may have potential application in this injury, particularly in complex concussion.⁶² Care givers are also encouraged to evaluate the concussed athlete for affective symptoms such as depression as these may be common in concussion.⁶⁰

OTHER ISSUES

Prevention

There is no clinical evidence that currently available protective equipment will prevent concussion. In certain sports, protective equipment may prevent other forms of head injury which may be an important issue for those sports.

Consideration of rule changes—for example, no head checking in ice hockey—to reduce the head injury rate may be appropriate where a clear-cut mechanism is implicated in a particular sport. Similarly, rule enforcement is a critical aspect of such approaches, and referees play an important role.

An important consideration in the use of protective equipment is the concept of risk compensation.⁶³ This is where the use of protective equipment results in behavioural change such as the adoption of more dangerous playing techniques, which can result in a paradoxical increase in injury rates. This may be a particular concern in child and adolescent athletes in whom head injury rates are often higher than in adult athletes.⁶⁴

Medicolegal considerations

Although agreement exists on the principal messages conveyed in this document, we acknowledge that the science of concussion is at an early stage, and therefore management and return to play decisions remain largely in the realm of clinical judgment on an individualised basis.

Education

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues, and the general public is a mainstay of progress in this field. Athletes and their healthcare providers must be educated about the detection of concussion, its clinical features, assessment techniques, and principles of safe return to play. Methods to improve education including web based resources, educational videos, and international outreach programmes such as Think First (www.thinkfirst.ca) are important in delivering the message. In addition, concussion working groups plus the support and endorsement of enlightened sport groups such as FIFA, IOC, and IIHF who initiated this endeavour have enormous value and must be pursued vigorously.

The promotion of fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly coaches, parents, and managers play an important part in ensuring that these values are implemented on the field of play.

Research methods

A number of research protocols and data evaluating concussion injury assessment, injury susceptibility, and brain function after injury were presented at both the Vienna and Prague conferences. Although they offer great potential for injury assessment, all of these techniques must be considered experimental at this time. Elite and professional teams are well placed to contribute to these efforts through athlete

recruitment for studies showing the scientific value of such approaches.

Such research is essential in contributing to the science of concussion and will potentially provide valuable information for such important issues as clinical management, return to play guidelines, and long term outcome. Therefore research should be continued and encouraged, by both academics and sporting organisations.

Future

The issue of sports concussion management is continually evolving, and the usefulness of expert consensus in establishing a standard of care has been demonstrated by the Vienna agreement. The consensus group established at that meeting has provided continuing leadership in this field based on the initial mandate established at that time.¹ We expect that this Prague agreement will be revised and updated at future meetings.

Authors' affiliations

M Aubry, Chief Medical Officer, International Ice Hockey Federation

R Cantu, Department of Surgery, Chief Neurosurgery Service and Director, Sports Medicine Service, Emerson Hospital, Concord, MA, USA; Medical Director, National Center for Catastrophic Sports Injury Research, Chapel Hill, NC, USA

J Dvorak, Chairman, FIFA Medical Research and Assessment Center (F-MARC); Chairman, Department of Neurology, Schulthess Clinic, Zurich, Switzerland

T Graf-Baumann, Director, Office for Science Management, Administration and Scientific Director, German Society for Musculo-Skeletal Medicine and Pain Therapy, FIFA Medical Research and Assessment Center (F-MARC), Teningen, Germany

K M Johnston, Neurosurgeon/Concussion Consultant, Departments of Neurosurgery, Kinesiology & Physical Education, McGill University; Director, Concussion Program, McGill Sport Medicine Centre, Montreal, Canada

J P Kelly, Professor of Neurosurgery and Rehabilitation Medicine, University of Colorado School of Medicine, Denver, CO, USA

M Lovell, Director, Sports Medicine Concussion Program, University of Pittsburgh; Co-director, National Hockey League Neuropsychology Program, Pittsburgh, PA, USA

P McCrory, Associate Professor, Center for Health, Exercise and Sports Medicine & The Brain Research Institute, University of Melbourne, Melbourne, Australia

W Meeuwisse, Professor and Medical Director, University of Calgary Sport Medicine Centre; Sport Injury Epidemiologist, National Hockey League, Calgary, Alberta, Canada

P Schamasch, Medical and Scientific Director, International Olympic Committee, Lausanne, Switzerland

Competing interests: Dr Lovell is a shareholder of ImPACT, a neuropsychological testing programme. No other author has any declared conflict of interest or concussion industry affiliation.

This article will also be published in the April 2005 issues of the *Clinical Journal of Sport Medicine*, *Physician and Sportsmedicine*, and *Neurosurgery*.

REFERENCES

- Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001. *Phys Sportsmed* 2002;**30**:57–62 (also co-published in *Br J Sports Med* 2002;**36**:3–7 and *Clin J Sport Med* 2002;**12**:6–12).
- Congress of Neurological Surgeons. Committee on Head Injury Nomenclature: glossary of head injury. *Clin Neurosurg* 1966;**12**:386–94.
- Johnston K, McCrory P, Mohtadi N, et al. Evidence based review of sport-related concussion: clinical science. *Clin J Sport Med* 2001;**11**:150–60.
- Hovda D, Lee S, Smith M, von Stuck S, et al. The neurochemical and metabolic cascade following brain injury: moving from animal models to man. *J Neurotrauma* 1995;**12**:903–6.
- McIntosh TK, Smith DH, Meaney DF, et al. Neuropathological sequelae of traumatic brain injury: relationship to neurochemical and biomechanical mechanisms. *Lab Invest* 1996;**74**:315–42.
- Cantu RC. Concussion severity should not be determined until all postconcussion symptoms have abated. *Lancet* 2004;**3**:437–8.
- Hinton-Bayre AD, Geffen G. Severity of sports-related concussion and neuropsychological test performance. *Neurology* 2002;**59**:1068–70.
- McCrory PR, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med* 2000;**10**:235–8.
- Mrazik M, Ferrara MS, Peterson CL, et al. Injury severity and neuropsychological and balance outcomes of four college athletes. *Brain Inj* 2000;**14**:921–31.
- Lovell MR, Collins MW, Iverson GL, et al. Recovery from mild concussion in high school athletes. *J Neurosurg* 2003;**98**:296–301.
- Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players [see comments]. *JAMA* 1999;**282**:964–70.
- Bleiberg J, Cernich A, Cameron K, et al. Duration of cognitive impairment after sports concussion. *Neurosurgery* 2004;**54**:1073–80.
- McCrory M, Kelly J, Randolph C, et al. Immediate neurocognitive effects of concussion. *Neurosurgery* 2002;**50**:1032–42.
- McCrory P, Johnston K, Meeuwisse W, et al. Evidence based review of sport related concussion: basic science. *Clin J Sport Med* 2001;**11**:160–6.
- Lovell M, Iverson G, Collins M, et al. Does loss of consciousness predict neuropsychological decrements after concussion. *Clin J Sport Med* 1999;**9**:193–8.
- Cantu RC. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *J Athl Train* 2001;**36**:244–8.
- Leninger B, Gramling S, Farrell A, et al. Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *J Neurol Neurosurg Psychiatry* 1990;**53**:293–6.
- Yarnell P, Lynch S. The 'ding': amnesic state in football trauma. *Neurology* 1973;**23**:196–7.
- Yarnell PR, Lynch S. Retrograde memory immediately after concussion. *Lancet* 1970;**1**:863–4.
- McCrory P, Collie A, Anderson V, et al. Can we manage sport-related concussion in children the same as adults? *Br J Sports Med* 2004;**38**:516–19.
- Guskiewicz K, Bruce S, Cantu R, et al. Recommendations on management of sport-related concussion: summary of the national Athletic Trainers' Association position statement. *Neurosurgery* 2004;**55**:891–2.
- McCrory P. Preparticipation assessment for head injury. *Clin J Sport Med* 2004;**14**:139–44.
- Johnston KM, Lassonde M, Pito A. A contemporary neurosurgical approach to sport-related head injury: The McGill concussion protocol. *J Am Coll Surg* 2001;**51**:5–24.
- Delaney JS, Lacroix VJ, Leclerc S, et al. Concussions during the 1997 Canadian Football League season. *Clin J Sport Med* 2000;**10**:9–14.
- Delaney J, Lacroix V, Leclerc S, et al. Concussions among university football and soccer players. *Clin J Sport Med* 2002;**12**:331–8.
- Iverson G, Gaetz M, Lovell M, et al. Relation between subjective foggiess and neuropsychological testing following concussion. *J Int Neuropsychol Soc* 2004;**10**:904–6.
- Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med* 1995;**5**:32–5.
- McCrory M, Kelly J, Randolph C, et al. Standardised assessment of concussion (SAC): on site mental status evaluation of the athlete. *J Head Trauma Rehabil* 1998;**13**:27–35.
- McCrory M, Kelly JP, Kluge J, et al. Standardized assessment of concussion in football players. *Neurology* 1997;**48**:586–8.
- McCrory P. Videoanalysis of the acute clinical manifestations of concussion in Australian rules football. In: *SMA/ACSP Annual Scientific Conference*; 1996. Canberra: SMA, 1996:214–15.
- McCrory P, Berkovic S. Videoanalysis of the motor and convulsive manifestations of concussion in acute sport related injury. *Neurology* 2000;**54**:1488–92.
- Kelly J, Rosenberg J. Diagnosis and management of concussion in sports. *Neurology* 1997;**48**:575–80.
- McCrory M, Randolph C, Kelly J. In: *The standardized assessment of concussion (SAC): manual for administration, scoring and interpretation*, 2nd ed. Waukesha, WI: CNS Inc, 2000.
- Turner M. Concussion and head injuries in horse racing. In: Turner M, ed. *The Jockey Club conference on head injury in sport*, 1998. London: The Jockey Club of England, 1998.
- Johnson K, McCrory P, Mohtadi N, et al. Evidence-based review of sports-related concussion: clinical science. *Clin J Sport Med* 2001;**11**:150–9.
- Grindel S, Lovell M, Collins M. The assessment of sport-related concussion: the evidence behind neuropsychological testing and management. *Clin J Sport Med* 2001;**11**:134–44.
- Collie A, Merouf P, Darby D. Computerized neuropsychological testing in sport. *Br J Sports Med* 2001;**35**:in press.
- Guskiewicz K. Postural stability assessment following concussion. *Clin J Sport Med* 2001;**11**:182–90.
- Johnston K, Pito A, Chankowsky J, et al. New frontiers in diagnostic imaging in concussive head injury. *Clin J Sport Med* 2001;**11**:166–76.
- Chen J, Johnston K, Frey S, et al. Functional abnormalities in symptomatic concussed athletes: an fMRI study. *Neuroimage* 2004;**22**:68–82.
- Kelly J, Jantzen B, Steinberg F, et al. A prospective functional MR imaging study of mild traumatic brain injury in college football players. *Am J Neuroradiol* 2004;**25**:738–45.
- Teasdale G, Nicol J, Murray G. Association of Apolipoprotein E polymorphism with outcome after head injury. *Lancet* 1997;**350**:1069–71.
- Friedman G, Froom P, Sazbon L, et al. Apolipoprotein E-epsilon 4 genotype predicts a poor outcome in survivors of traumatic brain injury. *Neurology* 1999;**52**:244–8.
- Gross R. APOE epsilon4 allele and chronic traumatic brain injury. *JAMA* 1997;**278**:2143.

- 45 **Katzman R**, Galasko DR, Saitoh T, *et al*. Apolipoprotein-epsilon4 and head trauma: synergistic or additive risks? [letter; comment]. *Neurology* 1996;**46**:889-91.
- 46 **Liberman J**, Stewart W, Wesnes K, *et al*. Apolipoprotein E epsilon4 and short term recovery from predominantly mild brain injury. *Neurology* 2002;**58**:1038-44.
- 47 **Nicoll JA**, Roberts GW, Graham DI. Apolipoprotein E epsilon 4 allele is associated with deposition of amyloid beta-protein following head injury [see comments]. *Nat Med* 1995;**1**:135-7.
- 48 **Nicoll JA**, Roberts GW, Graham DI. Amyloid beta-protein, APOE genotype and head injury. *Ann N Y Acad Sci* 1996;**777**:271-5.
- 49 **Jordan B**, Relkin N, Ravdin L. Apolipoprotein E epsilon 4 associated with chronic traumatic brain injury in boxing. *JAMA* 1997;**278**:136-40.
- 50 **Kors E**, Terwindt G, Vermeulen F, *et al*. Delayed cerebral edema and fatal coma after minor head trauma: role of the CACNA1A calcium channel subunit gene and relationship with familial hemiplegic migraine. *Ann Neurol* 2001;**49**:753-60.
- 51 **Dupuis F**, Johnston K, Lavoie M, *et al*. Concussion in athletes produces brain dysfunction as revealed by event related potentials. *Clin J Sport Med* 2005; in press.
- 52 **Gaetz M**, Goodman D, Weinberg H. Electrophysiological evidence for the cumulative effects of concussion. *Brain Inj* 2000;**14**:1077-88.
- 53 **Lavoie M**, Dupuis F, Johnston K, *et al*. Visual p300 effects beyond symptoms in concussed college athletes. *J Clin Exp Neuropsychol* 2004;**26**:55-73.
- 54 **Hinton-Bayre AD**, Geffen G, McFarland K. Mild head injury and speed of information processing: a prospective study of professional rugby league players. *J Clin Exp Neuropsychol* 1997;**19**:275-89.
- 55 **Clark CR**, O'Hanlon AP, Wright MJ, *et al*. Event-related potential measurement of deficits in information processing following moderate to severe closed head injury. *Brain inj* 1992;**6**:509-20.
- 56 **Cremona-Meytard SL**, Geffen GM. Visuospatial attention deficits following mild head injury in Australian rules football players. In: Hendy J, Caine D, Pfaff A, *et al*, eds. *The life cycle: development, maturation, senescence. Proceedings of the 16th Annual Brain Impairment Conference, 1993*. Sydney: Australian Academic Press, 1993:137-47.
- 57 **Cremona-Meytard SL**, Clark CR, Wright MJ, *et al*. Covert orientation of visual attention after closed head injury. *Neuropsychologia* 1992;**30**:123-32.
- 58 **Igebrigtsen T**, Romner B, Trumpy JH. Management of minor head injury: the value of early computed tomography and serum protein S-100 measurements. *J Clin Neurosci* 1997;**4**:29-34.
- 59 **Otto M**, Holthusen S, Bahn E, *et al*. Boxing and running lead to a rise in serum levels of S-100B protein. *Int J Sports Med* 2000;**21**:551-5.
- 60 **Johnston K**, Bloom G, Ramsay J, *et al*. Current concepts in concussion rehabilitation. *Curr Sports Med Rep* 2004;**3**:316-23.
- 61 **McCrory P**. Should we treat concussion pharmacologically? *Br J Sports Med* 2002;**36**:3-6.
- 62 **Bloom G**, Horton A, McCrory P, *et al*. Sport psychology and concussion: new impacts to explore. *Br J Sports Med* 2004;**38**:519-21.
- 63 **Hagel B**, Meeuwisse W. Risk compensation: a "side effect" of sport injury prevention? *Clin J Sport Med* 2004;**14**:193-6.
- 64 **Orchard J**, Wood T, Seward H, Broad A. Comparison of injuries in elite senior and junior Australian football. *J Sci Med Sport* 1998;**1**:83-8.

ORIGINAL PAPER

Recovery from sports concussion in high school and collegiate athletes

MICHAEL P. MCCLINCY^{1,2}, MARK R. LOVELL¹, JAMIE PARDINI¹,
MICHAEL W. COLLINS¹, & MOLLY K. SPORE¹

¹University of Pittsburgh Medical Center, Pittsburgh, PA, USA and ²Dartmouth College, Student, Department of Mathematics, Hanover, NH, USA

(Received 28 December 2004; accepted 11 August 2005)

Abstract

Introduction: Neuropsychological testing is a valuable tool in concussion diagnosis and management. ImPACT, a computerized neuropsychological testing program, consists of eight cognitive tasks and a 21-item symptom inventory.

Method: ImPACT was used to examine the cognitive performance of 104 concussed athletes at baseline, 2, 7 and 14 days post-injury. Dependent measures included composite scores from the ImPACT computerized test battery, as well as a total symptom score from the Post-Concussion Symptom Scale.

Results: Differences between baseline and day 2 post-injury scores were observed for all ImPACT composites (Verbal memory-VERM, visual memory-VISM, processing speed-PROC and reaction time-RT) as well as in total symptom score (SX). At day 7, concussed athletes continued to perform significantly poorer on VERM, VISM, RT and SX. At day 14, only VERM scores were significantly different from baseline.

Conclusions: Cognitive performance deficits in concussed athletes may persist to 7 and even to 14 days in some cases. In addition to symptom status, the athlete's post-concussion cognitive functioning should be considered when making return-to-play decisions.

Keywords: Concussion, sport, TBI

Introduction

American athletes suffer ~300 000 concussive injuries on a yearly basis and 19% of participants in contact sports such as football and rugby are likely to suffer a mild traumatic brain injury (TBI) during a season [1]. The majority of concussions occur at the high school level, where well over one million high school students participate in football. At the high school level, over 62 000 football players receive a concussive injury each year [2], whereas 34% of collegiate football players have been diagnosed with one concussion and 20% have been diagnosed with multiple concussions [3]. The frequency of this injury, as well as a lack in scientific understanding of recovery mechanisms and physiology, has led to increased attention from the sports medicine world.

The most hotly debated issue in sports concussion revolves around efforts to establish a scientifically grounded guide for return-to-play parameters, given that a second impact prior to recovery from an initial concussion can have deleterious effects. This idea is based on recent animal models which suggest that symptoms of sports concussion are likely related to acute metabolic dysfunction [4]. Post-traumatic hyperglycolysis and concomitant decreased cerebral blood flow have been implicated for the cause of this dysfunction. It has been hypothesized that metabolic dysfunction, until fully resolved, may heighten the athlete's neurological vulnerability if a subsequent trauma (even minor) is sustained [5]. The controversial second impact syndrome [6] and less severe, though potentially incapacitating post-concussion syndrome are two risks involved with returning an athlete to play

before complete recovery. Although long-term deficits in the form of post-concussion syndrome have been observed from a single concussive event [7], it is typically assumed that proper management of injury should lead to a good prognosis and minimal, if any, long-term neurological deficits. Therefore, the precise management of concussion is essential in safeguarding athletes from permanent cognitive impairment or even death.

A recent study published in the *Journal of the American Medical Association* examined the recovery times of concussed collegiate football players [8]. Ninety-four players were included in the study and were compared with 56 age-matched controls. The study's findings concluded that injured athletes had completely recovered from their concussive injury by the fifth day post-injury. Complete recovery was defined as having achieved baseline performance levels on the Graded Symptom Checklist (GSC), paper and pencil neurocognitive tests (HVLT, Trail-Making Test Part B, Symbol Digit Modalities Test, Stroop Colour-Word Test, COWAT) and the Balance Error Scoring System (BESS). All symptom and neurocognitive deficits had resolved by day 5 post-injury and the BESS scores had returned to baseline between days 3–5 post-injury.

Previous paper and pencil studies conducted by Macciocchi [9], Collins et al. [3], Lovell [10], Echemendia and Petukian [11] and McCrea and Kelly [12] have demonstrated measurable neurocognitive deficits that are typically evident within 1–2 days post-injury that invariably resolve by day 5 post-trauma. No prior studies examining paper and pencil measures have revealed significant neurocognitive deficits persisting beyond this time period. Notably, however, with the exception of Macciocchi et al. ($n=183$) and McCrea's recent analysis ($n=94$) sample sizes have been small and adequate group comparisons have been limited.

Moreover, two of the most widely utilized return-to-play guideline scales currently are the Colorado Guidelines [13] and the American Academy of Neurology Guidelines [14]. Each of these scales diagnose concussions on a three point scale with a grade 1 (mild), a grade 2 (moderate, no LOC) and a grade 3 (any LOC) concussion. For grade 1 concussions, the Colorado and AAN guidelines permit return-to-play the same day of injury if symptoms abate or do not appear within 20 minutes of injury. Further, both sets of guidelines permit all asymptomatic athletes sustaining a grade 2 concussion to return to athletic participation within 1 week of injury. It is noteworthy that many concussion grading scales and recent studies concluded all athletes should heal from concussive injury within 7 days. This is the traditional period of time between football games, incidentally the

sport most frequently linked with this injury at levels from junior high to the NFL.

A recent editorial in *JAMA* scrutinized the reliance on grading scales in managing concussive injuries. While these grading scales were initially useful in increasing knowledge about concussion and its signs and symptoms, they were formed solely by clinical experiences and lacked the utilization of scientific research [15]. Also, the scales generalize concussions for all ages, playing levels, and genders. Differences in the brain's ability to regain cognitive functioning and symptom reporting practices between individuals are not taken into account in any of the aforementioned return-to-play scales [16]. For example, a recent manuscript has found significant differences in recovery rates between high school and collegiate athletes [17].

The purpose of this paper is to examine the time of recovery from concussive injury for high school and collegiate athletes participating in a variety of sports. The vast majority of concussive injuries are suffered at the high school and collegiate levels of participation, yet many coaches, athletic trainers and team doctors may be unaware of the severe consequences that can arise in returning a player to participation prematurely. Recent studies claim that the average concussion ameliorates within 1 week of onset and many concussion grading scales also clear mildly and moderately injured athletes for participation within 1 week. It is the authors' hypothesis that even mild concussions often require more than 7 days to completely resolve (indicated by a return to baseline level of functioning). The results of this study will hopefully add to a body of literature that has raised awareness of the possible prolonged effects of concussive injury and further ensure that injured athletes are given a sufficient amount of time to recover before returning to the field of play.

Methods

Measures

This study was performed utilizing the ImPACT computerized neuropsychological testing platform which is designed to identify cognitive impairment following a concussive injury [18]. Through an ~20-minute series of tests, ImPACT provides data on cognitive functioning in the often-affected areas of visual and verbal memory, working memory, processing speed, visual motor skills and reaction time. Also, athletes were administered the Post-Concussion Symptom Scale, a detailed 21 symptom checklist that is widely utilized throughout the National Football League National Hockey League and amateur sports leagues [19].

Through the athlete's performance on the neuropsychological test battery, ImPACT calculates four composite scores detailing performance in the four distinct cognitive domains. The verbal memory composite is generated by performance on tests of word learning, word recognition memory and letter memory. The visual memory composite is comprised of tests revealing shape learning and memory, visual working memory and visual associative memory. The reaction time index is measured in hundredths of a second and consists of weighted performances on three different reaction time sub-tests. The processing speed composite is also measured in hundredths of a second and shows performance in visual-motor processing speed and visual scanning speed [17].

During the 1st International Symposium on Concussion in Sport, the council was concerned about various problems encountered with neuropsychological testing including sensitivity, specificity and learning/practice effects [20]. The symposium stated that traditional methods of neuropsychological testing, namely paper and pencil tests, may be susceptible to practice and learning effects. Based upon these prior data, sole use of paper and pencil neurocognitive measures may increase the risk of false negatives and may offer limited assessment sensitivity.

In a series of recent papers, ImPACT (Version 2.0) was shown to be sensitive to the mild effects of sports-related concussion. Specifically, when compared to non-injured controls and to baseline levels of functioning, 64 athletes sustaining mild concussion had reduced memory functioning at three post-injury intervals (36 hours, days 4 and 7) [21]. Moreover, controls included in the above study did not demonstrate any significant practice effects and produced consistent scores across the three testing sessions. In a follow-up study, other ImPACT composite scores (visual memory, reaction time and processing speed) were also able to distinguish mildly concussed high-school athletes from control peers [22].

Also, a recent manuscript detailed the reliability for each of ImPACT's composite scores [23]. This report concluded that no practice effects were found in three of four composite scores for cognitive functioning. One criterion of the current study that each participant met was the presence of a preinjury baseline testing session. With this baseline standard, the athlete's preinjury performance served as his or her own control throughout the study. By acquiring baseline data, the study avoided the difficulty of matching a control group to the injured sample in terms of age, gender and concussion background.

Participants

The current study was comprised of 104 high school and collegiate athletes who experienced a cerebral concussion while participating in an athletic event. Each athlete attended a high school or college which participated in the UPMC Sports Medicine programme. A master database of ImPACT data, acquired from these high schools and colleges, was examined in order to form the study's sample. Subjects were chosen based upon the presence of a pre-season baseline examination, a diagnosed concussive injury during their season of play and three subsequent testing sessions after sustaining their injury. Each concussed athlete included in the study consulted with one of the UPMC concussion specialists.

The concussive injuries were accumulated over a 30 month period spanning from September 2001 – February 2004. The group was predominantly male, with 91 participants (87.5%) and the average age was 16.11 years ($SD = 2.22$). On average, the sample had completed 9.74 years of education ($SD = 1.89$). The sample represented seven different sports, with football being represented most often ($n = 83$, 79.8%). Soccer ($n = 6$), basketball ($n = 5$), wrestling ($n = 5$), hockey ($n = 3$) and field hockey ($n = 1$) followed. One athlete's sport was unidentified.

In terms of previous concussive history, the group showed trends similar to predicted values. Seventy athletes (67.3%) had no previous history of concussion. Thirty-four athletes (32.7%) had a prior history of one concussion and 13 (12.5%) had more than one prior concussion. Regarding characteristics of prior concussions, 11 (10.6%) suffered loss of consciousness, 20 (19.2%) experienced overt confusion, 14 (13.5%) presented with anterograde amnesia and eight (7.7%) had retrograde amnesia following their previous concussive injuries.

Design and procedure

Every participant in this study underwent a baseline or pre-injury evaluation using the ImPACT battery during their sport's off-season. Upon receiving a concussion, the injured athletes again underwent computerized testing at least three times after being injured. On average, the athletes were first tested at day 2 ($M = 2.42$ days, $SD = 3.14$), 1 week ($M = 7.58$ days, $SD = 4.49$) and 2 weeks ($M = 14.35$ days, $SD = 7.34$) post-injury. To determine when an athlete was completely recovered from concussion, their post-concussion data was compared to their baseline testing information. All athletes diagnosed with an in season concussion did not return to play until they were symptom free at rest and exertion and their ImPACT data had returned to baseline levels.

The computerized neuropsychological test battery was administered to each athlete by a clinical neuropsychologist, athletic trainer or physician thoroughly trained in the administration of the measures. As ImPACT is a self-administered test battery, all information is gathered in a standardized manner. Further, test scores are automatically generated into a complete clinical report, reducing the possibility of variation in administration or data collection between participating sites.

Results

Concussion descriptions

The majority of concussions suffered were diagnosed as Grade 1 ($n = 78$, 75%) according to the guidelines set forth by the American Academy of Neurology. The remainder were diagnosed as grade 2 ($n = 16$, 15.4%) and grade 3 ($n = 9$, 8.7%) concussions. Only nine participants experienced a loss of consciousness and each lasted less than 20 seconds. Of the sample, 53 (51.0%) athletes experienced confusion following their injury. Anterograde amnesia was present in 23 injured athletes (22.1%) and 19 presented with retrograde amnesia (18.3%) following their concussive injury. Data for on-field markers of injury was missing for 11 study participants.

Main effects analysis

All statistical analyses were completed using Statistica 6.1 [24]. A Multiple Analysis of Variance (MANOVA) model was employed to evaluate the overall significance of time in regards to the athletes' performance on the neuropsychological test. Further, a Bonferroni analysis was employed post-hoc to test for any significant differences in cognitive performance between the baseline scores and the three post-concussions trials. The Bonferroni test is a very conservative test of pairwise comparisons and was used to supply a strict adjustment for experimentwise error.

Table I presents the detailed descriptive statistics for verbal and visual memory, processing speed, reaction time and symptom ratings. Also, the means and standard deviations for the concussed

athletes across baseline and three post-concussion testing sessions are shown in Table I. Pairwise comparisons between concussed athletes at baseline and the three follow-up testing sessions are illustrated in figures 1–5.

For the verbal memory composite score, there was a significant difference in performance across the evaluation period, $F(3,309) = 37.74$, $p < 0.01$. The sample showed a significant reduction in scores throughout the three different testing sessions. Pairwise comparisons (Figure 1) revealed significantly lower memory scores at day 2 ($p < 0.01$), day 7 ($p < 0.01$) and day 14 ($p < 0.01$).

In terms of visual memory, there again was a significant difference in test performance between baseline and post-concussion evaluations, $F(3,225) = 19.05$, $p < 0.01$. Pairwise comparisons (Figure 2) revealed a significant difference between baseline and the testing sessions at day 2 ($p < 0.01$) and day 7 ($p < 0.01$) post-injury. There was no significant difference between visual memory at baseline and 14 days post-injury. The visual memory composite was only analysed for 76 athletes because it was only recorded by ImPACT versions 2.0 and later. If an athlete took ImPACT before the release of version 2.0, they were not given a visual memory composite during that testing session and subsequently could not be analysed in the MANOVA.

For the processing speed composite score, there was a significant main effect for time, $F(3,309) = 26.74$, $p < 0.01$. Through pairwise comparisons (Figure 3), there was a significant reduction in performance between baseline and day 2 ($p < 0.01$) post-injury. There was no significance between the performances at baseline and the second post-injury session. At 14 days post-concussion, the processing speed composite had increased compared to baseline performance ($p < 0.05$). Of note is that the processing speed score achieved during the second testing session at day 7 showed significance ($p < 0.0007$) when compared to the post-concussion test on day 14.

With regards to reaction time, there was a significant difference in test performance between the baseline and post-concussion evaluations, $F(3,309) = 28.07$, $p < 0.01$. Specifically, pairwise

Table I. Average ImPACT composite scores and post-concussive symptoms.

| Variable | Baseline | Day 2 | Day 7 | Day 14 |
|----------------------------|---------------|---------------|---------------|---------------|
| Verbal memory composite | 85.75 (8.59) | 72.00 (14.87) | 75.88 (13.79) | 79.43 (13.60) |
| Visual memory composite | 74.04 (13.82) | 61.20 (12.92) | 66.96 (15.92) | 72.29 (14.31) |
| Processing speed composite | 35.05 (6.90) | 30.28 (9.06) | 33.99 (8.10) | 36.96 (8.30) |
| Reaction time composite | 0.573 (0.076) | 0.667 (0.151) | 0.635 (0.121) | 0.568 (0.088) |
| Post-concussion symptoms | 5.14 (7.87) | 26.18 (19.69) | 13.08 (15.55) | 7.18 (15.86) |

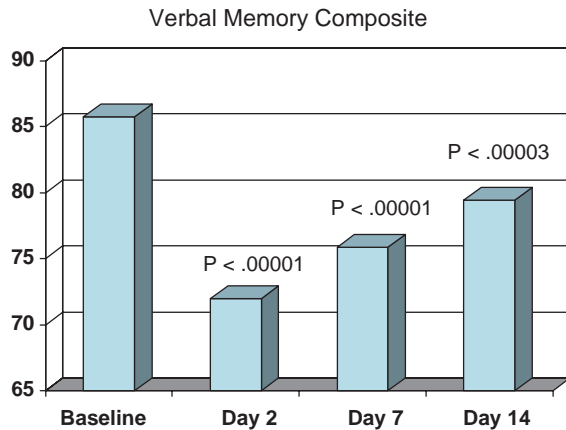


Figure 1. Mean performance on the *ImPACT* verbal memory composite for concussed samples across the four testing sessions. Scores are expressed as percentage correct. A higher score represents better performance. Pairwise comparisons are provided for each testing session. When compared to baseline performance, concussed athletes display significant deficits through day 14 testing.

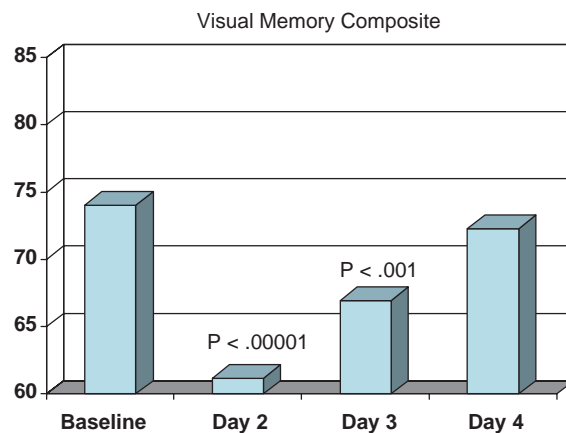


Figure 2. Mean performance on the *ImPACT* visual memory composite for concussed samples across the four testing sessions. Scores are expressed as percentage correct. A higher score represents better performance. Pairwise comparisons are provided for each testing session. When compared to baseline performance, concussed athletes display significant deficits through day 7.

comparisons (Figure 4) revealed significant differences in performance between baseline and post-injury tests at day 2 ($p < 0.01$) and day 7 ($p < 0.01$). There was no significant difference between the scores at baseline and day 14 post-injury (a lower score is better in terms of reaction time).

In terms of the symptom total score, again there was a significant difference in symptom reporting between the baseline and post-injury evaluations, $F(3,309) = 72.03$, $p < 0.01$. Specifically, significant differences were found by pairwise comparisons (Figure 5) between the baseline symptom reporting and day 2 ($p < 0.00001$) and week 1 ($p < 0.00001$) post-injury. There was no significance found

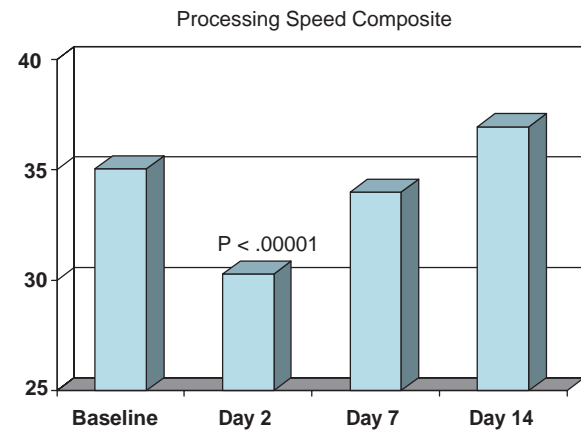


Figure 3. Mean performance on the *ImPACT* processing speed composite score. Scores are expressed in terms of average number of responses completed. A lower score is indicative of worse performance. When compared to baseline performance, the athletes showed significant deficits in functioning at 2 days post-injury.

between the baseline and third post-injury testing scores.

Discussion

In terms of neurocognitive performance, this study indicated persisting neurocognitive deficits that lasted for at least 14 days in a sample of collegiate and high school athletes. The results showed that, of the four composites, verbal memory required the longest amount of time to return to baseline levels. It showed significant deficits out to at least 14 days post injury. The other composite scores of visual memory, processing speed, reaction time and symptom reporting all showed significant differences compared to their baseline levels at days 2 and 7 post-injury. These domains did not exhibit significant deficits at day 14 post-injury, but recovery could have occurred at any point between days 8 and 14. These trends expand upon previous studies examining mild concussions in high school athletes where injured athletes still showed signs of cognitive impairment 7 days after injury [21, 22].

It is interesting to note that in this sample concussion recovery times do not appear related to concussion grade. After 1 week, three grade 1 concussions (5%) were classified as recovered and return to play was permitted. At 2 weeks post-injury, 19 had fully recovered (18.3%). The remainder of athletes maintained neurocognitive deficits or persisting symptoms past day 14. For grade 2 concussions, the recovery rate appeared to be slightly faster. Twelve had healed within 7 days (34.3%), and within 2 weeks of injury a total of 26 had returned to their sport (74%). Of the nine grade 3 concussions, one had healed within 1 week (11.1%) and four within 2 weeks (44.4%).

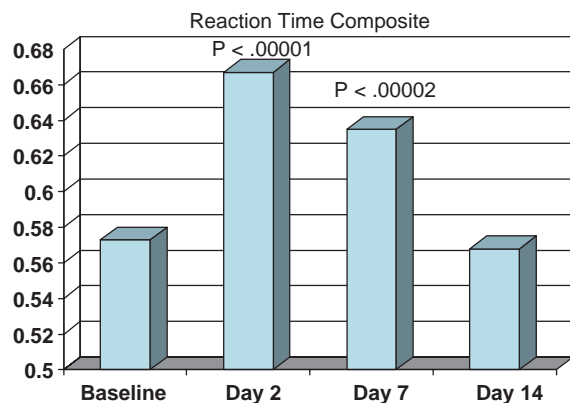


Figure 4. Mean performance on the *ImPACT* reaction time composite score. Scores are expressed in terms of average response time in seconds. A higher score is indicative of worse performance. When compared to baseline performance, concussed athletes showed deficits that persisted out to day 7 post-injury.

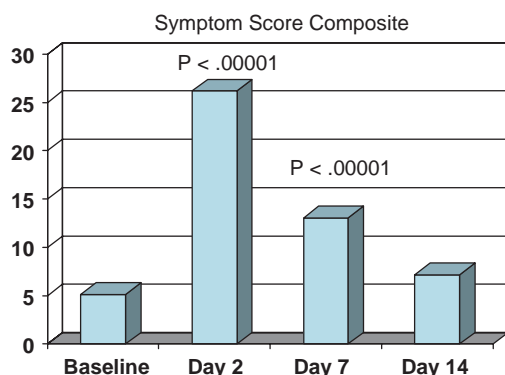


Figure 5. Mean performance on the *ImPACT* symptom composite for concussed athletes across the four testing sessions. Scores are expressed as total score on the symptom scale. A higher score is indicative of increased symptoms. When compared to baseline symptom reporting, concussed athletes demonstrate significantly higher symptoms out to day 7 post-injury.

This data suggests limitations to the guidelines set forth by the AAN and Colorado concussion grading scales. If return to play was based solely on guidelines, each player whose on-field concussion symptoms (confusion, amnesia, etc.) ameliorated within 15–20 minutes ($n=60$) would have been returned to participation before their cognitive functioning had recovered. Only 33% of grade 2 concussions had recovered rapidly enough to permit clearance 7 days post-injury. Altogether, potentially 80% of the athletes in this sample would have returned to play prematurely if that decision had been based solely on criteria outlined in the AAN and Colorado guidelines. Further, less than 10% of the entire sample had recovered within 5 days, suggesting much longer recovery

times than reported in the recently published study of concussed collegiate athletes [8].

It is also noteworthy that some cognitive deficits persisted, even after athletes were no longer reporting symptoms. Thus, cognitive deficits may remain after the injured athlete reports no overt symptoms of injury. This reaffirms the importance of neuropsychological testing in the management of concussion and return-to-play decisions following concussion, as athletes may be unaware of or unwilling to admit to the presence of concussive symptoms following injury.

The results of this study suggest that recovery from concussion may take longer than previously reported. These differences may be due to method variance in measuring cognitive changes following concussion, sample characteristics or other factors. A recent publication scrutinized the test-re-test reliabilities of many traditional paper-and-pencil neurocognitive testing measures [25]. The study detailed performance on multiple tests, including the Hopkins Verbal Learning Test, Trail Making Test, Controlled Oral Word Association Test and Digit Symbol Test. Overall, the paper-and-pencil tests were found to have an extremely low test-re-test reliability, suggestive of a possible practice effect. Consistent increases in performance over time were found in the Digit Symbol Test Trail Making Test and COWAT. The study did not find poor test-re-test reliabilities in the HVLT, but previous studies of this test have shown possible practice effects [26]. Thus, the use of computerized testing with randomized presentation of stimuli and a variety of test forms could be more sensitive in detecting subtle neurocognitive impairment at the later stages of recovery.

Although this study provides compelling evidence of protracted concussion recovery times compared to those found previously in the concussion literature, there are limitations which must be acknowledged. First, the age of the concussed sample ($M=16.11$ years) could limit the generalizability of the findings at other levels of athletic participation. Although some collegiate athletes were included ($n=14$) in the sample, the majority of participants competed at the high school athletic level. In a recent study, high school athletes were shown to require longer recovery times following injury than their collegiate counterparts [17, 21]. Further studies at the collegiate level would aid in both better examining recovery of collegiate athletes specifically and also further compare the recovery differences between the two levels of competition. Also, the use of clinical data is, in essence, a convenience sample which also presents limitations. Most significantly, as only patients who underwent three post-concussion testing sessions were included in

this study, the sample may exhibit a longer time of recovery than their peers who were tested fewer than three times on ImPACT.

The results of this study provide important recovery time data which could impact ideas about concussion management. The fact that significant cognitive deficits were apparent up to 14 days after injury suggests that cognitive recovery following a concussive injury may take longer than previously demonstrated. In a field where injury management and return to play decisions are complex and extremely important, the knowledge that even mild injuries may show protracted recovery times is essential to making informed decisions regarding a patient's ability to return to athletic participation. Clinicians must be cognizant that recovery time from concussive injuries can significantly vary from athlete to athlete, underscoring the importance of individualized concussion management.

References

- Gerberich SG, Priest JD, Boen JR. Concussion incidences and severity in secondary school varsity football players. *American Journal of Public Health* 1983;73:1370-1375.
- Powell JW, Barber-Foss KD. Traumatic brain injury in high school athletes. *Journal of the American Medical Association* 1999;282:958-963.
- Collins MW, Grindel SH, Lovell MR, Dede DE, Moser DJ, Phalin, Nogle S, Wasik M, Cordry D, Daugherty KM, Sears SF, Nicolette G, Indelicato P, McKeag DB. Relationship between concussion and neuropsychological test performance in college football players. *Journal of the American Medical Association* 1999;282:964-970.
- Hovda DA, Lee SM, von Stuck ML, Bergsneider M, Kelly D, Shalmon E, Martin N, Caron M, Mazziottra J, Phelps M, Becker DP. The neurometabolic and metabolic cascade following brain injury: Moving from animal models to man. *Journal of Neurotrauma* 1995;12:143-146.
- Hovda DA, Prins ML, Becker DP, Lee SM, Bergsneider M, Martin N. Neurobiology of concussion. In: Bailes JE, Lovell MR, Maroon JC, editors. *Sports related concussion*. St. Louis: Quality Medical Publishers, 1999. pp 12-51.
- Cantu RC, Voy R. Second impact syndrome: A risk in any sport. *Physician Sports Medicine* 1995;34:2327-2336.
- Collins MW, Hawn KL. The clinical management of sports concussion. *Current Sports Medicine Reports* 2002;1:12-22.
- McCrea M, Guskiewicz KM, Marshall SW. Acute effects and recovery time following concussion in collegiate football players. *Journal of the American Medical Association* 2003; 290:922-998.
- Macciocchi SN, Barth JT, Alves W, Rimel RW, Jane JA. Neuropsychological functioning and recovery after mild head injury in collegiate athletes. *Neurosurgery* 1996;39:510-514.
- Lovell MR, Collins MW. Neuropsychological assessment of the head-injured professional athlete. In Bailes JE, Day AL, editors. *Neurological sports medicine*. Rollins Meadows: American Association of Neurological Surgeons; 2001. pp 169-179.
- Echemendia RE, Petukian M. Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clinical Journal of Sports Medicine* 2001;11:23-31.
- McCrea M, Kelly JP, Randolph C, Cisler R, Berger L. Immediate neurocognitive effects of concussion. *Journal of Neurosurgery* 2000;50:1032-1040.
- Colorado Medical Society. Report of the sports medicine committee: Guidelines for the management of concussion in sports. Denver: Colorado Medical Society; 1991.
- Quality Standards Subcommittee, American Academy of Neurology. Practice parameter. *Neurology* 1997;48:581-585.
- McKeag DB. Understanding sports-related concussion: Coming into focus but still fuzzy. *JAMA* 2003;290: 2604-2605.
- Collins MW, Lovell MR, McKeag DB. Current issues in managing sports-related concussion. *JAMA* 1999;24:2283-2285.
- Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *Journal of Pediatrics* 2003;142:546-553.
- Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral concussion in athletes: evaluation and neuropsychological testing. *Neurosurgery* 2000 Sep 2000;47:659-669; discussion 669-672.
- Lovell MR, Collins MW. Neuropsychological assessment of the college football player. *Journal of Head Trauma Rehabilitation* 1998;13:9-26.
- Aubry M, Cantu R, Dvorak J, Graf-Bauman T, Johnston KM, Kelly J, Lovell MR, McCrory P, Meeuwisse WH, Schamasch P. Summary and agreement statement of the 1st international symposium on concussion in sport, Vienna 2001. *Clinical Journal of Sports Medicine* 2002;12: 6-11.
- Lovell MR, Collins MW, Iverson GL, Johnston KM, Bradley JP. Grade 1 or "ding" concussions in high school athletes. *American Journal of Sports Medicine* 2004;32:47-54.
- Lovell MR, Collins MW, Iverson GL, Field M, Maroon JC, Cantu R, Podell K, Powell JW, Belza M, Fu F. Recovery from mild concussion in high school athletes. *Journal of Neurosurgery* 2003;98:296-301.
- Iverson GL, Lovell MR, Collins MW. Interpreting change on ImPACT following sports concussion. *The Clinical Neuropsychologist* 2003;17:460-467.
- StatSoft: *Statistica* v6.0. Tulsa: StatSoft; 2003.
- Barr WB. Neuropsychological testing of high school athletes: Preliminary norms and test-retest indices. *Archives of Clinical Neuropsychology* 2003;18:91-101.
- Benedict RHB, Schretlen D, Groninger L, Brandt J. Hopkins verbal learning test-revised: Normative data and analysis of inter-form and test-retest reliability. *Clinical Neuropsychologist* 1998;12:43-55.



Name

Sport/team

Date/time of injury

Date/time of assessment

Age Gender ☐ M ☐ F

Years of education completed

Examiner

What is the SCAT2?

This tool represents a standardized method of evaluating injured athletes for concussion and can be used in athletes aged from 10 years and older. It supersedes the original SCAT published in 2005¹. This tool also enables the calculation of the Standardized Assessment of Concussion (SAC)^{2,4} score and the Maddocks questions³ for sideline concussion assessment.

Instructions for using the SCAT2

The SCAT2 is designed for the use of medical and health professionals. Preseason baseline testing with the SCAT2 can be helpful for interpreting post-injury test scores. Words in *italics* throughout the SCAT2 are the instructions given to the athlete by the tester.

This tool may be freely copied for distribution to individuals, teams, groups and organizations.

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms (like those listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (such as headache), or
- Physical signs (such as unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour.

Any athlete with a suspected concussion should be **REMOVED FROM PLAY**, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

Symptom Evaluation

How do you feel?

You should score yourself on the following symptoms, based on how you feel now.

| | none | 1 | 2 | 3 | 4 | 5 | 6 |
|--|------|---|---|---|---|---|---|
| Headache | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| "Pressure in head" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Neck Pain | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nausea or vomiting | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Dizziness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Blurred vision | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Balance problems | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to light | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to noise | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling slowed down | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling like "in a fog" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| "Don't feel right" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty concentrating | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty remembering | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Fatigue or low energy | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Confusion | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Drowsiness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Trouble falling asleep (if applicable) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| More emotional | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Irritability | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sadness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nervous or Anxious | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

Total number of symptoms (Maximum possible 22)

Symptom severity score

(Add all scores in table, maximum possible, 22 x 6 = 132)

Do the symptoms get worse with physical activity? ☐ Y ☐ N

Do the symptoms get worse with mental activity? ☐ Y ☐ N

Overall rating

If you know the athlete well prior to the injury, how different is the athlete acting compared to his / her usual self? Please circle one response.

☐ no different

☐ very different

☐ unsure

Cognitive & Physical Evaluation

1 Symptom score (from page 1)
22 minus number of symptoms of 22

2 Physical signs score

Was there loss of consciousness or unresponsiveness? ☐ Y ☐ N
If yes, how long? _____ minutes
Was there a balance problem/unsteadiness? ☐ Y ☐ N

Physical signs score (1 point for each negative response) of 2

3 Glasgow coma scale (GCS)

Best eye response (E)

No eye opening 1
Eye opening in response to pain 2
Eye opening to speech 3
Eyes opening spontaneously 4

Best verbal response (V)

No verbal response 1
Incomprehensible sounds 2
Inappropriate words 3
Confused 4
Oriented 5

Best motor response (M)

No motor response 1
Extension to pain 2
Abnormal flexion to pain 3
Flexion/Withdrawal to pain 4
Localizes to pain 5
Obeys commands 6

Glasgow Coma score (E + V + M) of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

4 Sideline Assessment – Maddocks Score

"I am going to ask you a few questions, please listen carefully and give your best effort."

Modified Maddocks questions (1 point for each correct answer)

At what venue are we at today? ☐ 0 ☐ 1
Which half is it now? ☐ 0 ☐ 1
Who scored last in this match? ☐ 0 ☐ 1
What team did you play last week/game? ☐ 0 ☐ 1
Did your team win the last game? ☐ 0 ☐ 1

Maddocks score of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not included in SCAT 2 summary score for serial testing.

5 Cognitive assessment

Standardized Assessment of Concussion (SAC)

Orientation (1 point for each correct answer)

What month is it? ☐ 0 ☐ 1
What is the date today? ☐ 0 ☐ 1
What is the day of the week? ☐ 0 ☐ 1
What year is it? ☐ 0 ☐ 1
What time is it right now? (within 1 hour) ☐ 0 ☐ 1

Orientation score of 5

Immediate memory

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."

Trials 2 & 3:

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

Complete all 3 trials regardless of score on trial 1 & 2. Read the words at a rate of one per second. Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do not inform the athlete that delayed recall will be tested.

| Word | Trial 1 | Trial 2 | Trial 3 | Alternative word list |
|--------|---|---|---|-----------------------|
| elbow | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | candle baby finger |
| apple | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | paper monkey penny |
| carpet | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | sugar perfume blanket |
| saddle | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | sandwich sunset lemon |
| bubble | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | wagon iron insect |

Total

Immediate memory score of 15

Concentration

Digits Backward:

"I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."

If correct, go to next string length. If incorrect, read trial 2. One point possible for each string length. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

| | | | Alternative digit lists | |
|-------------|---|-------------|-------------------------|-------------|
| 4-9-3 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | 6-2-9 | 5-2-6 | 4-1-5 |
| 3-8-1-4 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | 3-2-7-9 | 1-7-9-5 | 4-9-6-8 |
| 6-2-9-7-1 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | 1-5-2-8-6 | 3-8-5-2-7 | 6-1-8-4-3 |
| 7-1-8-4-6-2 | <input type="checkbox"/> 0 <input type="checkbox"/> 1 | 5-3-9-1-4-8 | 8-3-1-9-5-4 | 7-2-4-8-5-6 |

Months in Reverse Order:

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November... Go ahead"

1 pt. for entire sequence correct

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan ☐ 0 ☐ 1

Concentration score of 5

* This tool has been developed by a group of international experts at the 3rd International Consensus Meeting on Concussion in Sport held in Zurich, Switzerland in November 2008. The full details of the conference outcomes and the authors of the tool are published in British Journal of Sports Medicine, 2009, volume 43, supplement 1.

The outcome paper will also be simultaneously co-published in the May 2009 issues of Clinical Journal of Sports Medicine, Physical Medicine & Rehabilitation, Journal of Athletic Training, Journal of Clinical Neuroscience, Journal of Science & Medicine in Sport, Neurosurgery, Scandinavian Journal of Science & Medicine in Sport and the Journal of Clinical Sports Medicine.

McCrory P et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. British Journal of Sports Medicine, 2005, 39: 196-204.

* McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sports Medicine, 2001; 11: 176-181.

* McCrea M, Randolph C, Kelly J. Standardized Assessment of Concussion: Manual for administration, scoring and interpretation. Waukesha, Wisconsin, USA.

* Maddocks, DJ; Dicker, GD; Saling, MM. The assessment of orientation following concussion in athletes. Clin J Sport Med, 1995; 5(1):32-3.

* Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports, 2003, 2: 24-30.

6 Balance examination

This balance testing is based on a modified version of the Balance Error Scoring System (BESS). A stopwatch or watch with a second hand is required for this testing.

Balance testing

"I am now going to test your balance. Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."

(a) Double leg stance:

"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance:

"If you were to kick a ball, which foot would you use? [This will be the dominant foot] Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

(c) Tandem stance:

"Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

Balance testing – types of errors

- 1. Hands lifted off iliac crest
- 2. Opening eyes
- 3. Step, stumble, or fall
- 4. Moving hip into > 30 degrees abduction
- 5. Lifting forefoot or heel
- 6. Remaining out of test position > 5 sec

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the athlete. The examiner will begin counting errors only after the individual has assumed the proper start position. **The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum total number of errors for any single condition is 10.** If a athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once subject is set. Subjects that are unable to maintain the testing procedure for a minimum of **five seconds** at the start are assigned the highest possible score, ten, for that testing condition.

Which foot was tested: ☐ Left ☐ Right
(i.e. which is the non-dominant foot)

| Condition | Total errors |
|--|--------------|
| Double Leg Stance (feet together) | of 10 |
| Single leg stance (non-dominant foot) | of 10 |
| Tandem Stance (non-dominant foot at back) | of 10 |
| Balance examination score (30 minus total errors) | of 30 |

7 Coordination examination

Upper limb coordination

Finger-to-nose (FTN) task: "I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended). When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose as quickly and as accurately as possible."

Which arm was tested: ☐ Left ☐ Right

Scoring: 5 correct repetitions in < 4 seconds = 1

Note for testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. Failure should be scored as 0.

Coordination score of 1

8 Cognitive assessment

Standardized Assessment of Concussion (SAC)

Delayed recall

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Circle each word correctly recalled. Total score equals number of words recalled

| Word | Alternative word list | | |
|--------|-----------------------|---------|---------|
| elbow | candle | baby | finger |
| apple | paper | monkey | penny |
| carpet | sugar | perfume | blanket |
| saddle | sandwich | sunset | lemon |
| bubble | wagon | iron | insect |

Delayed recall score of 5

Overall score

| Test domain | Score |
|--------------------------------|---------------|
| Symptom score | of 22 |
| Physical signs score | of 2 |
| Glasgow Coma score (E + V + M) | of 15 |
| Balance examination score | of 30 |
| Coordination score | of 1 |
| Subtotal | of 70 |
| Orientation score | of 5 |
| Immediate memory score | of 5 |
| Concentration score | of 15 |
| Delayed recall score | of 5 |
| SAC subtotal | of 30 |
| SCAT2 total | of 100 |
| Maddocks Score | of 5 |

Definitive normative data for a SCAT2 "cut-off" score is not available at this time and will be developed in prospective studies. Embedded within the SCAT2 is the SAC score that can be utilized separately in concussion management. The scoring system also takes on particular clinical significance during serial assessment where it can be used to document either a decline or an improvement in neurological functioning.

Scoring data from the SCAT2 or SAC should not be used as a stand alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion.

Athlete Information

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

Signs to watch for

Problems could arise over the first 24-48 hours. You should not be left alone and must go to a hospital at once if you:

- Have a headache that gets worse
- Are very drowsy or can't be awakened (woken up)
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused, are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on your feet; have slurred speech

Remember, it is better to be safe.
Consult your doctor after a suspected concussion.

Return to play

Athletes should not be returned to play the same day of injury. When returning athletes to play, they should follow a stepwise symptom-limited program, with stages of progression, for example:

1. rest until asymptomatic (physical and mental rest)
2. light aerobic exercise (e.g. stationary cycle)
3. sport-specific exercise
4. non-contact training drills (start light resistance training)
5. full contact training after medical clearance
6. return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur. Resistance training should only be added in the later stages. Medical clearance should be given before return to play.

| Test | Test domain | Time | Score | | | |
|---|--------------------------------|------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | | Date tested | | | | |
| | | Days post injury | | | | |
| SCAT2 | Symptom score | | | | | |
| | Physical signs score | | | | | |
| | Glasgow Coma score (E + V + M) | | | | | |
| | Balance examination score | | | | | |
| | Coordination score | | | | | |
| | Orientation score | | | | | |
| SAC | Immediate memory score | | | | | |
| | Concentration score | | | | | |
| | Delayed recall score | | | | | |
| | SAC Score | | | | | |
| Total | SCAT2 | | | | | |
| Symptom severity score (max possible 132) | | | | | | |
| Return to play | | | <input type="radio"/> Y | <input type="radio"/> N | <input type="radio"/> Y | <input type="radio"/> N |

Additional comments

Concussion injury advice (To be given to concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. It is expected that recovery will be rapid, but the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

If you notice any change in behaviour, vomiting, dizziness, worsening headache, double vision or excessive drowsiness, please telephone the clinic or the nearest hospital emergency department immediately.

Other important points:

- Rest and avoid strenuous activity for at least 24 hours
- No alcohol
- No sleeping tablets
- Use paracetamol or codeine for headache. Do not use aspirin or anti-inflammatory medication
- Do not drive until medically cleared
- Do not train or play sport until medically cleared

Clinic phone number

Patient's name

Date/time of injury

Date/time of medical review

Treating physician

Contact details of stamp

Pocket SCAT2



FIFA®



Concussion should be suspected in the presence of **any one or more** of the following: symptoms (such as headache), or physical signs (such as unsteadiness), or impaired brain function (e.g. confusion) or abnormal behaviour.

1. Symptoms

Presence of any of the following signs & symptoms may suggest a concussion.

- Loss of consciousness
- Seizure or convulsion
- Amnesia
- Headache
- "Pressure in head"
- Neck Pain
- Nausea or vomiting
- Dizziness
- Blurred vision
- Balance problems
- Sensitivity to light
- Sensitivity to noise
- Feeling slowed down
- Feeling like "in a fog"
- "Don't feel right"
- Difficulty concentrating
- Difficulty remembering
- Fatigue or low energy
- Confusion
- Drowsiness
- More emotional
- Irritability
- Sadness
- Nervous or anxious

2. Memory function

Failure to answer all questions correctly may suggest a concussion.

"At what venue are we at today?"

"Which half is it now?"

"Who scored last in this game?"

"What team did you play last week / game?"

"Did your team win the last game?"

3. Balance testing

Instructions for tandem stance

*"Now stand heel-to-toe with your **non-dominant** foot in back. Your weight should be evenly distributed across both feet. You should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

Observe the athlete for 20 seconds. If they make more than 5 errors (such as lift their hands off their hips; open their eyes; lift their forefoot or heel; step, stumble, or fall; or remain out of the start position for more than 5 seconds) then this may suggest a concussion.

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, urgently assessed medically, should not be left alone and should not drive a motor vehicle.



Sensitivity and specificity of the ImPACT Test Battery for concussion in athletes

Philip Schatz^{a,*}, Jamie E. Pardini^b, Mark R. Lovell^b,
Michael W. Collins^b, Kenneth Podell^c

^a Saint Joseph's University, 5600 City Avenue, Post Hall 222, Philadelphia, PA 19131, USA

^b UPMC Center for Sports Medicine, Pittsburgh, PA, USA

^c Henry Ford Health System, Detroit, MI, USA

Accepted 3 August 2005

Abstract

This study explored the diagnostic utility of the composite scores of Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) and Post Concussion Symptom Scale scores (PCSS). Recently concussed high school athletes ($N=72$) were tested within 72 h of sustaining a concussion, and data were compared to non-concussed high school athletes with no history of concussion ($N=66$). Between-groups MANOVA revealed a significant multivariate effect of concussion on test performance ($p<.001$); univariate ANOVAS revealed all six measures contributed to the between-groups differences. A discriminant function analyses was conducted to measure the ability of the five ImPACT composite scores, as well as the PCSS to classify concussion status. One discriminant function was identified that consisted of the Visual Memory, Processing Speed, and Impulse Control composite scores PCSS, which correctly classified 85.5% of the cases. Approximately 82% of participants in the concussion group and 89% of participants in the control group were correctly classified. Using these data, the sensitivity of ImPACT was 81.9%, and the specificity was 89.4%. As part of a formal concussion management program, ImPACT is a useful tool for the assessment of the neurocognitive and neurobehavioral sequelae of concussion, and can also provide post-injury cognitive and symptom data that can assist a practitioner in making safer return to play decisions.

© 2005 National Academy of Neuropsychology. Published by Elsevier Ltd. All rights reserved.

Keywords: Processing Speed; Impulse Control; ImPACT; Concussion

The diagnosis, treatment, and management of sports related concussion has gained widespread attention, in recent years, in the fields of neuropsychology and sports medicine. This increase in interest is not spurious, given that approximately 300,000 sports-related mild traumatic brain injuries (MTBIs) occur each year; at the high school level alone, approximately 62,816 sports-related concussions occur yearly, with high school football players acquiring 60% of recorded concussions (Powell & Barber-Foss, 1999). Despite the vast number of concussions suffered on a yearly basis, data to aid in the diagnosis and management of sports concussion have only begun to emerge. Such clinical data may assist in the development of empirically-based concussion management guidelines, and can surely contribute to athletes' return-to-play decisions. Athletes with a history of concussion have been shown to have cumulative

* Corresponding author. Tel.: +1 610 660 1804; fax: +1 610 660 1819.

E-mail address: pscjatz@sju.edu (P. Schatz).

cognitive effects, as well as decreased cognitive performance relative to non-concussed and fully-recovered peers, as well as athletes with a history of only one previous concussion (Collins, Grindel, et al., 1999; Collins et al., 2002; Moser & Schatz, 2002). Further, as sustaining a cerebral concussion has been shown to increase the likelihood of sustaining another concussion (Guskiewicz et al., 2003), prevention of premature return-to-play following concussion may decrease the likelihood of sustaining subsequent concussions during athletic competition and participation.

In the early phases of concussion management, grading scales were utilized to classify the severity of injury and make return to play decisions. At least 14 (Collins, Lovell, & McKeag, 1999) different return-to-play scales and 25 (Johnston, McCrory, Mohtadi, & Meeuwisse, 2001) different injury-grading systems exist, each offering often differing recommendations for the diagnosis and management of concussion, including guidelines for making return-to-play decisions. These scales, though perhaps beneficial in classifying concussive injuries on a grand scale, were not empirically based, and the management and return-to-play strategies recommended were based on subjective clinical experience rather than empirical outcome-based research. In addition, these scales were unable to account for inter-individual variations in injury features and recovery course (Collins, Lovell, et al., 1999). Overall, the traditional grading-scale approach typically provided a predetermined recovery period following concussion based upon the concussion grade (though the requisite rest period often varied from one grading or return-to-play system to the next). Also, in this model, an athlete was not allowed to return to play unless they reported being asymptomatic. Because of the dependence on self-report of symptoms and the lack of individualized cognitive assessment tools and return-to-play guidelines, it was impossible to ensure that an individual injured athlete had regained cognitive functioning consistent with pre-injury levels (the defining factor in the recovery from a MTBI), regardless of symptom status (Collins, Stump, & Lovell, 2004).

Barth et al. (1989) initiated the first prospective study of sport-related concussion, which established the use of an athlete's pre-season baseline levels of performance for comparison to post-concussion levels. This approach addressed the problem of subjectivity inherent in the many concussion grading and guideline scales, as well as accounted for individual variation in premorbid functioning and recovery trajectory. In the decades following Barth et al.'s study, research and attention to sports-related concussion have grown considerably, and many schools and universities now provide or require formal clinical assessment of athletes who had sustained concussions. Athletes receiving post-concussion neurocognitive evaluations have typically completed traditional "paper and pencil" tests. While this testing approach was quite effective in diagnosis and management, it has not been without its share of problems. Traditional neuropsychological tests required a neuropsychologist or psychometrist to administer, score, and interpret each battery. This has been inconvenient and expensive for team organizations, where baseline testing could take days and even weeks to complete. Also, researchers have found that various "paper and pencil" tests did not have adequate norms or specificity and sensitivity, and also were vulnerable to significant practice effects in some athletes, with test scores returning to baseline before their concussion symptoms had ameliorated (Collie, Darby, & Maruff, 2001; Hinton-Bayre, Geffen, Geffen, McFarland, & Friis, 1999; Schatz & Zillmer, 2003).

The 1st International Symposium on Concussion in Sport was held in 2001 in Vienna (Aubry et al., 2002) to discuss the concerns of concussion diagnosis and management. The symposium reaffirmed the notion that neuropsychological testing should serve as the cornerstone of concussion management. The committee was also highly supportive of newer computerized neuropsychological test batteries, in that they were able to utilize infinitely variable test paradigms, which lessened the likelihood of a practice effect, and can be administered in larger groups and supervised by team physicians and athletic training staffs. However, the Vienna committee was concerned with the reliability and sensitivity of such testing batteries, and called for research into these aspects of the new test batteries. This endorsement of neuropsychological testing as a key component in concussion management was been reaffirmed by a second international conference in Prague in 2004 (McCrory et al., 2005).

In an attempt to increase the availability of neuropsychological testing within the athletic environment, Lovell et al. developed the ImPACT (Lovell, Collins, Podell, Powell, & Maroon, 2000; Maroon et al., 2000) Test Battery. Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) consists of three main parts: demographic data, neuropsychological tests, and the Post-Concussion Symptom Scale (PCSS), and these three sections combine to provide data to assist in accurately assessing and managing concussive injuries. The demographic data section supplies all relevant sport, medical, and concussion history information. The test modules and symptom checklist sections are described in detail below.

ImPACT (version 2.0) consists of six neuropsychological tests, each designed to target different aspects of cognitive functioning including attention, memory, Processing Speed, and reaction time. From these six tests, four separate

Table 1
The ImPACT Neuropsychological Test Battery

| Test name | Neurocognitive domain measured |
|-------------------------------|--|
| Word Memory | Verbal recognition memory (learning and retention) |
| Design Memory | Spatial recognition memory (learning and retention) |
| X's and O's | Visual working memory and cognitive speed |
| Symbol Match | Memory and visual-motor speed |
| Color Match | Impulse inhibition and visual-motor speed |
| Three Letter Memory | Verbal working memory and cognitive speed |
| Symptom Scale | Rating of individual self-reported symptoms |
| Composite scores | Contributing scores |
| Verbal Memory | Word Memory (learning and delayed), Symbol Match memory score Three Letters Memory score |
| Visual Memory | Design Memory (learning and delayed) X's and O's percent correct |
| Reaction time | X's and O's (average counted correct reaction time), Symbol Match (average weighted reaction time for correct responses), Color Match (average reaction time for correct response) |
| Visual Motor Processing Speed | X's and O's (average correct distracters), Symbol Match (average correct responses) Three letters (number of correct numbers correctly counted) |
| Impulse Control | X's and O's (number of incorrect distracters) Color Match (number of errors) |

composite scores are generated: Verbal Memory, Visual Memory, visuomotor speed, and reaction time. Table 1 lists the individual neuropsychological tests that make up the ImPACT Neuropsychological Test Battery, as well as the neuropsychological domains measured by each subtest. For a more thorough description, see Lovell et al. (2003), Iverson, Gaetz, Lovell, and Collins (2004), or Podell (2004). The Post-Concussion Symptom Scale (PCSS; Lovell & Collins, 1998) is also utilized in the ImPACT Test battery. The scale is used by many sports organizations to document and track concussion symptoms (Lovell, 1999; Lovell & Burke, 2002). The 21-symptom checklist asks the injured athlete to rate each symptom on a seven-point scale, with zero indicating no experience of a symptom and six indicating a severe symptom. This particular scale is quite useful because it presents “common” terms to describe symptoms and avoided jargon and less familiar medical terminology (e.g., sensitivity to light was used instead of photophobia).

ImPACT has been shown to be an effective tool for concussion management, and is not subject to the large practice effects sometimes seen on pencil and paper tests (Lovell et al., 2003). In the Lovell et al. (2003) study, concussed high school athletes were followed for 1-week post-injury, and were compared to age-matched control participants. Control group scores on the neuropsychological indicator examined (memory composite) did not increase with multiple testing opportunities, thus indicating that the ImPACT memory composite was not hindered by a practice effect. Concussed athletes also performed much lower on the Verbal Memory Test at 36 h, 4 and 7 days post-concussion compared to their individual baselines. When examining sub-groups of concussed athletes on the basis of severity of initial on-field symptoms, the more severe group (retrograde amnesia, anterograde amnesia, or disorientation for >5 min) demonstrated larger decreases from baseline scores, and also took longer to rebound to baseline than did the concussed athletes in the less severe group. A follow-up study of concussed high school athletes supported the above findings that Verbal Memory and symptom indicators on the ImPACT evaluation are indicative of the concussion injury and its severity (Lovell, Collins, Iverson, Johnston, & Bradley, 2004).

Iverson, Lovell & Collins (2002) examined several validity measurements of ImPACT using 120 high school and college athletes. Concurrent validity was established by examining the composite scores and their sensitivity to the acute effects of concussion. Concussed athletes reported significantly more symptoms, and performed worse on Memory and Reaction Time Indices. Decreased performance on the Symbol Digit Modalities Test was significantly correlated with ImPACT Processing Speed and Reaction Time Indices (Iverson, Gaetz, Lovell, & Collins, 2005) and post-concussive symptoms were significantly related to decreased performance on ImPACT Reaction Time, Verbal Memory, and Processing Speed Indices (Iverson, Gaetz, Lovell, & Collins, 2004), suggesting that ImPACT is sensitive to the acute effects of concussion. Divergent validity was examined through an inter-correlation matrix of composite

scores at preseason and post concussion. The non-significant correlations found between different test components (at preseason baseline testing) indicate they do not have much shared variance, and therefore appear to be measuring different constructs.

Research to date has empirically demonstrated that the neuropsychological test indices and Post-Concussion Symptom Scale on ImPACT reflect changes occurring as a result of concussion, and that these deficits resolve, or return to baseline, upon concussion recovery. The aim of this study was to further explore the diagnostic utility of ImPACT. We compared concussed athletes with non-concussed controls using MANOVA to establish group differences on the dependent measures, the five composite scores and symptom scale score. We then conducted a discriminant function analysis to identify those measures that contributed to identifying group membership.

1. Methods

1.1. Participants

The University of Pittsburgh and Saint Joseph's University Institutional Review Boards conducted appropriate reviews of our research with human participants and approved our study. The study extracted available data of 138 participants (72 concussed athletes, 66 non-concussed athletes with no history of concussion) from a much larger data set of approximately 1500 individuals. Criteria for inclusion in the concussion group required that participants were concussed high school athletes who were tested within 72 h of sustaining a concussion. Athletes in the control group were high school athletes with no history of concussion who completed baseline assessments. All athletes in the study participated in the Sports Medicine Concussion Program at the University of Pittsburgh Medical Center (in accordance with Field, Collins, Lovell, & Maroon, 2003). Athletes within the sample were included from high schools within the states of Pennsylvania, Michigan, Illinois, Oregon, and Maine, as part of an ongoing clinical program implementing baseline and post-injury neuropsychological testing to assist team sports-medicine personnel in making return-to-play decisions after the occurrence of sports-related concussions. Concussed athletes participated primarily in football (73%) while controls participated primarily in non-contact sports (79%) such as track and tennis (Table 2). Participants in the concussion group were significantly more likely to be male, and younger in age (Table 3). Of note, age did not emerge as a significant contributor when included as a covariate in between-groups analyses, as discussed in the results section below.

Data were collected regarding athletes' concussion status (independent variable) and ImPACT was the method by which baseline and post-concussion presentation of symptoms and constellation of cognitive abilities (dependent variables) were documented. As part of the Sports Medicine Concussion Program at the University of Pittsburgh Medical Center, all athletes in this study underwent a baseline or pre-injury evaluation, and were administered ImPACT before the 2000, 2001, or 2002 athletic seasons. Eleven individuals were excluded from the study, having achieved a score of 20 or higher on the Impulse Control, which raised questions regarding the general testing approach taken by those participants (Lovell, 2004).

Table 2
Participants' sport by concussion group

| Sport | Group | |
|----------------------------|----------------------------|--------------------------|
| | Concussed (<i>N</i> = 72) | Control (<i>N</i> = 66) |
| Football | 52 (72.7%) | 0 (0%) |
| Soccer | 5 (6.5%) | 12 (18.2%) |
| Ice Hockey | 4 (5.6%) | 0 (0%) |
| Field Hockey | 3 (4.2%) | 0 (0%) |
| Basketball | 3 (3.9%) | 0 (0%) |
| Other contact ^a | 5 (6.5%) | 2 (3.0%) |
| Non-contact ^b | 0 (0%) | 52 (78.8%) |

^a Other contact sports: softball, volleyball, and gymnastics.

^b Non-contact sports: track and tennis.

Table 3
Demographic data for concussed and non-concussed groups

| Variable | Concussion group | | F/χ^2 | Significance | ES ^a |
|---------------------|------------------|------------|------------|--------------|-----------------|
| | Concussed | Control | | | |
| Age | 16.5 (2.3) | 17.3 (1.7) | 5.35 | .022 | $d = .19$ |
| Education | 10.4 (2.0) | 10.8 (1.8) | 2.1 | .149 | $d = .10$ |
| Gender ^b | | | | | |
| Male | 79.2% | 43.9% | | | |
| Female | 20.8% | 56.1% | | | |
| Special education | 3% | 2% | 0.23 | .60 | $\phi = .04$ |
| Learning disability | 3% | 1% | 0.28 | .60 | $\phi = .04$ |

^a ES = Effect Size; ϕ for χ^2 analyses, d for ANOVA.

^b $\chi^2 = 18.2$, significance = .001, ES: $\phi = .38$.

1.2. Materials/procedures

All baseline data were collected during the off-season (i.e., before preseason contact drills). IMPACT is inclusive of a standardized demographic questionnaire that requires the athlete to document relevant educational, sports participation, and personal medical history. Test administrators were trained to define concussion as a “traumatically induced alteration in mental status that may or may not be accompanied by a loss of consciousness”, based on the standard American Academy of Neurology nomenclature (AAN, 1997). High school athletes in our study population who experienced a cerebral concussion were referred for and received post-injury IMPACT evaluation within 72 h of injury. In-season concussions were diagnosed on the basis of the following criteria (in accordance with Field et al., 2003): (1) any observable alteration in mental status or consciousness on following a blow to the head or body during sport participation, and/or (2) the presence of LOC and/or anterograde or retrograde amnesia identified in an on-field examination, and/or (3) any self-reported symptoms such as cognitive “fogginess”, headache, nausea and/or vomiting, dizziness, balance problems, and visual changes after a collision involving the head or body. Certified athletic trainers or team physicians who were present on the sideline at the time of injury made the initial diagnosis of concussion.

1.3. Analyses

One-way analyses of variance were conducted to identify between-group differences on age and education, and chi-square analyses were conducted to identify between-group differences on gender, handedness, diagnosis of learning disability, and history of special education. MANOVA was conducted to establish between-group differences on the dependent measures. Stepwise discriminant analysis was performed to identify variables that discriminated between concussion groups, with total score on the Symptom Scale, and performance on the five IMPACT Composite scores as the independent variables. All analyses were conducted with an alpha level of $p < .05$ using SPSS statistical software (SPSS, 2003). Effect Size was reported as either a correlation coefficient for the discriminant analysis, Cohen’s d for ANOVA, or Partial Eta² for MANOVA.

2. Results

Demographic variables were analyzed to establish between-group homogeneity, with no differences noted between concussion history groups on age, education, handedness, history of special education, or diagnosis of learning disability. Males were significantly more likely [$\chi^2(1) = 18.2$, $p = .001$, $\phi = .36$] to be in the concussion group (79%) than the control group (44%), although this is consistent with the available literature, in that many sports traditionally played by males (especially football) have significantly higher rates of concussion per athletic exposure (Powell & Barber-Foss, 1999). Athletes in the concussion group were significantly younger than athletes in the control group (16.5 versus 17.3) [$F(1,136) = 5.35$; $p = .022$; $d = .38$]. While none of the controls had a history of concussion, 83% of those in the concussed group had a history of one previous concussion, and 17% had a history of two or more concussions. Between groups analyses of demographic data are provided in Table 3.

Table 4

Univariate comparisons for variables in the MANOVA/discriminant analysis

| Variable | Concussion group | | $F(1,136)$ | Significance | Partial Eta ² |
|-------------------------|------------------|-------------|------------|--------------|--------------------------|
| | Concussed | Control | | | |
| Symptom checklist total | 26.5 (22.1) | 7.2 (12.0) | 39.6 | .0001 | .23 |
| Verbal Memory index | 79.1 (12.3) | 89.3 (8.2) | 32.4 | .0001 | .19 |
| Visual Memory index | 65.9 (14.8) | 79.6 (12.2) | 34.9 | .0001 | .20 |
| Reaction Time Index | .665 (.15) | .536 (.06) | 43.6 | .0001 | .24 |
| Processing Speed Index | 32.7 (7.5) | 42.2 (6.6) | 61.2 | .0001 | .31 |
| Impulse Control index | 6.8 (5.0) | 6.7 (4.2) | 0.26 | .87 | .00 |

MANOVA (Hotelling's Trace): [$F(6,131) = 16.6; p = .001$].

Table 5

Classification table for concussion status based on Post-Concussion Symptom Scale, and the ImpACT Impulse Control, Processing Speed, and Visual Memory composite scores

| Actual | Predicted group membership concussion group | | Total |
|---------------|---|---------|-------|
| | Concussed | Control | |
| Positive (N) | 59 | 13 | 72 |
| None | 7 | 59 | 66 |
| Concussed (%) | 81.9 | 18.1 | 100 |
| Not concussed | 10.6 | 89.4 | 100 |

Note. 85.5% of original grouped cases correctly classified.

A multivariate analysis of variance (MANOVA) was performed with concussion group as the independent variable and the five ImpACT composite scores and the symptom scale score as the dependent variables. Hotelling's Trace revealed a significant multivariate effect of concussion group on cognitive performance [$F(6,131) = 16.6; p = .001$]. Univariate ANOVAs revealed significant effects of concussion group on Verbal Memory [$F(1,136) = 32.4; p = .001$], Visual Memory [$F(1,136) = 34.9; p = .001$], reaction time [$F(1,136) = 43.6; p = .001$], Processing Speed [$F(1,136) = 61.1; p = .001$], and symptom scale scores [$F(1,136) = 39.6; p = .001$], but no effect of concussion group on Impulse Control scores [$F(1,136) = 0.3; p = .87$] (see Table 4 for Effect Size). Age did not emerge as a covariate, and did not account for a significant amount of between-group variance [$F(6,131) = 1.58; p = .16$; Partial Eta² = .07].

A stepwise discriminant analysis was conducted with the total score on the post-concussion symptom checklist and the five ImpACT composite scores. One discriminant function identified post-concussion checklist scores, Processing Speed composite, Visual Memory composite, and Impulse Control composite as significant factors [$\chi^2(4) = 74.4, p = .0001$], with 85.5% of cases correctly classified. Eighty-two percent of participants in the concussed group and 89.4% of participants in the non-concussed group were correctly classified. Means and standard deviations for the variables in the equation are provided in Table 4 and the classification matrix is provided in Table 5. The Eigenvalue for these data (.742) suggested that the discriminating power of the function was quite high, with a canonical correlation of .653. The significance of the discriminant function and the indices of power are shown in Tables 5 and 6, respectively. Standardized and canonical correlation coefficients are provided in Table 7.

Using the classification results of the DFA, the combined sensitivity of ImpACT and the symptom score (or the probability that a test result will be positive when a concussion is present) is 81.9%, and the specificity (the probability

Table 6

Significance of the discriminant function predicting concussion history, and discriminating power of the discriminant function

| Function | Wilks' lambda | χ^2 | d.f. | Significance |
|-----------------------|---------------|------------------------|-----------------------|--------------|
| 1 | .574 | 74.4 | 4 | .0001 |
| Discriminant function | Eigenvalue | Percentage of variance | Canonical correlation | |
| 1 | .742 | 100 | .653 | |

Table 7

Standardized canonical discriminant function coefficients and pooled within-groups correlations for Post-Concussion Symptom Scale, and the ImPACT Impulse Control, Processing Speed, and Visual Memory composite scores

| Factor | Standardized coefficients | Correlations |
|-------------------------------|---------------------------|--------------|
| Visual Memory composite | .347 | .588 |
| Processing Speed composite | .648 | .778 |
| Impulse Control composite | .361 | -.016 |
| Post-Concussion Symptom Scale | -.475 | -.626 |

that a test result will be negative when a concussion is not present) is 89.4%. The positive likelihood ratio (PLR—ratio between the probability of a positive test result given the presence of a concussion and the probability of a positive test result given the absence of a concussion) is 7.73:1. The negative likelihood ratio (NLR—ratio between the probability of a negative test result given the presence of a concussion and the probability of a negative test result given the absence of concussion) is .20:1. The positive predictive value (PPV—probability that a concussion is present when the test is positive) is 89.4% and the negative predictive value (NPV—probability that a concussion is not present when the test is negative) is 81.9%.

3. Discussion

Athletic participation is a daily activity for many youth, adolescents, and young adults, placing them at risk for sports-related concussion. Multiple sports-related concussions have been shown to result in impaired neurocognitive functioning post-injury (Collins, Lovell, et al., 1999), decreased performance on baseline testing (Moser & Schatz, 2002; Moser, Schatz, & Jordan, 2005), and place the athlete at increased risk for more severe on-field markers of concussion, such as loss of consciousness, anterograde amnesia, and confusion (Collins et al., 2002). Neuropsychological baseline assessment paradigms facilitate the detection and management of mild neurocognitive changes in athletes who have sustained a concussion (Schatz & Zillmer, 2003), and computerized assessment of sports-related concussion offers unique advantages to the athlete, athletic trainer, team physician, consulting neuropsychologist, coach, and the athlete's family (McKeever & Schatz, 2003).

The current study demonstrates that the ImPACT computerized test battery is both a sensitive and specific instrument for the assessment of the neurocognitive and neurobehavioral sequelae of concussion. More importantly, as a whole, ImPACT's PPV/NPV and PLR/NLR are very high, so poor performance on the composite score (either relative to baseline or compared to normative sample) yields a very strong likelihood of reflecting concussion. This can only serve to improve our ability to diagnose and subsequently treat sports concussion.

The difficult part of sports-concussion has always been having highly sensitive but accurate techniques to detect the presence of concussion, given that standard techniques of a neurological examination, neuroimaging, and electrophysiological techniques are notoriously poor at detecting concussions. It appears that ImPACT is clearly sensitive and specific in detecting sports concussions, at least relative to healthy controls.

It is not perfectly clear what the relatively weaker specificity in this study reflects. Not all concussed athletes show symptoms or cognitive deficits after a concussion, especially given that some were tested up to 72 h after the concussion. It is conceivable that some of the concussed athletes had "recovered" enough at the time of testing that they truly were back to baseline. This plausible scenario would artificially lower the sensitivity.

Our results show that ImPACT provides post-injury cognitive and symptom data that can assist a practitioner in making safer return to play decisions. Using the neuropsychological data provided by ImPACT alone, 85% of cases were correctly classified. In this study, cognitive impairments in Visual Memory, Processing Speed, and Impulse Control along with symptom status effectively classified most of the concussed and control athletes. When used appropriately, by a trained neuropsychologist and in conjunction with a thorough clinical interview, the utility of this instrument is likely to be further enhanced. Therefore, ImPACT can serve as an effective tool in the concussion management process. While our results are very strong at the group level, our findings do not directly address decision making at the individual level. For example, what combination of post-concussion symptom scores and ImPACT composite score changes are needed to identify a concussion? This will be the focus of future research using ImPACT.

This study is not without its limitations. While post-concussion evaluations were performed on a prospective “as needed” basis, the current research study was retrospective in nature. This retrospective “concussed versus athletic control” design yielded groups with significantly different ages, genders, and history of concussion. The concussion group was comprised of a significantly greater percentage of males, and was significantly (although less than 1 year) younger. In spite of the fact that age did not emerge as a significant predictor of between-group variance, a prospective truly matched-control design would be more appropriate. While all but the Impulse Control ImPACT composite score contributed to a multivariate between-groups difference (on MANOVA), Impulse Control emerged (along with Visual Memory, Processing Speed, and Symptom Scale scores) as variables that contributed towards discriminating between groups. It appears that shared variance among correlated predictor variables may have “cancelled out” certain predictor variables (such as Verbal Memory) and thus allowing other variables (such as Impulse Control) to contribute unique variance to the discriminant analysis. Concussed athletes participated exclusively in “at-risk” contact sports and had a history of concussion, while non-concussed athletes participated in low risk non-contact sports and had no history of concussion. Participants in the concussion group participated primarily in football, which in part explains why there were more males in this group.

ImPACT offers a thorough assessment of changes in cognitive functioning and symptom status following concussion, which is consistent with Concussion in Sport group recommendations that neuropsychological assessment become an integral aspect of concussion diagnosis and management (Aubry et al., 2002; McCrory et al., 2005), and that athletes should not return to competition until they are asymptomatic. Based on the recommendations of the Concussion in Sport groups and the current findings, it is recommended that any athlete participating in contact sport receive a baseline neurocognitive evaluation of some sort, whether computerized or traditional paper and pencil testing, dependent on the resources and preferences of the athlete’s program. This will not only improve the ability of sports medicine personnel to manage recovery and return to play decisions by providing an objective comparison with post-concussion levels of cognitive functioning, but also make participation in organized athletic programs safer for student athletes.

References

- AAN. (1997). Practice parameter: The management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee. *Neurology*, 48(3), 581–585.
- Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., et al. (2002). Summary and agreement statement of the 1st international symposium on concussion in sport, Vienna. *Clinical Journal of Sport Medicine*, 12, 6–11.
- Barth, J. T., Alves, W., Ryan, T., Macciocchi, S., Rimel, R. W., Jane, J. J., & Nelson, W. (1989). Mild head injury in sports: Neuropsychological sequelae and recovery of function. In L. H. S., E. H. M., & B. A. L. (Eds.), *Mild head injury* (pp. 257–275). New York: Oxford University Press.
- Collie, A., Darby, D., & Maruff, P. (2001). Computerised cognitive assessment of athletes with sports related head injury. *British Journal of Sports Medicine*, 35(5), 297–302.
- Collins, M. W., Grindel, S. H., Lovell, M. R., Dede, D. E., Moser, D. J., Phalin, B. R., et al. (1999). Relationship between concussion and neuropsychological performance in college football players. *Journal of the American Medical Association*, 282(10), 964–970.
- Collins, M. W., Lovell, M. R., Iverson, G. L., Cantu, R. C., Maroon, J. C., & Field, M. (2002). Cumulative effects of concussion in high school athletes. *Neurosurgery*, 51(5), 1175–1181.
- Collins, M. W., Lovell, M. R., & Mckeag, D. B. (1999). Current issues in managing sports-related concussion. *Journal of the American Medical Association*, 282(24), 2283–2285.
- Collins, M., Stump, J., & Lovell, M. (2004). New developments in the management of sports concussion. *Current Opinion in Orthopaedics*, 15, 100–107.
- Field, M., Collins, M. W., Lovell, M. R., & Maroon, J. (2003). Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *Journal of Pediatrics*, 142, 546–553.
- Guskiewicz, K. M., McCrea, M., Marshall, S. W., Cantu, R. C., Randolph, C., Barr, W., et al. (2003). Cumulative effects associated with recurrent concussion in collegiate football players: The NCAA concussion study. *Journal of the American Medical Association*, 290, 2549–2555.
- Hinton-Bayre, A. D., Geffen, G. M., Geffen, L. B., McFarland, K. A., & Friis, P. (1999). Concussion in contact sports: Reliable change indices of impairment and recovery. *Journal of Clinical and Experimental Neuropsychology*, 21(1), 70–86.
- Iverson, G., Gaetz, M., Lovell, M., & Collins, M. (2004). Relation between subjective foginess and neuropsychological testing following concussion. *Journal of the International Neuropsychology Society*, 10, 1–3.
- Iverson, G., Gaetz, M., Lovell, M., & Collins, M. (2005). Validity of ImPACT for measuring processing speed following sports-related concussion. *Journal of Clinical and Experimental Neuropsychology*, 27, 683–689.
- Iverson, G., Lovell, M., & Collins, M. (2002). Validity of ImPACT for measuring the effects of sports-related concussion. *Archives of Clinical Neuropsychology*, 17(8), 769.
- Johnston, K. M., McCrory, P., Mohtadi, N. G., & Meeuwisse, W. (2001). Evidence-Based review of sport-related concussion: Clinical science. *Clinical Journal of Sport Medicine*, 11(3), 150–159.

- Lovell, M. (1999). Evaluation of the professional athlete. In J. E. Bailes, M. Lovell, & J. Maroon (Eds.), *Sports-related concussion* (pp. 200–214). St. Louis: Quality Medical Publishing.
- Lovell, M. (2004). *ImPACT Version 2.0 Clinical User's Manual*. Accessed 8/2/2005 at <http://www.impacttest.com/clients.htm>.
- Lovell, M., & Burke, C. J. (2002). The NHL concussion program. In R. Cantu (Ed.), *Neurologic athletic head and spine injury* (pp. 32–45). Philadelphia: WB Saunders.
- Lovell, M., Collins, M., Iverson, G., Johnston, K., & Bradley, J. (2004). Grade 1 or “ding” concussions in high school athletes. *American Journal of Sports Medicine*, 32, 47–54.
- Lovell, M. R., & Collins, M. W. (1998). Neuropsychological assessment of the college football player. *Journal of Head Trauma Rehabilitation*, 13(2), 9–26.
- Lovell, M. R., Collins, M. W., Iverson, G. L., Field, M., Maroon, J. C., Cantu, R., et al. (2003). Recovery from mild concussion in high school athletes. *Journal of Neurosurgery*, 98(2), 296–301.
- Lovell, M. R., Collins, M. W., Podell, K., Powell, J., & Maroon, J. (2000). *ImPACT: Immediate post-concussion assessment and cognitive testing*. Pittsburgh, PA: NeuroHealth Systems, LLC.
- Maroon, J. C., Lovell, M. R., Norwig, J., Podell, K., Powell, J. W., & Hartl, R. (2000). Cerebral concussion in athletes: Evaluation and neuropsychological testing. *Neurosurgery*, 47(3), 659–669 (discussion, pp. 669–672).
- McCrory, P., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R., Dvorak, J., et al. (2004). Summary and agreement statement of the 2nd international conference on concussion in sport, Prague. *British Journal of Sports Medicine*, 29, 196–204.
- McKee, C. K., & Schatz, P. (2003). Current issues in the identification, assessment, and management of concussions in sports-related injuries. *Applied Neuropsychology*, 10(1), 4–11.
- Moser, R. S., & Schatz, P. (2002). Enduring effects of concussion in youth athletes. *Archives of Clinical Neuropsychology*, 17(1), 91–100.
- Moser, R. S., Schatz, P., & Jordan, B. (2005). Prolonged effects of concussion in high school athletes. *Neurosurgery*, 57, 300–306.
- Podell, K. (2004). Computerized assessment of sports-related concussions. In M. R. Lovell, et al. (Eds.), *Traumatic brain injury in sports* (pp. 375–396). Lisse, Netherlands: Swets & Zeitlinger.
- Powell, J. W., & Barber-Foss, K. D. (1999). Traumatic brain injury in high school athletes. *Journal of the American Medical Association*, 282(10), 958–963.
- Schatz, P., & Zillmer, E. A. (2003). Computer-based assessment of sports-related concussion. *Applied Neuropsychology*, 10(1), 42–47.
- SPSS. (2003). *SPSS for Macintosh, Release 11*. Chicago: SPSS, Inc.

The “Value Added” of Neurocognitive Testing After Sports-Related Concussion

Derk A. Van Kampen,* Mark R. Lovell,^{†‡} PhD, Jamie E. Pardini,[‡] PhD, Michael W. Collins,[‡] PhD, and Freddie H. Fu,[‡] MD

*From the *Department of Orthopaedics, University Medical Center Groningen, Groningen, the Netherlands, and the [‡]Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania*

Background: Neurocognitive testing has been endorsed as a “cornerstone” of concussion management by recent Vienna and Prague meetings of the Concussion in Sport Group. Neurocognitive testing is important given the potential unreliability of athlete self-report after injury. Relying only on athletes’ reports of symptoms may result in premature return of athletes to contact sport, potentially exposing them to additional injury.

Hypothesis: Use of computer-based neurocognitive testing results in an increased capacity to detect postconcussive abnormalities after injury.

Study Design: Case control study; Level of evidence, 3.

Methods: High school and college athletes diagnosed with a concussion were tested 2 days after injury. Postinjury neurocognitive performance (Immediate Postconcussion Assessment and Cognitive Testing) and symptom (postconcussion symptom) scores were compared with preinjury (baseline) scores and with those of an age- and education-matched noninjured athlete control group. “Abnormal” test performance was determined statistically with Reliable Change Index scores.

Results: Sixty-four percent of concussed athletes reported a significant increase in symptoms, as judged by postconcussion symptom scores, compared with preinjury baseline at 2 days after injury. Eighty-three percent of the concussed sample demonstrated significantly poorer neurocognitive test results relative to their own baseline performance. The addition of neurocognitive testing resulted in a net increase in sensitivity of 19%. Ninety-three percent of the sample had either abnormal neurocognitive test results or a significant increase in symptoms, relative to their own baseline; 30% of a control group demonstrated either abnormalities in neurocognitive testing or elevated symptoms, as judged by postconcussion symptom scores. For the concussed group, use of symptom and neurocognitive test results resulted in an increased yield of 29% overreliance on symptoms alone. In contrast, 0% of the control group had both symptoms and abnormal neurocognitive testing.

Conclusion: Reliance on patients’ self-reported symptoms after concussion is likely to result in underdiagnosis of concussion and may result in premature return to play. Neurocognitive testing increases diagnostic accuracy when used in conjunction with self-reported symptoms.

Keywords: concussion; neurocognitive testing; neuropsychological testing; Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)

Sports-related concussion is a transient neurologic condition that occurs as a result of traumatic biomechanical force.¹ Symptoms may include confusion, disorientation, memory loss, motor unsteadiness, dizziness, headache, or visual disturbances. These symptoms usually occur with no

detectable pathologic changes, and traditional neurodiagnostic tests such as CT, MRI, and electroencephalogram are generally insensitive in measuring the subtle neurologic changes after injury.¹⁷ Recent research has indicated that sports-related concussion is a very common injury and that a minimum of 1.5 million concussion injuries occur in American football in the United States alone.²

The diagnosis and management of sports-related concussion have traditionally relied heavily on an athlete’s self-report of symptoms, but these symptoms may not always be accurately reported to team medical personnel. However, as many clinicians have recognized, and recent research has suggested, an exclusive reliance on the athlete’s report of symptoms may result in potential exposure to additional injury.^{15,18}

[†]Address correspondence to Mark R. Lovell, PhD, Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, 3200 South Water Street, Pittsburgh, PA 15203 (e-mail: lovellmr@upmc.edu).

One or more of the authors have declared a potential conflict of interest as specified in the AJSM Conflict of Interest statement.

Recent research has demonstrated that even in mildly concussed athletes, there can be a pronounced memory decline, lasting for at least 7 days after injury.^{10,22} These data have led to a reexamination of previous return-to-play guidelines and a reconsideration of return-to-play standards that were heavily symptom based. More recently, neurocognitive testing has been endorsed as a “cornerstone” of concussion management by the Vienna Concussion in Sports Group. Specifically, neurocognitive testing has been identified as a helpful piece of additional information to assist in diagnosing and managing concussions.¹ This position was reaffirmed by a second international conference held in Prague in 2004.²⁵ The role of neurocognitive testing in the diagnosis and management of concussion has been emphasized because of the potential unreliability of athlete self-report of symptoms. The minimization of postconcussion symptoms (PCS) is a well-known phenomenon at all levels of competition.^{7,18,19} An athlete’s apparent fear of removal from a game or of losing his or her position on the team may tempt some athletes to deny or underreport postconcussive symptoms. Furthermore, prior research has suggested that premature return to play may be a particularly dangerous practice in children given a likely heightened degree of vulnerability in this group.^{4,5,9}

Despite the widespread acceptance of neurocognitive testing in professional,^{16,20} collegiate,^{6,8,19} and high school sports,^{22,23} few studies have been completed regarding the clinical utility of neurocognitive testing relative to player report of symptoms. In addition, although most concussion protocols espouse “return to baseline” on neurocognitive testing before return to sport activity,^{2,18,21} this fails to take into account test error or “practice effects” as a result of multiple exposures to the test or test battery.

Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) is a computer-based neurocognitive test battery designed specifically for sports-related concussion. This is a widely used program, allowing completion of neurocognitive testing in an expeditious and standardized manner. The ImPACT test battery has undergone extensive validation through multiple studies and is currently used throughout professional and amateur sports.^{11-14,22,23,31}

This study was designed to evaluate the individual and combined sensitivity and specificity of player symptom reporting, as judged by PCS score and neurocognitive testing in a group of high school and college athletes. Athletes were evaluated 2 days after concussion, and their test results were compared with the on-field diagnoses by a medical doctor or certified athletic trainer. The on-field diagnosis by medical staff has traditionally represented the “gold standard” for concussion diagnosis. We hypothesized that the use of computer-based neurocognitive testing (ImPACT) would result in an increased capacity to detect postconcussive abnormalities, compared with PCS alone, in a large group of athletes with diagnosed concussions.

MATERIALS AND METHODS

This study received approval from the University of Pittsburgh Institutional Review Board. All concussed athletes

($N = 122$) had undergone preseason baseline testing with ImPACT and had completed at least 1 follow-up evaluation within 2 days of injury. Athletes within the concussed sample were included from high schools and colleges within the states of Pennsylvania, Michigan, Illinois, Oregon, Maine, and California. This ongoing clinical program implements the use of baseline and postinjury neurocognitive testing to assist team medical staff in making return-to-play decisions after the occurrence of sports-related concussions.

All athletes in our clinical sample were included with the exception of athletes with a history of attention deficit disorder or a psychiatric disorder for which they were receiving medication. No athletes were included with a history of seizures or any other known neurologic disorder. To take into account the possible impact of prior concussions in the injured sample, a series of analyses was conducted to evaluate group differences between athletes with and without a history of prior concussion. There were no statistically significant differences in ImPACT test performance or in symptom reporting at either baseline or postconcussion with the exception of differences between the 2 groups at baseline with regard to the verbal memory composite score ($t = -2.72$, $P < .007$). However, the group with a history of past concussion actually performed better than the no concussion group.

For the purpose of comparison, a sample of 70 nonconcussed athletes composed a control group. This group underwent baseline testing followed by a second evaluation within 1 week of baseline testing to determine test-retest fluctuations. This group was employed in this study to allow a direct comparison of changes in ImPACT and PCS scores during 2 successive testing periods (as was the case with the concussed group). In addition, this control group made possible the completion of statistical analyses to evaluate the specificity of ImPACT testing and PCS scores.

For this study, concussion was defined as a “traumatically induced alteration in mental status with or without a loss of consciousness,” based on the standard American Academy of Neurology nomenclature.¹⁵ In addition to alteration of consciousness, athletes were diagnosed with concussion if they reported other typical symptoms of injury, such as headache, dizziness, balance dysfunction, or nausea, after a blow to the head or body. All injuries were diagnosed by a physician or certified athletic trainer who was present at the time of the injury.

The test battery used in this study was ImPACT.²⁴ The computer-based neurocognitive assessment tool includes a demographic questionnaire, symptom inventory, injury evaluation form, and a 20-minute neurocognitive test battery. The standardized demographic questionnaire requires the athlete to document relevant educational, sports participation, and personal medical history. This section also requires the athlete to report each prior concussion that had been formally diagnosed by a team physician or a certified athletic trainer. Also, ImPACT contains the 22-item PCS scale, which is also administered along with the test battery. The PCS scale evaluates common postconcussive symptoms (such as headache, nausea, dizziness, and trouble sleeping) as rated by the athlete on

TABLE 1
ImPACT Neurocognitive Test Battery^a

| Test Name | Neurocognitive Domain Measured |
|-------------------------------|---|
| Word Memory | Verbal recognition memory (learning and retention) |
| Design Memory | Spatial recognition memory (learning and retention) |
| X's and O's | Visual working memory and cognitive speed |
| Symbol Match | Memory and visual motor speed |
| Color Match | Impulse inhibition and visual motor speed |
| Three Letters Memory | Verbal working memory and cognitive speed |
| Symptom Scale | Rating of individual self-reported symptoms |
| Composite Score | Contributing Score |
| Verbal memory | Averaged percentage correct scores for the Word Memory (learning and delayed), Symbol Match memory test, and Three Letters Memory test |
| Visual memory | Averaged percentage correct scores for the Design Memory (learning and delayed) and the X's and O's test |
| Reaction time | Mean time in milliseconds for the X's and O's (mean counted correct reaction time), Symbol Match (mean weighted reaction time for correct responses), and Color Match (mean reaction time for correct response) |
| Visual motor processing speed | X's and O's (mean correct distracters), Symbol Match (mean correct responses), and Three Letters Memory (number of correct numbers correctly counted) |

^aImPACT, Immediate Postconcussion Assessment and Cognitive Testing.

a Likert scale from 0 (asymptomatic) to 6 (symptomatic) according to his or her condition at the moment of testing.

The ImPACT test battery evaluates multiple aspects of cognitive functioning and is relatively brief. The entire battery, including the demographic information and PCS scale, takes less than 25 minutes to administer, is automatically scored, and produces a 6-page report that is complete with age-referenced percentile scores for select indices. The ImPACT test battery is heavily oriented toward the evaluation of attention, visual scanning, and information processing, although it also evaluates visual memory, verbal memory, and visual motor speed. Multiple studies using the ImPACT test battery have indicated that it is both reliable and valid. For example, Iverson et al¹³ found no significant practice effects in a sample of noninjured high school athletes tested twice within several days. With regard to validity studies, the ImPACT test battery has been found to correlate highly with the Symbol Digit Modalities Test, an often-used test of cognitive speed in research with athletes.¹⁴ This test battery has also demonstrated good sensitivity and specificity in prior studies of young athletes, and ImPACT has the capability to discriminate even mildly concussed high school athletes.^{26,27,31} It has also been found to correlate with athlete self-report of neurocognitive decline and "foginess."¹²

Table 1 provides a listing of the individual ImPACT tests and a description of neurocognitive abilities assessed. From these 6 tests, 4 separate composite scores are generated: verbal memory, visual memory, visual motor speed, and reaction time. In addition, an impulse control composite score is calculated that serves as 1 indicator of test validity. These composite scores were constructed to measure the broad neurocognitive domains that their names suggest, and recent validity studies have indicated good convergence

with more traditional neuropsychological tests.¹⁴ Multiple composite scores were constructed to reflect the reality that athletes who have suffered a concussion may present with different neurocognitive deficits depending on the biomechanics of their injuries,³⁰ their ages,^{9,28} and a variety of other factors. Therefore, no one score can be used to assess severity of injury.

The administration of the ImPACT test battery was supervised by a team of clinical neuropsychologists, athletic trainers, and/or physicians who were trained and supervised in the administration of the standardized inventory. The ImPACT test battery, including the PCS scale, was administered within 2 days of injury. All of the data obtained from the administration process were automatically generated within the ImPACT clinical report and used in the current analysis.

Significant declines in test scores after concussion and significant increases in symptom scores were determined by the application of Reliable Change Index (RCI) scores as described by Iverson et al¹³ and presented in Figure 1. The use of RCI scores is an increasingly popular method

$SEM_1 = SD \sqrt{1 - r_{12}}$ Standard deviation from time 1 multiplied by the square root of 1 minus the test-retest coefficient.

$SEM_2 = SD \sqrt{1 - r_{12}}$ Standard deviation from time 2 multiplied by the square root of 1 minus the test-retest coefficient.

$S_{diff} = \sqrt{SEM_1^2 + SEM_2^2}$ Square root of the sum of the squared SEMs for each testing occasion.

Figure 1. Reliable Change Index score formula. SEM, standard error of the mean.

TABLE 2
Group Means and RCI Values for ImPACT Composite Scores^a

| ImPACT Composite Score | Concussed Group Baseline | Concussed Group at Follow-Up | RCI Value (.80) Confidence Interval |
|------------------------|--------------------------|------------------------------|-------------------------------------|
| Verbal memory | 85.7 (8.9) | 76.0 (14.4) | 8.75 |
| Visual memory | 74.0 (12.8) | 64.3 (13.8) | 13.55 |
| Reaction time | 0.57 (0.08) | 0.64 (0.13) | 0.06 |
| Processing speed | 36.0 (6.8) | 32.7 (8.6) | 4.98 |
| Symptom report | 6.8 (9.6) | 25.6 (19.9) | 9.18 |

^aRCI, Reliable Change Index, ImPACT, Immediate Postconcussion Assessment and Cognitive Testing. Standard deviations are in parentheses.

to account for practice effect and other factors that can influence test scores over repeated testing.^{3,10,27} The RCI scores allow a clinician to account for measurement error surrounding test-retest difference score and therefore adjust each score for practice effects secondary to multiple exposures to the particular test.

For this study, RCI indices were established for the verbal memory, visual memory, reaction time, visual motor processing speed, and PCS composite scores produced in the ImPACT report. An athlete's test performance was deemed to be reliably different relative to his or her own baseline if the difference between postconcussion and baseline scores on a given composite index of ImPACT was larger than the established RCI scores, as determined in previously published research by Iverson et al.¹³ Iverson et al have used these RCI scores in researching the ImPACT test battery by testing 56 healthy "not concussed" athletes twice within a few days to examine their test-retest reliability, practice effect, and reliable change parameters and to ultimately determine the normal variability of testing. Whenever an athlete exceeds these normal variations, he or she is judged as abnormal on the test score in question. For example, because the established RCI value for verbal memory is 8.75, any decline on this index (relative to baseline) that exceeds this value is rated as significantly different. Because the verbal memory composite scores are expressed as integers, a score that has decreased by 9 points or more would be categorized as abnormal. Additional RCI values are provided in Table 2.

Postconcussion Evaluation

All the athletes in our study had taken a preinjury (baseline) test from which difference scores could be calculated after injury. Whenever an athlete experienced a concussion during the period 2001 to 2004, he or she was referred for evaluation, which involved completion of the ImPACT test and PCS score. Concussions were diagnosed on the basis of the criteria described earlier.

Statistical Analysis

Abnormal performance was determined by comparing the athlete's postinjury scores to his or her baseline performance. Deviations from baseline performance larger than

the established RCI scores for the particular composite score were deemed to be abnormal. Statistical differences in concussion classification using symptoms and ImPACT test results were determined via χ^2 analyses. All statistical calculations were performed with the Statistical Package for the Social Sciences (SPSS Science Inc, Chicago, Ill).

RESULTS

Sample characteristics are displayed in Table 3 for both concussed and control groups. Ninety-seven of the 122 concussed athletes (80%) were high school students, and 25 (20%) were college students. The control group was composed of 50 (71%) high school and 20 college (29%) athletes. Mean education level for the collective sample was 10.2 years (range, 8-15 years). The concussed sample was largely male athletes (82%), whereas the control group consisted of more female than male athletes (54%). American football athletes composed a majority of the concussed sample (68%). Eleven percent were soccer athletes, 8% were basketball athletes, and the remaining 13% competed in ice hockey, wrestling, or lacrosse. For the control group, 50% were swimmers, 24% were soccer players, 17% were track athletes, and the remaining athletes participated in wrestling and lacrosse. With regard to concussion history, 76% of the concussed sample had no prior concussion history, and 24% had a past history of concussion. Fourteen percent of the concussed sample had a history of 1 prior injury. Eight percent of the sample had experienced 2 prior concussions, and only 2% had experienced 3 or more concussions. The control group had a slightly lower rate of concussion, with only 10% of the group having experienced a past concussion and none of the group having more than 1 concussion.

Based on their total PCS scores only, 64% of the athletes reported an increase in symptoms from their baseline that exceeded the RCI score. In contrast, only 9% of the control group reported a subjective increase in symptoms from baseline to their second evaluation ($\chi^2_1 = 55.4, P < .00000$). Eighty-three percent of the concussed sample demonstrated at least 1 ImPACT score that exceeded the RCI for that score, whereas 30% of the control group had 1 abnormal ImPACT score. Therefore, the addition of neurocognitive testing resulted in an increase in sensitivity from 64% to 83%, a net increase of 19% for the concussed group.

TABLE 3
Demographic Data of the Concussed
and Nonconcussed Athlete Sample^a

| Variable | Concussed Subjects (N = 122) | Control Subjects (N = 70) |
|--------------------------------------|---------------------------------|------------------------------|
| Mean (SD) age, y | 16.6 (12-27) | 17.3 (14-22) |
| Mean (SD) education, y | 10.2 (8-15) | 10.9 (8-16) |
| High school, % | 80 | 71 |
| College, % | 20 | 29 |
| Previous concussions, % | | |
| 0 | 76 | 90 |
| 1 | 14 | 10 |
| 2 | 8 | 0 |
| 3 | 2 | 0 |
| Gender: man/woman, % | 82 | 47 |
| Sport, % | | |
| American football | 68.0 | 0 |
| Soccer | 11.0 | 24 |
| Basketball | 7.6 | 0 |
| Swimmers | 0 | 50 |
| Track | 0 | 17 |
| Other | 14.4 | 9 |
| Time between injury to testing, d | 2 | 3 |
| On-field markers ^b | | |
| Positive LOC | 12.3% | NA |
| Retrograde amnesia | 53.5% | NA |
| Anterograde amnesia | 1.8% | NA |
| Confusion | 17.8% | NA |

^aLOC, loss of consciousness; NA, not applicable.

^bBecause of the natural difficulty of collecting on-field markers, some data were missing.

When either the symptom score or at least 1 neurocognitive test result was abnormal, 93% of concussed athletes were correctly identified as concussed when compared with the gold standard of on-field diagnosis. Whereas 30% of the control group did have 1 abnormal ImPACT score, no one (0%) in the control group had both abnormal neurocognitive performance and an increase in symptoms. Overall, the predictive value of having an abnormal PCS score was 93%, but the predictive value of not having an elevated symptom score was only 59%. If ImPACT was used in the absence of symptom data, the predictive value of having at least 1 abnormal neurocognitive test score was 83%, and the predictive value of a negative test result was 70%. However, when criteria for concussion classification were changed to requiring at least 1 abnormal ImPACT test and an abnormal PCS score, the predictive value of neurocognitive testing was 81%, and the predictive value of having a negative score was 83%.

DISCUSSION

Concussion has become a major public health issue because of the risk of both short- and long-term morbidity. Historically, return-to-play guidelines have relied heavily on the athletes' self-reports of symptoms. However, overreliance on athlete symptoms has recently been criticized based on

the tendency of some athletes to underreport symptoms, presumably in an attempt to speed their return to the playing field.¹⁸ We present data in this study that suggest reliance on symptoms alone is inadequate and is likely to lead to missed diagnosis of the injury in a significant number of athletes. We found that only 64% of our recently concussed sample reported a significant increase in symptoms on the PCS scale within 2 days of evaluation. Adding neurocognitive testing increased the number of athletes who were identified as being abnormal to 83%. However, if a significant increase in symptom self-report and a decline on neurocognitive testing were used as classificatory criteria, the "diagnostic yield" increased to 93% compared with the gold standard of on-field diagnosis. Furthermore, we found that although 93% of our concussed sample had either ImPACT or symptom scores that fell within the abnormal range compared to baseline level, none of the nonconcussed sample of athletes had both abnormal symptoms and abnormal ImPACT performance. These findings support previous studies that have indicated an imperfect agreement between self-reported symptoms and decreased neurocognitive test scores after concussion.^{6,10,22}

This is the first study to formally evaluate the sensitivity and specificity of the ImPACT test when used in combination with athlete report of symptoms. Given these results, it is of concern that most return-to-play decisions after concussion have relied heavily on the athlete's self-report of symptoms. In fact, in many sports settings, return-to-play decisions have been based almost exclusively on the self-reported symptoms.^{4,15} This study demonstrates that even athletes who report being symptom free may continue to exhibit neurocognitive deficits that they are either unaware of or are failing to report.

Recently, the Concussion in Sports Group^{1,25} recommended the use of neurocognitive testing in conjunction with other diagnostic information such as symptoms. This current study provides support for this recommendation. Furthermore, our data suggest that if neurocognitive testing is unavailable, the treating physician should be cautious in returning athletes to play based on their self-report of symptoms. This study also provides preliminary support for the use of the ImPACT composite scores as diagnostic indicators, with a higher number of abnormal composite scores suggesting a more severe concussion. In this study, 2 abnormal ImPACT scores did not occur in any of the nonconcussed athletes and may provide a clear marker of injury. However, this is not to suggest that athletes with 1 abnormal ImPACT score are presumed to be normal. Clearly, further study of the individual and aggregate use of ImPACT scores to evaluate the recovery process is needed.

We recognize several limitations with this study. First, our approach used a rigorous statistical method for determination of significant change after concussion, rather than a clinical approach. Therefore, given the relatively conservative nature of RCI scores, it is possible that we may have failed to correctly classify milder concussions in the sample whose scores did not fall outside of the RCI scores. Second, our sample primarily consisted of male high school and collegiate football players, which limits generalizability to other groups. In contrast, our control group consisted of athletes from more

traditionally noncontact sports such as swimming and track and field. Therefore, our concussed and control groups were not identical. However, it is important to note that our assessment of significant change after injury was based on whether the athletes differed relative to their own baseline scores rather than comparison with the control group. Therefore, differences between the concussed and control group with regard to the sport participated in and concussion history did not affect the classification of athletes with regard to whether their test performance was normal or abnormal. In the future, we hope to continue to investigate the relationship of neurocognitive performance and athletes' report of symptoms in other sport groups outside of football. In addition, because the study was conducted exclusively with nonprofessional athletes, our findings should not be generalized beyond those sports levels. Recent published studies of professional football athletes in the United States have suggested a quicker recovery rate and no significant effect of multiple injuries in this group when compared with younger nonprofessional athletes.^{28,29} Therefore, the development of different RCI criteria based on age and level of competition may be useful, as recommended by the recent Prague conference.²⁵

Based on the current study, we conclude that the use of neurocognitive testing (ImPACT) results in an increased sensitivity to detect postconcussion abnormalities. Therefore, we believe that neurocognitive assessment tools such as ImPACT provide "added value" to the more traditional assessment of symptoms.

ACKNOWLEDGMENT

The authors thank Michael McClincy of Dartmouth University for his input.

REFERENCES

- Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 1st International Symposium on Concussion in Sport, Vienna 2001. *Clin J Sport Med*. 2002;12:6-11.
- Bailes JE, Cantu RC. Head injury in athletes. *Neurosurgery*. 2001;48:26-45, discussion 45-26.
- Barr WB, McCrea M. Sensitivity and specificity of standardized neurocognitive testing immediately following sports concussion. *J Int Neuropsychol Soc*. 2001;7:693-702.
- Cantu RC. Cerebral concussion in sport: management and prevention. *Sports Med*. 1992;14:64-74.
- Cantu RC. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *J Athl Train*. 2001;36:244-248.
- Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA*. 1999;282:964-970.
- Delaney JS, Lacroix VJ, Leclerc S, Johnston KM. Concussions during the 1997 Canadian Football League season. *Clin J Sport Med*. 2000;10:9-14.
- Echemendia RJ, Putukian M, Mackin RS, Julian L, Shoss N. Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clin J Sport Med*. 2001;11:23-31.
- Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *J Pediatr*. 2003;142:546-553.
- Hinton-Bayre AD, Geffen GM, Geffen LB, McFarland KA, Friis P. Concussion in contact sports: reliable change indices of impairment and recovery. *J Clin Exp Neuropsychol*. 1999;21:70-86.
- Iverson GL, Gaetz M, Lovell MR, Collins MW. Cumulative effects of concussion in amateur athletes. *Brain Inj*. 2004;18:433-443.
- Iverson GL, Gaetz M, Lovell MR, Collins MW. Relation between subjective foggy and neuropsychological testing following concussion. *J Int Neuropsychol Soc*. 2004;10:904-906.
- Iverson GL, Lovell M, Collins M. Interpreting change on ImPACT following sport concussion. *Clin Neuropsychol*. 2003;17:460-467.
- Iverson GL, Lovell M, Collins MW. Validity of ImPACT for measuring processing speed following sports-related concussion. *J Clin Exp Neuropsychol*. 2005;27:683-689.
- Kelly JP, Rosenberg JH. Diagnosis and management of concussion in sports. *Neurology*. 1997;48:575-580.
- Lovell M, Barr W. American professional football. In: Lovell M, Echemendia R, Barth J, Collins M, eds. *Traumatic Brain Injury in Sports*. Lisse, Belgium: Swetz & Zeitlinger; 2004:209-220.
- Lovell M, Collins M, Bradley J. Return to play following sports-related concussion. *Clin Sports Med*. 2004;23:421-441, ix.
- Lovell M, Collins M, Maroon J, et al. Inaccuracy of symptom reporting following concussion in athletes. *Med Sci Sports Exerc*. 2002;34:S298.
- Lovell M, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil*. 1998;13:9-26.
- Lovell M, Echemendia R, Burke C. Professional ice hockey. In: Lovell M, Echemendia R, Barth J, Collins M, eds. *Traumatic Brain Injury in Sports*. Lisse, Belgium: Swetz & Zeitlinger; 2004:221-230.
- Lovell MR. Neuropsychological testing: past, present and future. Paper presented at: First Annual Meeting of the Concussion in Sport; November 2001; Vienna, Austria.
- Lovell MR, Collins MW, Iverson GL, et al. Recovery from mild concussion in high school athletes. *J Neurosurg*. 2003;98:296-301.
- Lovell MR, Collins MW, Iverson GL, Johnston KM, Bradley JP. Grade 1 or "ding" concussions in high school athletes. *Am J Sports Med*. 2004;32:47-54.
- Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral concussion in athletes: evaluation and neuropsychological testing. *Neurosurgery*. 2000;47:659-669, discussion 669-672.
- McCrary P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Clin J Sport Med*. 2005;15:48-55.
- Moser RS, Schatz P. Enduring effects of concussion in youth athletes. *Arch Clin Neuropsychol*. 2002;17:91-100.
- Naugle RI, Chelune GJ, Cheek R, Luders H, Awad IA. Detection of changes in material-specific memory following temporal lobectomy using the Wechsler Memory Scale-Revised. *Arch Clin Neuropsychol*. 1993;8:381-395.
- Pellman EJ, Lovell MR, Viano DC, Casson IR. Concussion in professional football: recovery of NFL and high school athletes assessed by computerized neuropsychological testing, part 12. *Neurosurgery*. 2006;58:263-274.
- Pellman EJ, Lovell MR, Viano DC, Casson IR, Tucher AM. Concussion in professional football: neuropsychological testing, part 6. *Neurosurgery*. 2004;55:1290-1305.
- Pellman EJ, Viano DC, Tucker AM, Casson IR, Waeckerle JF. Concussion in professional football: reconstruction of game impacts and injuries. *Neurosurgery*. 2003;53:799-814.
- Schatz P, Pardini JE, Lovell MR, Collins MW, Podell K. Sensitivity and specificity of the ImPACT test battery for concussion in athletes. *Arch Clin Neuropsychol*. 2006;21:91-9.

Summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001*

M Aubry, R Cantu, J Dvorak, T Graf-Baumann, K Johnston (Chair), J Kelly, M Lovell, P McCrory, W Meeuwisse, P Schamasch (the Concussion in Sport (CIS) Group)

Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries

In November 2001, the first International Symposium on Concussion in Sport was held in Vienna, Austria. This symposium was organised by the International Ice Hockey Federation (IIHF), the Federation Internationale de Football Association Medical Assessment and Research Centre (FIFA, F-MARC), and the International Olympic Committee Medical Commission (IOC).

The aim of the symposium was to provide recommendations for the improvement of safety and health of athletes who suffer concussive injuries in ice hockey, football (soccer), and other sports. To this end a range of experts were invited to address specific issues of epidemiology, basic and clinical science, grading systems, cognitive assessment, new research methods, protective equipment, management, prevention, and long term outcome, and to discuss a unitary model for understanding concussive injury. At the conclusion of the conference, a small group of experts were given a mandate by the conference delegates and organising bodies to draft a document describing the agreement position reached by those in attendance at that meeting. For the purpose of this paper, this group will be called the Concussion in Sport Group (CISG).

INTRODUCTION

This review seeks to summarise the findings of the Vienna conference and to provide a working document that will be widely applicable to sport related concussion. This document is developed for use by doctors, therapists, health professionals, coaches, and other people involved in the care of injured athletes, whether at the recreational, elite, or professional level.

During the course of the symposium, a persuasive argument was made that a comprehensive systematic approach to concussion would be of potential benefit to aid the injured athlete and direct

management decisions.¹ This protocol represents a work in progress, and, as with all other guidelines or proposals, it must undergo revision as new information is added to the current literature and understanding of this injury.

The concussion in sport protocol includes:

- (1) Clinical history
- (2) Evaluation
- (3) Neuropsychological testing
- (4) Imaging procedures
- (5) Research methods
- (6) Management and rehabilitation
- (7) Prevention
- (8) Education
- (9) Future directions
- (10) Medicolegal considerations

A REVISED DEFINITION OF CONCUSSION

Over 35 years ago, the committee on head injury nomenclature of the Congress of Neurological Surgeons proposed a "consensus" definition of concussion.² The American Medical Association and the International Neurotraumatology Association subsequently endorsed this definition.³ This definition was recognised as having a number of limitations in accounting for the common symptoms of concussion. In addition, there was an inability to include relatively minor impact injuries that result in persistent physical and/or cognitive symptoms. Seeking to transcend these limitations, the CISG has developed the following definition of concussion.

"Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be used in defining the nature of a concussive head injury include:

(1) Concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an "impulsive" force transmitted to the head.

(2) Concussion typically results in the rapid onset of short lived impairment of neurological function that resolves spontaneously.

(3) Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury.

(4) Concussion results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course.

(5) Concussion is typically associated with grossly normal structural neuroimaging studies.

THE CISG CONCUSSION PROTOCOL

Clinical history

Recognising the importance of a detailed concussion history and appreciating the fact that many athletes will not recognise all the concussions that they may have suffered in the past, a detailed concussion history is of value. The athlete currently at a high performance level in collision sport has seldom had the first concussion on presentation in the consultant's office. The history should include specific questions as to previous symptoms of a concussion, not just perceived number of past concussions.⁴ It is also worth noting that dependence on the recall of concussive injuries by teammates or coaches has been shown to be unreliable.⁵ The finding that there is increased risk of subsequent concussive injuries after a first concussion is documented, although the reasons for this remain controversial. The clinical history should also include information about all previous head, face, or neck injuries as these may have clinical relevance to the present injury. It is worth emphasising that, in the setting of faciomaxillary injuries, coexistent concussive injuries may be missed unless specifically assessed.

Specific questions about disproportionate impact and matching of symptom severity may allude to progressively increasing vulnerability to injury—that is, more pronounced persistent symptoms from smaller hits. The pathophysiological nature of this phenomenon remains unclear.

* This statement is being published simultaneously with the *Clinical Journal of Sport Medicine and the Physician and Sportsmedicine*.

Table 1 Scale of postconcussion symptoms

| | Rating | | | | | | |
|---------------------------|--------|---|---|----------|---|---|--------|
| | None | | | Moderate | | | Severe |
| Headache | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nausea | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Vomiting | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Drowsiness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Numbness or tingling | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Dizziness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Balance problems | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sleeping more than usual | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to light | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to noise | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling slowed down | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling like "in a fog" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty concentrating | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty remembering | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Trouble falling asleep | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| More emotional than usual | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Irritability | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sadness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nervousness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Other | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

Adapted from Lovell and Collins.¹³

One of the issues that was speculated upon at the conference was whether concussion represents a unitary phenomenon with a linear spectrum of injury severity or whether different concussion subtypes exist. These subtypes may represent differences in clinical manifestations (confusion, memory problems, loss of consciousness), anatomical localisation (cerebral *v* brainstem, for example), biomechanical impact (rotational *v* linear force), genetic phenotype (ApoE4 positive *v* ApoE4 negative), neuropathological change (structural injury *v* no structural injury), or an as yet undefined difference. These factors may operate independently or interact with each other. It is clear that the variations in clinical outcome from the same impact force require a more sophisticated approach to the understanding of this phenomenon than is currently available.⁶

The traditional approach to severe traumatic brain injury using loss of consciousness as the primary measure of injury severity has acknowledged limitations in assessing the severity of concussive injury. Findings in this field describe association of loss of consciousness with specific early deficits but does not necessarily imply severity. Further work in this area may help to explain these findings.⁷

There is renewed interest in the role of amnesia (anterograde/retrograde) and its manifestation of injury severity.⁸ Published evidence suggests that the nature, burden, and duration of the clinical postconcussive symptoms may be more important than previously recognised.⁹⁻¹¹

Concussion grading scales

The CISG recognised the strengths and weaknesses of several existing concus-

sion grading scales that attempt to characterise injury severity, but no single system was endorsed. It was the recommendation of the CISG that combined measures of recovery (see below) should be used to assess injury severity (and/or prognosis) and hence individually guide decisions on return to play.

In the absence of scientifically validated return to play guidelines, a clinical construct is recommended using an assessment of injury recovery and graded return to play. The protocol outlined below is adapted from the Canadian Academy of Sport Medicine (CASM) guidelines.¹² Sideline evaluation includes clinical evaluation of signs and symptoms, ideally using a standardised scale of postconcussion symptoms (table 1) for comparison purposes, and acute injury testing as described below under neuropsychological testing.

Evaluation

Sideline evaluation including neurological assessment and mental status testing is an essential component in the protocol. These evaluations are ideally developed in language translations for international sporting groups (an example of such a sideline evaluation developed at McGill University is available in English and French; for a copy, contact author KMJ). In the acute assessment of concussive injury—that is, concussion diagnosis—brief neuropsychological test batteries that assess attention and memory function have been shown to be practical and effective. Such tests include the Maddock's questions¹⁴ and the Standardised Assessment of Concussion (SAC).¹⁵ It is worth noting that standard orientation questions—for example, time, place, person—have been shown to

be unreliable in the sporting situation compared with memory assessment.^{14, 16}

It is recognised, however, that abbreviated testing paradigms are designed for rapid evaluation of concussion on the sidelines and are not meant to replace comprehensive neuropsychological testing, which is sensitive enough to detect subtle deficits that may exist beyond the acute episode.

Signs and symptoms of acute concussion

If any one of the following symptoms or problems is present, a head injury should be suspected, and appropriate management instituted. A player does not need to have lost consciousness to suffer a concussion.

(a) Cognitive features

Unaware of period, opposition, score of game

Confusion

Amnesia

Loss of consciousness

Unaware of time, date, place

(b) Typical symptoms

Headache

Dizziness

Nausea

Unsteadiness/loss of balance

Feeling "dinged" or stunned or "dazed"

"Having my bell rung"

Seeing stars or flashing lights

ringing in the ears

Double vision

Other symptoms such as sleepiness, sleep disturbance, and a subjective feeling of slowness and fatigue in the setting of an impact may indicate that a concussion has occurred or has not resolved.

(c) Physical signs

Loss of consciousness/impaired conscious state

Poor coordination or balance

Concussive convulsion/impact seizure

Gait unsteadiness/loss of balance

Slow to answer questions or follow directions

Easily distracted, poor concentration

Displaying unusual or inappropriate emotions, such as laughing or crying

Nausea/vomiting

Vacant stare/glassy eyed

Slurred speech

Personality changes

Inappropriate playing behavior—for example, running in the wrong direction

Appreciably decreased playing ability

Neuropsychological assessment after concussion

The application of neuropsychological testing in concussion has been shown to be of value and continues to contribute significant information in concussion evaluation.¹⁷ It has been shown that cognitive recovery may precede or follow resolution of clinical symptoms, suggesting that the assessment of cognitive function should be an important component in any return to play protocol.

In the consideration of injury recovery or return to play, such test strategies must assess the cognitive domains of information processing, planning, memory, and switching mental set. Numerous paradigms are in current use. Examples of these include paper and pencil tests (McGill ACE, SAC), condensed batteries (McGill ACE), comprehensive protocols administered by neuropsychologists (NHL, Australian football), and computerised test platforms—for example, IMPACT, CogSport, ANAM, Headminders.¹⁸

The consensus of the CISG was that neuropsychological testing is one of the cornerstones of concussion evaluation and contributes significantly to both understanding of the injury and management of the individual.

Overriding principles common to all neuropsychological test batteries is the need for and benefit of baseline preinjury testing and serial follow up. Recent work with computerised platforms, however, suggests that performance variability may be a key measure for diagnosis of acute concussion even in the absence of a baseline test. This strategy is currently the subject of continuing research. Inherent problems with most neuropsychological tests include the normal ranges, sensitivity and specificity of tests, and practice or learning effect, as well as the observation that players may return to baseline while still symptomatic.^{17, 19} In part, these may be a problem of the currently available pen and paper tests. Computerised testing using infinitely variable test paradigms may overcome these concerns. Computerised testing also has the logistical advantage that the tests may be administered by the team doctor or be web based rather than having to employ a neuropsychologist for a formal assessment. The strengths and weaknesses of such testing have been recently reviewed.¹⁸

The consensus of the CISG was that neuropsychological testing is one of the

cornerstones of concussion evaluation and contributes significantly to both understanding of the injury and management of the individual. Organised sport federations have access to and should attempt to employ such testing as appropriate. To maximise the clinical utility of such neuropsychological assessment, baseline testing is recommended.

Neuroimaging

It was recognised by the CISG that conventional structural neuroimaging is usually normal in concussive injury. Given that caveat, the following suggestions are made. Brain computed tomography (or where available magnetic resonance imaging (MRI) brain scan) contributes little to concussion evaluation, but should be used whenever suspicion of a structural lesion exists. Examples of such situations may include prolonged disturbance of conscious state, focal neurological deficit, seizure activity, or persistent clinical or cognitive symptoms.

Newer structural MRI modalities, including gradient echo, perfusion, and diffusion weighted imaging, have greater sensitivity for structural abnormalities; however, the lack of published studies as well as the absence of preinjury neuroimaging data limits the usefulness of this approach in clinical studies at the present time. In addition, the predictive value of various MRI abnormalities that may be incidentally discovered is not established at the present time. Promising new functional imaging—for example, PET/SPECT/fMRI—technologies, while producing some compelling findings, are still at the early stages of development.²⁰

Although neuroimaging may play a part in postconcussive return to play decisions or for the assessment of moderate to severe brain injury, it is not essential for otherwise uncomplicated concussive injury.

Research methods

A number of research protocols and data evaluating concussion injury assessment, injury susceptibility, and brain function after injury were presented at the Vienna conference. All of these techniques, while offering great potential for injury assessment, must be considered experimental at this time. As much as possible, elite and professional teams are well placed to contribute to these efforts through athlete recruitment for studies showing the scientific value of such approaches.

Electrophysiological recording (ERP, EEG) has shown reproducible abnormalities in the postconcussive state in brain function.¹⁹ Similarly, balance testing has shown impairment after injury, although the mechanism for this is not

established. Biochemical serum markers of brain injury (including S-100b, NSE, MBP) were proposed as means of detecting cellular damage if present.

Genetic phenotyping has been shown to be of benefit in traumatic brain injury. Published studies have shown that ApoE4 is a risk factor for adverse outcome following moderate to severe brain injury.²¹ Similarly ApoE4 has been shown to be a risk factor for the development of chronic traumatic encephalopathy in boxers.²² The significance of ApoE4 in concussion risk or injury outcome is unclear. Other published studies have noted the association of a particular calcium subunit gene abnormality with brain swelling after minor head trauma.²³

Such research is vital in contributing to the science of concussion and will potentially provide valuable information for such important issues as clinical management, return to play guidelines, and long term outcome. Therefore research should be continued and encouraged by sporting organisations.

Management and rehabilitation

Acute response

When a player shows ANY symptoms or signs of a concussion:

- (1) The player should not be allowed to return to play in the current game or practice.
- (2) The player should not be left alone; and regular monitoring for deterioration is essential.
- (3) The player should be medically evaluated after the injury.
- (4) Return to play must follow a medically supervised stepwise process.

A player should never return to play while symptomatic. "When in doubt, sit them out!"

Rehabilitation

It was the consensus of the CISG that a structured and supervised concussion rehabilitation protocol is conducive to optimal injury recovery and safe and successful return to play. The rehabilitation principles were common to all identified programmes and are outlined below. Important principles state that the athlete be completely asymptomatic and have normal neurological and cognitive evaluations before the start of the rehabilitation programme. Therefore the more prolonged the symptom duration, the longer the athlete will have sat out. The athlete will then proceed stepwise with gradual incremental increases in exercise duration and intensity, and pause or backtrack with any recurrence of concussive symptoms. It is appreciated that, although each step may take a minimum of one day, depending on the duration of symptoms, proceeding through each step may take longer in individual circumstances.

Return to play protocol

Return to play after a concussion follows a stepwise process:

- (1) No activity, complete rest. Once asymptomatic, proceed to level (2).
- (2) Light aerobic exercise such as walking or stationary cycling.
- (3) Sport specific training—for example, skating in hockey, running in soccer.
- (4) Non-contact training drills.
- (5) Full contact training after medical clearance.
- (6) Game play.

With this stepwise progression, the athlete should continue to proceed to the next level if asymptomatic at the current level. If any symptoms occur after concussion, the patient should drop back to the previous asymptomatic level and try to progress again after 24 hours.

Prevention

As part of the clinical history, it is advised that details of the protective equipment used at the time of injury be sought, for both recent and remote injuries. The benefit of this approach allows modification and optimisation of protective behaviour and an opportunity for education. That said, there are relatively few methods by which concussive brain injury may be minimised in sport. The brain is not an organ that can be conditioned to withstand injury. Thus, extrinsic mechanisms of injury prevention must be sought.

Rule changes and rule enforcement play a key role in reducing and preventing concussions.

Helmets have been proposed as a means of protecting the head and theoretically reducing the risk of brain injury. In sports in which high speed collisions can occur or which have the potential for missile injuries—for example, baseball—or for falls on to hard surfaces—for example, gridiron, ice hockey—there is published evidence that use of sport specific helmets reduces head injuries.³ For other sports such as soccer and rugby, no sport specific helmets have been shown to be of benefit in reducing rates of head injury.²⁴ Some believe that the use of protective equipment may deleteriously alter playing behaviour so that the athlete actually increases his or her risk of brain injury.²⁵

Although the use of correctly fitting mouthguards can reduce the rate of dental, orofacial, and mandibular injuries, the evidence that they reduce cerebral injuries is largely theoretical, and no clinical evidence for a beneficial effect in reducing concussion rates has yet been demonstrated clinically.²⁶

Consideration of rule changes, such as no head checking in ice hockey, to reduce the head injury rate may be appropriate where a clear cut mechanism is implicated in a particular sport. Similarly, rule enforcement is a critical aspect of such approaches and referees play an important role.

Conditioning of the neck muscles may be of value in reducing impact forces transmitted to the brain. Biomechanical concepts dictate that the energy from an impacting object is dispersed over the greater mass of an athlete if the head is held rigidly. Although attractive from a theoretical standpoint, there is little scientific evidence for the effectiveness of such measures.

Rule changes and rule enforcement play a key role in reducing and preventing concussions.

Education

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues, and those working with them, as well as the general public is a mainstay of progress in this field. Athletes and their healthcare providers must be taught how to detect concussion, its clinical features, assessment techniques, and principles of safe return to play. Methods to improve education including various web based resources (for example, www.concussionsafety.com), educational videos, outreach programmes, concussion working groups, and the support and endorsement of enlightened sport groups such as FIFA, IOC, and IIHF who initiated this endeavour have enormous value and must be pursued vigorously.

The promotion of fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly coaches, parents, and managers play an important part in ensuring these values are implemented on the field of play.

Future directions

Efforts to evaluate long term outcome and any association with repeated concussion, molecular markers, imaging, and functional deficits must guide continuing investigation in this work. Efforts to expand knowledge of injury that may or may not be associated with particular manoeuvres inherent to the game, such as heading in soccer, must be elucidated.

A proposal was made that this concussion working group be identified and given a mandate to provide continuing leadership in the continued development and updating of guidelines and maintenance of the pursuit of a high standard of care in concussion.

Medicolegal considerations

Although agreement exists about the principal messages conveyed by this

document, the authors acknowledge that the science of concussion is at the early stages and therefore management and return to play decisions remain largely in the realm of clinical judgment on an individual basis. It is the intention of the group to analyse the medicolegal aspect of concussions in sports and to offer here a summary of the state of the art and to direct future efforts.

ACKNOWLEDGEMENTS

The Vienna CIS Group thanks the other participants of the symposium for input and enthusiasm, which generated discussion of these ideas. We also thank Darlene Scheurich whose expert organisational abilities contributed to the success of this symposium.

Br J Sports Med 2002;**36**:6–10

Authors' affiliations

M Aubry, Chief Medical Officer, International Ice Hockey Federation

R Cantu, Chief, Neurosurgery Service and Director, Sports Medicine Service, Emerson Hospital, Concord, MA, USA. Medical Director, National Center for Catastrophic Sports Injury Research, Chapel Hill, NC, USA

J Dvorak, Chairman, FIFA Medical Research and Assessment Center (F-MARC), Wilhelm Neurologist and Director of Schulthess Clinic, Zurich, Switzerland

T Graf-Baumann, FIFA Medical Research and Assessment Center (F-MARC), Tenningen, Germany

K Johnston, Chair, Concussion in Sport Group, FIFA, IIHF, IOC; Neurosurgeon and Director of Neurotrauma, McGill University Health Centre (MUHC), McGill University and McGill Sport Medicine Centre, Montreal, Canada

J Kelly, Associate Professor of Clinical Neurology, Northwestern University Medical School, Chicago Neurological Institute, Chicago, IL, USA

M Lovell, Director, Sports Medicine Concussion Program, University of Pittsburgh. Co-director, National Hockey League Neuropsychology Program, Pittsburgh, PA, USA

P McCrory, Brain Research Institute and Center for Sports Medicine Research and Education, University of Melbourne, Melbourne, Australia
W Meeuwisse, University of Calgary Sport Medicine Center, Sport Injury Consultant, National Hockey League, Calgary, Alberta, Canada

P Schamasch, Director, International Olympic Committee Medical Commission, Lausanne, Switzerland

Correspondence to: Dr Johnston, Division of Neurosurgery, Montreal General Hospital, 1650 Cedar Ave, Room L7-524, Montreal, Quebec, Canada H3G 1A4

REFERENCES

- 1 Johnston KM, Lassonde M, Pito A. A contemporary neurosurgical approach to sport-related head injury: the McGill concussion protocol. *J Am Coll Surg* 2001;**192**:515–24.
- 2 Congress of Neurological Surgeons. Committee on Head Injury Nomenclature: glossary of head injury. *Clin Neurosurg* 1966;**12**:386–94.
- 3 Johnston K, McCrory P, Mohtadi N, et al. Evidence based review of sport-related concussion: clinical science. *Clin J Sport Med* 2001;**11**:150–60.
- 4 Delaney JS, Lacroix V, Leclerc S, et al. Concussion during the 1997 Canadian football league season. *Clin J Sport Med* 2000;**10**:9–14.

- 5 **McCrory PR**, Berkovic SF. Second impact syndrome. *Neurology* 1998;**50**:677–83.
- 6 **McCrory P**, Johnston K, Meeuwisse W, *et al*. Evidence based review of sport related concussion: basic science. *Clin J Sport Med* 2001;**11**:160–6.
- 7 **Kelly J**. Loss of consciousness: pathophysiology and implications in grading and safe return to play. *Journal of Athletic Training* 2001;**36**:249–52.
- 8 **Cantu R**. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *Journal of Athletic Training* 2001;**36**:244–8.
- 9 **Lovell M**, Iverson G, Collins M, *et al*. Does loss of consciousness predict neuropsychological decrements after concussion. *Clin J Sports Med* 1999;**9**:193–9.
- 10 **Leninger B**, Gramling S, Farrell A, *et al*. Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *J Neurol Neurosurg Psychiatry* 1990;**53**:293–6.
- 11 **McCrory PR**, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med* 2000;**10**:235–8.
- 12 **Committee CAoSMC**. CASM Guidelines for assessment and management of sport-related concussion. *Clin J Sport Med* 2000;**10**:209–11.
- 13 **Lovell MR**, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil* 1998;**13**:9–26.
- 14 **Maddocks DL**, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med* 1995;**5**:32–5.
- 15 **McCrea M**, Kelly J, Randolph C, *et al*. Standardised assessment of concussion (SAC): on site mental status evaluation of the athlete. *J Head Trauma Rehabil* 1998;**13**:27–36.
- 16 **McCrea M**, Kelly JP, Kluge J, *et al*. Standardized assessment of concussion in football players. *Neurology* 1997;**48**:586–8.
- 17 **Grindel S**, Lovell M, Collins M. The assessment of sport-related concussion: the evidence behind neuropsychological testing and management. *Clin J Sport Med* 2001;**11**:134–44.
- 18 **Collie A**, Merouf P, Darby D. Computerised neuropsychological testing in sport. *Br J Sports Med* 2002;**36**:in press.
- 19 **Dupuis F**, Johnston KM, Lavoie M, *et al*. Concussions in athletes produce brain dysfunction as revealed by event-related potentials. *NeuroReport* 2000;**11**:4087–92.
- 20 **Johnston K**, Piito A, Chankowsky J, *et al*. New frontiers in diagnostic imaging in concussive head injury. *Clin J Sport Med* 2001;**11**:166–76.
- 21 **Teasdale G**, Nicol J, Murray G. Association of Apolipoprotein E polymorphism with outcome after head injury. *Lancet* 1997;**350**:1069–71.
- 22 **Jordan B**, Relkin N, Ravdin L. Apolipoprotein E epsilon 4 associated with chronic traumatic brain injury in boxing. *JAMA* 1997;**278**:136–40.
- 23 **Kors E**, Terwindt G, Vermeulen F, *et al*. Delayed cerebral edema and fatal coma after minor head trauma: role of the CACNA1A calcium channel subunit gene and relationship with familial hemiplegic migraine. *Ann Neurol* 2001;**49**:753–60.
- 24 **McIntosh A**, McCrory P. Impact energy attenuation performance of football headgear. *Br J Sports Med* 2000;**34**:337–42.
- 25 **Finch C**, McIntosh A, McCrory P. What do under 15 year old schoolboy rugby union players think about protective headgear? *Br J Sports Med* 2001;**35**:89–95.
- 26 **McCrory P**. Do mouthguards prevent concussion? *Br J Sports Med* 2001;**35**:81–3.

Female athlete triad syndrome

New criteria for female athlete triad syndrome?

K M Khan, T Liu-Ambrose, M M Sran, M C Ashe, M G Donaldson, J D Wark

As osteoporosis is rare, should osteopenia be among the criteria for defining the female athlete triad syndrome?

The American College of Sports Medicine (ACSM) has provided a great deal of impetus to educating health-care providers, athletes, and the general public about the potential harm of a “serious syndrome consisting of disordered eating, amenorrhoea and osteoporosis”.¹ We recognise and respect the importance of research and attention to this clinical problem and commend the ACSM on its contribution to date.² To their credit, the authors of the most recent position stand acknowledged that there were no data reporting prevalence on this condition,³ and they encouraged further research. Since then, Mayo Clinic physiatrist Tamara Lauder⁴ has published two important papers showing a 0% prevalence of the female athlete triad (as defined by ACSM) despite 34% of this military population being at risk of disordered eating. Therefore we re-examined the prevalence of one component of the female athlete triad, osteoporosis, in studies of athletic women with menstrual disturbance. The syndrome can be no more prevalent than any one of its diagnostic criteria alone. Thus, if osteoporosis is only present in a

small proportion of the population, then it follows that the female athlete triad can only be prevalent in an equally small, or smaller, proportion of that population.

DIFFERENTIATING OSTEOPOROSIS FROM OSTEOPENIA

Because of the increasing public awareness of osteoporosis and its complications, medical practitioners must not use the term as a synonym for “low bone mass”.⁵ The current standard for measuring bone mass (bone mineral density; BMD) is by dual energy x ray absorptiometry, and since 1994 the term osteoporosis has had diagnostic criteria based on this technique.^{3, 6, 7} Osteoporosis is defined as BMD more than 2.5 standard deviations below the mean of young adults. The term osteopenia describes BMD scores between 1 and 2.5 standard deviations below the mean of young adults. Scrutiny of many papers examining BMD data in athletes at risk of the female athlete triad syndrome (table 1) suggests that osteopenia has a significant prevalence but that osteoporosis is relatively uncommon, even in this selected population. In the substantial

reviews of Bennell *et al*,^{8, 9} menstrual disturbance was associated with a mean 10.3% lower lumbar spine BMD, which reflects the lower limit of normal BMD and very early osteopenia (T score about –1.0). Not surprisingly, numerous authors reporting bone health of sportswomen have used osteopenia as the appropriate term.^{8, 10–13} Interestingly, even in the significant pathology of anorexia nervosa, the mean BMD of patients reflects osteopenia rather than osteoporosis.¹¹ A crucial point is that significant osteopenia—that is, T-score of –2.0—in a 20 year old may provide a worse prognosis for long term bone health than osteoporosis in a 65 year old with a T-score of –2.6.

Osteoporosis can, and does, occur in athletes^{14, 15} (table 1), but we argue that requiring this condition to be present in the female athlete triad syndrome relegates the syndrome to relative obscurity. It is unlikely that the prevalence of osteoporosis in athletes with disordered eating could be greater than the prevalence of osteoporosis in anorexia nervosa (table 2). Therefore, the female athlete triad, as currently defined, most likely has a lower prevalence than anorexia nervosa. This is borne out by the data of Lauder *et al*⁴ showing that the prevalence of anorexia nervosa was < 8% but the prevalence of the female athlete triad was 0%. Anorexia nervosa has an overall age adjusted incidence per 100 000 person years of 14.6 for females and 1.8 for males.¹⁶ Thus, if osteoporosis is a diagnostic criterion for the female athlete triad, the triad should have an age adjusted incidence of substantially less than 0.015% in the population at large. Note that this calculation is not based on anorexia being an essential component of the triad—it is not. These data merely recognise the fact that osteoporosis, as strictly defined, affects only a proportion

Consensus Statement on Concussion in Sport: The 3rd International Conference on Concussion in Sport Held in Zurich, November 2008

Paul McCrory, MBBS, PhD*; **Willem Meeuwisse, MD, PhD†**; **Karen Johnston, MD, PhD‡**; **Jiri Dvorak, MD§**; **Mark Aubry, MD||**; **Mick Molloy, MD¶**; **Robert Cantu, MD††#**

*University of Melbourne, Parkville, Australia; †University of Calgary, Calgary, Alberta, Canada; ‡Toronto Rehabilitation Institute, Toronto, Ontario, Canada; §FIFA Medical Assessment and Research Center and Schulthess Clinic, Zurich, Switzerland; ||International Ice Hockey Federation, Hockey Canada, and Ottawa Sport Medicine Centre, Ottawa, Ontario, Canada; ¶International Rugby Board, Dublin, Ireland; #Emerson Hospital, Concord, MA

Preamble

This paper is a revision and update of the recommendations developed following the 1st (Vienna) and 2nd (Prague) International Symposia on Concussion in Sport.^{1,2} The Zurich Consensus statement is designed to build on the principles outlined in the original Vienna and Prague documents and to develop further conceptual understanding of this problem using a formal consensus-based approach. A detailed description of the consensus process is outlined at the end of this document under the background section (see Section 11). This document is developed for use by physicians, therapists, certified athletic trainers, health professionals, coaches, and other people involved in the care of injured athletes, whether at the recreational, elite, or professional level.

While agreement exists pertaining to principal messages conveyed within this document, the authors acknowledge that the science of concussion is evolving and, therefore, management and return-to-play (RTP) decisions remain in the realm of clinical judgment on an individualized basis. Readers are encouraged to copy and distribute freely the Zurich Consensus document and the Sports Concussion Assessment Tool (SCAT2) card, and neither is subject to any copyright restriction. The authors request, however, that the document and the SCAT2 card be distributed in their full and complete format.

††Footnote: Consensus panelists (listed in alphabetical order): In addition to the authors above, the consensus panelists were Broglio S, Davis G, Dick R, Dvorak J, Echemendia R, Gioia G, Guskiewicz K, Herring S, Iverson G, Kelly J, Kissick J, Makdissi M, McCrea M, Pfitz A, Purcell L, Putukian M. Also invited but not in attendance: Bahr R, Engebretsen L, Hamlyn P, Jordan B, Schamasch P.

This statement is also being published in the *Clinical Journal of Sport Medicine*, *Journal of Clinical Neuroscience*, *Journal of Clinical Sport Medicine*, *Journal of Science & Medicine in Sport*, *Neurosurgery*, *Physical Medicine & Rehabilitation*, and *Scandinavian Journal of Science & Medicine in Sport*. The manuscript was prepared by the authors and is printed here without editing.

The following focus questions formed the foundation for the Zurich concussion consensus statement:

Acute Simple Concussion

- Which symptom scale and which sideline assessment tool is best for diagnosis and/or follow-up?
- How extensive should the cognitive assessment be in elite athletes?
- How extensive should clinical and neuropsychological (NP) testing be at non-elite level?
- Who should do/interpret the cognitive assessment?
- Is there a sex difference in concussion incidence and outcomes?

RTP Issues

- Is provocative exercise testing useful in guiding RTP?
- What is the best RTP strategy for elite athletes?
- What is the best RTP strategy for non-elite athletes?
- Is protective equipment (eg, mouthguards and helmets) useful in reducing concussion incidence and/or severity?

Complex Concussion and Long-Term Issues

- Is the simple versus complex classification a valid and useful differentiation?
- Are there specific patient populations at risk of long-term problems?
- Is there a role for additional tests (eg, structural and/or functional magnetic resonance [MR] imaging, balance testing, biomarkers)?
- Should athletes with persistent symptoms be screened for depression/anxiety?

Pediatric Concussion

- Which symptom scale is appropriate for this age group?
- Which tests are useful, and how often should baseline testing be performed in this age group?

- What are the most appropriate RTP guidelines for elite and non-elite child and adolescent athletes?

Future Directions

- What is the best method of knowledge transfer and education?
- Is there evidence that new and novel injury prevention strategies work (eg, changes to rules of the game, fair play strategies, etc)?

The Zurich document additionally examines the management issues raised in the previous Prague and Vienna documents and applies the consensus questions to these areas.

SPECIFIC RESEARCH QUESTIONS AND CONSENSUS DISCUSSION

1) CONCUSSION

1.1 Definition of Concussion

Panel discussion regarding the definition of concussion and its separation from mild traumatic brain injury (mTBI) was held. Although there was acknowledgment that the terms refer to different injury constructs and should not be used interchangeably, it was not felt that the panel would define mTBI for the purpose of this document. There was unanimous agreement, however, that concussion is defined as follows:

Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathologic, and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include

1. Concussion may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an “impulsive” force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously.
3. Concussion may result in neuropathologic changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
4. Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course; however, it is important to note that in a small percentage of cases, postconcussive symptoms may be prolonged.
5. No abnormality on standard structural neuroimaging studies is seen in concussion.

1.2 Classification of Concussion

There was unanimous agreement to abandon the “simple” versus “complex” terminology that had been proposed in the Prague agreement statement, as the panel felt that the terminology itself did not fully describe the

entities. The panel, however, unanimously retained the concept that the majority (80%–90%) of concussions resolve in a short (7- to 10-day) period, although the recovery time frame may be longer in children and adolescents.²

2) CONCUSSION EVALUATION

2.1 Symptoms and Signs of Acute Concussion

The panel agreed that the diagnosis of acute concussion usually involves the assessment of a range of domains, including clinical symptoms, physical signs, behaviour, balance, sleep, and cognition. Furthermore, a detailed concussion history is an important part of the evaluation, both in the injured athlete and when conducting a preparticipation examination. The detailed clinical assessment of concussion is outlined in the SCAT2 form, which is an appendix to this document.

The suspected diagnosis of concussion can include one or more of the following clinical domains:

- (a) Symptoms: somatic (eg, headache), cognitive (eg, feeling “like in a fog”) and/or emotional symptoms (eg, lability),
- (b) Physical signs (eg, loss of consciousness, amnesia),
- (c) Behavioural changes (eg, irritability),
- (d) Cognitive impairment (eg, slowed reaction times),
- (e) Sleep disturbance (eg, drowsiness).

If any one or more of these components is present, a concussion should be suspected and the appropriate management strategy instituted.

2.2 On-Field or Sideline Evaluation of Acute Concussion

When a player shows ANY features of a concussion

- (a) The player should be medically evaluated onsite using standard emergency management principles, and particular attention should be given to excluding a cervical spine injury.
- (b) The appropriate disposition of the player must be determined by the treating health care provider in a timely manner. If no health care provider is available, the player should be safely removed from practice or play and urgent referral to a physician arranged.
- (c) Once the first aid issues are addressed, then an assessment of the concussive injury should be made using the SCAT2 or other similar tool.
- (d) The player should not be left alone following the injury, and serial monitoring for deterioration is essential over the initial few hours following injury.
- (e) A player with diagnosed concussion should not be allowed to RTP on the day of injury. Occasionally, in adult athletes, there may be RTP on the same day as the injury. See section 4.2.

It was unanimously agreed that sufficient time for assessment and adequate facilities should be provided for the appropriate medical assessment, both on and off the field, for all injured athletes. In some sports, this may

require rule change to allow an off-field medical assessment to occur without affecting the flow of the game or unduly penalizing the injured player's team.

Sideline evaluation of cognitive function is an essential component in the assessment of this injury. Brief neuropsychological test batteries that assess attention and memory function have been shown to be practical and effective. Such tests include the Maddocks questions^{3,4} and the Standardized Assessment of Concussion (SAC).⁵⁻⁷ It is worth noting that standard orientation questions (eg, time, place, person) have been shown to be unreliable in the sporting situation when compared with memory assessment.^{4,8} It is recognized, however, that abbreviated testing paradigms are designed for rapid concussion screening on the sidelines and are not meant to replace comprehensive neuropsychological testing, which is sensitive to detecting subtle deficits that may exist beyond the acute episode, nor should they be used as a stand-alone tool for the ongoing management of sports concussions.

It should also be recognized that the appearance of symptoms might be delayed several hours following a concussive episode.

2.3 Evaluation in Emergency Room or Office by Medical Personnel

An athlete with concussion may be evaluated in the emergency room or doctor's office as a point of first contact following injury or may have been referred from another care provider. In addition to the points outlined above, the key features of this exam should encompass

- (a) A medical assessment including a comprehensive history and detailed neurologic examination, including a thorough assessment of mental status, cognitive functioning, and gait and balance.
- (b) A determination of the clinical status of the patient, including whether there has been improvement or deterioration since the time of injury. This may involve seeking additional information from parents, coaches, teammates, and eyewitnesses to the injury.
- (c) A determination of the need for emergent neuroimaging in order to exclude a more severe brain injury involving a structural abnormality.

In large part, the points above are included in the SCAT2 assessment, which is included in the Zurich consensus statement.

3) CONCUSSION INVESTIGATIONS

A range of additional investigations may be utilized to assist in the diagnosis and/or exclusion of injury. These include the following.

3.1 Neuroimaging

It was recognized by the panelists that conventional structural neuroimaging is normal in concussive injury. Given that caveat, the following suggestions are made: Brain computed tomography (CT) (or, where available, MR brain scan) contributes little to concussion evaluation but should be employed whenever suspicion of an intracerebral structural lesion exists. Examples of such

situations may include prolonged disturbance of conscious state, focal neurologic deficit, or worsening symptoms.

Newer structural MR imaging modalities, including gradient echo, perfusion, and diffusion imaging, have greater sensitivity for structural abnormalities. However, the lack of published studies as well as absent preinjury neuroimaging data limits the usefulness of this approach in clinical management at the present time. In addition, the predictive value of various MR abnormalities that may be incidentally discovered is not established at the present time.

Other imaging modalities such as functional magnetic resonance imaging (fMRI) demonstrate activation patterns that correlate with symptom severity and recovery in concussion.⁹⁻¹³ While not part of routine assessment at the present time, they nevertheless provide additional insight to pathophysiologic mechanisms. Alternative imaging technologies (eg, positron emission tomography, diffusion tensor imaging, magnetic resonance spectroscopy, functional connectivity), while demonstrating some compelling findings, are still at early stages of development and cannot be recommended other than in a research setting.

3.2 Objective Balance Assessment

Published studies using both sophisticated force plate technology as well as those using less sophisticated clinical balance tests (eg, Balance Error Scoring System [BESS]) have identified postural stability deficits lasting approximately 72 hours following sport-related concussion. It appears that postural stability testing provides a useful tool for objectively assessing the motor domain of neurologic functioning and should be considered a reliable and valid addition to the assessment of athletes suffering from concussion, particularly when symptoms or signs indicate a balance component.¹⁴⁻²⁰

3.3 Neuropsychological Assessment

The application of neuropsychological (NP) testing in concussion has been shown to be of clinical value and continues to contribute significant information in concussion evaluation.²¹⁻²⁶ Although in most cases cognitive recovery largely overlaps with the time course of symptom recovery, it has been demonstrated that cognitive recovery may occasionally precede or more commonly follow clinical symptom resolution, suggesting that the assessment of cognitive function should be an important component in any RTP protocol.^{27,28} It must be emphasized, however, that NP assessment should not be the sole basis of management decisions; rather, it should be seen as an aid to the clinical decision-making process in conjunction with a range of clinical domains and investigational results.

Neuropsychologists are in the best position to interpret NP tests by virtue of their background and training. However, there may be situations where neuropsychologists are not available and other medical professionals may perform or interpret NP screening tests. The ultimate RTP decision should remain a medical one, in which a multidisciplinary approach, when possible, has been taken. In the absence of NP and other (eg, formal balance assessment) testing, a more conservative return-to-play approach may be appropriate.

In the majority of cases, NP testing will be used to assist RTP decisions and will not be done until the patient is

Table 1. Graduated Return-to-Play Protocol

| Rehabilitation Stage | Functional Exercise at Each Stage of Rehabilitation | Objective of Each Stage |
|--------------------------------|---|---|
| 1. No activity | Complete physical and cognitive rest | Recovery |
| 2. Light aerobic exercise | Walking, swimming, or stationary cycling, keeping intensity to <70% of maximum predicted heart rate; no resistance training | Increase heart rate |
| 3. Sport-specific exercise | Skating drills in ice hockey, running drills in soccer; no head impact activities | Add movement |
| 4. Non-contact training drills | Progression to more complex training drills, eg, passing drills in football and ice hockey; may start progressive resistance training | Exercise, coordination, and cognitive load |
| 5. Full-contact practice | Following medical clearance, participate in normal training activities | Restore athlete's confidence; coaching staff assesses functional skills |
| 6. Return to play | Normal game play | |

symptom free.^{29,30} There may be persons (eg, child and adolescent athletes) in whom testing may be performed early while the patient is still symptomatic to assist in determining management. This will normally be best determined in consultation with a trained neuropsychologist.^{31,32}

3.4 Genetic Testing

The significance of apolipoprotein (Apo) E4, ApoE promotor gene, tau polymerase, and other genetic markers in the management of sports concussion risk or injury outcome is unclear at this time.^{33,34} Evidence from human and animal studies in more severe traumatic brain injury demonstrates induction of a variety of genetic and cytokine factors, such as insulin-like growth factor-1 (IGF-1), IGF binding protein-2, fibroblast growth factor, Cu-Zn superoxide dismutase, superoxide dismutase-1 (SOD-1), nerve growth factor, glial fibrillary acidic protein (GFAP), and S-100. Whether such factors are affected in sport concussion is not known at this stage.^{35–42}

3.5 Experimental Concussion Assessment Modalities

Different electrophysiologic recording techniques (eg, evoked response potential [ERP], cortical magnetic stimulation, and electroencephalography) have demonstrated reproducible abnormalities in the postconcussive state. However, not all studies reliably differentiated concussed athletes from controls.^{43–49} The clinical significance of these changes remains to be established.

In addition, biochemical serum and cerebrospinal fluid markers of brain injury (including S-100, neuron specific enolase [NSE], myelin basic protein [MBP], GFAP, tau, etc) have been proposed as means by which cellular damage may be detected if present.^{50–56} There is currently insufficient evidence, however, to justify the routine use of these biomarkers clinically.

4) CONCUSSION MANAGEMENT

The cornerstone of concussion management is physical and cognitive rest until symptoms resolve and then a graded program of exertion prior to medical clearance and RTP. The recovery and outcome of this injury may be modified by a number of factors that may require more sophisticated management strategies. These are outlined in the section on modifiers below.

As described above, the majority of patients will recover spontaneously over several days. In these situations, it is expected that an athlete will proceed progressively through

a stepwise RTP strategy.⁵⁷ During this period of recovery while symptomatic following an injury, it is important to emphasize to the athlete that physical AND cognitive rest is required. Activities that require concentration and attention (eg, scholastic work, video games, text messaging, etc) may exacerbate symptoms and possibly delay recovery. In such cases, apart from limiting relevant physical and cognitive activities (and other risk-taking opportunities for reinjury) while symptomatic, no further intervention is required during the period of recovery, and the athlete typically resumes sport without further problem.

4.1 Graduated RTP Protocol

Return-to-play protocol following a concussion follows a stepwise process as outlined in Table 1.

With this stepwise progression, the athlete should continue to proceed to the next level if asymptomatic at the current level. Generally each step should take 24 hours, so that an athlete would take approximately 1 week to proceed through the full rehabilitation protocol once asymptomatic at rest and with provocative exercise. If any postconcussion symptoms occur while in the stepwise program, then the patient should drop back to the previous asymptomatic level and try to progress again after a further 24-hour period of rest has passed.

4.2 Same-Day RTP

With adult athletes, in some settings, where there are team physicians experienced in concussion management and sufficient resources (eg, access to neuropsychologists, consultants, neuroimaging, etc) as well as access to immediate (ie, sideline) neurocognitive assessment, RTP management may be more rapid. The RTP strategy must still follow the same basic management principles: namely, full clinical and cognitive recovery before consideration of RTP. This approach is supported by published guidelines, such as those from the American Academy of Neurology, US Team Physician Consensus Statement, and US National Athletic Trainers' Association position statement.^{58–60} This issue was extensively discussed by the consensus panelists, and it was acknowledged that there is evidence that some professional American football players are able to RTP more quickly, with even same-day RTP supported by National Football League studies without a risk of recurrence or sequelae.⁶¹ There are data, however, demonstrating that at the collegiate and high school levels, athletes allowed to RTP on the same day may demonstrate NP deficits postinjury that may not be evident on the

sidelines and are more likely to have delayed onset of symptoms.^{62–68} Yet it should be emphasized that the young (less than 18 years old) elite athlete should be treated more conservatively, even though the resources may be the same as for an older professional athlete (see section 6.1).

4.3 Psychological Management and Mental Health Issues

In addition, psychological approaches may have potential application in this injury, particularly with the modifiers listed below.^{69,70} Caregivers are also encouraged to evaluate the concussed athlete for affective symptoms, such as depression, as these symptoms may be common in concussed athletes.⁵⁷

4.4 The Role of Pharmacologic Therapy

Pharmacologic therapy in sports concussion may be applied in 2 distinct situations. The first of these situations is the management of specific, prolonged symptoms (eg, sleep disturbance, anxiety, etc). The second situation is where drug therapy is used to modify the underlying pathophysiology of the condition with the aim of shortening the duration of the concussion symptoms.⁷¹ In broad terms, this approach to management should only be considered by clinicians experienced in concussion management.

An important consideration in RTP is that concussed athletes should not only be symptom free but also should not be taking any pharmacologic agents or medications that may mask or modify the symptoms of concussion. Where antidepressant therapy may be commenced during the management of a concussion, the decision to RTP while still on such medication must be considered carefully by the treating clinician.

4.5 The Role of Preparticipation Concussion Evaluation

Recognizing the importance of a concussion history and appreciating the fact that many athletes will not recognize all the concussions they may have suffered in the past, a detailed concussion history is of value.^{72–75} Such a history may identify early those athletes who fit into a high-risk category and provides an opportunity for the health care provider to educate the athlete in regard to the significance of concussive injury. A structured concussion history should include specific questions as to previous symptoms of a concussion, not just the perceived number of past concussions. It is also worth noting that dependence upon the recall of concussive injuries by teammates or coaches has been demonstrated to be unreliable.⁷² The clinical history should also include information about all previous head, face, and cervical spine injuries, as these may also have clinical relevance. It is worth emphasizing that in the setting of maxillofacial and cervical spine injuries, coexistent concussive injuries may be missed unless specifically assessed. Questions pertaining to disproportionate impact versus symptom severity may alert the clinician to a progressively increasing vulnerability to injury. As part of the clinical history, it is advised that details regarding protective equipment employed at time of injury be sought, both for recent and remote injuries. A comprehensive

Table 2. Concussion Modifiers

| Factors | Modifier |
|----------------------------------|---|
| Symptoms | Number Duration (>10 d) Severity |
| Signs | Prolonged loss of consciousness (>1 min), amnesia |
| Sequela | Concussive convulsions |
| Temporal | Frequency: repeated concussions over time Timing: injuries close together in time “Recency”: recent concussion or traumatic brain injury |
| Threshold | Repeated concussions occurring with progressively less impact force or slower recovery after each successive concussion |
| Age | Child or adolescent (<18 y old) |
| Comorbidities and premorbidities | Migraine, depression, or other mental health disorders, attention deficit hyperactivity disorder (ADHD), learning disabilities (LDs), sleep disorders |
| Medication | Psychoactive drugs, anticoagulants |
| Behaviour | Dangerous style of play |
| Sport | High-risk activity, contact and collision sport, high sporting level |

preparticipation concussion evaluation allows for modification and optimization of protective behaviour and an opportunity for education.

5) MODIFYING FACTORS IN CONCUSSION MANAGEMENT

The consensus panel agreed that a range of “modifying” factors may influence the investigation and management of concussion and, in some cases, may predict the potential for prolonged or persistent symptoms. These modifiers would also be important to consider in a detailed concussion history and are outlined in Table 2.

In this setting, there may be additional management considerations beyond simple RTP advice. There may be a more important role for additional investigations including formal NP testing, balance assessment, and neuroimaging. It is envisioned that athletes with such modifying features would be managed in a multidisciplinary manner coordinated by a physician with specific expertise in the management of concussive injury.

The role of female gender as a possible modifier in the management of concussion was discussed at length by the panel. There was not unanimous agreement that the current published research evidence is conclusive that this should be included as a modifying factor, although it was accepted that sex may be a risk factor for injury and/or influence injury severity.^{76–78}

5.1 The Significance of Loss of Consciousness

In the overall management of moderate to severe traumatic brain injury, duration of loss of consciousness (LOC) is an acknowledged predictor of outcome.⁷⁹ While published findings in concussion describe LOC associated with specific early cognitive deficits, it has not been noted as a measure of injury severity.^{80,81} Consensus discussion determined that prolonged (greater than 1 minute in

duration) LOC would be considered as a factor that may modify management.

5.2 The Significance of Amnesia and Other Symptoms

There is renewed interest in the role of posttraumatic amnesia and its role as a surrogate measure of injury severity.^{67,82,83} Published evidence suggests that the nature, burden, and duration of the clinical postconcussive symptoms may be more important than the presence or duration of amnesia alone.^{80,84,85} Further, it must be noted that retrograde amnesia varies with the time of measurement postinjury and, hence, is poorly reflective of injury severity.^{86,87}

5.3 Motor and Convulsive Phenomena

A variety of immediate motor phenomena (eg, tonic posturing) or convulsive movements may accompany a concussion. Although dramatic, these clinical features are generally benign and require no specific management beyond the standard treatment of the underlying concussive injury.^{88,89}

5.4 Depression

Mental health issues (such as depression) have been reported as a long-term consequences of traumatic brain injury, including sports-related concussion. Neuroimaging studies using fMRI suggest that a depressed mood following concussion may reflect an underlying pathophysiologic abnormality consistent with a limbic-frontal model of depression.^{52,90–100}

6) SPECIAL POPULATIONS

6.1 The Child or Adolescent Athlete

There was unanimous agreement by the panel that the evaluation and management recommendations contained herein could be applied to children and adolescents down to the age of 10 years. Below that age, children report different concussion symptoms from adults and would require age-appropriate symptom checklists as a component of assessment. An additional consideration in assessing the child or adolescent athlete with a concussion is that in the clinical evaluation by the health care professional, there may be the need to include both patient and parental input, as well as teacher and school input, when appropriate.^{101–107}

The decision to use NP testing is broadly the same as in the adult assessment paradigm. However, timing of testing may differ in order to assist planning in school and home management (and may be performed while the patient is still symptomatic). If cognitive testing is performed, then it must be developmentally sensitive until the late teen years, due to the ongoing cognitive maturation that occurs during this period, which, in turn, makes the utility of comparison to either the person's own baseline performance or to population norms limited.²⁰ In this age group, it is more important to consider the use of trained neuropsychologists to interpret assessment data, particularly in children with learning disorders and/or attention deficit hyperactivity disorder (ADHD),

who may need more sophisticated assessment strategies.^{31,32,101}

The panel strongly endorsed the view that children should not be returned to practice or play until clinically completely symptom free, which may require a longer time frame than for adults. In addition, the concept of "cognitive rest" was highlighted, with special reference to a child's need to limit exertion with activities of daily living and to limit scholastic and other cognitive stressors (eg, text messaging, video games, etc) while symptomatic. School attendance and activities may also need to be modified to avoid provocation of symptoms.

Because of the different physiological response and longer recovery after concussion and specific risks (eg, diffuse cerebral swelling) related to head impact during childhood and adolescence, a more conservative RTP approach is recommended. It is appropriate to extend the amount of time of asymptomatic rest and/or the length of the graded exertion in children and adolescents. It is not appropriate for a child or adolescent athlete with concussion to RTP on the same day as the injury, regardless of the level of athletic performance. Concussion modifiers apply even more to this population than to adults and may mandate more cautious RTP advice.

6.2 Elite Versus Non-Elite Athletes

The panel unanimously agreed that all athletes, regardless of level of participation, should be managed using the same treatment and RTP paradigm. A more useful construct was agreed to, whereby the available resources and expertise in concussion evaluation were of more importance in determining management than a separation between elite and non-elite athlete management. Although formal baseline NP screening may be beyond the resources of many sports or individuals, it is recommended that in all organized high-risk sports, consideration be given to having this cognitive evaluation, regardless of the age or level of performance.

6.3 Chronic Traumatic Brain Injury

Epidemiologic studies have suggested an association between repeated sports concussions during a career and late-life cognitive impairment. Similarly, case reports have noted anecdotal cases in which neuropathologic evidence of chronic traumatic encephalopathy was observed in retired football players.^{108–112} Panel discussion was held, and no consensus was reached on the significance of such observations at this stage. Clinicians need to be mindful of the potential for long-term problems in the management of all athletes.

7) INJURY PREVENTION

7.1 Protective Equipment: Mouthguards and Helmets

There is no good clinical evidence that currently available protective equipment will prevent concussion, although mouthguards have a definite role in preventing dental and orofacial injury. Biomechanical studies have shown a reduction in impact forces to the brain with the use of head gear and helmets, but these findings have not been translated to show a reduction in concussion

incidence. For skiing and snowboarding, there are a number of studies to suggest that helmets provide protection against head and facial injury and, hence, should be recommended for participants in alpine sports.^{113–116} In specific sports such as cycling, motor, and equestrian sports, protective helmets may prevent other forms of head injury (eg, skull fracture) that are related to falling on hard road surfaces, and these may be an important injury prevention issue for those sports.^{116–128}

7.2 Rule Change

Consideration of rule changes to reduce the head injury incidence or severity may be appropriate where a clear-cut mechanism is implicated in a particular sport. An example of this is in football (soccer), in which research studies demonstrated that upper limb-to-head contact in heading contests accounted for approximately 50% of concussions.¹²⁹ As noted earlier, rule changes also may be needed in some sports to allow an effective off-field medical assessment to occur without compromising the athlete's welfare, affecting the flow of the game, or unduly penalizing the player's team. It is important to note that rule enforcement may be a critical aspect of modifying injury risk in these settings, and referees play an important role in this regard.

7.3 Risk Compensation

An important consideration in the use of protective equipment is the concept of risk compensation.¹³⁰ This is where the use of protective equipment results in behavioural change, such as the adoption of more dangerous playing techniques, which can result in a paradoxical increase in injury rates. This may be a particular concern in child and adolescent athletes, in whom head injury rates are often higher than in adult athletes.^{131–133}

7.4 Aggression Versus Violence in Sport

The competitive/aggressive nature of sport that makes it fun to play and watch should not be discouraged. However, sporting organizations should be encouraged to address violence that may increase concussion risk.^{134,135} Fair play and respect should be supported as key elements of sport.

8) KNOWLEDGE TRANSFER

As the ability to treat or reduce the effects of concussive injury after the event is minimal, education of athletes, colleagues, and the general public is a mainstay of progress in this field. Athletes, referees, administrators, parents, coaches, and health care providers must be educated regarding the detection of concussion, its clinical features, assessment techniques, and principles of safe RTP. Methods to improve education, including Web-based resources, educational videos, and international outreach programs, are important in delivering the message. In addition, concussion working groups plus the support and endorsement of enlightened sport groups such as Fédération Internationale de Football Association (FIFA), International Olympic Commission (IOC), International Rugby Board (IRB), and International Ice Hockey

Federation (IIHF), who initiated this endeavor, have enormous value and must be pursued vigorously. Fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly coaches, parents, and managers play an important part in ensuring these values are implemented on the field of play.^{57,136–148}

9) FUTURE DIRECTIONS

The consensus panelists recognize that research is needed across a range of areas in order to answer some critical research questions. The key areas for research identified include

- Validation of the SCAT2
- Sex effects on injury risk, severity, and outcome
- Paediatric injury and management paradigms
- Virtual reality tools in the assessment of injury
- Rehabilitation strategies (eg, exercise therapy)
- Novel imaging modalities and their role in clinical assessment
- Concussion surveillance using consistent definitions and outcome measures
- Clinical assessment when no baseline assessment has been performed
- “Best practice” neuropsychological testing
- Long-term outcomes
- On-field injury severity predictors

10) MEDICAL-LEGAL CONSIDERATIONS

This consensus document reflects the current state of knowledge and will need to be modified according to the development of new knowledge. It provides an overview of issues that may be of importance to health care providers involved in the management of sports-related concussion. It is not intended as a standard of care and should not be interpreted as such. This document is only a guide, and is of a general nature, consistent with the reasonable practice of a health care professional. Individual treatment will depend on the facts and circumstances specific to each individual case.

It is intended that this document will be formally reviewed and updated prior to December 1, 2012.

11) STATEMENT ON BACKGROUND TO CONSENSUS PROCESS

In November 2001, the 1st International Conference on Concussion in Sport was held in Vienna, Austria. This meeting was organized by the IIHF in partnership with FIFA and the Medical Commission of the IOC. As part of the resulting mandate for the future, the need for leadership and future updates was identified. The 2nd International Conference on Concussion in Sport was organized by the same group, with the additional involvement of the IRB, and was held in Prague, Czech Republic, in November 2004. The original aims of the symposia were to provide recommendations for the improvement of safety and health of athletes who suffer concussive injuries in ice hockey, rugby, football (soccer), and other sports. To this end, a range of experts were

invited to both meetings to address specific issues of epidemiology, basic and clinical science, injury grading systems, cognitive assessment, new research methods, protective equipment, management, prevention, and long-term outcome.^{1,2}

The 3rd International Conference on Concussion in Sport was held in Zurich, Switzerland, on October 29–30, 2008, and was designed as a formal consensus meeting following the organizational guidelines set forth by the US National Institutes of Health. (Details of the consensus methodology can be obtained at: <http://consensus.nih.gov/ABOUTCDP.htm>.) The basic principles governing the conduct of a consensus development conference are summarized below:

1. A broad-based, nongovernment, nonadvocacy panel was assembled to give balanced, objective, and knowledgeable attention to the topic. Panel members excluded anyone with scientific or commercial conflicts of interest and included researchers in clinical medicine, sports medicine, neuroscience, neuroimaging, athletic training, and sports science.
2. These experts presented data in a public session, followed by inquiry and discussion. The panel then met in an executive session to prepare the consensus statement.
3. A number of specific questions were prepared and posed in advance to define the scope and guide the direction of the conference. The principal task of the panel was to elucidate responses to these questions. These questions are outlined below.
4. A systematic literature review was prepared and circulated in advance for use by the panel in addressing the conference questions.
5. The consensus statement is intended to serve as the scientific record of the conference.
6. The consensus statement will be widely disseminated to achieve maximum impact on both current health care practice and future medical research.

The panel chairperson (W.M.) did not identify with any advocacy position. The chairperson was responsible for directing the consensus session and guiding the panel's deliberations. Panelists were drawn from clinical practice, academics, and research in the field of sports-related concussion. They do not represent organizations per se but were selected for their expertise, experience, and understanding of this field.

REFERENCES

1. Aubry M, Cantu R, Dvorak J, Graf-Baumann T, Johnston K, Kelly J, et al. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001: recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med*. 2002;36(1):6–10.
2. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med*. 2005;39(4):196–204.
3. Maddocks D, Dicker G. An objective measure of recovery from concussion in Australian rules footballers. *Sport Health*. 1989;7(suppl):6–7.
4. Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med*. 1995;5(1):32–35.
5. McCrea M. Standardized mental status assessment of sports concussion. *Clin J Sport Med*. 2001;11(3):176–181.
6. McCrea M, Kelly J, Randolph C, et al. Standardized assessment of concussion (SAC): on-site mental status evaluation of the athlete. *J Head Trauma Rehabil*. 1998;13(2):27–36.
7. McCrea M, Randolph C, Kelly J. *The Standardized Assessment of Concussion (SAC): Manual for Administration, Scoring and Interpretation*. 2nd ed. Waukesha, WI: 2000.
8. McCrea M, Kelly JP, Kluge J, Ackley B, Randolph C. Standardized assessment of concussion in football players. *Neurology*. 1997;48(3):586–588.
9. Chen JK, Johnston KM, Collie A, McCrory P, Ptito A. A validation of the post concussion symptom scale in the assessment of complex concussion using cognitive testing and functional MRI. *J Neurol Neurosurg Psychiatry*. 2007;78(11):1231–1238.
10. Chen JK, Johnston KM, Frey S, Petrides M, Worsley K, Ptito A. Functional abnormalities in symptomatic concussed athletes: an fMRI study. *Neuroimage*. 2004;22(1):68–82.
11. Chen JK, Johnston KM, Collie A, McCrory P, Ptito A. Association between symptom severity, CogSport tests results, and functional MRI activation in symptomatic concussed athletes [abstract]. *Clin J Sport Med*. 2004;14(6):379.
12. Chen JK, Johnston KM, Collie A, McCrory P, Ptito A. Behavioural and functional imaging outcomes in symptomatic concussed athletes measured with CogSport and functional MRI. *Br J Sports Med*. 2004;38(5):659.
13. Ptito A, Chen JK, Johnston KM. Contributions of functional magnetic resonance imaging (fMRI) to sport concussion evaluation. *NeuroRehabilitation*. 2007;22(3):217–227.
14. Guskiewicz K. Postural stability assessment following concussion: one piece of the puzzle. *Clin J Sport Med*. 2001;11(3):182–190.
15. Guskiewicz KM. Assessment of postural stability following sport-related concussion. *Curr Sports Med Rep*. 2003;2(1):24–30.
16. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train*. 2001;36(3):263–273.
17. Cavanaugh JT, Guskiewicz KM, Giuliani C, Marshall S, Mercer V, Stergiou N. Detecting altered postural control after cerebral concussion in athletes with normal postural stability. *Br J Sports Med*. 2005;39(11):805–811.
18. Cavanaugh JT, Guskiewicz KM, Giuliani C, Marshall S, Mercer VS, Stergiou N. Recovery of postural control after cerebral concussion: new insights using approximate entropy. *J Athl Train*. 2006;41(3):305–313.
19. Cavanaugh JT, Guskiewicz KM, Stergiou N. A nonlinear dynamic approach for evaluating postural control: new directions for the management of sport-related cerebral concussion. *Sports Med*. 2005;35(11):935–950.
20. Fox ZG, Mihalik JP, Blackburn JT, Battaglini CL, Guskiewicz KM. Return of postural control to baseline after anaerobic and aerobic exercise protocols. *J Athl Train*. 2008;43(5):456–463.
21. Collie A, Darby D, Maruff P. Computerised cognitive assessment of athletes with sports related head injury. *Br J Sports Med*. 2001;35(5):297–302.
22. Collie A, Maruff P. Computerised neuropsychological testing. *Br J Sports Med*. 2003;37(1):2–3.
23. Collie A, Maruff P, McStephen M, Darby DG. Psychometric issues associated with computerised neuropsychological assessment of concussed athletes. *Br J Sports Med*. 2003;37(6):556–559.
24. Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA*. 1999;282(10):964–970.
25. Lovell MR. The relevance of neuropsychologic testing for sports-related head injuries. *Curr Sports Med Rep*. 2002;1(1):7–11.
26. Lovell MR, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil*. 1998;13(2):9–26.

27. Bleiberg J, Cernich AN, Cameron K, et al. Duration of cognitive impairment after sports concussion. *Neurosurgery*. 2004;54(5):1073–1080.
28. Bleiberg J, Warden D. Duration of cognitive impairment after sports concussion. *Neurosurgery*. 2005;56(5):E1166.
29. Broglio SP, Macciocchi SN, Ferrara MS. Neurocognitive performance of concussed athletes when symptom free. *J Athl Train*. 2007;42(4):504–508.
30. Broglio SP, Macciocchi SN, Ferrara MS. Sensitivity of the concussion assessment battery. *Neurosurgery*. 2007;60(6):1050–1058.
31. Gioia GA, Janusz JA, Gilstein K, Iverson GL. Neuropsychological management of concussion in children and adolescents: effects of age and gender on ImPact [abstract]. *Br J Sports Med*. 2004;38:657.
32. McCrory P, Collie A, Anderson V, Davis G. Can we manage sport related concussion in children the same as in adults? *Br J Sports Med*. 2004;38(5):516–519.
33. Kristman VL, Tator CH, Kreiger N, et al. Does the apolipoprotein epsilon 4 allele predispose varsity athletes to concussion? A prospective cohort study. *Clin J Sport Med*. 2008;18(4):322–328.
34. Terrell TR, Bostick RM, Abramson R, et al. APOE, APOE promoter, and Tau genotypes and risk for concussion in college athletes. *Clin J Sport Med*. 2008;18(1):10–17.
35. Vagnozzi R, Tavazzi B, Signoretti S, et al. Temporal window of metabolic brain vulnerability to concussions: mitochondrial-related impairment, part I. *Neurosurgery*. 2007;61(2):379–389.
36. Hang CH, Chen G, Shi JX, Zhang X, Li JS. Cortical expression of nuclear factor kappaB after human brain contusion. *Brain Res*. 2006;131109(1):14–21.
37. Peng RY, Gao YB, Xiao XY, et al. [Study on the expressions of basic fibroblast growth factor and nervous growth factor genes in rat cerebral concussion]. *Zhongguo Wei Zhong Bing Ji Jiu Yi Xue*. 2003;15(4):213–216.
38. Yunoki M, Kawauchi M, Ukita N, et al. Effects of lecithinized SOD on sequential change in SOD activity after cerebral contusion in rats. *Acta Neurochir Suppl*. 1998;71:142–145.
39. Hinkle DA, Baldwin SA, Scheff SW, Wise PM. GFAP and S100beta expression in the cortex and hippocampus in response to mild cortical contusion. *J Neurotrauma*. 1997;14(10):729–738.
40. Holmin S, Schalling M, Hojeberg B, Nordqvist AC, Skeftruna AK, Mathiesen T. Delayed cytokine expression in rat brain following experimental contusion. *J Neurosurgery*. 1997;86(3):493–504.
41. Sandberg Nordqvist AC, von Holst H, Holmin S, Sara VR, Bellander BM, Schalling M. Increase of insulin-like growth factor (IGF)-1, IGF binding protein-2 and -4 mRNAs following cerebral contusion. *Brain Res Mol Brain Res*. 1996;38(2):285–293.
42. Fukuhara T, Nishio S, Ono Y, Kawauchi M, Asari S, Ohmoto T. Induction of Cu,Zn-superoxide dismutase after cortical contusion injury during hypothermia. *Brain Res*. 1994;657(1–2):333–336.
43. Boutin D, Lassonde M, Robert M, Vanassing P, Ellemberg D. Neurophysiological assessment prior to and following sports-related concussion during childhood: a case study. *Neurocase*. 2008;14(3):239–248.
44. De Beaumont L, Brisson B, Lassonde M, Jolicoeur P. Long-term electrophysiological changes in athletes with a history of multiple concussions. *Brain Inj*. 2007;21(6):631–644.
45. De Beaumont L, Lassonde M, Leclerc S, Theoret H. Long-term and cumulative effects of sports concussion on motor cortex inhibition. *Neurosurgery*. 2007;61(2):329–337.
46. Gaetz M, Weinberg H. Electrophysiological indices of persistent post-concussion symptoms. *Brain Inj*. 2000;14(9):815–832.
47. Gosselin N, Theriault M, Leclerc S, Montplaisir J, Lassonde M. Neurophysiological anomalies in symptomatic and asymptomatic concussed athletes. *Neurosurgery*. 2006;58(6):1151–1161.
48. Lavoie ME, Dupuis F, Johnston KM, Leclerc S, Lassonde M. Visual p300 effects beyond symptoms in concussed college athletes. *J Clin Exp Neuropsychol*. 2004;26(1):55–73.
49. Rousseff RT, Tzvetanov P, Atanassova PA, Volkov I, Hristova I. Correlation between cognitive P300 changes and the grade of closed head injury. *Electromyogr Clin Neurophysiol*. 2006;46(5):275–277.
50. Begaz T, Kyriacou DN, Segal J, Bazarian JJ. Serum biochemical markers for post-concussion syndrome in patients with mild traumatic brain injury. *J Neurotrauma*. 2006;23(8):1201–1210.
51. de Boussard CN, Lundin A, Karlstedt D, Edman G, Bartfai A, Borg J. S100 and cognitive impairment after mild traumatic brain injury. *J Rehabil Med*. 2005;37(1):53–57.
52. Lima DP, Simao Filho C, Abib Sde C, de Figueiredo LF. Quality of life and neuropsychological changes in mild head trauma: late analysis and correlation with S100B protein and cranial CT scan performed at hospital admission. *Injury*. 2008;39(5):604–611.
53. Ma M, Lindsell CJ, Rosenberry CM, Shaw GJ, Zemlan FP. Serum cleaved tau does not predict postconcussion syndrome after mild traumatic brain injury. *Am J Emerg Med*. 2008;26(7):763–768.
54. Stalnacke BM, Tegner Y, Sojka P. Playing ice hockey and basketball increases serum levels of S-100B in elite players: a pilot study. *Clin J Sport Med*. 2003;13(5):292–302.
55. Stalnacke BM, Tegner Y, Sojka P. Playing soccer increases serum concentrations of the biochemical markers of brain damage S-100B and neuron-specific enolase in elite players: a pilot study. *Brain Inj*. 2004;18(9):899–909.
56. Townend W, Ingebrigtsen T. Head injury outcome prediction: a role for protein S-100B? *Injury*. 2006;37(12):1098–1108.
57. Johnston KM, Bloom GA, Ramsay JK, et al. Current concepts in concussion rehabilitation. *Curr Sports Med Rep*. 2004;3:316–323.
58. Guskiewicz KM, Bruce SL, Cantu RC, Ferrara MS, Kelly JP, McCrea M, et al. National Athletic Trainers' Association position statement: management of sport-related concussion. *J Athl Train*. 2004;39(3):280–297.
59. Concussion (mild traumatic brain injury) and the team physician: a consensus statement. *Med Sci Sports Exerc*. 2006;38(2):395–399.
60. Kelly JP, Rosenberg JH. The development of guidelines for the management of concussion in sports. *J Head Trauma Rehabil*. 1998;13(2):53–65.
61. Pellman EJ, Viano DC, Casson IR, Arfken C, Feuer H. Concussion in professional football: players returning to the same game, part 7. *Neurosurgery*. 2005;56(1):79–92.
62. Guskiewicz KM, McCrea M, Marshall SW, et al. Cumulative effects associated with recurrent concussion in collegiate football players. *JAMA*. 2003;290(19):2549–2555.
63. Lovell M, Collins M, Bradley J. Return to play following sports-related concussion. *Clin Sports Med*. 2004;23(3):421–441,ix.
64. Collins MW, Field M, Lovell MR, et al. Relationship between postconcussion headache and neuropsychological test performance in high school athletes. *Am J Sports Med*. 2003;31(2):168–173.
65. Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA*. 1999;282(10):964–970.
66. Collins MW, Lovell MR, Iverson GL, Cantu RC, Maroon JC, Field M. Cumulative effects of concussion in high school athletes. *Neurosurgery*. 2002;51(5):1175–1181.
67. McCrea M, Guskiewicz KM, Marshall SW. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA*. 2003;290(19):2556–2563.
68. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med*. 2004;14(1):13–17.
69. Bloom GA, Horton AS, McCrory P, Johnston KM. Sport psychology and concussion: new impacts to explore. *Br J Sports Med*. 2004;38(5):519–521.
70. Weiss MR, Gill DL. What goes around comes around: re-emerging themes in sport and exercise psychology. *Res Q Exerc Sport*. 2005;76(suppl 2):S71–S87.
71. McCrory P. Should we treat concussion pharmacologically? The need for evidence based pharmacological treatment for the concussed athlete. *Br J Sports Med*. 2002;36(1):3–5.
72. McCrory P. Preparticipation assessment for head injury. *Clin J Sport Med*. 2004;14(3):139–144.

73. Johnston KM, Lassonde M, Ptito A. A contemporary neurosurgical approach to sport-related head injury: the McGill concussion protocol. *J Am Coll Surg*. 2001;192(4):515–524.
74. Delaney J, Lacroix V, Leclerc S, Johnston K. Concussions during the 1997 Canadian Football League Season. *Clin J Sport Med*. 2000;10(1):9–14.
75. Delaney J, Lacroix VJ, Leclerc S, Johnston KM. Concussions among university football and soccer players. *Clin J Sport Med*. 2002;12(6):331–338.
76. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. *J Athl Train*. 2007;42(4):495–503.
77. Dvorak J, Junge A, Fuller C, McCrory P. Medical issues in women's football. *Br J Sports Med*. 2007;41(suppl 1):i1.
78. Dvorak J, McCrory P, Kirkendall DT. Head injuries in the female football player: incidence, mechanisms, risk factors and management. *Br J Sports Med*. 2007;41(suppl 1):i44–46.
79. Jennett B, Bond M. Assessment of outcome after severe brain damage: a practical scale. *Lancet*. 1975;1(7905):480–484.
80. Leininger BE, Gramling SE, Farrell AD, Kreutzer JS, Peck ES 3rd. Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *J Neurol Neurosurg Psychiatry*. 1990;53(4):293–296.
81. Lovell M, Iverson G, Collins M, McKeag D, Maroon J. Does loss of consciousness predict neuropsychological decrements after concussion. *Clin J Sp Med*. 1999;9(4):193–199.
82. McCrea M, Kelly JP, Randolph C, Cisler R, Berger L. Immediate neurocognitive effects of concussion. *Neurosurgery*. 2002;50(5):1032–1042.
83. Cantu RC. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *J Athl Train*. 2001;36(3):244–248.
84. Lovell MR, Collins MW, Iverson GL, et al. Recovery from mild concussion in high school athletes. *J Neurosurg*. 2003;98(2):296–301.
85. McCrory PR, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med*. 2000;10(4):235–238.
86. Yarnell PR, Lynch S. The 'ding': amnesic state in football trauma. *Neurology*. 1973;23(2):196–197.
87. Yarnell PR, Lynch S. Retrograde memory immediately after concussion. *Lancet*. 1970;1(7652):863–864.
88. McCrory PR, Berkovic SF. Video analysis of acute motor and convulsive manifestations in sport-related concussion. *Neurology*. 2000;54(7):1488–1491.
89. McCrory PR, Bladin PF, Berkovic SF. Retrospective study of concussive convulsions in elite Australian rules and rugby league footballers: phenomenology, aetiology, and outcome. *BMJ*. 1997;314(7075):171–174.
90. Fleminger S. Long-term psychiatric disorders after traumatic brain injury. *Eur J Anaesthesiol Suppl*. 2008;42:123–130.
91. Chen JK, Johnston KM, Petrides M, Ptito A. Neural substrates of symptoms of depression following concussion in male athletes with persisting postconcussion symptoms. *Arch Gen Psychiatry*. 2008;65(1):81–89.
92. Bryant RA. Disentangling mild traumatic brain injury and stress reactions. *New Engl J Med*. 2008;358(5):525–527.
93. Vanderploeg RD, Curtiss G, Luis CA, Salazar AM. Long-term morbidities following self-reported mild traumatic brain injury. *J Clin Exp Neuropsychol*. 2007;29(6):585–598.
94. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc*. 2007;39(6):903–909.
95. Kashluba S, Casey JE, Paniak C. Evaluating the utility of ICD-10 diagnostic criteria for postconcussion syndrome following mild traumatic brain injury. *J Int Neuropsychol Soc*. 2006;12(1):111–118.
96. Iverson GL. Misdiagnosis of the persistent postconcussion syndrome in patients with depression. *Arch Clin Neuropsychol*. 2006;21(4):303–310.
97. Chamelian L, Feinstein A. The effect of major depression on subjective and objective cognitive deficits in mild to moderate traumatic brain injury. *J Neuropsychiatry Clin Neurosci*. 2006;18(1):33–38.
98. Mooney G, Speed J, Sheppard S. Factors related to recovery after mild traumatic brain injury. *Brain Inj*. 2005;19(12):975–987.
99. Broshek DK, Freeman JR. Psychiatric and neuropsychological issues in sport medicine. *Clin Sports Med*. 2005;24(3):663–679.
100. Pellman EJ. Background on the National Football League's research on concussion in professional football. *Neurosurgery*. 2003;53(4):797–798.
101. Purcell L, Carson J. Sport-related concussion in pediatric athletes. *Clin Pediatr (Phila)*. 2008;47(2):106–113.
102. Lee LK. Controversies in the sequelae of pediatric mild traumatic brain injury. *Pediatr Emerg Care*. 2007;23(8):580–586.
103. Schnadower D, Vazquez H, Lee J, Dayan P, Roskind CG. Controversies in the evaluation and management of minor blunt head trauma in children. *Curr Opin Pediatr*. 2007;19(3):258–264.
104. Wozniak JR, Krach L, Ward E, Mueller BA, Muetzel R, Schnoebelen S, et al. Neurocognitive and neuroimaging correlates of pediatric traumatic brain injury: a diffusion tensor imaging (DTI) study. *Arch Clin Neuropsychol*. 2007;22(5):555–568.
105. Hayden MG, Jandial R, Duenas HA, Mahajan R, Levy M. Pediatric concussions in sports: a simple and rapid assessment tool for concussive injury in children and adults. *Child Nerv Syst*. 2007;23(4):431–435.
106. Lee MA. Adolescent concussions—management recommendations: a practical approach. *Conn Med*. 2006;70(6):377–380.
107. Kirkwood MW, Yeates KO, Wilson PE. Pediatric sport-related concussion: a review of the clinical management of an oft-neglected population. *Pediatrics*. 2006;117(4):1359–1371.
108. Guskiewicz KM, Marshall SW, Bailes J, et al. Association between recurrent concussion and late-life cognitive impairment in retired professional football players. *Neurosurgery*. 2005;57(4):719–726.
109. Nandoe RD, Scheltens P, Eikelenboom P. Head trauma and Alzheimer's disease. *J Alzheimers Dis*. 2002;4(4):303–308.
110. Stern MB. Head trauma as a risk factor for Parkinson's disease. *Mov Disord*. 1991;6(2):95–97.
111. Omalu BI, DeKosky ST, Hamilton RL, et al. Chronic traumatic encephalopathy in a National Football League player: part II. *Neurosurgery*. 2006;59(5):1086–1093.
112. Omalu BI, DeKosky ST, Minster RL, Kamboh MI, Hamilton RL, Wecht CH. Chronic traumatic encephalopathy in a National Football League player. *Neurosurgery*. 2005;57(1):128–134.
113. Hagel BE, Pless IB, Goulet C, Platt RW, Robitaille Y. Effectiveness of helmets in skiers and snowboarders: case-control and case crossover study. *BMJ*. 2005;330(7486):281.
114. McCrory P. The role of helmets in skiing and snowboarding. *Br J Sports Med*. 2002;36(5):314.
115. Mueller BA, Cummings P, Rivara FP, Brooks MA, Terasaki RD. Injuries of the head, face, and neck in relation to ski helmet use. *Epidemiology*. 2008;19(2):270–276.
116. Sulheim S, Holme I, Ekeland A, Bahr R. Helmet use and risk of head injuries in alpine skiers and snowboarders. *JAMA*. 2006;295(8):919–924.
117. Delaney JS, Al-Kashmiri A, Drummond R, Correa JA. The effect of protective headgear on head injuries and concussions in adolescent football (soccer) players. *Br J Sports Med*. 2008;42(2):110–115.
118. Viano DC, Pellman EJ, Withnall C, Shewchenko N. Concussion in professional football: performance of newer helmets in reconstructed game impacts—part 13. *Neurosurgery*. 2006;59(3):591–606.
119. Finch C, Braham R, McIntosh A, McCrory P, Wolfe R. Should football players wear custom fitted mouthguards? Results from a group randomised controlled trial. *Inj Prev*. 2005;11(4):242–246.
120. McIntosh A, McCrory P. The dynamics of concussive head impacts in rugby and Australian rules football. *Med Sci Sports Exerc*. 2000;32:1980–1984.
121. McIntosh AS, McCrory P, Comerford J. Impact energy attenuation performance of football headgear. *Br J Sports Med*. 2000;34(12):337–342.

122. McIntosh A, McCrory P. Effectiveness of headgear in a pilot study of under 15 rugby union football. *Br J Sports Med.* 2001;35(3):167–169.
123. McIntosh A, McCrory P, Finch C, Best J, Chalmers D. *Rugby Headgear Study Report*. Sydney, Australia: School of Safety Science, The University of New South Wales; 2005.
124. Finch C, Newstead S, Cameron M, Vulcan A. *Head Injury Reductions in Victoria Two Years After the Introduction of Mandatory Bicycle Helmet Use*. Melbourne, Australia: Monash University Accident Research Centre; 1993. Report No. 51.
125. Curnow WJ. Bicycle helmets and public health in Australia. *Health Promot J Austr.* 2008;19(1):10–15.
126. Hewson PJ. Cycle helmets and road casualties in the UK. *Traffic Inj Prev.* 2005;6(2):127–134.
127. Davidson JA. Epidemiology and outcome of bicycle injuries presenting to an emergency department in the United Kingdom. *Eur J Emerg Med.* 2005;12(1):24–29.
128. Hansen KS, Engesaeter LB, Viste A. Protective effect of different types of bicycle helmets. *Traffic Inj Prev.* 2003;4(4):285–290.
129. Andersen T, Arnason A, Engebretsen L, Bahr R. Mechanism of head injuries in elite football. *Br J Sports Med.* 2004;38(6):690–696.
130. Hagel B, Meeuwisse W. Risk compensation: a “side effect” of sport injury prevention? *Clin J Sp Med.* 2004;14(4):193–196.
131. Finch CF, McIntosh AS, McCrory P, Zazryn T. A pilot study of the attitudes of Australian Rules footballers towards protective headgear. *J Sci Med Sport.* 2003;6(4):505–511.
132. Finch CF, McIntosh AS, McCrory P. What do under 15 year old schoolboy rugby union players think about protective headgear? *Br J Sports Med.* 2001;35(2):89–94.
133. Finch CF, McIntosh AS, McCrory P, Zazryn T. What is the evidence base for the use of protective headgear and mouthguards in Australian football? *Sport Health.* 2000;18(4):35–38.
134. Reece RM, Sege R. Childhood head injuries: accidental or inflicted? *Arch Pediatr Adolesc Med.* 2000;154(1):11–15.
135. Shaw NH. Bodychecking in hockey. *CMAJ.* 2004 Jan 6;170(1):15–18.
136. Denke NJ. Brain injury in sports. *J Emerg Nurs.* 2008;34(4):363–364.
137. Gianotti S, Hume PA. Concussion sideline management intervention for rugby union leads to reduced concussion claims. *Neuro-Rehabilitation.* 2007;22(3):181–189.
138. Guilmette TJ, Malia LA, McQuiggan MD. Concussion understanding and management among New England high school football coaches. *Brain Inj.* 2007;21(10):1039–1047.
139. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train.* 2007;42(2):311–319.
140. Valovich McLeod TC, Schwartz C, Bay RC. Sport-related concussion misunderstandings among youth coaches. *Clin J Sport Med.* 2007;17(2):140–142.
141. Sye G, Sullivan SJ, McCrory P. High school rugby players’ understanding of concussion and return to play guidelines. *Br J Sports Med.* 2006;40(12):1003–1005.
142. Theye F, Mueller KA. “Heads up”: concussions in high school sports. *Clin Med Res.* 2004;2(3):165–171.
143. Kashluba S, Paniak C, Blake T, Reynolds S, Toller-Lobe G, Nagy J. A longitudinal, controlled study of patient complaints following treated mild traumatic brain injury. *Arch Clin Neuropsychol.* 2004;19(6):805–816.
144. Gabbe B, Finch CF, Wajswelner H, Bennell K. Does community-level Australian football support injury prevention research? *J Sci Med Sport.* 2003;6(2):231–236.
145. Kaut KP, DePompei R, Kerr J, Congeni J. Reports of head injury and symptom knowledge among college athletes: implications for assessment and educational intervention. *Clin J Sport Med.* 2003;13(4):213–221.
146. Davidhizar R, Cramer C. “The best thing about the hospitalization was that the nurses kept me well informed.” Issues and strategies of client education. *Accid Emerg Nurs.* 2002;10(3):149–154.
147. McCrory P. What advice should we give to athletes postconcussion? *Br J Sports Med.* 2002;36(5):316–318.
148. Bazarian JJ, Veenema T, Brayer AF, Lee E. Knowledge of concussion guidelines among practitioners caring for children. *Clin Pediatr (Phila).* 2001;40(4):207–212.

Address correspondence to Paul McCrory, MBBS, PhD, Centre for Health, Exercise & Sports Medicine, University of Melbourne, Parkville, Australia 3010. Address e-mail to paulmccr@bigpond.net.au.

APPENDIX. POCKET SPORT CONCUSSION ASSESSMENT TOOL 2 (SCAT2) AND SCAT2.

Pocket SCAT2



Concussion should be suspected in the presence of **any one or more** of the following: symptoms (such as headache), or physical signs (such as unsteadiness), or impaired brain function (e.g. confusion) or abnormal behaviour.

1. Symptoms

Presence of any of the following signs & symptoms may suggest a concussion.

- Loss of consciousness
- Seizure or convulsion
- Amnesia
- Headache
- “Pressure in head”
- Neck Pain
- Nausea or vomiting
- Dizziness
- Blurred vision
- Balance problems
- Sensitivity to light
- Sensitivity to noise
- Feeling slowed down
- Feeling like “in a fog”
- “Don’t feel right”
- Difficulty concentrating
- Difficulty remembering
- Fatigue or low energy
- Confusion
- Drowsiness
- More emotional
- Irritability
- Sadness
- Nervous or anxious

2. Memory function

Failure to answer all questions correctly may suggest a concussion.

- “At what venue are we at today?”
- “Which half is it now?”
- “Who scored last in this game?”
- “What team did you play last week / game?”
- “Did your team win the last game?”

3. Balance testing

Instructions for tandem stance

“Now stand heel-to-toe with your **non-dominant** foot in back. Your weight should be evenly distributed across both feet. You should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes.”

Observe the athlete for 20 seconds. If they make more than 5 errors (such as lift their hands off their hips; open their eyes; lift their forefoot or heel; step, stumble, or fall; or remain out of the start position for more than 5 seconds) then this may suggest a concussion.

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, urgently assessed medically, should not be left alone and should not drive a motor vehicle.

SCAT2

Sport Concussion Assessment Tool 2



Name

Sport/team

Date/time of injury

Date/time of assessment

Age Gender ☐ M ☐ F

Years of education completed

Examiner

What is the SCAT2?

This tool represents a standardized method of evaluating injured athletes for concussion and can be used in athletes aged from 10 years and older. It supersedes the original SCAT published in 2005². This tool also enables the calculation of the Standardized Assessment of Concussion (SAC)^{3,4} score and the Maddocks questions⁵ for sideline concussion assessment.

Instructions for using the SCAT2

The SCAT2 is designed for the use of medical and health professionals. Preseason baseline testing with the SCAT2 can be helpful for interpreting post-injury test scores. Words in *italics* throughout the SCAT2 are the instructions given to the athlete by the tester.

This tool may be freely copied for distribution to individuals, teams, groups and organizations.

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms (like those listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (such as headache), or
- Physical signs (such as unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour.

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

Symptom Evaluation

How do you feel?

You should score yourself on the following symptoms, based on how you feel now.

| | none | mild | moderate | severe | | | |
|--|------|------|----------|--------|---|---|---|
| Headache | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| “Pressure in head” | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Neck Pain | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nausea or vomiting | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Dizziness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Blurred vision | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Balance problems | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to light | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to noise | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling slowed down | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling like “in a fog” | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| “Don’t feel right” | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty concentrating | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty remembering | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Fatigue or low energy | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Confusion | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Drowsiness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Trouble falling asleep (if applicable) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| More emotional | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Irritability | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sadness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nervous or Anxious | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

Total number of symptoms (Maximum possible 22)

Symptom severity score

(Add all scores in table, maximum possible: 22 x 6 = 132)

Do the symptoms get worse with physical activity? ☐ Y ☐ N

Do the symptoms get worse with mental activity? ☐ Y ☐ N

Overall rating

If you know the athlete well prior to the injury, how different is the athlete acting compared to his / her usual self? Please circle one response.

☐ no different ☐ very different ☐ unsure

Cognitive & Physical Evaluation

1 Symptom score (from page 1)
22 minus number of symptoms of 22

2 Physical signs score
Was there loss of consciousness or unresponsiveness? ☐ Y ☐ N
If yes, how long? minutes
Was there a balance problem/unsteadiness? ☐ Y ☐ N
Physical signs score (1 point for each negative response) of 2

3 Glasgow coma scale (GCS)
Best eye response (E)
No eye opening 1
Eye opening in response to pain 2
Eye opening to speech 3
Eyes opening spontaneously 4
Best verbal response (V)
No verbal response 1
Incomprehensible sounds 2
Inappropriate words 3
Confused 4
Oriented 5
Best motor response (M)
No motor response 1
Extension to pain 2
Abnormal flexion to pain 3
Flexion/Withdrawal to pain 4
Localizes to pain 5
Obeys commands 6
Glasgow Coma score (E + V + M) of 15
GCS should be recorded for all athletes in case of subsequent deterioration.

4 Sideline Assessment – Maddocks Score
"I am going to ask you a few questions, please listen carefully and give your best effort."
Modified Maddocks questions (1 point for each correct answer)
At what venue are we at today? 0 1
Which half is it now? 0 1
Who scored last in this match? 0 1
What team did you play last week/game? 0 1
Did your team win the last game? 0 1
Maddocks score of 5
Maddocks score is validated for sideline diagnosis of concussion only and is not included in SCAT 2 summary score for serial testing.

¹ This tool has been developed by a group of international experts at the 3rd International Consensus meeting on Concussion in Sport held in Zurich, Switzerland in November 2008. The full details of the conference outcomes and the authors of the tool are published in British Journal of Sports Medicine, 2009, volume 43, supplement 1.
The outcome paper will also be simultaneously co-published in the May 2009 issues of Clinical Journal of Sports Medicine, Physical Medicine & Rehabilitation, Journal of Athletic Training, Journal of Clinical Neuroscience, Journal of Science & Medicine in Sport, Neurosurgery, Scandinavian Journal of Science & Medicine in Sport and the Journal of Clinical Sports Medicine.

² McCrory P et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. British Journal of Sports Medicine. 2005; 39: 196-204

5 Cognitive assessment
Standardized Assessment of Concussion (SAC)

Orientation (1 point for each correct answer)

What month is it? 0 1
What is the date today? 0 1
What is the day of the week? 0 1
What year is it? 0 1
What time is it right now? (within 1 hour) 0 1

Orientation score of 5

Immediate memory

"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."

Trials 2 & 3:

"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."

Complete all 3 trials regardless of score on trial 1 & 2. Read the words at a rate of one per second. Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do not inform the athlete that delayed recall will be tested.

| List | Trial 1 | Trial 2 | Trial 3 | Alternative word list |
|--------------|---------|---------|---------|-----------------------|
| elbow | 0 1 | 0 1 | 0 1 | candle baby finger |
| apple | 0 1 | 0 1 | 0 1 | paper monkey penny |
| carpet | 0 1 | 0 1 | 0 1 | sugar perfume blanket |
| saddle | 0 1 | 0 1 | 0 1 | sandwich sunset lemon |
| bubble | 0 1 | 0 1 | 0 1 | wagon iron insect |
| Total | | | | |

Immediate memory score of 15

Concentration

Digits Backward:

"I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."

If correct, go to next string length. If incorrect, read trial 2. One point possible for each string length. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

| | | Alternative digit lists |
|-------------|-----|-------------------------------------|
| 4-9-3 | 0 1 | 6-2-9 5-2-6 4-1-5 |
| 3-8-1-4 | 0 1 | 3-2-7-9 1-7-9-5 4-9-6-8 |
| 6-2-9-7-1 | 0 1 | 1-5-2-8-6 3-8-5-2-7 6-1-8-4-3 |
| 7-1-8-4-6-2 | 0 1 | 5-3-9-1-4-8 8-3-1-9-6-4 7-2-4-8-5-6 |

Months in Reverse Order:

"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November ... Go ahead"

1 pt. for entire sequence correct

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan 0 1

Concentration score of 5

³ McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sports Medicine. 2001; 11: 176-181

⁴ McCrea M, Randolph C, Kelly J. Standardized Assessment of Concussion: Manual for administration, scoring and interpretation, Waukesha, Wisconsin, USA.

⁵ Maddocks, DL; Dicker, GD; Saling, MM. The assessment of orientation following concussion in athletes. Clin J Sport Med. 1995;5(1):32-3

⁶ Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24-30

Balance examination

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)⁶. A stopwatch or watch with a second hand is required for this testing.

Balance testing

"I am now going to test your balance. Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."

(a) Double leg stance:

"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."

(b) Single leg stance:

"If you were to kick a ball, which foot would you use? [This will be the dominant foot] Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

(c) Tandem stance:

"Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."

Balance testing – types of errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 sec

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the athlete. The examiner will begin counting errors only after the individual has assumed the proper start position. **The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum total number of errors for any single condition is 10.** If a athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once subject is set. Subjects that are unable to maintain the testing procedure for a minimum of **five seconds** at the start are assigned the highest possible score, ten, for that testing condition.

Which foot was tested: ☐ Left ☐ Right
(i.e. which is the **non-dominant** foot)

Condition

| Condition | Total errors |
|--|--------------|
| Double Leg Stance (feet together) | of 10 |
| Single leg stance (non-dominant foot) | of 10 |
| Tandem stance (non-dominant foot at back) | of 10 |
| Balance examination score (30 minus total errors) | of 30 |

Coordination examination

Upper limb coordination

Finger-to-nose (FTN) task: *"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended). When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose as quickly and as accurately as possible."*

Which arm was tested: ☐ Left ☐ Right

Scoring: 5 correct repetitions in < 4 seconds = 1

Note for testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. Failure should be scored as 0.

Coordination score

of 1

Cognitive assessment

Standardized Assessment of Concussion (SAC)

Delayed recall

"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."

Circle each word correctly recalled. Total score equals number of words recalled.

| List | Alternative word list | | |
|--------|-----------------------|---------|---------|
| elbow | candle | baby | finger |
| apple | paper | monkey | penny |
| carpet | sugar | perfume | blanket |
| saddle | sandwich | sunset | lemon |
| bubble | wagon | iron | insect |

Delayed recall score

of 5

Overall score

| Test domain | Score |
|--------------------------------|---------------|
| Symptom score | of 22 |
| Physical signs score | of 2 |
| Glasgow Coma score (E + V + M) | of 15 |
| Balance examination score | of 30 |
| Coordination score | of 1 |
| Subtotal | of 70 |
| Orientation score | of 5 |
| Immediate memory score | of 5 |
| Concentration score | of 15 |
| Delayed recall score | of 5 |
| SAC subtotal | of 30 |
| SCAT2 total | of 100 |
| Maddocks Score | of 5 |

Definitive normative data for a SCAT2 "cut-off" score is not available at this time and will be developed in prospective studies. Embedded within the SCAT2 is the SAC score that can be utilized separately in concussion management. The scoring system also takes on particular clinical significance during serial assessment where it can be used to document either a decline or an improvement in neurological functioning.

Scoring data from the SCAT2 or SAC should not be used as a stand alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion.

Athlete Information

Any athlete suspected of having a concussion should be removed from play, and then seek medical evaluation.

Signs to watch for

Problems could arise over the first 24-48 hours. You should not be left alone and must go to a hospital at once if you:

- Have a headache that gets worse
- Are very drowsy or can't be awakened (woken up)
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused; are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on your feet; have slurred speech

Remember, it is better to be safe.

Consult your doctor after a suspected concussion.

Return to play

Athletes should not be returned to play the same day of injury.

When returning athletes to play, they should follow a stepwise symptom-limited program, with stages of progression. For example:

1. rest until asymptomatic (physical and mental rest)
2. light aerobic exercise (e.g. stationary cycle)
3. sport-specific exercise
4. non-contact training drills (start light resistance training)
5. full contact training after medical clearance
6. return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should return to stage 1 if symptoms recur. Resistance training should only be added in the later stages.

Medical clearance should be given before return to play.

| Tool | Test domain | Time | Score | | | |
|---|--------------------------------|------------------|---|---|---|---|
| | | Date tested | | | | |
| | | Days post injury | | | | |
| SCAT2 | Symptom score | | | | | |
| | Physical signs score | | | | | |
| | Glasgow Coma score (E + V + M) | | | | | |
| | Balance examination score | | | | | |
| | Coordination score | | | | | |
| | Orientation score | | | | | |
| | Immediate memory score | | | | | |
| | Concentration score | | | | | |
| | Delayed recall score | | | | | |
| | SAC Score | | | | | |
| Total | SCAT2 | | | | | |
| Symptom severity score (max possible 132) | | | | | | |
| Return to play | | | <input type="checkbox"/> Y <input type="checkbox"/> N | <input type="checkbox"/> Y <input type="checkbox"/> N | <input type="checkbox"/> Y <input type="checkbox"/> N | <input type="checkbox"/> Y <input type="checkbox"/> N |

Additional comments

Concussion injury advice (To be given to concussed athlete)

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. It is expected that recovery will be rapid, but the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

If you notice any change in behaviour, vomiting, dizziness, worsening headache, double vision or excessive drowsiness, please telephone the clinic or the nearest hospital emergency department immediately.

Other important points:

- Rest and avoid strenuous activity for at least 24 hours
- No alcohol
- No sleeping tablets
- Use paracetamol or codeine for headache. Do not use aspirin or anti-inflammatory medication
- Do not drive until medically cleared
- Do not train or play sport until medically cleared

Clinic phone number

Patient's name

Date/time of injury

Date/time of medical review

Treating physician

Contact details or stamp

National Athletic Trainers' Association Position Statement: Management of Sport- Related Concussion

Kevin M. Guskiewicz*; **Scott L. Bruce†**; **Robert C. Cantu‡**; **Michael S. Ferrara§**; **James P. Kelly||**; **Michael McCrea¶**; **Margot Putukian#**;
Tamara C. Valovich McLeod**

*University of North Carolina at Chapel Hill, Chapel Hill, NC; †California University of Pennsylvania, California, PA;
‡Emerson Hospital, Concord, MA; §University of Georgia, Athens, GA; ||University of Colorado, Denver, CO;
¶Waukesha Memorial Hospital, Waukesha, WI; #Princeton University, Princeton, NJ; **Arizona School of Health
Sciences, Mesa, AZ

Kevin M. Guskiewicz, PhD, ATC, FACSM; Scott L. Bruce, MS, ATC; Robert C. Cantu, MD, FACSM; Michael S. Ferrara, PhD, ATC; James P. Kelly, MD; Michael McCrea, PhD; Margot Putukian, MD, FACSM; and Tamara C. Valovich McLeod, PhD, ATC, CSCS, contributed to conception and design, acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article.

Address correspondence to National Athletic Trainers' Association, Communications Department, 2952 Stemmons Freeway, Dallas, TX 75247.

Sport in today's society is more popular than probably ever imagined. Large numbers of athletes participate in a variety of youth, high school, collegiate, professional, and recreational sports. As sport becomes more of a fixture in the lives of Americans, a burden of responsibility falls on the shoulders of the various organizations, coaches, parents, clinicians, officials, and researchers to provide an environment that minimizes the risk of injury in all sports. For example, the research-based recommendations made for football between 1976 and 1980 resulted in a significant reduction in the incidence of fatalities and nonfatal catastrophic injuries. In 1968, 36 brain and cervical spine fatalities occurred in high school and collegiate football. The number had dropped to zero in 1990 and has averaged about 5 per year since then.¹ This decrease was attributed to a variety of factors, including (1) rule changes, which have outlawed spearing and butt blocking, (2) player education about the rule changes and the consequences of not following the rules, (3) implementation of equipment standards, (4) availability of alternative assessment techniques, (5) a marked reduction in physical contact time during practice sessions, (6) a heightened awareness among clinicians of the dangers involved in returning an athlete to competition too early, and (7) the athlete's awareness of the risks associated with concussion.

Research in the area of sport-related concussion has provided the athletic training and medical professions with valuable new knowledge in recent years. Certified athletic trainers, who on average care for 7 concussive injuries per year,² have been forced to rethink how they manage sport-related concussion. Recurrent concussions to several high-profile athletes, some of whom were forced into retirement as a result, have increased awareness among sports medicine personnel and the general public. Bridging the gap between research and clinical practice

is the key to reducing the incidence and severity of sport-related concussion and improving return-to-play decisions. This position statement should provide valuable information and recommendations for certified athletic trainers (ATCs), physicians, and other medical professionals caring for athletes at the youth, high school, collegiate, and elite levels. The following recommendations are derived from the most recent scientific and clinic-based literature on sport-related concussion. The justification for these recommendations is presented in the summary statement following the recommendations. The summary statement is organized into the following sections: "Defining and Recognizing Concussion," "Evaluating and Making the Return-to-Play Decision," "Concussion Assessment Tools," "When to Refer an Athlete to a Physician After Concussion," "When to Disqualify an Athlete," "Special Considerations for the Young Athlete," "Home Care," and "Equipment Issues."

RECOMMENDATIONS

Defining and Recognizing Concussion

1. The ATC should develop a high sensitivity for the various mechanisms and presentations of traumatic brain injury (TBI), including mild, moderate, and severe cerebral concussion, as well as the more severe, but less common, head injuries that can cause damage to the brain stem and other vital centers of the brain.
2. The colloquial term "ding" should not be used to describe a sport-related concussion. This stunned confusional state is a concussion most often reflected by the athlete's initial confusion, which may disappear within minutes, leaving

no outwardly observable signs and symptoms. Use of the term “ding” generally carries a connotation that diminishes the seriousness of the injury. If an athlete shows concussion-like signs and reports symptoms after a contact to the head, the athlete has, *at the very least*, sustained a mild concussion and should be treated for a concussion.

3. To detect deteriorating signs and symptoms that may indicate a more serious head injury, the ATC should be able to recognize both the obvious signs (eg, fluctuating levels of consciousness, balance problems, and memory and concentration difficulties) and the more common, self-reported symptoms (eg, headache, ringing in the ears, and nausea).
4. The ATC should play an active role in educating athletes, coaches, and parents about the signs and symptoms associated with concussion, as well as the potential risks of playing while still symptomatic.
5. The ATC should document all pertinent information surrounding the concussive injury, including but not limited to (1) mechanism of injury; (2) initial signs and symptoms; (3) state of consciousness; (4) findings on serial testing of symptoms and neuropsychological function and postural-stability tests (noting any deficits compared with baseline); (5) instructions given to the athlete and/or parent; (6) recommendations provided by the physician; (7) date and time of the athlete’s return to participation; and (8) relevant information on the player’s history of prior concussion and associated recovery pattern(s).³

Evaluating and Making the Return-to-Play Decision

6. Working together, ATCs and team physicians should agree on a philosophy for managing sport-related concussion before the start of the athletic season. Currently 3 approaches are commonly used: (1) grading the concussion at the time of the injury, (2) deferring final grading until all symptoms have resolved, or (3) not using a grading scale but rather focusing attention on the athlete’s recovery via symptoms, neurocognitive testing, and postural-stability testing. After deciding on an approach, the ATC-physician team should be consistent in its use regardless of the athlete, sport, or circumstances surrounding the injury.
7. For athletes playing sports with a high risk of concussion, baseline cognitive and postural-stability testing should be considered. In addition to the concussion injury assessment, the evaluation should also include an assessment of the cervical spine and cranial nerves to identify any cervical spine or vascular intracerebral injuries.
8. The ATC should record the time of the initial injury and document serial assessments of the injured athlete, noting the presence or absence of signs and symptoms of injury. The ATC should monitor vital signs and level of consciousness every 5 minutes after a concussion until the athlete’s condition improves. The athlete should also be monitored over the next few days after the injury for the presence of delayed signs and symptoms and to assess recovery.
9. Concussion severity should be determined by paying close attention to the severity and persistence of *all* signs and symptoms, including the presence of amnesia (retrograde and anterograde) and loss of consciousness (LOC), as well as headache, concentration problems, dizziness, blurred

vision, and so on. It is recommended that ATCs and physicians consistently use a symptom checklist similar to the one provided in Appendix A.

10. In addition to a thorough clinical evaluation, formal cognitive and postural-stability testing is recommended to assist in objectively determining injury severity and readiness to return to play (RTP). No one test should be used solely to determine recovery or RTP, as concussion presents in many different ways.
11. Once symptom free, the athlete should be reassessed to establish that cognition and postural stability have returned to normal for that player, preferably by comparison with preinjury baseline test results. The RTP decision should be made after an incremental increase in activity with an initial cardiovascular challenge, followed by sport-specific activities that do not place the athlete at risk for concussion. The athlete can be released to full participation as long as no recurrent signs or symptoms are present.

Concussion Assessment Tools

12. Baseline testing on concussion assessment measures is recommended to establish the individual athlete’s “normal” preinjury performance and to provide the most reliable benchmark against which to measure postinjury recovery. Baseline testing also controls for extraneous variables (eg, attention deficit disorder, learning disabilities, age, and education) and for the effects of earlier concussion while also evaluating the possible cumulative effects of recurrent concussions.
13. The use of objective concussion assessment tools will help ATCs more accurately identify deficits caused by injury and postinjury recovery and protect players from the potential risks associated with prematurely returning to competition and sustaining a repeat concussion. The concussion assessment battery should include a combination of tests for cognition, postural stability, and self-reported symptoms known to be affected by concussion.
14. A combination of brief screening tools appropriate for use on the sideline (eg, Standardized Assessment of Concussion [SAC], Balance Error Scoring System [BESS], symptom checklist) and more extensive measures (eg, neuropsychological testing, computerized balance testing) to more precisely evaluate recovery later after injury is recommended.
15. Before instituting a concussion neuropsychological testing battery, the ATC should understand the test’s user requirements, copyright restrictions, and standardized instructions for administration and scoring. All evaluators should be appropriately trained in the standardized instructions for test administration and scoring before embarking on testing or adopting an instrument for clinical use. Ideally, the sports medicine team should include a neuropsychologist, but in reality, many ATCs may not have access to a neuropsychologist for interpretation and consultation, nor the financial resources to support a neuropsychological testing program. In this case, it is recommended that the ATC use screening instruments (eg, SAC, BESS, symptom checklist) that have been developed specifically for use by sports medicine clinicians without extensive

training in psychometric or standardized testing and that do not require a special license to administer or interpret.

16. Athletic trainers should adopt for clinical use only those neuropsychological and postural stability measures with population-specific normative data, test-retest reliability, clinical validity, and sufficient sensitivity and specificity established in the peer-reviewed literature. These standards provide the basis for how well the test can distinguish between those with and without cerebral dysfunction in order to reduce the possibility of false-positive and false-negative errors, which could lead to clinical decision-making errors.
17. As is the case with all clinical instruments, results from assessment measures to evaluate concussion should be integrated with all aspects of the injury evaluation (eg, physical examination, neurologic evaluation, neuroimaging, and player's history) for the most effective approach to injury management and RTP decision making. Decisions about an athlete's RTP should never be based solely on the use of any one test.

When to Refer an Athlete to a Physician After Concussion

18. The ATC or team physician should monitor an athlete with a concussion at 5-minute intervals from the time of the injury until the athlete's condition completely clears or the athlete is referred for further care. Coaches should be informed that in situations when a concussion is suspected but an ATC or physician is not available, their primary role is to ensure that the athlete is immediately seen by an ATC or physician.
19. An athlete with a concussion should be referred to a physician on the day of injury if he or she lost consciousness, experienced amnesia lasting longer than 15 minutes, or meets any of the criteria outlined in Appendix B.
20. A team approach to the assessment of concussion should be taken and include a variety of medical specialists. In addition to family practice or general medicine physician referrals, the ATC should secure other specialist referral sources within the community. For example, neurologists are trained to assist in the management of patients experiencing persistent signs and symptoms, including sleep disturbances. Similarly, a neuropsychologist should be identified as part of the sports medicine team for assisting athletes who require more extensive neuropsychological testing and for interpreting the results of neuropsychological tests.
21. A team approach should be used in making RTP decisions after concussion. This approach should involve input from the ATC, physician, athlete, and any referral sources. The assessment of all information, including the physical examination, imaging studies, objective tests, and exertional tests, should be considered prior to making an RTP decision.

When to Disqualify an Athlete

22. Athletes who are symptomatic at rest and after exertion for at least 20 minutes should be disqualified from returning to participation on the day of the injury. Exertional

exercises should include sideline jogging followed by sprinting, sit-ups, push-ups, and any sport-specific, non-contact activities (or positions or stances) the athlete might need to perform on returning to participation. Athletes who return on the same day because symptoms resolved quickly (<20 minutes) should be monitored closely after they return to play. They should be repeatedly reevaluated on the sideline after the practice or game and again at 24 and 48 hours postinjury to identify any delayed onset of symptoms.

23. Athletes who experience LOC or amnesia should be disqualified from participating on the day of the injury.
24. The decision to disqualify from further participation on the day of a concussion should be based on a comprehensive physical examination; assessment of self-reported postconcussion signs and symptoms; functional impairments, and the athlete's past history of concussions. If assessment tools such as the SAC, BESS, neuropsychological test battery, and symptom checklist are not used, a 7-day symptom-free waiting period before returning to participation is recommended. Some circumstances, however, will warrant even more conservative treatment (see recommendation 25).
25. Athletic trainers should be more conservative with athletes who have a history of concussion. Athletes with a history of concussion are at increased risk for sustaining subsequent injuries as well as for slowed recovery of self-reported postconcussion signs and symptoms, cognitive dysfunction, and postural instability after subsequent injuries. In athletes with a history of 3 or more concussions and experiencing slowed recovery, temporary or permanent disqualification from contact sports may be indicated.

Special Considerations for the Young Athlete

26. Athletic trainers working with younger (pediatric) athletes should be aware that recovery may take longer than in older athletes. Additionally, these younger athletes are maturing at a relatively fast rate and will likely require more frequent updates of baseline measures compared with older athletes.
27. Many young athletes experience sport-related concussion. Athletic trainers should play an active role in helping to educate young athletes, their parents, and coaches about the dangers of repeated concussions. Continued research into the epidemiology of sport-related concussion in young athletes and prospective investigations to determine the acute and long-term effects of recurrent concussions in younger athletes are warranted.
28. Because damage to the maturing brain of a young athlete can be catastrophic (ie, almost all reported cases of second-impact syndrome are in young athletes), athletes under age 18 years should be managed more conservatively, using stricter RTP guidelines than those used to manage concussion in the more mature athlete.

Home Care

29. An athlete with a concussion should be instructed to avoid taking medications except acetaminophen after the injury. Acetaminophen and other medications should be given

only at the recommendation of a physician. Additionally, the athlete should be instructed to avoid ingesting alcohol, illicit drugs, or other substances that might interfere with cognitive function and neurologic recovery.

30. Any athlete with a concussion should be instructed to rest, but complete bed rest is not recommended. The athlete should resume normal activities of daily living as tolerated while avoiding activities that potentially increase symptoms. Once he or she is symptom free, the athlete may resume a graded program of physical and mental exertion, without contact or risk of concussion, up to the point at which postconcussion signs and symptoms recur. If symptoms appear, the exertion level should be scaled back to allow maximal activity without triggering symptoms.
31. An athlete with a concussion should be instructed to eat a well-balanced diet that is nutritious in both quality and quantity.
32. An athlete should be awakened during the night to check on deteriorating signs and symptoms only if he or she experienced LOC, had prolonged periods of amnesia, or was still experiencing significant symptoms at bedtime. The purpose of the wake-ups is to check for deteriorating signs and symptoms, such as decreased levels of consciousness or increasing headache, which could indicate a more serious head injury or a late-onset complication, such as an intracranial bleed.
33. Oral and written instructions for home care should be given to the athlete and to a responsible adult (eg, parent or roommate) who will observe and supervise the athlete during the acute phase of the concussion while at home or in the dormitory. The ATC and physician should agree on a standard concussion home-instruction form similar to the one presented in Appendix C, and it should be used consistently for all concussions.

Equipment Issues

34. The ATC should enforce the standard use of helmets for protecting against catastrophic head injuries and reducing the severity of cerebral concussions. In sports that require helmet protection (football, lacrosse, ice hockey, baseball/softball, etc), the ATC should ensure that all equipment meets either the National Operating Committee on Standards for Athletic Equipment (NOCSAE) or American Society for Testing and Materials (ASTM) standards.
35. The ATC should enforce the standard use of mouth guards for protection against dental injuries; however, there is no scientific evidence supporting their use for reducing concussive injury.
36. At this time, the ATC should neither endorse nor discourage the use of soccer headgear for protecting against concussion or the consequences of cumulative, subconcussive impacts to the head. Currently no scientific evidence supports the use of headgear in soccer for reducing concussive injury to the head.

DEFINING AND RECOGNIZING CONCUSSION

Perhaps the most challenging aspect of managing sport-related concussion is recognizing the injury, especially in athletes with no obvious signs that a concussion has actually occurred. The immediate management of the head-injured athlete

depends on the nature and severity of the injury. Several terms are used to describe this injury, the most global being TBI, which can be classified into 2 types: focal and diffuse. Focal or posttraumatic intracranial mass lesions include subdural hematomas, epidural hematomas, cerebral contusions, and intracerebral hemorrhages and hematomas. These are considered uncommon in sport but are serious injuries; the ATC must be able to detect signs of clinical deterioration or worsening symptoms during serial assessments. Signs and symptoms of these focal vascular emergencies can include LOC, cranial nerve deficits, mental status deterioration, and worsening symptoms. Concern for a significant focal injury should also be raised if these signs or symptoms occur after an initial lucid period in which the athlete seemed normal.

Diffuse brain injuries can result in widespread or global disruption of neurologic function and are not usually associated with macroscopically visible brain lesions except in the most severe cases. Most diffuse injuries involve an acceleration-deceleration motion, either within a linear plane or in a rotational direction or both. In these cases, lesions are caused by the brain being shaken within the skull.^{4,5} The brain is suspended within the skull in cerebrospinal fluid (CSF) and has several dural attachments to bony ridges that make up the inner contours of the skull. With a linear acceleration-deceleration mechanism (side to side or front to back), the brain experiences a sudden momentum change that can result in tissue damage. The key elements of injury mechanism are the velocity of the head before impact, the time over which the force is applied, and the magnitude of the force.^{4,5} Rotational acceleration-deceleration injuries are believed to be the primary injury mechanism for the most severe diffuse brain injuries. Structural diffuse brain injury (diffuse axonal injury [DAI]) is the most severe type of diffuse injury because axonal disruption occurs, typically resulting in disturbance of cognitive functions, such as concentration and memory. In its most severe form, DAI can disrupt the brain-stem centers responsible for breathing, heart rate, and wakefulness.^{4,5}

Cerebral concussion, which is the focus of this position statement, can best be classified as a mild diffuse injury and is often referred to as mild TBI (MTBI). The injury involves an acceleration-deceleration mechanism in which a blow to the head or the head striking an object results in 1 or more of the following conditions: headache, nausea, vomiting, dizziness, balance problems, feeling "slowed down," fatigue, trouble sleeping, drowsiness, sensitivity to light or noise, LOC, blurred vision, difficulty remembering, or difficulty concentrating.⁶ In 1966, the Congress of Neurological Surgeons proposed the following consensus definition of concussion, subsequently endorsed by a variety of medical associations: "Concussion is a clinical syndrome characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision, equilibrium, etc, due to mechanical forces."⁷ Although the definition received widespread consensus in 1966, more contemporary opinion (as concluded at the First International Conference on Concussion in Sport, Vienna, 2001⁸) was that this definition fails to include many of the predominant clinical features of concussion, such as headache and nausea. It is often reported that there is no universal agreement on the standard definition or nature of concussion; however, agreement does exist on several features that incorporate clinical, pathologic, and biomechanical injury constructs associated with head injury:

1. Concussion may be caused by a direct blow to the head or elsewhere on the body from an “impulsive” force transmitted to the head.
2. Concussion may cause an immediate and short-lived impairment of neurologic function.
3. Concussion may cause neuropathologic changes; however, the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
4. Concussion may cause a gradient of clinical syndromes that may or may not involve LOC. Resolution of the clinical and cognitive symptoms typically follows a sequential course.
5. Concussion is most often associated with normal results on conventional neuroimaging studies.⁸

Occasionally, players sustain a blow to the head resulting in a stunned confusional state that resolves within minutes. The colloquial term “ding” is often used to describe this initial state. However, the use of this term is not recommended because this stunned confusional state is still considered a concussion resulting in symptoms, although only very short in duration, that should not be dismissed in a cavalier fashion. It is essential that this injury be reevaluated frequently to determine if a more serious injury has occurred, because often the evolving signs and symptoms of a concussion are not evident until several minutes to hours later.

Although it is important for the ATC to recognize and eventually classify the concussive injury, it is equally important for the athlete to understand the signs and symptoms of a concussion as well as the potential negative consequences (eg, second-impact syndrome and predisposition to future concussions) of not reporting a concussive injury. Once the athlete has a better understanding of the injury, he or she can provide a more accurate report of the concussion history.

Mechanisms of Injury

A forceful blow to the resting, movable head usually produces maximum brain injury beneath the point of cranial impact (coup injury). A moving head hitting an unyielding object usually produces maximum brain injury opposite the site of cranial impact (contrecoup injury) as the brain shifts within the cranium. When the head is accelerated before impact, the brain lags toward the trailing surface, thus squeezing away the CSF and creating maximal shearing forces at this site. This brain lag actually thickens the layer of CSF under the point of impact, which explains the lack of coup injury in the moving head. Alternatively, when the head is stationary before impact, neither brain lag nor disproportionate distribution of CSF occurs, accounting for the absence of contrecoup injury and the presence of coup injury.^{4,5}

No scientific evidence suggests that one type of injury (coup or contrecoup) is more serious than the other or that symptoms present any differently. Many sport-related concussions are the result of a combined coup-contrecoup mechanism, involving damage to the brain on both the side of initial impact and the opposite side of the brain due to brain lag. Regardless of whether the athlete has sustained a coup, contrecoup, or combined coup-contrecoup injury, the ATC should manage the injury the same.

Three types of stresses can be generated by an applied force to injure the brain: compressive, tensile, and shearing. Compression involves a crushing force in which the tissue cannot absorb any additional force or load. Tension involves pulling

or stretching of tissue, whereas shearing involves a force that moves across the parallel organization of the tissue. Brief, uniform compressive stresses are fairly well tolerated by neural tissue, but tension and shearing stresses are very poorly tolerated.^{4,9}

Neuroimaging of Cerebral Concussion

Traditionally, computed tomography (CT) and magnetic resonance imaging (MRI) have been considered useful in identifying certain types of brain lesions; however, they have been of little value in assessing less severe head injuries, such as cerebral concussion, and contributing to the RTP decision. A CT scan is often indicated emergently if a focal injury such as an acute subdural or epidural bleed is suspected; this study easily demonstrates acute blood collection and skull fracture, but an MRI is superior at demonstrating an isodense subacute or chronic subdural hematoma that may be weeks old.^{10,11} Newer structural MRI modalities, including gradient echo, perfusion, and diffusion-weighted imaging, are more sensitive for structural abnormalities (eg, vascular shearing) compared with other diagnostic imaging techniques.¹⁰ Functional imaging technologies (eg, positron emission tomography [PET], single-photon emission computerized tomography [SPECT], and functional MRI [fMRI]) are also yielding promising early results and may help define concussion recovery.¹² Presently, no neuroanatomic or physiologic measurements can be used to determine the severity of a concussion or when complete recovery has occurred in an individual athlete after a concussion.

EVALUATING AND MAKING THE RETURN-TO-PLAY DECISION

Clinical Evaluation

Results from a thorough clinical examination conducted by both the ATC and the physician cannot be overlooked and should be considered very important pieces of the concussion puzzle. These evaluations should include a thorough *history* (including number and severity of previous head injuries), *observation* (including pupil responses), *palpation*, and *special tests* (including simple tests of memory, concentration, and coordination and a cranial nerve assessment). In many situations, a physician will not be present at the time of the concussion, and the ATC will be forced to act on behalf of the sports medicine team. More formal neuropsychological testing and postural-stability testing should be viewed as adjuncts to the initial clinical and repeat evaluations (see “Concussion Assessment Tools”). The ATC-physician team must also consider referral options to specialists such as neurologists, neurosurgeons, neuropsychologists, and neuro-otologists, depending on the injury severity and situation. Referrals for imaging tests such as CT, MRI, or electronystagmography are also options that sometimes can aid in the diagnosis and/or management of sport-related concussion but are typically used only in cases involving LOC, severe amnesia, abnormal physical or neurologic findings, or increasing or intensified symptoms.

Determining Injury Severity

The definition of concussion is often expanded to include mild, moderate, and severe injuries. Several early grading scales and RTP guidelines early were proposed for classifying

and managing cerebral concussions.^{6,13–20} None of the scales have been universally accepted or followed with much consistency by the sports medicine community. In addition, most of these classification systems denote the most severe injuries as associated with LOC, which we now know is not always predictive of recovery after a brain injury.^{21,22} It is important for the ATC and other health care providers to recognize the importance of identifying retrograde amnesia and anterograde amnesia, LOC, and other signs and symptoms present and to manage each episode independently.

The ATC must recognize that no 2 concussions are identical and that the resulting symptoms can be very different, depending on the force of the blow to the head, the degree of metabolic dysfunction, the tissue damage and duration of time needed to recover, the number of previous concussions, and the time between injuries. All these factors must be considered when managing an athlete suffering from cerebral concussion.³ The 2 most recognizable signs of a concussion are LOC and amnesia; yet, as previously mentioned, neither is required for an injury to be classified as a concussion. A 2000 study of 1003 concussions sustained by high school and collegiate football players revealed that LOC and amnesia presented infrequently, 9% and 27% of all cases, respectively, whereas other signs and symptoms, such as headache, dizziness, confusion, disorientation, and blurred vision, were much more common.²³ After the initial concussion evaluation, the ATC should determine whether the athlete requires more advanced medical intervention on an emergent basis or whether the team physician should be contacted for an RTP decision (Appendix B). It may be helpful if the injury is graded throughout the process, but this grading is likely to be more important for treating subsequent injuries than the current injury.

Most grading systems rely heavily on LOC and amnesia as indicators of injury severity. Recent research, however, suggests that these 2 factors, either alone or in combination, are not good predictors of injury severity. A number of authors have documented no association between brief (<1 minute) LOC and abnormalities on neuropsychological testing at 48 hours, raising concern for brief LOC as a predictor of recovery after concussion.^{8,22,24–27} Studies involving high school and collegiate athletes with concussion revealed no association between (1) LOC and duration of symptoms or (2) LOC and neuropsychological and balance tests at 3, 24, 48, 72, and 96 hours postinjury.^{21,28,29} In other words, athletes experiencing LOC were similar to athletes without LOC on these same injury-severity markers.

With respect to amnesia, the issue is more clouded because findings have been inconsistent. Several studies of nonathletes^{30–37} suggest that the duration of posttraumatic amnesia correlates with the severity and outcome of severe TBI but not with mild TBI or concussion.^{38–40} More contemporary studies of athletes with concussion are also clouded. Two unrelated, prospective studies of concussion suggest that the presence of amnesia best correlates with abnormal neuropsychological testing at 48 hours and with the duration and number of other postconcussion signs and symptoms.^{24,41} However, more recently, investigations of high school and collegiate athletes with concussion revealed no association between (1) amnesia and duration of symptoms or (2) amnesia and neuropsychological and balance tests at 3, 24, 48, 72, and 96 hours postinjury.^{21,28,29} Of importance in these studies is the significant association between symptom-severity score (within the initial 3 hours postinjury) and the total duration of symptoms (mea-

Table 1. American Academy of Neurology Concussion Grading Scale⁶

| | |
|--------------------|--|
| Grade 1 (mild) | Transient confusion; no LOC*; symptoms and mental status abnormalities resolve <15 min |
| Grade 2 (moderate) | Transient confusion; no LOC; symptoms and mental status abnormalities last >15 min |
| Grade 3 (severe) | Any LOC |

*LOC indicates loss of consciousness.

sured until asymptomatic). Although these findings suggest that initial symptom severity is probably a better indicator than either LOC or amnesia in predicting length of recovery, amnesia was recently found to predict symptom and neurocognitive deficits at 2 days postinjury.⁴² More research is needed in this area to help improve clinical decision making.

It has been suggested that LOC and amnesia, especially when prolonged, should not be ignored,^{43,44} but evidence for their usefulness in establishing RTP guidelines is scarce. Loss of consciousness, whether it occurs immediately or after an initially lucid interval, is important in that it may signify a more serious vascular brain injury. Other postconcussion signs and symptoms should be specifically addressed for presence and duration when the ATC is evaluating the athlete. Determining whether a cervical spine injury has occurred is also of major importance because it is often associated with head injury and should not be missed. If the athlete complains of neck pain or has cervical spine tenderness, cervical spine immobilization should be considered. If a cervical spine injury is ruled out and the athlete is taken to the sideline, a thorough clinical examination should follow, including a complete neurologic examination and cognitive evaluation. The ATC must note the time of the injury and then maintain a timed assessment form to follow the athlete's symptoms and examinations serially. It is often difficult to pay attention to the time that has passed after an injury. Therefore, it is important for one member of the medical team to track time during the evaluation process and record all pertinent information. After an initial evaluation, the clinician must determine whether the injured athlete requires more advanced medical intervention and eventually grade the injury and make an RTP decision that can occur within minutes, hours, days, or weeks of the injury.

There are currently 3 approaches to grading sport-related concussion. One approach is to grade the concussion at the time of the injury on the basis of the signs and symptoms present at the time of the concussion and within the first 15 minutes after injury. The American Academy of Neurology Concussion Grading Scale (Table 1)⁶ has been widely used with this approach. It permits the ATC to grade the injury primarily on the basis of LOC and to provide the athlete, coach, and parent with an estimation of injury severity. A disadvantage to this approach is that many injuries behave differently than expected on initial evaluation, potentially creating more difficulties with the athlete, coach, or parent and making the RTP decision more challenging. Another approach is to grade the concussion on the basis of the presence and overall duration of symptoms. This approach is best addressed using the Cantu Evidence-Based Grading Scale (Table 2),⁴³ which guides the ATC to grade the injury only after all concussion signs and symptoms have resolved. This scale places less emphasis on LOC as a potential predictor of subsequent impairment and additional weight on overall symptom dura-

Table 2. Cantu Evidence-Based Grading System for Concussion⁴³

| | |
|--------------------|--|
| Grade 1 (mild) | No LOC*, PTA† <30 min, PCSS‡ <24 h |
| Grade 2 (moderate) | LOC <1 min or PTA ≥30 min <24 h or PCSS ≥24 h <7 d |
| Grade 3 (severe) | LOC ≥1 min or PTA ≥24 h or PCSS ≥7 d |

*LOC indicates loss of consciousness.

†PTA indicates posttraumatic amnesia (anterograde/retrograde).

‡PCSS indicates postconcussion signs and symptoms other than amnesia.

tion.^{3,43} Finally, a third approach to the grading-scale dilemma is to not use a grading scale but rather focus attention on the athlete's recovery via symptoms, neuropsychological tests, and postural-stability tests. This line of thinking is that the ATC should not place too much emphasis on the grading system or grade but should instead focus on whether the athlete is symptomatic or symptom free. Once the athlete is asymptomatic, a stepwise progression should be implemented that increases demands over several days. This progression will be different for athletes who are withheld for several weeks compared with those athletes withheld for just a few days. This multitiered approach was summarized and supported by consensus at the 2001 Vienna Conference on Concussion in Sport.⁸

Making the Return-to-Play Decision

The question raised most often regarding the concussion grading and RTP systems is one of practicality in the sport setting. Many clinicians believe that the RTP guidelines are too conservative and, therefore, choose to base decisions on clinical judgment of individual cases rather than on a general recommendation. It has been reported that 30% of all high school and collegiate football players sustaining concussions return to competition on the same day of injury; the remaining 70% average 4 days of rest before returning to participation.²³ Many RTP guidelines call for the athlete to be symptom free for at least 7 days before returning to participation after a grade 1 or 2 concussion.^{6,13,15,17,43,44} Although many clinicians deviate from these recommendations and are more liberal in making RTP decisions, recent studies by Guskiewicz and McCrea et al^{21,29} suggest that perhaps the 7-day waiting period can minimize the risk of recurrent injury. On average, athletes required 7 days to fully recover after concussion. Same-season repeat injuries typically take place within a short window of time, 7 to 10 days after the first concussion,²¹ supporting the concept that there may be increased neuronal vulnerability or blood-flow changes during that time, similar to those reported by Giza, Hovda, et al^{45–47} in animal models.

Returning an athlete to participation should follow a progression that begins once the athlete is completely symptom free. All signs and symptoms should be evaluated using a graded symptom scale or checklist (described in "Concussion Assessment Tools") when performing follow-up assessments and should be evaluated both at rest and after exertional maneuvers such as biking, jogging, sit-ups, and push-ups. Baseline measurements of neuropsychological and postural stability are strongly recommended for comparing with postinjury measurements. If these exertional tests do not produce symptoms, either acutely or in delayed fashion, the athlete can then participate in sport-specific skills that allow return to practice but should remain out of any activities that put him or her at risk for recurrent head injury. For the basketball player, this may

include shooting baskets or participating in walk-throughs, and for the soccer player, this may include dribbling or shooting drills or other sport-specific activities. These restricted and monitored activities should be continued for the first few days after becoming symptom free. The athlete should be monitored periodically throughout and after these sessions to determine if any symptoms develop or increase in intensity. Before returning to full contact participation, the athlete should be reassessed using neuropsychological and postural-stability tests if available. If all scores have returned to baseline or better, return to full participation can be considered after further clinical evaluation. It is strongly recommended that after recurrent injury, especially within-season repeat injuries, the athlete be withheld for an extended period of time (approximately 7 days) after symptoms have resolved.

CONCUSSION ASSESSMENT TOOLS

Sports medicine clinicians are increasingly using standardized methods to obtain a more objective measurement of postconcussion signs and symptoms, cognitive dysfunction, and postural instability. These methods allow the clinician to quantify the severity of injury and measure the player's progress over the course of postinjury recovery. An emerging model of sport concussion assessment involves the use of brief screening tools to evaluate postconcussion signs and symptoms, cognitive functioning, and postural stability on the sideline immediately after a concussion and neuropsychological testing to track recovery further out from the time of injury. Ultimately, these tests, when interpreted with the physical examination and other aspects of the injury evaluation, assist the ATC and other sports medicine professionals in the RTP decision-making process.

Data from objective measures of cognitive functioning, postural stability, and postconcussion signs and symptoms are most helpful in making a determination about severity of injury and postinjury recovery when preinjury baseline data for an individual athlete are available.^{3,8,24,29,41} Baseline testing provides an indicator of what is "normal" for that particular athlete while also establishing the most accurate and reliable benchmark against which postinjury results can be compared. It is important to obtain a baseline symptom assessment in addition to baseline cognitive and other ability testing. Without baseline measures, the athlete's postinjury performance on neuropsychological testing and other concussion assessment measures must be interpreted by comparison with available population normative values, which ideally are based on a large sample of the representative population. Normative data for competitive athletes on conventional (ie, paper-and-pencil) and computerized neuropsychological tests and other concussion assessment measures are now more readily available from large-scale research studies, but baseline data on an individual athlete still provide the greatest clinical accuracy in interpreting postinjury test results. When performing baseline testing, a suitable testing environment eliminates all distractions that could alter the baseline performance and enhances the likelihood that all athletes are providing maximal effort. Most important, all evaluators should be aware of a test's user requirements and be appropriately trained in the standardized instructions for test administration and scoring before embarking on baseline testing or adopting a concussion testing paradigm for clinical use.

Several models exist for implementing baseline testing. Ide-

ally, preseason baseline testing is conducted before athletes are exposed to the risk of concussion during sport participation (eg, before contact drills during football). Some programs choose to conduct baseline testing as part of the preparticipation physical examination process. In this model, stations are established for various testing methods (eg, history collection, symptom assessment, neuropsychological testing, and balance testing), and athletes complete the evaluation sequence after being seen by the attending physician or ATC. This approach has the advantage of testing large groups of athletes in 1 session, while they are already in the mindset of undergoing a preseason physical examination. When preseason examinations are not conducted in a systematic group arrangement, alternative approaches can be considered. In any case, it is helpful to conduct all modules of baseline testing on players in 1 session to limit the complications of scheduling multiple testing times and to keep testing conditions constant for the athletes. One should allow adequate planning time (eg, 3 months) to implement a baseline testing module. Often this equates to conducting baseline testing for fall sports during the spring semester, before school is recessed for the summer. The benefits of interpreting postinjury data for an athlete after a concussion far outweigh the considerable time and human resources dedicated to baseline testing.

Collecting histories on individual athletes is also a vital part of baseline testing, especially in establishing whether the athlete has any history of concussion, neurologic disorder, or other remarkable medical conditions. Specifically with respect to concussion, it is important to establish (1) whether the player has any history of concussions and, if so, how many and (2) injury characteristics of previous concussions (eg, LOC, amnesia, symptoms, recovery time, time lost from participation, and medical treatment). For athletes with a history of multiple concussions, it is also important to clarify any apparent pattern of (1) concussions occurring as a result of lighter impacts, (2) concussions occurring closer together in time, (3) a lengthier recovery time with successive concussions, and (4) a less complete recovery with each injury. Documenting a history of attentional disorders, learning disability, or other cognitive development disorders is also critical, especially in interpreting an individual player's baseline and postinjury performance on neuropsychological testing. If resources do not allow for preseason examinations in all athletes, at least a concerted effort to evaluate those athletes with a previous history of concussion should be made because of the awareness of increased risk for subsequent concussions in this group.

Postconcussion Symptom Assessment

Self-reported symptoms are among the more obvious and recognizable ways to assess the effects of concussion. Typical self-reported symptoms after a concussion include but are not limited to headache; dizziness; nausea; vomiting; feeling "in a fog"; feeling "slowed down"; trouble falling asleep; sleeping more than usual; fatigue; drowsiness; sensitivity to light or noise; unsteadiness or loss of balance; feeling "dinged," dazed, or stunned; seeing stars or flashing lights; ringing in the ears; and double vision.^{8,26,48} Self-reported symptoms are referenced by many of the concussion grading scales.^{10,43,44,49} The presence of self-reported symptoms serves as a major contraindication for RTP, and, based on current recommendations, the athlete should be fully symptom free for at least 7 days at rest and during exertion before returning to play.^{43,44}

A number of concussion symptom checklists^{43,50–52} and scales^{26,41,48,53} have been used in both research and clinical settings. A symptom checklist that provides a list of concussion-related symptoms allows the athlete to report whether the symptom is present by responding either "yes" (experiencing the symptom) or "no" (not experiencing the symptom). A symptom scale is a summative measure that allows the athlete to describe the extent to which he or she is experiencing the symptom. These instruments commonly incorporate a Likert-type scale that allows the player to rate the severity or frequency of postconcussion symptoms. These scores are then summed to form a composite score that yields a quantitative measure of overall injury severity and a benchmark against which to track postinjury symptom recovery. Initial evidence has been provided for the structural validity of a self-report concussion symptom scale.⁴⁸ Obtaining a baseline symptom score is helpful to establish any preexisting symptoms attributable to factors other than the head injury (eg, illness, fatigue, or somatization). Serial administration of the symptom checklist is the recommended method of tracking symptom resolution over time (see Appendix A).

Mental Status Screening

Cognitive screening instruments similar to the physician's mini mental status examination objectify what is often a subjective impression of cognitive abnormalities. Various methods have been suggested for a systematic survey of mental status and cognitive function in the athlete with a concussion. The SAC was developed to provide sports medicine clinicians with a brief, objective tool for assessing the injured athlete's mental status during the acute period after concussion (eg, sport sideline, locker room, and clinic).⁵⁴ The SAC includes measures of orientation, immediate memory, concentration, and delayed recall that sum to 30 points.⁵⁵ Lower scores on the SAC indicate more severe cognitive impairment. The SAC also includes assessments of strength, sensation, and coordination and a standard neurologic examination but should not replace the clinician's thorough physical examination or referral for more extensive neuropsychological evaluation when indicated. Information about the occurrence and duration of LOC and amnesia is also recorded on the SAC. Alternate forms of the SAC are available to minimize the practice effects during retesting. The SAC takes about 5 minutes to administer and should be used only after the clinician's thorough review of the training manual and instructional video on the administration, scoring, and interpretation of the instrument.

The SAC has demonstrated reliability^{29,55,56} and validity^{29,56,57} in detecting mental status changes after a concussion. Recent evidence suggests that a decline of 1 point or more from baseline classified injured and uninjured players with a level of 94% sensitivity and 76% specificity.⁵⁶ The SAC is also sensitive to detecting more severe neurocognitive changes in injured athletes with LOC or amnesia associated with their concussions.⁵⁷ The SAC is most useful in the assessment of acute cognitive dysfunction resulting from concussion, with sensitivity and specificity comparable with extensive neuropsychological testing batteries during the initial 2 to 3 days after concussion.^{29,58,59} As with neuropsychological testing, sensitivity and specificity of the SAC in concussion assessment are maximized when individual baseline test data are available.^{29,55,56,60}

Postural-Stability Assessment

A number of postural-stability tests have been used to assess the effects of concussion in the clinical and laboratory settings. The Romberg and stork stand were basic tests used to assess balance and coordination. Riemann et al^{61–62} developed the Balance Error Scoring System (BESS) based on existing theories of posturography. The BESS uses 3 stance positions and tests on both a firm and a foam surface with the eyes closed (for a total of 6 trials). The administration and scoring procedures are found in several publications.^{61–63} The BESS has established good test-retest reliability and good concurrent validity when compared with laboratory forceplate measures^{52,62} and significant group differences, with an increased number of errors for days 1, 3, and 5 postinjury when compared with controls.⁵² Thus, the BESS can be used as a clinical measure in identifying balance impairment that could indicate a neurologic deficit.

The NeuroCom Smart Balance Master System (NeuroCom International, Clackamas, OR) is a forceplate system that measures vertical ground reaction forces produced by the body's center of gravity moving around a fixed base of support. The Sensory Organization Test (SOT, NeuroCom International) is designed to disrupt various sensory systems, including the visual, somatosensory, and vestibular systems. The SOT consists of 6 conditions with 3 trials per condition, for a total of 18 trials, with each trial lasting 20 seconds. The complete administration has been described previously.^{52,64} The SOT has produced significant findings related to the assessment of concussion recovery. In a sample of 36 athletes with concussion, the mean stability (composite score) and vestibular and visual ratios demonstrated deficits for up to 5 days postinjury.⁵² The greatest deficits were seen 24 hours postinjury, and the athletes with concussion demonstrated a gradual recovery during the 5-day period to within 6% of baseline scores. These results were confirmed by Peterson et al,⁶⁵ who found that these deficits continued for up to 10 days after concussion. These findings reveal a sensory interaction problem from the effects of concussion with measurable changes in overall postural stability.

Neuropsychological Testing

Neuropsychological testing has historically been used to evaluate various cognitive domains known to be preferentially susceptible to the effects of concussion and TBI. In recent years, neuropsychological testing to evaluate the effects of sport-related concussion has gained much attention in the sport concussion literature.^{20,21,26,29,48,52,58,59,65–69} The work of Barth et al,⁷⁰ who studied more than 2000 collegiate football players from 10 universities, was the first project to institute baseline neuropsychological testing. Similar programs are now commonplace among many collegiate and professional teams, and interest is growing at the high school level. Several recent studies have supported the use of neuropsychological testing as a valuable tool to evaluate the cognitive effects and recovery after sport-related concussion,^{24,28,29,41,42,50–52,57,65,66,71–75} but its feasibility for sideline use is not likely realistic. As is the case with other concussion assessment tools, baseline neuropsychological testing is recommended, when possible, to establish a normative level of neurocognitive functioning for individual athletes.^{24,28,29,41,50–52,57–59,66,69,73–75} Baseline neuropsychological testing typically takes 20 to 30 minutes per athlete.

Before implementing a neuropsychological testing program, the ATC must consider several issues, including test-specific training requirements and methodologic issues, the practicality of baseline testing, the reliability and validity of individual tests comprising the test battery, and the protocol for interpretation of the postinjury test results. Barr⁷⁶ provided an excellent review on the methodologic and professional issues associated with neuropsychological testing in sport concussion assessment. Most states require advanced training and licensure to purchase and use neuropsychological tests for clinical purposes. Neuropsychological tests are also copyright protected to prevent inappropriate distribution or use by unqualified professionals. At present, these requirements necessitate that a licensed psychologist, preferably one Board certified in clinical neuropsychology or with clinical experience in the evaluation of sport-related concussion, oversee and supervise the clinical application of neuropsychological testing for sport concussion assessment. These factors likely restrict how widely neuropsychological testing can be used to assess sport-related concussion, especially at the high school level and in rural areas where neuropsychologists are not readily available for consultation.

Neuropsychologists, ATCs, and sports medicine clinicians are faced with the challenge of designing a model that jointly upholds the testing standards of neuropsychology and meets the clinical needs of the sports medicine community without undue burden. The cost of neuropsychological testing, either conventional or computerized, is also a factor in how widely this method can be implemented, especially at the high school level. Consultation fees for the neuropsychologist can be considerable if work is not done on a pro bono basis, and some computerized testing companies charge a consulting fee for interpreting postinjury test results by telephone.

Although no clear indications exist as to which are the best individual neuropsychological tests to evaluate sport concussion, the use of multiple instruments as a “test battery” offers clinicians greater potential for recognizing any cognitive deficits incurred from the injury. A number of neuropsychological tests and test batteries have been used to assess sport-related concussion. Table 3 provides a brief description of the paper-and-pencil neuropsychological tests commonly used by neuropsychologists in the assessment of sport concussion. Sport concussion batteries should include measures of cognitive abilities most susceptible to change after concussion, including attention and concentration, cognitive processing (speed and efficiency), learning and memory, working memory, executive functioning, and verbal fluency. Tests of attention and concentration^{50,52,74,77} and memory functioning⁴¹ have been reported as the most sensitive to the acute effects of concussion. The athlete's age, sex, primary language, and level of education should be considered when selecting a test battery.⁶⁸

Computerized Neuropsychological Tests. Recently, a number of computerized neuropsychological testing programs have been designed for the assessment of athletes after concussion. The Automated Neuropsychological Assessment Metrics (ANAM), CogSport, Concussion Resolution Index, and Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) are all currently available and have shown promise for reliable and valid concussion assessment (Table 4).^{24,41,51,53,66,71,72,75,78–84} The primary advantages to computerized testing are the ease of administration, ability to baseline test a large number of athletes in a short period of time, and multiple forms used within the testing paradigm to reduce the

Table 3. Common Neuropsychological Tests Used in Sport Concussion Assessment

| Neuropsychological Test | Cognitive Domain |
|---|---|
| Controlled Oral Word Association Test | Verbal fluency |
| Hopkins Verbal Learning Test | Verbal learning, immediate and delayed memory |
| Trail Making: Parts A and B | Visual scanning, attention, information processing speed, psychomotor speed |
| Wechsler Letter Number Sequencing Test | Verbal working memory |
| Wechsler Digit Span: Digits Forward and Digits Backward | Attention, concentration |
| Wechsler Digit Symbol Test | Psychomotor speed, attention, concentration |
| Symbol Digit Modalities Test | Psychomotor speed, attention, concentration |
| Paced Auditory Serial Addition Test | Attention, concentration |
| Stroop Color Word Test | Attention, information processing speed |

practice effects. Collie et al⁷¹ summarized the advantage and disadvantages of computerized versus traditional paper-and-pencil testing.

As outlined, in the case of conventional neuropsychological testing, several of the same challenges must be addressed before computerized testing becomes a widely used method of sport concussion assessment. Issues requiring further consideration include demonstrated test reliability; validity, sensitivity, and specificity in the peer-reviewed literature; required user training and qualifications; the necessary role of the licensed psychologist for clinical interpretation of postinjury test results; hardware and software issues inherent to computerized testing; and user costs.⁷¹ Progress is being made on many of these issues, but further clinical research is required

to provide clinicians with the most effective neuropsychological assessment tools and maintain the testing standards of neuropsychology.

Neuropsychological Testing Methods. Neuropsychological testing is not a tool that should be used to diagnose the injury (ie, concussion); however, it can be very useful in measuring recovery once it has been determined that a concussion has occurred. The point(s) at which postinjury neuropsychological testing should occur has been a topic of debate. A variety of testing formats has been used to evaluate short-term recovery from concussion.^{24,41,50,73,75,82} Two approaches are most common. The first incorporates neuropsychological testing only after the injured player reports that his or her symptoms are completely gone. This approach is based on the conceptual foundation that an athlete should not participate while symptomatic, regardless of neuropsychological test performance. Unnecessary serial neuropsychological testing, in addition to being burdensome and costly to the athlete and medical staff, also introduces practice effects that may confound the interpretation of performance in subsequent postinjury testing sessions.⁸⁵ The second approach incorporates neuropsychological testing at fixed time points (eg, postinjury day 1, day 7, and so on) to track postinjury recovery. This approach is often appropriate for prospective research protocols but is unnecessary in a clinical setting when the player is still symptomatic and will be withheld from competition regardless of the neuropsychological test results. In this model, serial testing can be used until neuropsychological testing returns to normal, preinjury levels and the player is completely symptom free.

Measuring “recovery” on neuropsychological tests and other clinical instruments is often a complex statistical matter, further complicated by practice effects and other psychometric dynamics affected by serial testing, even when preinjury baseline data are available for individual athletes. The use of statistical models that empirically identify meaningful change while controlling for practice effects on serial testing may provide the clinician with the most precise benchmark in deter-

Table 4. Computerized Neuropsychological Tests

| Neuropsychological Test | Developer (Contact Information) | Cognitive Domains |
|--|---|---|
| Automated Neuropsychological Assessment Metrics (ANAM) | National Rehabilitation Hospital Assistive Technology and Neuroscience Center, Washington, DC ⁸⁴ (jsb2@mhg.edu) | Simple Reaction Metrics Sternberg Memory Math Processing Continuous Performance Matching to Sample Spatial Processing Code Substitution |
| CogSport | CogState Ltd, Victoria, Australia (www.cogsport.com) | Simple Reaction Time Complex Reaction Time One-Back Continuous Learning |
| Concussion Resolution Index | HeadMinder Inc, New York, NY (www.headminder.com) | Reaction Time Cued Reaction Time Visual Recognition 1 Visual Recognition 2 Animal Decoding Symbol Scanning |
| Immediate Postconcussion Assessment and Cognitive Testing (ImPACT) | University of Pittsburgh Medical Center, Pittsburgh, PA (www.impacttest.com) | Verbal Memory Visual Memory Information Processing Speed Reaction Time Impulse Control |

Table 5. Factors Influencing Neuropsychological Test Performance^{68*}

| |
|--|
| Previous concussions |
| Educational background |
| Preinjury level of cognitive functioning |
| Cultural background |
| Age |
| Test anxiety |
| Distractions |
| Sleep deprivation |
| Medications, alcohol, or drugs |
| Psychiatric disorders |
| Learning disability |
| Attention deficit/hyperactivity |
| Certain medical conditions |
| Primary language other than English |
| Previous neuropsychological testing |

*Reprinted with permission of Grindel SH, Lovell MR, Collins MW. The assessment of sport-related concussion: the evidence behind neuropsychological testing and management. *Clin J Sport Med.* 2001; 11: 134–143.

mining postinjury recovery, above and beyond the simple conclusion that the player is “back to baseline.” The complexity of this analysis is the basis for the neuropsychologist overseeing the clinical interpretation of test data to determine injury severity and recovery. Further research is required to clarify the guidelines for determining and tracking recovery on specific measures after concussion. The clinician should also be aware that any concussion assessment tool, either brief screening instruments or more extensive neuropsychological testing, comes with some degree of risk for false negatives (eg, a player performs within what would be considered the normal range on the measure before actually reaching a complete clinical recovery after concussion). Therefore, test results should always be interpreted in the context of all clinical information, including the player’s medical history. Also, caution should be exercised in neuropsychological test interpretation when preinjury baseline data do not exist. Numerous factors apart from the direct effects of concussion can influence test performance (Table 5).

WHEN TO REFER AN ATHLETE TO A PHYSICIAN AFTER CONCUSSION

Although most sport-related concussions are considered mild head injuries, the potential exists for complications and life-threatening injuries. Each ATC should be concerned about the potential for the condition of an athlete with a concussion to deteriorate. This downward trend can occur immediately (minutes to hours) or over several days after the injury. As discussed earlier, the spectrum of sport-related head injuries includes more threatening injuries, such as epidural and subdural hematomas and second-impact syndrome. Postconcussion syndrome, however, is a more likely consequence of a sport-related concussion. Not every sport-related concussion warrants immediate physician referral, but ATCs must be able to recognize those injuries that require further attention and provide an appropriate referral for advanced care, which may include neuroimaging. Serial assessments and physician follow-up are important parts of the evaluation of the athlete with a concussion. Referrals should be made to medical personnel with experience managing sport-related concussion. The ATC should monitor vital signs and level of consciousness every 5

minutes after a concussion until the athlete’s condition stabilizes and improves. The athlete should also be monitored over the next few hours and days after the injury for delayed signs and symptoms and to assess recovery. Appendix B outlines scenarios that warrant physician referral or, in many cases, transport to the nearest hospital emergency department.

WHEN TO DISQUALIFY AN ATHLETE

Return to participation after severe or repetitive concussive injury should be considered only if the athlete is completely symptom free and has a normal neurologic examination, normal neuropsychological and postural-stability examinations, and, if obtained, normal neuroimaging studies (ie, MRI with gradient echo). It may not be practical or even possible to use all these assessments in all athletes or young children, but a cautious clinical judgment should take into account all evaluation options. Each injured athlete should be considered individually, with consideration for factors including age, level of participation, nature of the sport (high risk versus low risk), and concussion history.

Standardized neuropsychological testing, which typically assesses orientation, immediate and delayed memory recall, and concentration may assist the ATC and physician in determining when to disqualify an athlete from further participation.⁶⁰ Balance testing may provide additional information to assist the clinician in the decision-making process of whether to disqualify an individual after a concussion.⁵² When to disqualify the athlete is one of the most important decisions facing the ATC and team physician when dealing with an athlete suffering from a concussion. This includes not only when to disqualify for a single practice or event but also when to disqualify for the season or for a career.

Disqualifying for the Game or Practice

The decision to disqualify an individual from further participation on the day of the concussive episode is based on the sideline evaluation, the symptoms the athlete is experiencing, the severity of the apparent symptoms, and the patient’s past history.⁸⁶ The literature is clear: any episode involving LOC or persistent symptoms related to concussion (headache, dizziness, amnesia, and so on), regardless of how mild and transient, warrants disqualification for the remainder of that day’s activities.^{8,9,13,19,43,60,87} More recent studies of high school and collegiate athletes underscore the importance of ensuring that the athlete is symptom free before returning to participation on the same day; even when the player is symptom free within 15 to 20 minutes after the concussive episode, he or she may still demonstrate delayed symptoms or depressed neurocognitive levels. Lovell et al⁸⁸ found significant memory deficits 36 hours postinjury in athletes who were symptom free within 15 minutes of a mild concussion. Guskiewicz et al²¹ found that 33% (10/30) of the players with concussion who returned on the same day of injury experienced delayed onset of symptoms at 3 hours postinjury, as compared with only 12.6% (20/158) of those who did not return to play on the same day of injury. Although more prospective work is needed in this area, these studies raise questions as to whether the RTP criteria for grade 1 (mild) concussions are conservative enough.

Disqualifying for the Season

Guidelines from Cantu⁴³ and the American Academy of Neurology⁶ both recommend termination of the season after the third concussion within the same season. The decision is more difficult if one of the injuries was more severe or was a severe injury resulting from a minimal blow, suggesting that the athlete's brain may be at particular risk for recurrent injury. In addition, because many athletes participate in year-round activities, once they are disqualified for the "season," it may be difficult to determine at what point they can resume contact play. Other issues without clear-cut answers in the literature are when to disqualify an athlete who has not been rendered unconscious and whose symptoms cleared rapidly or one who suffered multiple mild to moderate concussions throughout the career and whether youth athletes should be treated differently for initial and recurrent concussive injuries.

Disqualifying for the Career

When to disqualify an athlete for a career is a more difficult question to answer. The duration of symptoms may be a better criterion as to when to disqualify an athlete for the season or longer. Merrill Hoge, Eric Lindros, Chris Miller, Al Toon, and Steve Young provide highly publicized cases of athletes sustaining multiple concussions with recurrent or postconcussion signs and symptoms that lasted for lengthy periods of time.⁴³

Once an athlete has suffered a concussion, he or she is at increased risk for subsequent head injuries.^{21,43,86} Guskiewicz et al^{21,23} found that collegiate athletes had a 3-fold greater risk of suffering a concussion if they had sustained 3 or more previous concussions in a 7-year period and that players with 2 or more previous concussions required a longer time for total symptom resolution after subsequent injuries.²¹ Players also had a 3-fold greater risk for subsequent concussions in the same season,²³ whereas recurrent, in-season injuries occurred within 10 days of the initial injury 92% of the time.²¹ In a similar study of high school athletes, Collins et al⁸² found that athletes with 3 or more prior concussions were at an increased risk of experiencing LOC (8-fold greater risk), anterograde amnesia (5.5-fold greater risk), and confusion (5.1-fold greater risk) after subsequent concussion. Despite the increasing body of literature on this topic, debate still surrounds the question of how many concussions are enough to recommend ending the player's career. Some research suggests that the magic number may be 3 concussions in a career.^{21,23,82} Although these findings are important, they should be carefully interpreted because concussions present in varying degrees of severity, and all athletes do not respond in the same way to concussive insults. Most important is that these data provide evidence for exercising caution when managing younger athletes with concussion and athletes with a history of previous concussions.

SPECIAL CONSIDERATIONS FOR THE YOUNG ATHLETE

Many epidemiologic studies on concussion have focused on professional or collegiate athletes. However, this focus seems to now be shifting to the high school level and even to youth sports. Special consideration must be given to the young athlete. The fact that the brain of the young athlete is still developing cannot be ignored, and the effect of concussion on the developing brain is still not entirely understood. Even sub-

tle damage may lead to deficits in learning that adversely influence development. Therefore, it has been suggested that pediatric athletes suffering a concussion should be restricted from further participation for the day and that additional consideration should be given as to when to return these individuals to activity.⁴⁶

Recent epidemiologic investigations of head-injury rates in high school athletes have shown that 13.3% of all reported injuries in high school football affect the head and neck, whereas the numbers in other sports range from 1.9% to 9.5% in baseball and wrestling, respectively.⁸⁹ Guskiewicz et al²³ prospectively examined concussion incidence in high school and collegiate football players and found that the greatest incidence was at the high school level (5.6%), compared with the National Collegiate Athletic Association Division I (4.4%), Division II (4.5%), and Division III (5.5%).

Authors who have tracked symptoms and neuropsychological function after concussion suggest that age-related differences exist between high school and collegiate athletes with regard to recovery. Lovell et al⁴¹ reported that the duration of on-field mental status changes in high school athletes, such as retrograde amnesia and posttraumatic confusion, was related to the presence of memory impairment at 36 hours, 4 days, and 7 days postinjury as well as slower resolution of self-reported symptoms. These findings further emphasize the need to collect these on-field measures after concussion and to use the information wisely in making RTP decisions, especially when dealing with younger athletes. Field et al⁹⁰ found that high school athletes who sustained a concussion demonstrated prolonged memory dysfunction compared with collegiate athletes who sustained a concussion. The high school athletes performed significantly worse on select tests of memory than age-matched control subjects at 7 days postinjury when compared with collegiate athletes and their age-matched control subjects. We hope these important studies and others will eventually lead to more specific guidelines for managing concussions in high school athletes.

Very few investigators have studied sport-related injuries in the youth population, and even fewer focused specifically on sport-related concussion. One group⁹¹ reported that 15% of the children (mean = 8.34 ± 5.31 years) who were admitted to hospitals after MTBI suffered from a sport-related mechanism of injury. Another group⁹² found that sport-related head injury accounted for 3% of all sport-related injuries and 24% of all serious head injuries treated in an emergency department. Additionally, sport-related concussion represented a substantial percentage of all head injuries in children under the age of 10 years (18.2%) and 10- to 14-year-old (53.4%) and 15- to 19-year-old (42.9%) populations.⁹² Thus, sport-related head injury has a relatively high incidence rate and is a significant public health concern in youth athletes, not just participants at higher competitive levels.

Although no prospective investigations in younger athletes (younger than 15 years old) have been undertaken regarding symptom resolution and cognitive or postural-stability recovery, Valovich McLeod et al⁹³ recently determined the reliability and validity of brief concussion assessment tools in a group of healthy young athletes (9–14 years old). The SAC is valid within 48 hours of injury and reliable for testing of youths above age 5 years, but younger athletes score slightly below high school and collegiate athletes.⁵⁵ This issue is remedied, however, if preseason baseline testing is conducted for all players and a preinjury baseline score established for each

athlete against which changes resulting from concussion can be detected and other factors that affect test performance can be controlled. Users of standardized clinical tools should be aware of the effects of age and education on cognitive test performance and make certain to select the appropriate normative group for comparison when testing an injured athlete at a specific competitive level. Uncertainties about the effects of concussion on young children warrant further study.

HOME CARE

Once the athlete has been thoroughly evaluated and determined to have sustained a concussion, a comprehensive medical management plan should be implemented. This plan should include frequent medical evaluations and observations, continued monitoring of postconcussion signs and symptoms, and postinjury cognitive and balance testing. If symptoms persist or worsen or the level of consciousness deteriorates at all after a concussion, neuroimaging should be performed. Although scientific evidence for the evaluation and resolution of the concussion is ample, specific management advice to be given to the athlete on leaving the athletic training room is lacking.⁹⁴ Athletic trainers and hospital emergency rooms have created various home instruction forms, but minimal scientific evidence supports these instructions. However, despite these limitations, a concussion instruction form (Appendix C) should be given to the athlete and a responsible adult who will have direct contact with the athlete for the initial 24 hours after the injury. This form helps the companion to know what signs and symptoms to watch for and provides useful recommendations on follow-up care.

Medications

At this time, the clinician has no evidence-based pharmacologic treatment options for an athlete with a concussion.⁹⁵ Most pharmacologic studies have been performed in severely head-injured patients. It has been suggested that athletes with concussion avoid medications containing aspirin or nonsteroidal anti-inflammatories, which decrease platelet function and potentially increase intracranial bleeding, mask the severity and duration of symptoms, and possibly lead to a more severe injury. It is also recommended that acetaminophen (Tylenol, McNeil Consumer & Specialty Pharmaceuticals, Fort Washington, PA) be used sparingly in the treatment of headache-like symptoms in the athlete with a concussion. Other substances to avoid during the acute postconcussion period include those that adversely affect central nervous function, in particular alcohol and narcotics.

Wake-Ups and Rest

Once it has been determined that a concussion has been sustained, a decision must be made as to whether the athlete can return home or should be considered for overnight observation or admission to the hospital. For more severe injuries, the athlete should be evaluated by the team physician or emergency room physician if the team physician is not available. If the athlete is allowed to return home or to the dormitory room, the ATC should counsel a friend, teammate, or parent to closely monitor the athlete. Traditionally, part of these instructions included a recommendation to wake up the athlete every 3 to 4 hours during the night to evaluate changes in

symptoms and rule out the possibility of an intracranial bleed, such as a subdural hematoma. This recommendation has raised some debate about unnecessary wake-ups that disrupt the athlete's sleep pattern and may increase symptoms the next day because of the combined effects of the injury and sleep deprivation. It is further suggested that the concussed athlete have a teammate or friend stay during the night and that the athlete not be left alone. No documented evidence suggests what severity of injury requires this treatment. However, a good rule to use is if the athlete experienced LOC, had prolonged periods of amnesia, or is still experiencing significant symptoms, he or she should be awakened during the night. Both oral and written instructions should be given to both the athlete and the caregiver regarding waking.⁹⁶ The use of written and oral instructions increases the compliance to 55% for purposeful waking in the middle of the night. In the treatment of concussion, complete bed rest was ineffective in decreasing postconcussion signs and symptoms.⁹⁷ The athlete should avoid activities that may increase symptoms (eg, staying up late studying and physical education class) and should resume normal activities of daily living, such as attending class and driving, once symptoms begin to resolve or decrease in severity. As previously discussed, a graded test of exertion should be used to determine the athlete's ability to safely return to full activity.

Diet

Evidence is limited to support the best type of diet for aiding in the recovery process after a concussion. A cascade of neurochemical, ionic, and metabolic changes occur after brain injury.⁴⁷ Furthermore, some areas of the brain demonstrate glycolytic increases and go into a state of metabolic depression as a result of decreases in both glucose and oxidative metabolism with a reduction in cerebral blood flow. Severely brain-injured subjects ate larger meals and increased their daily caloric intake when compared with controls.⁹⁸ Although limited information is available regarding the recommended diet for the management of concussion, it is well accepted that athletes should be instructed to avoid alcohol, illicit drugs, and central nervous system medications that may interfere with cognitive function. A normal, well-balanced diet should be maintained to provide the needed nutrients to aid in the recovery process from the injury.

EQUIPMENT ISSUES

Helmets and Headgear

Although wearing a helmet will not prevent all head injuries, a properly fitted helmet for certain sports reduces the risk of such injuries. A poorly fitted helmet is limited in the amount of protection it can provide, and the ATC must play a role in enforcing the proper fitting and use of the helmet. Protective sport helmets are designed primarily to prevent catastrophic injuries (ie, skull fractures and intracranial hematomas) and are not designed to prevent concussions. A helmet that protects the head from a skull fracture does not adequately prevent the rotational and shearing forces that lead to many concussions.⁹⁹

The National Collegiate Athletic Association requires helmets be worn for the following sports: baseball, field hockey (goalkeepers only), football, ice hockey, women's lacrosse (goalkeepers only), men's lacrosse, and skiing. Helmets are

also recommended for recreational sports such as bicycling, skiing, mountain biking, roller and inline skating, and speed skating. Headgear standards are established and tested by the National Operating Committee on Standards for Athletic Equipment and the American Society for Testing and Materials.⁹⁹

Efforts to establish and verify standards continue to be tested and refined, but rarely are the forces and conditions experienced on the field by the athletes duplicated. In addition to direction, speed, and amount of the forces delivered and received by the athlete, conditions not controlled in the testing process include weather conditions, changes in external temperatures and temperatures inside the helmet, humidity levels, coefficient of friction for the surfaces of the equipment and ground, and density of the equipment and ground. However, equipment that does meet the standards is effective in reducing head injuries.⁹⁹

More recently, the issue of headgear for soccer players has received much attention. Although several soccer organizations and governing bodies have approved the use of protective headbands in soccer, no published, peer-reviewed studies support their use. Recommendations supporting the use and performance of headgear for soccer are limited by a critical gap in biomechanical information about head impacts in the sport of soccer. Without data linking the severity and type of impacts and the clinical sequelae of single and repeated impacts, specifications for soccer headgear cannot be established scientifically. These types of headgear may reduce the “sting” of a head impact, yet they likely do not meet other sports headgear performance standards. This type of headgear may actually increase the incidence of injury. Players wearing headgear may have the false impression that the headgear will protect them during more aggressive play and thereby subject themselves to even more severe impacts that may not be attenuated by the headgear.

Mouth Guards

The wearing of a mouth guard is thought by some to provide additional protection for the athlete against concussion by either reducing the risk of injury or reducing the severity of the injury itself.¹⁰⁰ Mouth guards aid in the separation between the head of the condyle of the mandible and the base of the skull. It is thought that wearing an improperly fitted mouth guard or none at all increases this contact point. This theory, which is based on Newtonian laws of physics, suggests that the increased separation between 2 adjacent structures increases the time to contact, thus decreasing the amount of contact and decreasing the trauma done to the brain.¹⁰⁰ However, no biomechanical studies support the theory that the increased separation results in less force being delivered to the brain.

High school football and National Collegiate Athletic Association football rules mandate the wearing of a mouth guard, but the National Football League rulebook does not require players to wear a mouth guard. The National Collegiate Athletic Association requires mouth guards to be worn by all athletes in football, field hockey, ice hockey, and lacrosse. Researchers^{101,102} have found no advantage in wearing a custom-made mouth guard over a boil-and-bite mouth guard to reduce the rise of cerebral concussion in athletes. However, ATCs and coaches should mandate the regular use of mouth guards because a properly fitted mouth guard, with no alterations such as cutting off the back part, is of great value in

protecting the teeth and preventing fractures and avulsions that could require many years of expensive dental care.

ACKNOWLEDGMENTS

We gratefully acknowledge the efforts of Kent Scriber, PhD, ATC; Scott Anderson, MS, ATC; Michael Collins, PhD; Vito A. Perriello, Jr, MD, PhD; Karen Johnston, MD, PhD; and the Pronouncements Committee in the preparation of this document.

REFERENCES

1. Mueller FO, Cantu RC. *Nineteenth Annual Report of the National Center for Catastrophic Sports Injury Research: Fall 1982–Spring 2001*. Chapel Hill, NC: National Center for Catastrophic Sports Injury Research; 2002.
2. Ferrara MS, McCrea M, Peterson CL, Guskiewicz KM. A survey of practice patterns in concussion assessment and management. *J Athl Train*. 2001;36:145–149.
3. Guskiewicz KM, Cantu RC. The concussion puzzle: evaluation of sport-related concussion. *Am J Med Sports*. 2004;6:13–21.
4. Gennarelli T. Mechanisms of brain injury. *J Emerg Med*. 1993;11(suppl 1):5–11.
5. Schneider RC. *Head and Neck Injuries in Football: Mechanisms, Treatment and Prevention*. Baltimore, MD: Williams & Wilkins; 1973.
6. Practice parameter: the management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology*. 1997;48:581–585.
7. Congress of Neurological Surgeons Committee on Head Injury Nomenclature. Glossary of head injury. *Clin Neurosurg*. 1966;12:386–394.
8. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001: recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med*. 2002;36:6–10.
9. Cantu RC. Athletic head injuries. *Clin Sports Med*. 1997;16:531–542.
10. Bailes JE, Hudson V. Classification of sport-related head trauma: a spectrum of mild to severe injury. *J Athl Train*. 2001;36:236–243.
11. Cantu RC. Intracranial hematoma. In: *Neurologic Athletic Head and Spine Injuries*. Philadelphia, PA: WB Saunders; 2000:124–131.
12. Johnston KM, Pfito A, Chankowsky J, Chen JK. New frontiers in diagnostic imaging in concussive head injury. *Clin J Sport Med*. 2001;11:166–175.
13. Cantu RC. Guidelines for return to contact sports after a cerebral concussion. *Physician Sportsmed*. 1986;14(10):75–83.
14. Report of the Sports Medicine Committee. Guidelines for the management of concussion in sports. Denver, CO: Colorado Medical Society; 1990 (revised May 1991).
15. Jordan B. Head injuries in sports. In: Jordan B, Tsairis P, Warren R, eds. *Sports Neurology*. Rockville, MD: Aspen Publishers, Inc; 1989.
16. Nelson W, Jane J, Gieck J. Minor head injuries in sports: a new system of classification and management. *Physician Sportsmed*. 1984;12(3):103–107.
17. Roberts W. Who plays? Who sits? Managing concussion on the sidelines. *Physician Sportsmed*. 1992;20(6):66–72.
18. Torg JS, Vegso JJ, Sennett B, Das M. The National Football Head and Neck Injury Registry: 14-year report on cervical quadriplegia, 1971 through 1984. *JAMA*. 1985;254:3439–3443.
19. Wilberger JE Jr, Maroon JC. Head injuries in athletes. *Clin Sports Med*. 1989;8:1–9.
20. Wojtys EM, Hovda DA, Landry G, et al. Current concepts: concussion in sports. *Am J Sports Med*. 1999;27:676–687.
21. Guskiewicz KM, McCrea M, Marshall SW, et al. Cumulative effects of recurrent concussion in collegiate football players: the NCAA Concussion Study. *JAMA*. 2003;290:2549–2555.
22. Lovell MR, Iverson GL, Collins MW, McKeag D, Maroon JC. Does loss of consciousness predict neuropsychological decrements after concussion? *Clin J Sport Med*. 1999;9:193–198.
23. Guskiewicz KM, Weaver NL, Padua DA, Garrett WE Jr. Epidemiology

- of concussion in collegiate and high school football players. *Am J Sports Med.* 2000;28:643–650.
24. Erlanger D, Saliba E, Barth JT, Almquist J, Webright W, Freeman JR. Monitoring resolution of postconcussion symptoms in athletes: preliminary results of a Web-based neuropsychological test protocol. *J Athl Train.* 2001;36:280–287.
25. Leininger BE, Gramling SE, Ferrell AD, Kreutzer JS, Peck EA III. Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *J Neurol Neurosurg Psychiatry.* 1990; 53:293–296.
26. Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral concussion in athletes: evaluation and neuropsychological testing. *Neurosurgery.* 2000;47:659–669.
27. McCrory PR, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med.* 2000; 10:235–238.
28. Brown CN, Guskiewicz KM, Bleiberg J, McCrea M, Marshall SW, Matthews A. Comprehensive assessment of concussion in high school and collegiate athletes [abstract]. *J Athl Train.* 2003;38:S-24.
29. McCrea M, Guskiewicz KM, Barr W, et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA.* 2003;290:2556–2563.
30. Levin HS, Benton AL, Grossman RG, eds. *Neurobehavioral Consequences of Closed Head Injury.* New York, NY: Oxford University Press; 1982:221–230.
31. Levin HS, O'Donnell VM, Grossman RG. The Galveston Orientation and Amnesia Test: a practical scale to assess cognition after head injury. *J Nerv Ment Dis.* 1979;167:675–684.
32. Richardson JTE. *Clinical and Neuropsychological Aspects of Closed Head Injury.* London, UK: Taylor and Francis; 1990:1–273.
33. Russell WR. The after effects of head injury. *Edinburgh Med J.* 1934; 41:129–144.
34. Russell WR, Nathan P. Traumatic amnesia. *Brain.* 1946;69:280–300.
35. Russell WR, Smith A. Post-traumatic amnesia in closed head injury. *Arch Neurol.* 1961;5:4–17.
36. Sciarra D. Head injury. In: Merritt HH, Rowland LP, eds. *Merritt's Textbook of Neurology.* 7th ed. Philadelphia, PA: Lea & Febiger; 1984:277–279.
37. Smith A. Duration of impaired consciousness as an index of severity in closed head injury: a review. *Dis Nerv Sys.* 1961;22:69–74.
38. Fisher CM. Concussion amnesia. *Neurology.* 1966;16:826–830.
39. Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med.* 1995;5:32–35.
40. Yarnell PR, Lynch S. The 'ding': amnesic states in football trauma. *Neurology.* 1973;23:196–197.
41. Lovell MR, Collins MW, Iverson GL, et al. Recovery from mild concussion in high school athletes. *J Neurosurg.* 2003;98:296–301.
42. Collins MW, Iverson GL, Lovell MR, McKeag DB, Norwig J, Maroon J. On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clin J Sport Med.* 2003;13:222–229.
43. Cantu RC. Posttraumatic retrograde and anterograde amnesia: pathophysiology and implications in grading and safe return to play. *J Athl Train.* 2001;36:244–248.
44. Kelly JP. Loss of consciousness: Pathophysiology and implications in grading and safe return to play. *J Athl Train.* 2001;36:249–252.
45. Giza CC, Hovda DA. Ionic and metabolic consequences of concussion. In: Cantu RC, ed. *Neurologic Athletic Head and Spine Injuries.* Philadelphia, PA: WB Saunders; 2000:80–100.
46. Giza CC, Hovda DA. The neurometabolic cascade of concussion. *J Athl Train.* 2001;36:228–235.
47. Hovda DA, Yoshino A, Kawamata T, Katayama Y, Becker DP. Diffuse prolonged depression of cerebral oxidative metabolism following concussive brain injury in the rat: a cytochrome oxidase histochemistry study. *Brain Res.* 1991;567:1–10.
48. Piland SG, Moti RW, Ferrara MS, Peterson CL. Evidence for the factorial and construct validity of a self-report concussion symptom scale. *J Athl Train.* 2003;38:104–114.
49. Guskiewicz KM. Concussion in sport: the grading-system dilemma. *Athl Ther Today.* 2001;6(1):18–27.
50. Echemendia R, Putukian M, Mackin RS, Julian L, Shoss N. Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clin J Sport Med.* 2001;11:23–31.
51. Erlanger D, Kaushik T, Cantu R, et al. Symptom-based assessment of the severity of a concussion. *J Neurosurg.* 2003;98:477–484.
52. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train.* 2001;36:263–273.
53. Collins MW, Field M, Lovell MR, et al. Relationship between postconcussion headache and neuropsychological test performance in high school athletes. *Am J Sports Med.* 2003;31:168–173.
54. McCrea M. Standardized mental status assessment of sports concussion. *Clin J Sport Med.* 2001;11:176–181.
55. McCrea M, Randolph C, Kelly JP. *Standardized Assessment of Concussion (SAC): Manual for Administration, Scoring and Interpretation.* Waukesha, WI: CNS Inc; 1997.
56. Barr WB, McCrea M. Sensitivity and specificity of standardized neurocognitive testing immediately following sports concussion. *J Int Neuropsychol Soc.* 2001;7:693–702.
57. McCrea M, Kelly JP, Randolph C, Cisar R, Berger L. Immediate neurocognitive effects of concussion. *Neurosurgery.* 2002;50:1032–1042.
58. McCrea M, Kelly JP, Kluge J, Ackley B, Randolph C. Standardized assessment of concussion in football players. *Neurology.* 1997;48:586–588.
59. McCrea M, Kelly JP, Randolph C, et al. Standardized Assessment of Concussion (SAC): on-site mental evaluation of the athlete. *J Head Trauma Rehabil.* 1998;13:27–35.
60. McCrea M. Standardized mental status testing on the sideline after sport-related concussion. *J Athl Train.* 2001;36:274–279.
61. Riemann BL, Guskiewicz KM. Effects of mild head injury on postural stability as measured through clinical balance testing. *J Athl Train.* 2000; 35:19–25.
62. Riemann BL, Guskiewicz KM, Shields EW. Relationship between clinical and forceplate measures of postural stability. *J Sport Rehabil.* 1999; 8:71–62.
63. Valovich TC, Perrin DH, Gansneder BM. Repeat administration elicits a practice effect with the Balance Error Scoring System but not with the Standardized Assessment of Concussion in high school athletes. *J Athl Train.* 2003;38:51–56.
64. Guskiewicz KM. Postural stability assessment following concussion: one piece of the puzzle. *Clin J Sport Med.* 2001;11:182–189.
65. Peterson CL, Ferrara MS, Mrazik M, Piland SG. An analysis of domain score and posturography following cerebral concussion. *Clin J Sport Med.* 2003;13:230–237.
66. Bleiberg J, Cernich AN, Cameron K, et al. Duration of cognitive impairment after sports concussion. *Neurosurgery.* 2004;54:1073–1080.
67. Bailes JE, Cantu RC. Head injury in athletes. *Neurosurgery.* 2001;48: 26–45.
68. Grindel SH, Lovell MR, Collins MW. The assessment of sport-related concussion: the evidence behind neuropsychological testing and management. *Clin J Sport Med.* 2001;11:134–143.
69. Pottinger L, Cullum M, Stallings RL. Cognitive recovery following concussion in high school athletes. *Arch Clin Neuropsychol.* 1999;14:39–40.
70. Barth JT, Alves WM, Ryan TV, et al. Mild head injury in sports: neuropsychological sequelae and recovery of function. In: Levin HS, Eichenberg HA, Benton AL, eds. *Mild Head Injury.* New York, NY: Oxford University Press; 1989:257–275.
71. Collie A, Darby D, Maruff P. Computerised cognitive assessment of athletes with sports related head injury. *Br J Sports Med.* 2001;35:297–302.
72. Collie A, Maruff P, Makdissi M, McCrory P, McStephen M, Darby D. CogSport: reliability and correlation with conventional cognitive tests used in postconcussion medical evaluations. *Clin J Sport Med.* 2003;13: 28–32.
73. Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA.* 1999;282:964–970.
74. Macciocchi SN, Barth JT, Alves WM, Rimel RW, Jane JA. Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clin J Sport Med.* 2001;11:23–31.

- chological functioning and recovery after mild head injury in collegiate athletes. *Neurosurgery*. 1996;39:510–514.
75. Makdissi M, Collie A, Maruff P, et al. Computerised cognitive assessment of concussed Australian rules footballers. *Br J Sports Med*. 2001;35:354–360.
 76. Barr WB. Methodologic issues in neuropsychological testing. *J Athl Train*. 2001;36:297–302.
 77. Macciocchi SN, Barth JT, Littlefield LM. Outcome after mild head injury. *Clin Sports Med*. 1998;17:27–36.
 78. Bleiberg J, Garmoe WS, Halpern EL, Reeves DL, Nadler JD. Consistency of within-day and across-day performance after mild brain injury. *Neuropsychiatry Neuropsychol Behav Neurol*. 1997;10:247–253.
 79. Bleiberg J, Halpern EL, Reeves D, Daniel JC. Future directions for the neuropsychological assessment of sports concussion. *J Head Trauma Rehabil*. 1998;13:36–44.
 80. Bleiberg J, Kane RL, Reeves DL, Garmoe WS, Halpern E. Factor analysis of computerized and traditional tests used in mild brain injury research. *Clin Neuropsychol*. 2000;14:287–94.
 81. Collie A, Maruff P, Darby DG, McStephen M. The effects of practice on the cognitive test performance of neurologically normal individuals assessed at brief test-retest intervals. *J Int Neuropsychol Soc*. 2003;9:419–428.
 82. Collins MW, Lovell MR, Iverson GL, Cantu RC, Maroon JC, Field M. Cumulative effects of concussion in high school athletes. *Neurosurgery*. 2002;51:1175–1181.
 83. Daniel JC, Olesniewicz MH, Reeves DL, et al. Repeated measures of cognitive processing efficiency in adolescent athletes: implications for monitoring recovery from concussion. *Neuropsychiatry Neuropsychol Behav Neurol*. 1999;12:167–169.
 84. Reeves D, Thorne R, Winter S, Hegge F. Cognitive Performance Assessment Battery (UTC-PAB). Report 89-1. San Diego, CA: Naval Aerospace Medical Research Laboratory and Walter Reed Army Institute of Research; 1989.
 85. McCrea M, Barr WB, Guskiewicz KM, et al. Standard regression-based methods for measuring recovery after sport-related concussion. *J Int Neuropsychol Soc*. In press.
 86. Oliaro S, Anderson S, Hooker D. Management of cerebral concussion in sports: the athletic trainer's perspective. *J Athl Train*. 2001;36:257–262.
 87. Wilberger JE. Minor head injuries in American football: prevention of long term sequelae. *Sports Med*. 1993;15:338–343.
 88. Lovell MR, Collins MW, Iverson GL, Johnston KM, Bradley JP. Grade 1 or “ding” concussions in high school athletes. *Am J Sports Med*. 2004;32:47–54.
 89. Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995–1997 seasons. *J Athl Train*. 1999;34:277–284.
 90. Field M, Collins MW, Lovell MR. Does age play a role in recovery from sports related concussion? A comparison of high school and collegiate athletes. *Am J Pediatr*. 2003;142:546–553.
 91. Adams J, Frumiento C, Shatney-Leach L, Vane DW. Mandatory admission after isolated mild closed head injury in children: is it necessary? *J Pediatr Surg*. 2001;36:119–121.
 92. Kelly KD, Lissel HL, Rowe BH, Vincenten JA, Voaklander DC. Sport and recreation-related head injuries treated in the emergency department. *Clin J Sport Med*. 2001;11:77–81.
 93. Valovich McLeod TC, Perrin DH, Guskiewicz KM, Diamond R, Shultz SJ, Gansneder BM. Serial administration of clinical concussion assessments and learning effects in healthy young athletes. *Clin J Sport Med*. In press.
 94. McCrory P. What advice should we give to athletes postconcussion? *Br J Sports Med*. 2002;36:316–318.
 95. McCrory P. New treatments for concussion: the next millennium beckons. *Clin J Sport Med*. 2001;11:190–193.
 96. de Louw A, Twijnstra A, Leffers P. Lack of uniformity and low compliance concerning wake-up advice following head trauma. *Ned Tijdschr Geneesk*. 1994;138:2197–2199.
 97. de Kruijk JR, Leffers P, Meerhoff S, Rutten J, Twijnstra A. Effectiveness of bed rest after mild traumatic brain injury: a randomised trial of no versus six days of bed rest. *J Neurol Neurosurg Psychiatry*. 2002;73:167–172.
 98. Henson MB, De Castro JM, Stringer AY, Johnson C. Food intake by brain-injury humans who are in the chronic phase of recovery. *Brain Inj*. 1993;7:169–178.
 99. Halstead DP. Performance testing updates in head, face, and eye protection. *J Athl Train*. 2001;36:322–327.
 100. Winters JE Sr. Commentary: role of properly fitted mouthguards in prevention of sport-related concussion. *J Athl Train*. 2001;36:339–341.
 101. Labella CR, Smith BW, Sigurdsson A. Effect of mouthguards on dental injuries and concussions in college basketball. *Med Sci Sports Exerc*. 2002;34:41–44.
 102. Wisniewski JF, Guskiewicz KM, Trope M, Sigurdsson A. Incidence of cerebral concussions associated with type of mouthguard used in college football. *Dent Traumatol*. 2004;20:143–149.

| Graded Symptom Checklist (GSC) | | | | | |
|---------------------------------------|-----------------------|-----------------------------|----------------------------|----------------------------|----------------------------|
| Symptom | Time of injury | 2-3 Hours postinjury | 24 Hours postinjury | 48 Hours postinjury | 72 Hours postinjury |
| Blurred vision | | | | | |
| Dizziness | | | | | |
| Drowsiness | | | | | |
| Excess sleep | | | | | |
| Easily distracted | | | | | |
| Fatigue | | | | | |
| Feel "in a fog" | | | | | |
| Feel "slowed down" | | | | | |
| Headache | | | | | |
| Inappropriate emotions | | | | | |
| Irritability | | | | | |
| Loss of consciousness | | | | | |
| Loss of orientation | | | | | |
| Memory problems | | | | | |
| Nausea | | | | | |
| Nervousness | | | | | |
| Personality change | | | | | |
| Poor balance/coordination | | | | | |
| Poor concentration | | | | | |
| Ringing in ears | | | | | |
| Sadness | | | | | |
| Seeing stars | | | | | |
| Sensitivity to light | | | | | |
| Sensitivity to noise | | | | | |
| Sleep disturbance | | | | | |
| Vacant stare/glassy eyed | | | | | |
| Vomiting | | | | | |

NOTE: The GSC should be used not only for the initial evaluation but for each subsequent follow-up assessment until all signs and symptoms have cleared at rest and during physical exertion. In lieu of simply checking each symptom present, the ATC can ask the athlete to grade or score the severity of the symptom on a scale of 0-6, where 0=not present, 1=mild, 3=moderate, and 6=most severe.

Appendix B. Physician Referral Checklist

Day-of-injury referral

1. Loss of consciousness on the field
2. Amnesia lasting longer than 15 min
3. Deterioration of neurologic function*
4. Decreasing level of consciousness*
5. Decrease or irregularity in respirations*
6. Decrease or irregularity in pulse*
7. Increase in blood pressure
8. Unequal, dilated, or unreactive pupils*
9. Cranial nerve deficits
10. Any signs or symptoms of associated injuries, spine or skull fracture, or bleeding*
11. Mental status changes: lethargy, difficulty maintaining arousal, confusion, or agitation*
12. Seizure activity*
13. Vomiting

14. Motor deficits subsequent to initial on-field assessment
15. Sensory deficits subsequent to initial on-field assessment
16. Balance deficits subsequent to initial on-field assessment
17. Cranial nerve deficits subsequent to initial on-field assessment
18. Postconcussion symptoms that worsen
19. Additional postconcussion symptoms as compared with those on the field
20. Athlete is still symptomatic at the end of the game (especially at high school level)

Delayed referral (after the day of injury)

1. Any of the findings in the day-of-injury referral category
2. Postconcussion symptoms worsen or do not improve over time
3. Increase in the number of postconcussion symptoms reported
4. Postconcussion symptoms begin to interfere with the athlete's daily activities (ie, sleep disturbances or cognitive difficulties)

*Requires that the athlete be transported immediately to the nearest emergency department.

Appendix C. Concussion Home Instructions

I believe that _____ sustained a concussion on _____. To make sure he/she recovers, please follow the following important recommendations:

1. Please **remind** _____ to report to the athletic training room tomorrow at _____ for a follow-up evaluation.
2. Please **review** the items outlined on the enclosed **Physician Referral Checklist**. If any of these problems develop prior to his/her visit, please call _____ at _____ or contact the local emergency medical system or your family physician. Otherwise, you can follow the instructions outlined below.

It is OK to:

- Use acetaminophen (Tylenol) for headaches
- Use ice pack on head and neck as needed for comfort
- Eat a light diet
- Return to school
- Go to sleep
- Rest (no strenuous activity or sports)

There is NO need to:

- Check eyes with flashlight
- Wake up every hour
- Test reflexes
- Stay in bed

Do NOT:

- Drink alcohol
- Eat spicy foods

Specific recommendations:

Recommendations provided to: _____

Recommendations provided by: _____ Date: _____ Time: _____

Please feel free to contact me if you have any questions. I can be reached at: _____

Signature: _____ Date: _____

Current Symptoms and Conditions

Name: _____

Date: _____

Date of Last Concussion: _____ (month-day-year)

Total Hours of Sleep last night: _____

Current Medications: _____

See to which you are **CURRENTLY** experiencing the following symptoms:

No Symptoms = 0

Moderate = 3

Severe = 6

| | | | | | | | |
|--------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Headache | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Nausea | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Vomiting | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Balance Problems | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Dizziness | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Fatigue | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Trouble Falling Asleep | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Excessive Sleep | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Loss of Sleep | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Drowsiness | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Light Sensitivity | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Noise Sensitivity | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Irritability | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Sadness | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Nervousness | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| More Emotional | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Numbness | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Feeling "slow" | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Feeling "foggy" | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Difficulty concentrating | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Difficulty remembering | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Visual Problems | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |
| Total Symptoms | <input type="text"/> 0 | <input type="text"/> 1 | <input type="text"/> 2 | <input type="text"/> 3 | <input type="text"/> 4 | <input type="text"/> 5 | <input type="text"/> 6 |

Total

St. Mark's School of Texas
Athletic Training
Concussion Home Instructions

Athlete _____ Date of injury _____ Sport _____

Home phone _____ Parent/guardian name _____

Your son has sustained a head injury while participating in _____. In some instances, the signs of a concussion do not become obvious until several hours or even days after the injury. Please be especially observant for the following signs and symptoms.

1. Headache (especially one that increases in intensity*)
2. Nausea and vomiting*
3. Difference in pupil size from right to left eye, dilated pupils*
4. Mental confusion/behavior changes
5. Dizziness
6. Memory loss
7. Ringing in the ears
8. Changes in gait or balance
9. Blurry or double vision*
10. Slurred speech*
11. Noticeable changes in the level of consciousness (difficulty awakening, or losing consciousness suddenly)*
12. Seizure activity*
13. Decreased or irregular pulse OR respiration*

*** Seek medical attention at the nearest emergency department.**

The best guideline is to note symptoms that worsen, and behaviors that seem to represent a change in your son. If you have any question or concern at all about the symptoms you are observing, contact your family physician for instructions, or seek medical attention at the closest emergency department. Otherwise, you can follow the instructions outlined below.

It is OK to:

- Use acetaminophen (Tylenol) for headaches
- Use ice pack on head & neck as needed for comfort
- Eat a light diet
- Go to sleep
- Rest (no strenuous activity or sports)

There is NO need to:

- Check eyes with a flashlight
- Wake up every hour
- Test reflexes
- Stay in bed

Do NOT:

- Drink alcohol
- Drive while symptomatic
- Exercise or lift weights
- Take ibuprofen, aspirin, naproxen or other non-steroidal anti-inflammatory medications

Please remind your child to check in with the School Nurse prior to going to class, on the first day he returns to school. Your child should also follow up with the Certified Athletic Trainer after school.

Recommendations provided to: _____ Phone #: _____

Recommendations provided by: _____ Phone #: _____

Date: _____ Time: _____

St. Mark's School of Texas: Protocol and Procedures for the Management of the Sports-Related Concussion

Medical management of sports-related concussion is evolving. In recent years, there has been a significant amount of research into sports-related concussion in high school athletes. St. Mark's School of Texas has established this protocol to provide education about concussions for athletic department staff and other school personnel. This protocol outlines procedures for staff to follow in managing head injuries, and outlines school policy as it pertains to return to play issues after a concussion.

St. Mark's School of Texas seeks to provide a safe return to activity for all athletes after injury, particularly after a concussion. In order to effectively and consistently manage these injuries, procedures have been developed to aid in insuring that concussed athletes are identified, treated and referred appropriately, receive appropriate follow-up medical care during the school day, including academic assistance, and are fully recovered prior to returning to activity.

In addition to recent research, two (2) primary documents were consulted in developing this protocol. The "Summary and Agreement Statement of the 2nd International Conference on Concussion in Sport, Prague 2004" ¹(referred to in this document as the Prague Statement), and the "National Athletic Trainers' Association Position Statement: Management of Sport-Related Concussion" ²(referred to in this document as the NATA Statement).

This protocol will be reviewed on a yearly basis, by the St. Mark's medical staff. Any changes or modifications will be reviewed and given to athletic department staff and appropriate school personnel in writing.

Contents:

- I. Recognition of concussion
- II. Management and referral guidelines for all staff
- III. Procedures for the Certified Athletic Trainer (AT)
- IV. Follow-up care during the school day
- V. Return to play procedures

I. Recognition of Concussion

A. Common signs and symptoms of sports-related concussion

1. Signs:

- Athlete appears dazed or stunned
- Confusion (about assignment, plays, etc.)
- Forgets plays
- Unsure about game, score, opponent
- Moves clumsily (altered coordination)
- Balance problems
- Personality change
- Responds slowly to questions
- Forgets events prior to hit
- Forgets events after the hit
- Loss of consciousness (any duration)

2. Symptoms:

- Headache
- Fatigue
- Nausea or vomiting
- Double vision, blurry vision
- Sensitive to light or noise
- Feels sluggish
- Feels “foggy”
- Problems concentrating
- Problems remembering

3. These signs and symptoms are indicative of a probable concussion. Other causes for symptoms should also be considered.

B. Cognitive impairment (altered or diminished cognitive function)

- i. General cognitive status can be determined by sideline cognitive testing. Athletic Trainer (AT) will utilize sideline concussion card (See handout 1).

II. ImPACT neuropsychological testing requirements

1. ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) is a research-based software tool utilized to evaluate recovery after concussion. It was developed at the University of Pittsburgh Medical Center (UPMC). ImPACT evaluates multiple aspects of neurocognitive function, including memory, attention, brain processing speed, reaction time, and post-concussion symptoms.
2. All upper school athletes at St. Mark's are required to take a baseline ImPACT test prior to participation in sports that have a significant or moderate risk of concussion. (Football, Wrestling, Water Polo, Basketball, Soccer, Baseball, Lacrosse). Middle school athletes participating in the football program will take a baseline.

III. Management and Referral Guidelines for All Staff

- A. Suggested Guidelines for Management of Sports-Related Concussion³
 1. Any athlete with a witnessed loss of consciousness (LOC) of any duration should be spine boarded and transported immediately to nearest emergency department via emergency vehicle.
 2. Any athlete who has symptoms of a concussion, and who is not stable (i.e., condition is changing or deteriorating), is to be transported immediately to the nearest emergency department via emergency vehicle.
 3. An athlete who exhibits any of the following symptoms should be transported Immediately to the nearest emergency department, via emergency vehicle.
 - a. deterioration of neurological function
 - b. decreasing level of consciousness
 - c. decrease or irregularity in respirations
 - d. decrease or irregularity in pulse
 - e. unequal, dilated, or unreactive pupils
 - f. any signs or symptoms of associated injuries, spine or skull fracture, or bleeding
 - g. mental status changes: lethargy, difficulty maintaining arousal, confusion or agitation
 - h. seizure activity
 - i. cranial nerve deficits
 4. An athlete who is symptomatic but stable, may be transported by his parents. The parents should be advised to contact the athlete's primary care physician, ImPACT Certified physician, or seek care at the nearest emergency department, on the day of the injury.
 - a. ALWAYS give parents the option of emergency transportation, even if you do not feel it is necessary.

III. Procedures for the Certified Athletic Trainer (AT)

A. The AT will assess the injury, or provide guidance to the coach if unable to personally attend to the athlete.

1. Immediate referral to the athlete's primary care physician, ImPACT physician or to the hospital will be made when medically appropriate.
2. The AT will perform serial assessments following recommendations in the NATA Statement, and utilize sideline card.
 - a. The AT will notify the athlete's parents and give written and verbal home and follow-up care instructions (See handout 2).

B. The AT will notify the school nurse of the injury as soon as possible so that the school RN can initiate appropriate follow-up care.

V. FOLLOW-UP CARE OF THE ATHLETE DURING THE SCHOOL DAY

A. Responsibilities of the school nurse after notification of student's concussion

1. The athlete will be instructed to report to the school nurse upon his or her return to school. At that point, the school nurse will:
 - a. re-evaluate the athlete utilizing a graded symptom checklist (See handout 3)
 - b. Administering post-concussion ImPACT test
 - i. The initial post-concussion test will be administered within 48-72 hours post-injury, or whenever possible.
 - ii. Repeat post-concussion tests will be given at appropriate intervals, usually 7 days unless specified by the physician
 - c. Notify the school psychologist of the injury
 - d. Notify the School administration
 - i. Head Master
 - ii. Dean of Students
 - iii. Head of Upper School or Middle School
2. If the school RN receives notification of a student-athlete who has sustained a concussion from someone other than the AT (athlete's parent, athlete, physician note), the AT should be notified as soon as possible.

3. Monitor the athlete on a regular basis during the school day. Inform AT of symptoms that may develop during the school day.

VI. RETURN TO PLAY (RTP) PROCEDURES AFTER CONCUSSION

- A. Returning to participate on the same day of injury
 - a. As previously discussed in this document, an athlete who exhibits signs or symptoms of concussion, or has abnormal cognitive testing, should not be permitted to return to play. Any athlete who denies symptoms but has abnormal sideline cognitive testing should be held out of activity.
 - b. “When in doubt, hold them out.”

- B. Return to play after concussion

1. The athlete must meet all of the following criteria in order to progress to activity:
 - a. Asymptomatic at rest and with exertion (including mental exertion in school) AND:
 - b. Within normal range of baseline on post-concussion ImPACT testing AND:
 - c. Have written clearance from primary care physician or specialist (athlete must be cleared for progression to activity by a physician other than an Emergency Room physician)
2. Once the above criteria are met, the athlete will be progressed back to full activity following a stepwise process, (as recommended by both the Prague and NATA Statements), under the supervision of the AT.
3. Progression is individualized, and will be determined on a case by case basis. Factors that may affect the rate of progression include: previous history of concussion, duration and type of symptoms, age of the athlete, and sport/activity in which the athlete participates. An athlete with a prior history of concussion, one who has had an extended duration of symptoms, or one who is participating in a collision or contact sport should be progressed more slowly.
4. Stepwise progression as described in the Prague Statement:
 - a) No activity – do not progress to step 2 until asymptomatic
 - b) Light aerobic exercise – walking, stationary bike
 - c) Sport-specific training (e.g., skating in hockey, running in soccer)
 - d) Non-contact training drills
 - e) Full-contact training
 - f) Game play

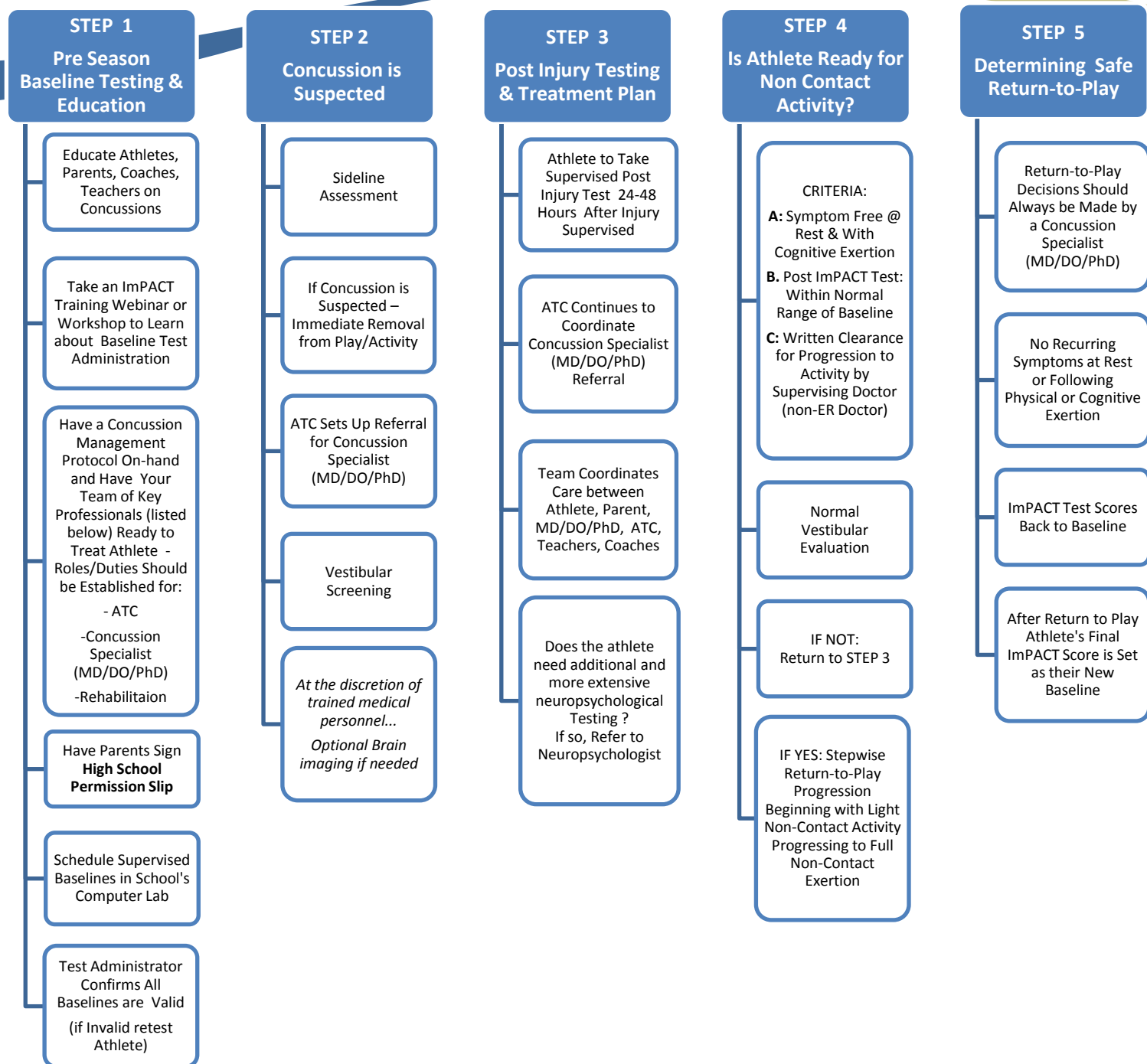
Note: If the athlete experiences post-concussion symptoms during any phase, the athlete should drop back to the previous asymptomatic level and resume the progression after 24 hours.

-
- ¹ McCrory P, et al. Summary and Agreement Statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Clin J Sports Med.* 2005; 15(2):48-55.
- ² Guskiewicz KM, et al. National Athletic Trainers' Association Position Statement: Management of Sport-Related Concussion. *J Athl Train.* 2004;39(3):280-297.



BEST PRACTICES

Concussion Management Model for Schools and Teams



In accordance with the American College of Sports Medicine Guidelines:

http://www.acsm.org/AM/Template.cfm?Section=ACSM_News_Releases&CONTENTID=12895&TEMPLATE=/CM/ContentDisplay.cfm

ACSM's Team Physicians Consensus Statement on Concussion:

http://www.acsm.org/AM/Template.cfm?Section=Home_Page&SECTION=Annual_Meeting&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=12896

Copyright © 2011 by ImPACT Applications, Inc. All rights reserved. No part of this publication may be reproduced in whole or in part or transmitted in any form or by any means without the prior written permission of ImPACT Applications, Inc. For information regarding permission, please write to ImPACT Applications, Inc., LRUSSO@impacttest.com. ImPACT™ and associated logos are trademarks of ImPACT Applications, Inc.

Facts for Physicians



Heads Up

Facts for Physicians About
Mild Traumatic Brain Injury
(MTBI)

DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION

Heads Up

Facts for Physicians About Mild Traumatic Brain Injury (MTBI)

Mild traumatic brain injury (MTBI), commonly known as concussion, is one of the most common neurologic disorders.¹ Physicians can play a key role in helping to reduce the occurrence of MTBI by educating patients and the community about risks and injury prevention. Physicians can also improve patient outcomes when MTBI is suspected or diagnosed by implementing early treatment and appropriate referral.

Early MTBI symptoms may appear mild, but they can lead to significant, life-long impairment in an individual's ability to function physically, cognitively, and psychologically. Although currently there are no standards for treatment and management of MTBI, appropriate diagnosis, referral, and patient and family education are critical for helping MTBI patients achieve optimal recovery and to reduce or avoid significant sequelae.²

Magnitude of Traumatic Brain Injury (TBI) and MTBI

TBI

Each year in the United States:

- Approximately 1.5 million Americans sustain traumatic brain injuries, ranging from mild to severe;³
- 50,000 people die from TBIs;³
- 230,000 people are hospitalized due to TBIs and survive;³



- More than 1 million are treated in emergency departments for TBIs;⁴
- An estimated \$56 billion is spent in direct and indirect costs as a result of all TBIs;⁵ and
- 80,000 to 90,000 Americans experience onset of long-term disability from TBIs.⁶

MTBI

- Data suggest that as many as 75% of all brain-injured people sustain MTBIs.⁷
- MTBIs cost the nation nearly \$17 billion each year.⁶
- An unknown proportion of those who are not hospitalized may experience long-term problems, such as:^{2, 8}
 - Persistent headache,
 - Confusion,
 - Pain,
 - Cognitive and/or memory problems,
 - Fatigue,
 - Changes in sleep patterns,
 - Mood changes, and/or
 - Sensory problems such as changes in vision or hearing (post-concussion syndrome).
- In most cases of diagnosed MTBI, the patient recovers fully.^{2, 8, 9}
- Some research indicates that up to 15% of patients diagnosed with MTBI may have experienced persistent disabling problems.^{8, 9}



Data suggest that as many as 75% of all brain-injured people sustain MTBI.⁷

Conceptual Definition of MTBI

Experts from the Centers for Disease Control and Prevention's MTBI Working Group define a case of MTBI as the occurrence of injury to the head arising from blunt trauma or acceleration or deceleration forces with one or more of the following conditions attributable to the head injury:

Any period of observed or self-reported:

- Transient confusion, disorientation, or impaired consciousness;
- Dysfunction of memory around the time of injury; or
- Loss of consciousness lasting less than 30 minutes.



Observed signs of other neurological or neuropsychological dysfunction, such as:

- Seizures acutely following injury to the head;
- Irritability, lethargy, or vomiting following head injury, especially among infants and very young children; or
- Headache, dizziness, irritability, fatigue, or poor concentration, especially among older children and adults.



TBIs may include both concussions and contusions. The term “concussion” is used at times interchangeably with the term “mild

TBI.” But the category of diagnosed concussions covers a clinical spectrum. Concussion may occur without loss of consciousness. Mild concussion may be present even if there is no external sign of trauma to the head. The Quality Standards Subcommittee of the American Academy of Neurology defines the spectrum of concussions related to sports injuries as follows:¹⁰

Grade 1 Concussion

Transient confusion, no loss of consciousness, and duration of mental status abnormalities on examination that resolve in less than 15 minutes.



Grade 2 Concussion

Transient confusion, no loss of consciousness, concussion symptoms or mental status abnormalities on examination that last more than 15 minutes.

For guidelines about concussions not related to sports, see the article by McCrea, Kelly, et al. contained on the CD-ROM in this brain injury tool kit.

Grade 3 Concussion

Any loss of consciousness, either brief (seconds) or prolonged (minutes).

Leading causes of TBI

- Motor vehicle crashes⁵,
- Falls⁵,
- Firearm use⁵, and
- Sports/recreational activities⁷.

Groups most at risk for TBI⁵

- Adolescents and young adults (ages 15 to 24) and
- Older adults (ages 65 and older)



Primary Prevention

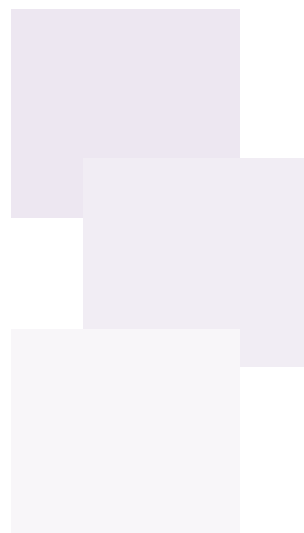
As part of preventive care, physicians can provide information to patients, families, and caregivers about risk behaviors and activities that increase potential for TBIs of all types. Recommendations for preventing TBIs include those listed below. (These tips also are available on the patient information sheet, *Heads Up: Preventing Brain Injury*, contained in this brain injury tool kit.)

- Wear a seat belt every time you drive or ride in a motor vehicle.
- Never drive while under the influence of alcohol or drugs.
- Always buckle your child into a child safety seat, booster seat, or seat belt (depending on the child's height, weight, and age) in the car.
- Wear a helmet and make sure your children wear helmets when:
 - Riding a bike, motorcycle, snow mobile, or all-terrain vehicle;
 - Playing a contact sport, such as football, ice hockey, or boxing;
 - Using in-line skates or riding a skateboard;
 - Batting and running bases in baseball or softball;
 - Riding a horse; and
 - Skiing or snowboarding.



- Avoid falls in the home by:
 - Using a step stool with a grab bar to reach objects on high shelves;
 - Installing handrails on stairways;
 - Installing window guards to keep young children from falling out of open windows;
 - Using safety gates at the top and bottom of stairs when young children are around;
 - Maintaining a regular exercise program to improve strength, balance, and coordination;
 - Removing tripping hazards, using non-slip mats in the bathtub and on shower floors, and putting grab bars next to the toilet and in the tub or shower; and
 - Having vision tested regularly to decrease the risk of falling.
- Make sure the surface on your child's playground is made of shock-absorbing material (e.g., hardwood mulch, sand); and
- Keep firearms stored unloaded in a locked cabinet or safe. Store bullets in a separate secure location.

Have vision tested regularly to decrease the risk of falling



Signs and Symptoms

Signs and symptoms of an injury to the brain may include:^{2, 8, 9, 11}

DIAGNOSIS

| Cognitive symptoms | Physical symptoms | Behavioral changes |
|---|--|--|
| <ul style="list-style-type: none">• Attention difficulties,• Concentration problems,• Memory problems, and/or• Orientation problems. | <ul style="list-style-type: none">• Headaches,• Dizziness,• Insomnia,• Fatigue,• Uneven gait,• Nausea,• Blurred vision, and/or• Seizures. | <ul style="list-style-type: none">• Irritability,• Depression,• Anxiety,• Sleep disturbances,• Problems with emotional control,• Loss of initiative, and/or• Problems related to employment, marriage, relationships, home management, or school management. |

Diagnosis

MTBI diagnosis should be considered when one or more of the following conditions occur following a brain injury:^{2, 8}

- Confusion or disorientation,
- Amnesia near the time of the injury,
- Loss of consciousness up to 30 minutes,
- Neurological or neuropsychological problems, and/or
- Score of 13 or higher on the Glasgow Coma Scale (GCS).

Diagnosing MTBIs can be challenging because symptoms often are common to other medical problems, and onset of symptoms may occur days, weeks, or months after the initial injury.^{2, 8} In diagnosing children, physicians can refer to the 1999 recommendations of the American Academy of Family Physicians and the American Academy of Pediatrics contained on the CD-ROM in this brain injury tool kit and available on the Internet at <http://www.aap.org/policy/ac9858.html>.

In assessing patients for possible MTBI, it is important for physicians to determine whether there is any evidence that a brain or other intracranial injury is present or is likely to have occurred, especially among:

- Patients who did not see a physician after sustaining an injury,
- Patients referred by an emergency department,
- Patients facing orthopedic or facial trauma surgery, and
- Patients who did not receive follow-up care following admission to a hospital for an injury.

Diagnostic tests

Diagnostic tests may include imaging. In certain circumstances (for example, when a patient is a participant in sporting events) evidence-based evaluation guidelines, such as the American Academy of Neurology Practice Parameter: The Management of Concussion in Sports, can be used. The CD-ROM in this brain injury tool kit contains the summary statement of these guidelines. For information about non-sports-related concussions, refer to the McCrae, Kelly, et al. article, also contained on the CD-ROM. Neuropsychological tests are useful to identify cognitive deficits, both acutely and during the follow-up period.

History Taking

Close, careful history taking is essential in diagnosing MTBI. Questioning patients as to whether they have had an injury or accident is an important first step because some patients may not mention it to their physicians. Reasons for this may include:

- Some may not consider the injury serious because they were told the condition was mild or just a "bump on the head,"
- Some may not realize they received a head injury because they were briefly unconscious at the time of the incident,
- Some may focus on a more severe injury that occurred at the same time,
- Some may be too embarrassed to mention certain symptoms, such as memory problems.²

For these reasons careful history taking to ascertain the nature of the problem is very important.



Clinical Management

Because the effects of MTBI can be so diverse, no standard treatment exists. But physicians can take many actions to improve outcomes for patients with MTBI. Treatment outcome is dependent on the appropriate diagnosis of factors potentially responsible for persistent symptoms such as psychiatric problems and post-injury conditions (for example, post-traumatic migraine among persons with family history of migraine).^{2,8} Management of patients with MTBI may include a spectrum of approaches, beginning with patient and family education and possibly encompassing medical treatment, physical-psychiatric therapies, and occupational interventions.²

Management Approaches

Consideration of physical, emotional, and/or behavioral signs and symptoms will guide management plans. Those plans may include some or all of the following approaches:^{2,8}

- Evaluating and treating patients who present early for somatic complaints and documenting baseline neurological findings, including cognitive and emotional state;
- Assessing the ability of the patient to return to everyday activities, such as sports, work, or operating motor vehicles;
- Educating patients and their families about the treatment plan and expected outcomes;
- Prescribing medication, as appropriate, for significant anxiety or depression;
- Referring patients, as appropriate, to neurologists and/or psychiatrists when emotional or cognitive symptoms interfere with normal routines and relationships;
- Referring patients to specialized multidisciplinary cognitive therapy programs, as appropriate. Such programs may include psychotherapy, occupational/vocational, or adaptive strategy training;
- Providing copies of the enclosed patient materials, *Heads Up: Preventing Brain Injury* and *Facts about Concussion and Brain Injury*, when appropriate.

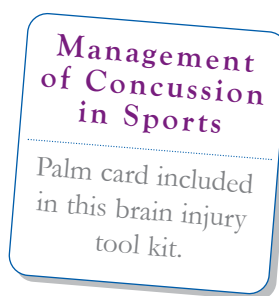
More detailed information about clinical management of patients with MTBI can be found on the CD-ROM contained in this brain injury tool kit, including several journal publications and a 1998 National Institutes of Health Consensus Development Conference Statement outlining approaches to recovery and rehabilitation for the full spectrum of traumatic brain injuries (also available on the Internet at http://odp.od.nih.gov/consensus/cons/109/109_statement.htm).

For in-depth information about treating children, physicians can refer to the 1999 recommendations of the American Academy Family Physicians and the American Academy of Pediatrics contained on the CD-ROM in this brain injury tool kit and available on the Internet at <http://www.aap.org/policy/ac9858.html>. Encourage parents to be vigilant in observing small children who may have sustained even a slight bump on the head, and instruct them about signs and symptoms to watch for.²

Preventing Secondary Injury

MTBI is associated with diminished reaction time and risk for secondary injury. Providing written instructions on a patient's discharge sheet regarding timing for return to regular and high-risk activities may help prevent this type of injury, especially in regard to the following:¹²

- Returning to high-risk sports participation (i.e., horseback riding, snowboarding, skiing, roller blading, cycling);
- Driving a motor vehicle; and
- Operating machinery.



Written instructions also may be used by families to provide information to teachers and coaches of children and young adults in school and college settings. The *Management of Concussion in Sports* palm card provided in this brain injury tool kit may be suitable for sharing with school and coaching personnel.

Communication

Working with MTBI Patients, Family Members, and Caregivers

Effective physician-patient communications are always challenging, especially given the time constraints most practitioners face today. Communicating with patients who may have MTBI may be even more difficult depending on the degree of the patient's impairment. Physicians may sometimes find it useful to prompt patients for additional information about the injury. A parent, guardian, or other caregiver also may be able to share additional information about the nature and circumstances of the injury.

COMMUNICATION



Approaches for Enhancing Physician-Patient Communication¹³

- Observe the patient closely to check for physical, cognitive, or behavioral changes that might signal MTBI.
- Question your patient and/or the caregiver closely. When possible, ask questions to elicit more details about the injury, such as “Tell me about,” or “Describe...”
- Listen carefully for information the patient or caregiver may give you about difficulties in physical, cognitive, or behavioral status.
- Provide additional printed information to patients about the condition and expectations, appropriate referrals, and available community resources.
- Write out clear instructions for the patient and/or caregiver to take home and, as appropriate, to share with workplace supervisors or school staff.
- Refer patients to physicians who specialize in brain injury, as necessary.
- Steer patients to available community resources that may provide additional support.
- Follow up with patients to ensure that any MTBI-related problems are addressed in a timely fashion. Flag charts or otherwise make note of the need to follow individuals who have possible MTBIs.



References

1. Kurtzke JF, Jurland LT. The epidemiology of neurologic disease. In: Joynt RJ, editor. *Clinical Neurology*, Rev. Philadelphia: JB Lippincott; 1993.
2. Centers for Disease Control and Prevention, Advisory Group, Mild Traumatic Injury Tool Kit. Unpublished meeting summary; 2001.
3. Thurman D, Alverson C, Dunn K, Guerrero J, Sniezek J. Traumatic brain injury in the United States: a public health perspective. *Journal of Head Trauma and Rehabilitation* 1999;14(6):602–15.
4. Guerrero J, Thurman D, Sniezek J. Emergency department visits associated with traumatic brain injury: United States, 1995-1996. *Brain Injury* 2000;14(12):181-86.
5. Thurman D, The epidemiology and economics of head trauma. In: Miller L, Ayes R, editors. *Head Trauma: Basic, Preclinical, and Clinical Directions*. New York: John Wiley and Sons; 2001. pp. 327-47.
6. Thurman D, et al. Traumatic Brain Injury in the United States: A Report to Congress. Atlanta: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control;1999.
7. Sosin DM, Sniezek JE, Thurman, DJ. Incidence of mild and moderate brain injury in the United States, 1991. *Brain Injury* 1996;10:47–54.
8. Kushner DS. Mild traumatic brain injury, *Arch Internal Medicine* 1998;158:1617–24.
9. Alexander MP. Mild traumatic brain injury: pathophysiology, natural history, and clinical management. *Neurology* 1995;45:1253–60.
10. American Academy of Neurology. Special report: practice parameter: the management of concussion in sports (summary statement). *Neurology* 1997;48:581-85.
11. Gerber DJ, Schraa JC. Mild traumatic brain injury: searching for the syndrome. *Journal of Head Trauma Rehabilitation* 1995;10(4):28–40.

12. Kushner DS. Concussion in Sports: Minimizing the Risk for Complications. *American Family Physician* 2001;64:6:1007–14.
13. National Institute on Aging. *Working with Your Older Patient: A Clinician's Handbook* 1994. Available from: url: <http://www.nia.nih.gov/health/pubs/clinicians-handbook>.

CDC does not endorse the articles, products, or guidelines of other organizations or individuals referenced in these materials. CDC provides this information to raise awareness about the magnitude of mild traumatic brain injury as a public health issue and to offer a scientific overview of the topic.

The Centers for Disease Control and Prevention gratefully acknowledges the following organizations for their participation in this project:

- American Academy of Family Physicians
- American Academy of Physical Medicine and Rehabilitation
- American College of Physicians-American Society of Internal Medicine
- American Osteopathic Association
- American Trauma Society
- Brain Injury Association of America
- Brain Injury Medicine and Rehabilitation Program, Rehabilitation Institute of Chicago
- Defense and Veterans Head Injury Program
- International Brain Injury Association
- Research and Training Center on the Community Integration of Individuals with TBI, Mount Sinai School of Medicine
- U.S. Health Resources and Services Administration



SAFER • HEALTHIER • PEOPLE™

DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION



Michael Makdissi

Sports related concussion

Management in general practice

Background

Concussive injuries are common in many sports and recreational activities, especially those involving body contact, collisions or high speed. Over the past 8 years, international experts met on three occasions to address key issues in the understanding and management of concussion in sport; most recently in Zurich in November 2008. The consensus statement produced from this meeting provides an outline of up-to-date knowledge and best practice management guidelines on concussion in sport.

Objective

The aim of this article is to provide an overview of the key concepts from the Zurich consensus statement, including an understanding of concussion and an outline of potential risks and recommended management as applicable to the general practice setting.

Discussion

Concussion is thought to reflect a functional injury to the brain. Clinical features are typically short lived and resolve spontaneously, with the majority of affected individuals recovering within 10–14 days. However, complications can occur including prolonged symptoms or cognitive deficit, depression, and cumulative deterioration in brain function. The potential for adverse outcomes and the absence of direct measures of recovery following a concussive injury, make decisions regarding return to play a challenge. Clinical management includes confirming the diagnosis, differentiating concussion from structural head injury, estimating the severity of injury, and determining when the patient can return safely to competition. Players should return to play in a graded fashion after clinical features have resolved and cognitive function has returned to 'normal' on neuropsychological testing.

Keywords: wounds and injuries, athletic injuries; brain concussion



Concussion is a common problem in many sports and recreational pursuits, especially those involving body contact, collisions or high speeds. In general practice, concussive brain injuries may present acutely following head trauma. More commonly, patients present some time after their head injury, either with ongoing symptoms or for medical clearance to allow them to return to play. Clinical management involves confirming the diagnosis, differentiating concussion from structural head injury, estimating the severity of injury and determining when the patient can return safely to competition.

Recent figures from the United States of America estimate approximately 1.6–3.8 million cases of sports and recreation related traumatic brain injury each year.¹ In the USA the majority of head injuries are observed in American football (incidence: 0.7–9.4 concussions per 1000 player hours),^{2,3} ice hockey (incidence: 1.5–6.0 per 1000 player hours),^{4,5} and soccer (incidence: 0.4–0.7 per 1000 player hours).^{6,7} Common participation sports played in Australia, such as Australian Football League (AFL), rugby league and rugby union have among the highest rates of head injury of any team sports in the world. The reported incidence of concussion in these sports is 5.9–9.8 concussive injuries per 1000 player hours,^{8–10} which equates to an average of approximately five injuries per team per season. This represents a significant public health issue in active communities.

Over the past 8 years, international experts met on three occasions to address key issues in the understanding and management of concussion in sport;^{11–13} most recently in Zurich in November 2008.¹³ The consensus statement produced from the Zurich meeting provides an outline of up-to-date knowledge and best practice management guidelines on concussion in sport.¹³ The following article is an overview of the key concepts from this consensus statement, including an understanding of concussion and an outline of its potential risks and recommended management as applicable to the general practice setting.

Traumatic brain injury and concussion

Traumatic brain injury (TBI) is a broad term that encompasses a spectrum of injuries to the brain resulting from trauma. On the



severe end of the spectrum, TBI can result in demonstrable structural injury that may be focal (eg. intracerebral, subarachnoid, subdural or extradural haemorrhage) or diffuse (eg. petechial haemorrhages, cerebral oedema). Milder TBI results in a functional deficit, ie. change in patterns of neuron activation, known as 'concussion'. The Glasgow Coma Scale is commonly used in the clinical setting to monitor patients following TBI.¹⁴ The overall score (Glasgow Coma Score [GCS]) at 6 hours after injury, provides an estimate of injury severity – mild, moderate, and severe.¹⁵ Patients with sports related concussion typically have a GCS at 6 hours that indicates a 'mild' injury.

Pathophysiology of concussion

Concussion can be defined as a clinical syndrome of neurological impairment that results from traumatic biomechanical forces transmitted to the brain (either directly or indirectly).^{11,12} The clinical features typically come on rapidly after injury and resolve spontaneously over a sequential course. While the pathophysiology remains poorly understood, the current consensus is that concussion reflects a disturbance of brain function rather than a structural injury.^{11–13} Data derived from animal models of concussion suggest that linear acceleration or rotational shearing forces may result in short lived neurochemical, metabolic or gene-expression changes.¹⁶

Complications of concussion

Symptoms and signs following a concussive injury are typically temporary and resolve spontaneously and uneventfully within 10–14 days of injury. However, the process of recovery varies from person-to-person and injury-to-injury. A number of complications or adverse outcomes have been reported. These are summarised in *Table 1*.

Risk factors for complications or adverse outcomes remain unclear and genetic factors may play an important role.¹⁷ However, the current consensus is that premature return to play (and subsequent second injury before the athlete has fully recovered from the initial concussion) may predispose to poorer outcomes following a concussive injury.^{11–13}

Diagnosis of concussion

The clinical history is most important in making a diagnosis of sports related concussion. Common symptoms include headache, nausea, dizziness and balance problems, blurred vision or other visual disturbance, confusion, memory loss and a feeling of slowness or fatigue. The following symptoms are highly specific to a diagnosis of concussion, although they may not be present in all cases:

- loss of consciousness (LOC)
- confusion or attention deficit
- memory disturbance, and
- balance disturbance.

Most symptoms appear rapidly following a concussive incident, however some may be delayed. The diagnosis should be suspected in any patient that presents with any of the above symptoms following a collision or direct trauma to the head. Questioning close relatives, especially parents or guardians in the case of children and adolescents,

is often valuable. Any report that the individual 'does not seem right' or 'is not themselves' following trauma is strongly suggestive of a concussive injury.

A graded symptom checklist, such as that included in the Sport Concussion Assessment Tool 2 (SCAT2), is often helpful (see *Resources*). The SCAT2 was developed as part of the consensus statement produced after the Zurich expert meeting in 2008.¹³ Using a symptom checklist enables the range of symptoms commonly observed following concussion to be covered and provides a measure of symptom severity.

It is important to differentiate concussion from structural head injury. Clinical features that may raise concerns of structural head injury include:

- the mechanism of injury, particularly if high speeds, falls from height or high velocity projectiles (eg. baseball or cricket ball) are involved
- progression of clinical features over time. Clinical features of concussion typically resolve within 10–14 days of injury. Any deterioration in clinical state, in particular worsening headache, nausea or vomiting, or deterioration in conscious state, should raise suspicion of a structural head injury and warrant further investigation. Similarly, structural head injury should be kept in mind in any case where symptoms persist beyond 10–14 days
- finding of any focal neurological deficit on clinical examination.

Conventional imaging techniques such as X-ray, computerised tomography (CT) and magnetic resonance imaging (MRI) are typically normal following acute concussion. These investigations should only be ordered if there is a suspicion of structural pathology.

Estimating the severity of injury

Over the years, numerous concussion severity scales have been proposed. The main objective of these scales has been to identify higher grades of concussion severity or increased potential for adverse outcomes and subsequently guide management. Many of the more popular scales, such as the Cantu classification system and Colorado guidelines, rely heavily on LOC to estimate injury severity and guide return to sport. Traditionally, impairment of consciousness was considered to be a hallmark of primary diffuse head injury, and the depth and duration of LOC to correlate with severity of brain injury.¹⁴ However, more recent studies on sports related concussion have consistently demonstrated that brief LOC does not reflect injury severity or predict time to recovery.^{18–20}

At the First International Conference on Concussion in Sport the strengths and weaknesses of all existing injury severity scales were considered, however, none of the scales were endorsed.¹¹ The expert consensus was that combined clinical measures of recovery should be used to assess injury severity and prognosis.¹¹

At the most recent International Conference on Concussion in Sport, a range of clinical factors that may be associated with longer duration of symptoms or increased risk of adverse outcomes following concussive injury were identified.^{13,21} These 'modifying'



Table 1. Summary of complications and adverse outcomes associated with sports related concussive injury

| Complication | Comments | Relative risk | Evidence |
|--|--|--|---|
| Impaired performance and increased injury risk on return to play | Return to play with ongoing cognitive deficits (eg. slowed reaction time and reduced ability to process information) may result in impaired performance, or predispose the individual to increased risk of further injury, including repeated concussion | Unclear, probably common if returned to play before full recovery | Anecdotal report ³¹ Increased incidence of repeat concussion after an initial injury ^{5,32} |
| Acute, progressive diffuse cerebral oedema | Also referred to as 'second impact syndrome' due to a possible association with repeated head trauma ³³ | Rare condition reported in younger athletes | Case reports ^{34,35} |
| Prolonged symptoms | | 5–10% of concussed athletes take longer than 10–14 days to recover, <1% have 'postconcussion syndrome' (ie. symptoms lasting longer than 3 months) ³⁶ | Long recognised complication of mild TBI ^{37–39} Prospective cohort studies monitoring clinical recovery following concussion ^{8,40} |
| Depression | Link demonstrated between head injury and risk of clinical depression later in life ⁴¹ | Possible 2–3 times increase in relative risk of clinical depression | Cross sectional study in retired football players ⁴¹ |
| Cumulative cognitive deficits | Recurrent head trauma has been implicated in progressive deterioration in brain function | Unclear, probably uncommon. Likely to be related to genetic predisposition ^{17,42} | Some athletes demonstrate persistent cognitive deficits postconcussion ^{24,43,44} Case reports of chronic traumatic encephalopathy in elite American football players ^{45,46} Greater cognitive deficits have been demonstrated in subjects reporting previous head injury ^{47–50} |

factors are summarised in *Table 2*.¹³ The presence of any 'modifying' factor after a concussive injury suggests the need for a more conservative approach, including more detailed assessment and slower time to return to sport. In this setting, referral to a neuropsychologist and/or doctor with expertise in managing concussive injuries should be considered.

Timing of return to play

The decision regarding the timing of return to play following a concussive injury is a difficult one. Expert guidelines recommend that players should not be allowed to return to competition until they have recovered completely from their concussive injury.^{11–13} However, there is no single gold standard measure of brain disturbance and recovery following sports related concussion. Instead, clinicians must rely on indirect measures to inform clinical judgement. In practical terms this involves a comprehensive clinical approach, including:

- early rest – a period of cognitive and physical rest to facilitate recovery
- monitoring recovery of postconcussion symptoms and signs
- the use of neuropsychological tests to estimate recovery of cognitive function, and

- a graduated return to activity with monitoring for recurrence of symptoms.

Early rest

Early rest is important to allow recovery following a concussive injury. Physical activity, physiological stress (eg. altitude and flying) and cognitive loads (eg. school work, video games, computer) can all worsen symptoms and possibly delay recovery following concussion.¹³ Individuals should be advised to rest from these activities in the early stages after a concussive injury, especially while symptomatic (see 'Concussion injury advice' page 4 of SCAT2, see *Resources*).¹³ Similarly, the use of alcohol, sedatives or recreational drugs can exacerbate symptoms following head trauma, delay recovery or mask deterioration and should also be avoided. Specific advice should also be given on avoidance of activities that place the individual at risk of further injury, such as driving.^{13,22}

Monitoring recovery

The SCAT is a standardised method of evaluating and monitoring individuals following a concussive injury (see *Resources*).¹³ However, the SCAT is an overall assessment tool, so some of its components (eg. Maddocks Questions, Glasgow Coma Score) are most useful in



the acute setting following a concussive injury. The most important components of the tool for follow up include the graded symptom checklist, clinical tests of balance and cognitive assessment.

Neuropsychological tests

Cognitive deficits associated with concussion are typically subtle and may exist in a number of domains. Common deficits include^{23–26}:

- reduced attention and ability to process information
- slowed reaction times, and
- impaired memory.

The use of neuropsychological tests overcomes the reliance on subjective symptoms, which are known to be poorly recognised and variably reported,^{27–29} and allows detection of specific cognitive deficits, which may outlast symptoms in the setting of concussion.²⁴

Formal neuropsychological testing remains the clinical standard for the assessment of cognitive function and is recommended in any case where there is uncertainty about recovery or in difficult cases such as prolonged recovery. However, in most patients, screening neuropsychological tests are adequate when combined with a more conservative return to play plan. Ideally, the tests should be compared to the individual's own pre-injury baseline. Where a baseline does not exist, which is common in the general practice setting, the test result can be compared to population normative data and the test repeated until the individual's performance has stabilised.

A number of screening neuropsychological tests have been validated for use following concussion in sport and are readily available. These include simple paper and pencil tests such as the digit symbol substitution test,³⁰ and computerised test platforms such as

Table 2. Concussion modifiers¹³

| Factors | Modifier |
|--|---|
| Symptoms | High number, long duration (>10 days), high severity |
| Signs | Prolonged loss of consciousness (>1 minute), amnesia |
| Sequelae | Prolonged concussive convulsions* |
| Temporal | <ul style="list-style-type: none"> • Frequency – repeated concussions over time • Timing – injuries close together in time • 'Recency' – a recent concussion or traumatic brain injury |
| Threshold | Repeated concussions occurring with progressively less impact force or slower recovery after each successive concussion |
| Age | Child and adolescent (<18 years of age) |
| Co- and pre-morbidities | Migraine, depression or other mental health disorders, attention deficit hyperactivity disorder, learning disabilities, sleep disorders |
| Medication | Psychoactive drugs, anticoagulants |
| Behaviour | Dangerous style of play |
| Sport | High risk activity, contact and collision sport, high sporting level |
| * Concussive convulsions or impact seizures are occasionally observed following concussion in sport. These are usually brief in duration (<1 minute) and range from tonic posturing to full tonic-clonic seizures. Brief concussive convulsions are benign, with no adverse clinical outcomes. ²⁰ Consequently, investigations are not required, anti-epileptic treatment is not indicated, and prolonged absence from sport is not warranted in the majority of cases ^{51,52} | |

Table 3. Graduated return to play protocol¹³

| Rehabilitation stage | Functional exercise | Objective |
|----------------------------|--|---|
| No activity | Complete physical and cognitive rest | Recovery |
| Light aerobic exercise | Walking, swimming or stationary cycling keeping intensity to less than 70% of maximum predicted heart rate No resistance training | Increase heart rate |
| Sport specific exercise | Light training drills (eg. running, ball work); no head impact activities | Add movement |
| Noncontact training drills | Progression to more complex training drills. May start progressive resistance training | Exercise, coordination and cognitive load |
| Full contact practise | Following medical clearance participate in normal training activities | Restore confidence and assess functional skills by coaching staff |
| Return to play | Normal game play | |



CogState Sport (see *Resources*) or ImPACT™ (see *Resources*). Ideally, computerised test platforms should be used, however, paper and pencil tests (with a more conservative return to play approach) are useful in cases where costs and time restrictions limit the use of computerised testing. Overall, it is important to remember that neuropsychological testing is only one component of assessment, and should not be the sole basis of management decisions.

Graduated return to activity

Following a concussive injury, players should be returned to play in a graded fashion (*Table 3*) once clinical features have resolved and cognitive function returned to 'normal' on neuropsychological testing. A more conservative approach (ie. longer time to return to sport) should be used where there is any uncertainty about the player's recovery – 'if in doubt sit them out'.

Progression through the rehabilitation program should occur with 24 hours between stages. The player should be instructed that if any symptoms recur while progressing through their return to play program that they should drop back to the previous asymptomatic level and try to progress again after a further 24 hour period of rest.

Summary

Concussion in sport reflects a functional disturbance rather than a structural injury to the brain. The majority of individuals recover uneventfully following a concussive injury, however complications and adverse outcomes can occur, particularly with premature return to sport. The key components of safe return to play decisions include rest until all symptoms have resolved, neuropsychological testing to ensure objective recovery of cognitive function, and then a graded program of exertion before return to sport. In difficult or complicated cases, referral to a neuropsychologist and/or doctor with expertise in managing concussive injuries should be considered.

Resources

- SCAT2: http://bjssportmed.com/content/43/Suppl_1/i85.full.pdf
- CogState Sport: www.cogstate.com/go/Sport
- ImPACT™: www.impacttest.com

Author

Michael Makdissi, BSc(Hons), MBBS, PhD, FACSP, is NHMRC Post-Doctoral Fellow, Brain Research Institute, Heidelberg and Australasian College of Sports Physicians, and a sports physician, Olympic Park Sports Medicine Centre, Melbourne, Victoria. makdissi@unimelb.edu.au

Conflict of interest: none declared.

References

1. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil* 2006;21:375–8.
2. Buckley WE. Concussions in college football. A multivariate analysis. *Am J Sports Med* 1988;16:51–6.
3. Pellman EJ, Powell JW, Viano DC, et al. Concussion in professional football: epidemiological features of game injuries and review of the literature – part 3. *Neurosurgery* 2004;54:81–94; discussion 94–6.
4. Benson BV, Mohtadi NG, Rose MS, Meeuwisse WH. Head and neck injuries among ice hockey players wearing full face shields vs half face shields. *JAMA* 1999;282:2328–32.
5. Goodman D, Gaetz M, Meichenbaum D. Concussions in hockey: there is cause for concern. *Med Sci Sports Exerc* 2001;33:2004–9.
6. Powell JW, Barber-Foss KD. Traumatic brain injury in high school athletes. *JAMA* 1999;282:958–63.
7. Boden BP, Kirkendall DT, Garrett WE, Jr. Concussion incidence in elite college soccer players. *Am J Sports Med* 1998;26:238–41.
8. Makdissi M, McCrory P, Ugoni A, Darby D, Brukner P. A prospective study of postconcussive outcomes after return to play in Australian football. *Am J Sports Med* 2009;37:877–83.
9. Kemp SP, Hudson Z, Brooks JH, Fuller CW. The epidemiology of head injuries in English professional rugby union. *Clin J Sport Med* 2008;18:227–34.
10. Hinton-Bayre AD, Geffen G, Friis P. Presentation and mechanisms of concussion in professional Rugby League Football. *J Sci Med Sport* 2004;7:400–4.
11. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 1st International Symposium on Concussion in Sport, Vienna 2001. *Clin J Sport Med* 2002;12:6–11.
12. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med* 2005;39:196–204.
13. McCrory P, Meeuwisse W, Johnston K, et al. Consensus Statement on Concussion in Sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *Br J Sports Med* 2009;43(Suppl 1):i76–90.
14. Teasdale G, Jennett B. Assessment of coma and impaired consciousness: a practical scale. *Lancet* 1974;7:81–4.
15. Teasdale G, Murray G, Parker L, Jennett B. Adding up the Glasgow Coma Score. *Acta Neurochir Suppl (Wien)* 1979;28:13–6.
16. Giza CC, Hovda DA. The neurometabolic cascade of concussion. *J Athl Train* 2001;36:228–35.
17. Jordan BD, Relkin NR, Ravdin LD, Jacobs AR, Bennett A, Gandy S. Apolipoprotein E epsilon4 associated with chronic traumatic brain injury in boxing. *JAMA* 1997;278:136–40.
18. Lovell MR, Iverson GL, Collins MW, McKeag D, Maroon JC. Does loss of consciousness predict neuropsychological decrements after concussion? *Clin J Sport Med* 1999;9:193–8.
19. Collins MW, Iverson GL, Lovell MR, McKeag DB, Norwig J, Maroon J. On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clin J Sport Med* 2003;13:222–9.
20. McCrory PR, Ariens T, Berkovic SF. The nature and duration of acute concussive symptoms in Australian football. *Clin J Sport Med* 2000;10:235–8.
21. Makdissi M. Is the simple versus complex classification of concussion a valid and useful differentiation? *Br J Sports Med* 2009;43(Suppl 1):i23–7.
22. Maruff P, Falletti MG, Collie A, Darby D, McStephen M. Fatigue-related impairment in the speed, accuracy and variability of psychomotor performance: comparison with blood alcohol levels. *J Sleep Res* 2005;14:21–7.
23. Collie A, Makdissi M, Maruff P, Bennell K, McCrory P. Cognition in the days following concussion: comparison of symptomatic versus asymptomatic athletes. *J Neurol Neurosurg Psychiatry* 2006;77:241–5.
24. Lovell MR, Collins MW, Iverson GL, et al. Recovery from mild concussion in high school athletes. *J Neurosurg* 2003;98:296–301.
25. Maddocks D, Saling M. Neuropsychological deficits following concussion. *Brain Inj* 1996;10:99–103.
26. Barth JT, Macciocchi SN, Giordani B, Rimel R, Jane JA, Boll TJ. Neuropsychological sequelae of minor head injury. *Neurosurgery* 1983;13:529–33.
27. Delaney JS, Lacroix VJ, Leclerc S, Johnston KM. Concussions during the 1997 Canadian Football League season. *Clin J Sport Med* 2000;10:9–14.
28. Kaut KP, DePompei R, Kerr J, Congeni J. Reports of head injury and symptom knowledge among college athletes: implications for assessment and educational intervention. *Clin J Sport Med* 2003;13:213–21.
29. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz K. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med* 2004;14:13–7.
30. Weschler D. Weschler adult intelligence scale – revised: manual. New York: Psychological Corporation, 1981.
31. Wrightson P, Gronwall D. Concussion and sport: a guide for coaches and administrators. *Pat Management* 1983;3:79–82.
32. Gerberich SG, Priest JD, Boen JR, Straub CP, Maxwell RE. Concussion incidences and severity in secondary school varsity football players. *Am J Public Health* 1983;73:1370–5.
33. McCrory PR, Berkovic SF. Second impact syndrome. *Neurology* 1998;50:677–83.



34. Cantu RC. Second-impact syndrome. *Clin Sports Med* 1998;17:37–44.
35. Kelly JP, Nichols JS, Filley CM, Lillehei KO, Rubinstein D, Kleinschmidt-DeMasters BK. Concussion in sports. Guidelines for the prevention of catastrophic outcome. *JAMA* 1991;266:2867–9.
36. Ryan LM, Warden DL. Post concussion syndrome. *Int Rev Psychiatry* 2003;15:310–6.
37. Rutherford WH, Merrett JD, McDonald JR. Symptoms at one year following concussion from minor head injuries. *Injury* 1979;10:225–30.
38. Rutherford WH. Sequelae of concussion caused by minor head injuries. *Lancet* 1977;1:1–4.
39. Levin HS, Mattis S, Ruff RM, et al. Neurobehavioral outcome following minor head injury: a three-center study. *J Neurosurg* 1987;66:234–43.
40. Pellman EJ, Viano DC, Casson IR, Arfken C, Powell J. Concussion in professional football: injuries involving 7 or more days out – part 5. *Neurosurgery* 2004;55:1100–19.
41. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc* 2007;39:903–9.
42. Jordan B. Genetic susceptibility to brain injury in sports: a role for genetic testing in athletes? *Phys Sportsmed* 1998;26:25–6.
43. Cremona-Meteyard SL, Geffen GM. Persistent visuospatial attention deficits following mild head injury in Australian Rules football players. *Neuropsychologia* 1994;32:649–62.
44. Lovell MR, Collins MW, Iverson GL, Johnston KM, Bradley JP. Grade 1 or 'ding' concussions in high school athletes. *Am J Sports Med* 2004;32:47–54.
45. Omalu BI, DeKosky ST, Hamilton RL, et al. Chronic traumatic encephalopathy in a national football league player: part II. *Neurosurgery* 2006;59:1086–92; discussion 92–3.
46. Omalu BI, DeKosky ST, Minster RL, Kamboh MI, Hamilton RL, Wecht CH. Chronic traumatic encephalopathy in a national football league player. *Neurosurgery* 2005;57:128–34; discussion 34.
47. Gronwall D, Wrightson P. Cumulative effect of concussion. *Lancet* 1975;2:995–7.
48. Matser EJ, Kessels AG, Lezak MD, Jordan BD, Troost J. Neuropsychological impairment in amateur soccer players. *JAMA* 1999;282:971–3.
49. Ravdin LD, Barr WB, Jordan B, Lathan WE, Relkin NR. Assessment of cognitive recovery following sports related head trauma in boxers. *Clin J Sport Med* 2003;13:21–7.
50. Iverson GL, Gaetz M, Lovell MR, Collins MW. Cumulative effects of concussion in amateur athletes. *Brain Inj* 2004;18:433–43.
51. McCrory PR, Berkovic SF. Concussive convulsions. Incidence in sport and treatment recommendations. *Sports Med* 1998;25:131–6.
52. Chadwick D. Concussive convulsions. Wrong diagnosis may deprive people of their livelihood. *BMJ* 1997;314:1283.

New Concussion Management Guidelines: Concussion Question and Answer Document For Physicians

Members of the College of Family Physicians of Canada may claim Mainpro-M2 credits for this unaccredited educational program.

1. What is a concussion?

Of course, the most important key to managing any condition is to know exactly what you are dealing with. Through the years, a number of definitions of concussion have been proposed, often leading to confusion. The “Consensus Statement on Concussion In Sport” (Zurich 2008)¹ – released after the 3rd International Conference on Concussion in Sport, defines concussion as:

“a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be used in defining the nature of a concussive head injury include:

1. Concussion may be caused by either a direct blow to the head, face, neck or elsewhere on the body with an “impulsive” force transmitted to the head.
2. Concussion typically results in the rapid onset of short lived impairment of neurological function that resolves spontaneously.
3. Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
4. Concussion results in a graded set of clinical syndromes that may or may not involve a loss of consciousness. Resolution of the clinical and cognitive symptoms typically follow a sequential course; however, it is important to note that, in a small percentage of cases, post-concussive symptoms may be prolonged.
5. No abnormality on standard structural neuroimaging is seen in concussion.”

2. Do you have to lose consciousness to have a concussion?

Perhaps the most important mistake made when trying to define a concussion is that it involves a loss of consciousness (LOC). In fact, most concussions occur without LOC. LOC is just one symptom of concussion, and, in fact, recent research has suggested that a brief (less than one minute) LOC is not necessarily as significant an indicator of concussion severity as once thought. It is important to realize that many people will report a loss of consciousness because they cannot recall events before, during or after their concussion. Unless this is witnessed as a true loss of consciousness, it may be that the person is experiencing amnesia, which is an important post- concussive symptom.

It is also important to note that concussion is not simply caused by a direct blow to the head. Blows to the face and to the jaw (which result in a force being transmitted to the brain) are

also common causes of concussion. Even a significant blow elsewhere on the body (for example a hard tackle in football or rugby; being body checked in hockey) can cause concussive symptoms through a rapid movement of the soft brain inside the hard case of the skull.

In some head injuries, there may be a structural injury to the brain, such as a bleed. Obviously, it is critical to rule out a bleed, and doing so does not affect early head injury management. However, the more typical sport related concussion does not result in any structural injury, but rather a functional injury to the brain cells. A helpful way to explain this to patients is to imagine the brain as a computer. If the computer is clearly damaged (for example, an axe through the CPU or monitor!) then this would define a structural injury. Obviously the computer would not work well due to this damage. In a concussion, the computer looks normal but is not working well (ie. not processing programs as quickly as possible, running at a slower speed, etc.). This is the same situation as in a concussion. Unfortunately, what exactly happens to cause this functional disturbance is not completely known. Given the lack of structural injury, conventional neuroimaging studies (CT, MRI) will be negative.

3. Who gets a concussion?

The majority of concussions that a family physician will see are sport or activity related. Sports which involve contact or collision (hockey, football, rugby) are among the most common sports where concussion is seen. Other sports, such as soccer and basketball, also often involve contact and therefore a higher concussion risk than non-contact activities. However, a concussion can occur in virtually any activity, including non-sporting activity where a blow to the head, face or jaw, or other force to the head occurs. You should ask about potential concussion when you have a patient who notes a history of a whiplash injury, or an injury around the neck and shoulder area. For example, someone who fell directly on the shoulder may report mainly shoulder pain at the time, but may also have post concussive symptoms which are critical to deal with.

4. What are the signs and symptoms?

Post concussive symptoms can be physical, cognitive and emotional.

- *Physical symptoms* include: headache, dizziness, nausea, feeling unsteady, feeling “dinged” or “stunned” or “dazed”, feeling like their “bell was rung”, seeing stars or other visual disturbances, ringing in the ears, double vision, simply “not feeling right”.
- *Physical signs* of concussion include: loss of consciousness or impaired consciousness, poor coordination or balance, easy distractability and poor concentration, slowness answering questions and following directions, vomiting, looking “glassy eyed”, photophobia, slurred speech, personality or behavior changes (including inappropriate playing behavior such as skating or running in the wrong direction) and significantly decreased performance or playing ability.
- *Cognitive symptoms* include: confusion, amnesia, disorientation, poor concentration, and memory disturbance.
- *Emotional symptoms* include: feeling of depression or moodiness.

It is important to note that not all concussions will include all of these features. If any one of the aforementioned symptoms (or other similar symptoms) is present, concussion should be

suspected. Keep in mind that symptoms and signs may be more pronounced later or the next day after the injury. *Again, it is critical to remember that a person does not have to have lost consciousness to have sustained a concussion.*

5. What exactly causes the symptoms?

The pathology behind concussion and its resultant symptoms is, as yet, poorly understood. This is obviously a significant limiting factor in our assessment and management, in that there is no simple “test” which will give all the answers about diagnosis and resolution of the problem. It is, therefore, critical to be aware of the multiple post concussive signs and symptoms, and of appropriate management, which will be described further below.

6. How do I make a diagnosis? What about grading systems?

If any of the above symptoms or signs is noted in a setting of potential head injury (and don't forget that head injury can occur in association with neck, shoulder and upper body injuries), the diagnosis of concussion should be considered. **If there are no other obvious reasons for the symptoms, then it should be firmly diagnosed as a concussion.**

Through the years, a number of “grading systems” have been proposed for concussion assessment and management. Unfortunately, all these systems are anecdotal, based on the experience of their authors, with no scientific evidence to support them. In the second consensus statement on concussion in sport (Prague, 2004)², the consensus panel wrote that it

“recognizes the strength and weaknesses of several existing concussion grading scales that attempt to characterize injury severity, but no single system was endorsed. It was the recommendation of the group that combined measures of recovery should be used to assess injury severity (and/or prognosis) and hence individually guide return to play decisions.”

These “combined measures of recovery” will be discussed in more detail below.

Comparing the existing grading systems will show that one system's “second degree” concussion is another system's “third degree”. The proposed management and return to play advice is also different. Many of these use loss of consciousness as a significant indicator of severity, and, as previously noted, this may not be the case. As a result, it may be possible to draw inappropriate conclusions. While it would be very nice and easy to have a system that one could follow as a “recipe”, unfortunately this is not the case at this time.

The Zurich consensus group agreed that there are a number of “modifying factors” which may influence the investigation and management of concussion, and may predict the potential for more prolonged symptoms. These include:

- Number and duration of symptoms
- Prolonged loss of consciousness (> 1 minute), amnesia
- Concussive convulsion
- Repeated concussions over a period of time
- Recent concussion

- Repeated concussion occurring with progressively less force, or slower recovery after each successive concussion
- Children and adolescents
- Co and pre-morbidities (migraine, depression, ADHD, learning disability, sleep disorder)
- Medication and drug use (eg psychoactive drugs, anticoagulants)
- Dangerous style of play
- High risk sport or activity

In these settings, where possible, the athlete would be best managed in a multi-disciplinary manner coordinated by a physician with specific expertise in concussion management.

7. I'm at the rink or the field and I suspect someone has sustained a concussion. How do I deal with this?

As with any injury, it is critical to assess airway, breathing and circulation first! *If the player is unconscious, it is critical to understand that a cervical spine injury could also have occurred* and the athlete must be dealt with accordingly, using full cervical spine precautions and management techniques, and rapid transport to hospital by ambulance. If the player is conscious, but clearly confused and unable to provide a reasonable history (such as noting neck pain, feeling an extremity, etc.), then it is better to err on the side of caution and also treat this as a potential cervical spine injury. More typically, the player will exhibit symptoms and signs as discussed in question 3 above. *It is critical to understand that the symptoms may not seem that significant initially, but may continue to evolve and become more severe with time.* Thus, any player that you suspect to have had a concussion should be removed from the game or practice and not allowed to return. No medication should be given, and the *signs and symptoms should be monitored for increasing severity.*

Signs of a structural brain injury could include: increasingly severe headaches, decreasing level of consciousness, increasing tiredness and confusion, any lateralizing weakness, seizure temporally remote from the injury, or persistent vomiting. Anyone with these symptoms needs immediate emergency assessment. If you, as a physician, are dealing with a concussion at the rink or the field, it is important to do only what you feel comfortable within your level of expertise. If you have extensive experience dealing with concussion, the player may not need further medical assessment. If not, the player should be referred for further assessment, whether in the emergency department acutely, or to another physician with more concussion expertise as soon as possible. All concussed individuals should be seen by a physician, though.

In many cases, you may be asked to discuss concussion assessment and management with parents, coaches, and trainers. The previously mentioned principles apply. When a concussed athlete is being assessed by a non-physician, it is important that the athlete be assessed by a physician as soon as possible after the injury.

8. A concussed athlete comes into my office for assessment. How do I do this?

As with all medical problems, a thorough history, and physical examination are the key to diagnosis and management. It is most helpful if the concussed athlete comes to the office

with a friend, parent, etc. who can often provide some of the history that may be difficult for the concussed person to remember. Start by asking about the injury: What happened? Was there a loss of consciousness, and if so for how long? (Remember, a more prolonged loss of consciousness is significant). Is there any amnesia for the event? What are the symptoms? What is the clinical course of the symptoms (improving, worsening)?

It is also extremely important to ask about a past history of concussions, and to get specific details regarding these. It has been found that there may be an increased risk of sustaining subsequent concussive injuries after a first concussion. Thus, the athlete with multiple concussions may be at significantly more risk. The athlete who is becoming concussed more and more easily, and frequently, with more severe and longer lasting symptoms, is of significant concern. When asking about previous concussions it is important to not just ask about documented concussions, but about any episodes where the person had any post concussive symptoms. Many will not make the connection between the symptoms and the fact that they may have been concussed. For example “having your bell rung” or “seeing stars” are often not perceived as a concussion by many, but are in fact consistent with post concussive symptoms even if only transient.

Following the history, an appropriate *physical examination* should be performed. This should look at the head, the neck (it is very common in the setting of a blow to the head or the face that neck pain can result, and can contribute to such things as headaches), eyes, ear, nose and throat. A full neurologic assessment is important to rule out structural injury or other neurologic causes of symptoms. It is rarely helpful in the setting of pure concussion, though.

Balance and coordination testing is helpful. The Zurich consensus group developed the SCAT2 (Sport Concussion Assessment Tool 2), which can be downloaded from this site (Think First Canada, thinkfirst.ca/programs/documents/SCAT2.pdf). This is an excellent assessment tool which can be used at the sideline or in the office. The SCAT2 describes a modified BESS (Balance Error Scoring System) which can be performed in the office. Remember, though, that many people will have some difficulty with balance, even when not concussed!

In addition to physical tests, cognitive tests must be done. The standard mini mental status exam is not adequate. Tests of orientation, memory and concentration should be performed. Tests of orientation are usually more useful right after the injury, and can include: Who are you playing? Where are we now? What is the score? Memory testing can be done by giving the patient five words to remember, and asking them to repeat them right away (immediate memory) and five minutes later (short term memory). Concentration tests include reciting the months of the year backwards, and reciting strings of digits backwards. Serial subtraction tests such as “Serial 7’s” are often poorly performed even by non-concussed people, so are no longer used in assessment.

It is important to note that, without doing any “baseline” testing of the same test prior to concussion, it is often hard to tell whether or not an impairment exists. However, if the athlete is obviously significantly impaired in memory and concentration relevant to their age or academic standing, then these tests will bring this out fairly clearly. Their performance in the test can also be used to track improvement as they are reassessed. If you are looking after a team where there is a risk of concussion, a good idea is to perform baseline testing in some

of these areas first, so that you will have something to compare against in the future, should there be an injury during the season.

9. Do I need to order any imaging?

As noted previously, concussion is a functional injury not a structural injury, and thus, imaging studies will not be useful. If there is any suspicion of a structural injury, such as a bleed (for example increasingly severe headaches), then imaging with an MRI or CT may be indicated. If there is any concern about associated injuries, such as facial fractures, injuries to the neck, etc, then appropriate imaging should be ordered.

10. How can I manage this player? What sort of treatment options do I have? You said that grading systems are not useful, so how do I know when to allow them back to sport?

This is certainly where things appear to get tough. However, by following a few simple management guidelines, you can successfully, and safely, guide the injured athlete through their post concussive phase and re-introduce them to activity.

As was previously discussed, *when a player shows any signs or symptoms of concussion, they should not be allowed to return to play in the current game or practice.* They should not be left alone; regular monitoring for deterioration is essential given that symptoms can progress. *It is clear that physical and cognitive (mental) activity increases post concussive symptom severity and prolongs their course. Thus, the most important initial management feature for concussion is rest, from both physical and cognitive exertion.* In someone with severe symptoms, this may need to be fairly significant rest, such as staying in bed, staying seated, etc. However, most are able to carry on with very light daily activities (excluding exercise, weight training, sport participation, and other exertional activities). If their symptoms are worsened, they should reduce their level of activity. It is very important to make this clear to the player, friends and family, as the lack of rest early on can often be a significant cause for prolonged symptoms.

It is now clear that cognitive exertion aggravates post-concussive symptoms as well. This can include activities which require focus, concentration, memorization and multi-tasking. Students often find that going to school makes their symptoms worse, so may need to stay home until they feel better; that is, until these cognitive activities no longer make them feel worse. They should then start back to school part time (eg half days), progressing to full time if they have no problems. This can often be frustrating for the student, their parents and teachers, as it is impossible to state specifically how long they will need to be off. Once back to school, the student's workload should be managed appropriately, given that an increase in cognitive exertion may aggravate their symptoms. The patient may need to be off work, depending on the requirements of their job.

Once the person is completely asymptomatic at rest, a graduated increase in activities should be undertaken. Being "asymptomatic" refers to physical, cognitive, and emotional manifestations of concussion. It is helpful to compare this step-wise process to a "dimmer switch" for lights. The brightness should be turned up very gradually, with adjustments downward as necessary if there are symptoms. This contrasts to the "on - off switch" approach that many use, where they go from no activity to full activity. The lack of this graduated, step wise increase is a chief cause of very prolonged post concussive courses in many. (Another way to explain

it to your patients is that it is a series of single steps forward. If symptoms return at any step, the patient simply takes one step back, rather than two or three steps forward, then six steps back).

A typical return to play or activity protocol is as follows:

(*Please note that each level is a step, not a day. It may take more than one day to proceed between each step. However, each step should take a minimum of one day.)

1. No activity, only complete rest. Proceed to step two only when symptoms are gone.
2. Light aerobic exercise such as walking or stationary cycling. Monitor for symptoms and signs. No resistance training or weight lifting.
3. Sport - specific activities and training (eg. skating in hockey). No contact or risk of contact.
4. Drills without body contact. May add light resistance training at step 3 or 4 and then progress to heavy weights.
The time needed to progress from non-contact to contact exercise will vary with the severity of the concussion and player.
5. Begin drills with body contact.
6. Game play.

The key to this approach is that the athlete should only continue to the next level if asymptomatic at the current level. This step-wise progression should be monitored by a physician.

If any post concussive symptoms occur then they should drop back to the previous asymptomatic level and then try to progress again after a day or so of rest. As you can appreciate, this protocol means that **it will take a minimum of one week following complete resolution of symptoms before an athlete can return to play**. However, it is critical to note that the athlete may not be able to progress from one step to another on a daily basis. So, when asked “How long will I be out?” by the athlete, parent or coach, it is clear that it is impossible to give a specific answer. Sport-specific post- concussion rehab programs are being developed by concussion experts, but follow the guidelines given above.

To summarize this important management information, remember that the athlete should rest until completely asymptomatic, and then progress to a medically-supervised step-wise return to play protocol such as suggested above. *An athlete should not return to play until cleared to do so by a physician.*

CRITICAL POINTS:

It is always unsafe to return to play while symptomatic (higher risk of a new concussion, higher risk of more severe post concussive symptoms, higher risk of other injury), and too rapid a progression while still symptomatic will often prolong the post concussive course.

11. When should I provide clearance to return to play if I am asked to do so?

The concussed athlete should be managed as described above. Once you are certain that the athlete is completely asymptomatic, and has proceeded through a graduated return to play type protocol, then you can more confidently indicate that the player is fit to return to play.

Always remember, a player should never return to play while symptomatic! And, *“when in doubt, sit them out!”*

12. What about somebody who has had multiple concussions? When should I be telling them it is not a good idea to return to contact or collision sports?

This is always a very difficult question to deal with, as we still do not completely know the pathophysiology behind concussion. It has certainly been observed that once one has had one concussion, there is an increased risk of subsequent concussive injuries. However, there are multiple factors which come into play, including possibly genetics. Thus, it is not possible to give a “cookbook” type answer to this. If you have an athlete who has had numerous concussions, it is wise to be very careful, and to seek further opinion from a physician with expertise in dealing with concussion.

Three concerning scenarios are:

1. the athlete who has had numerous concussions, with each concussion seemingly more easily obtained, and with symptoms which are more severe and longer lasting;
2. any athlete who has residual neurocognitive problems after other symptoms have all resolved (eg. memory or concentration impairment); and
3. protracted, prolonged symptoms.

These are people potentially at risk for significant long term problems and would best be advised to give up any contact or collision activities which put them at risk. However, it would be best to involve the advice of a concussion expert in this regard where possible.

13. Are children managed differently?

The Zurich consensus group agreed that the evaluation and management recommendations contained in the Consensus Statement (and described here) could be applied to children and adolescents down to the age of 10. However, with children, it is extremely important to be conservative, and always err on the side of caution. The concept of “cognitive exertion” is very important in children; this refers to school, home computer use, video games, etc. These may exacerbate post-concussion symptoms. Thus, it is necessary to rest from these activities as well, until asymptomatic, then gradually re-introduce.

14. Is there anything I can do to try to prevent concussion?

Absolutely! Protective equipment use is often highlighted in relation to brain injury prevention, but it is not the only prevention strategy. A physician is in an excellent position to educate and encourage the athletes, parents, coaches/trainers about ways to recognize the injury, and to reduce the risk of concussion. Recognition of the injury is of primary importance, since appropriate management can begin only when concussion is recognized. Nonetheless, it is important to ask about protective equipment when assessing a patient for concussion.

Although helmets provide excellent protection against injuries such as fractures and lacerations; they cannot effectively prevent all concussions – *there is no such thing as a concussion-proof helmet*. It is important to try to determine if the helmet is in good condition, and whether it is being worn properly. If you are unsure about this yourself, try to consult someone in your community who may be more expert in this regard (a sporting good

manufacturer, hockey trainer, etc.). A helmet that is not worn properly or done up properly may not protect the head. In addition, any helmet that has sustained structural damage will also not protect the head. Helmet liners, whether made of foam, or polystyrene, will deteriorate with time, even though they may look normal. Perfumes, shampoos, and hair gels will contribute to this. There is no definite consensus, but it is often felt that hockey helmets, for example, should be replaced every year or two in someone who plays on a regular basis. Other helmets may come with replacement recommendations from the manufacturer. Helmets should be encouraged in other sports such as skiing, snowboarding, in line skating and cycling. Newer types of head gear are now being seen in soccer.

Mouthguards are a controversial area. To date, there is no good scientific evidence that a mouthguard will definitely reduce the risk of concussion. But, theoretically, it is very possible that they will, when a blow comes to the jaw area. Scientific evidence is clear that mouth guards will help to prevent against dental injury, so should be worn for this reason in many sports anyway.

While there is no evidence, strengthening of the neck muscles may one day prove to be useful in reducing concussion risk as well, particularly in sports where significant collisions occur, and with heading in soccer. Discussing the concepts of fair and clean play with your patient, as well as encouraging them to improve playing style and technique (for example learning how to go into the boards appropriately in hockey) are also very important. Advocating for enforcement of rules and rule changes to make games safer is also very important and the physician plays a significant role in this regard as a community expert. Try to be aware of educational resources available. ThinkFirst Canada may be able to connect you to local Chapters or community workers for this purpose.

15. What does the future hold? Is there research going on?

There are still significant gaps in our knowledge about concussion. Extensive research is going on throughout the world to try to answer some of these very important questions. Work is being done in diagnostic modalities and imaging techniques, as well as in concussion evaluation. Neuropsychological testing has been found to be a very useful way to assess concussion severity and subsequent resolution. More recently, shorter, computer based neuropsychological tests make these more available to people and are found to be a very useful adjunct.

It is our hope that the answers to the above questions will help to make physicians more comfortable and confident in dealing with concussion. There are certainly things that are still not known about concussion, and significant controversy in some areas. The use of grading systems, while convenient, is discouraged due to lack of scientific evidence. The key points to remember, though, are:

- 1. Concussion is a functional injury to the brain. You do not have to be knocked out to have sustained a concussion. Concussions do not appear on standard imaging tests.**
- 2. It is always unsafe to return to play while symptomatic.**
- 3. Initial concussion management begins with injury recognition and rest until the patient is asymptomatic. Once asymptomatic, a gradual, step-wise return to activity**

should be followed.

4. “When in doubt, sit them out”.

5. If you are not sure, seek the help of a physician with concussion expertise where possible.

6. Prevention is critical!

Prepared by the ThinkFirst-SportSmart Concussion Education and Awareness Committee. Last updated, May 2010.

¹ McCrory P, Meeuwisse W, Johnston K, Dvorak J, Aubry M, Molloy M, Cantu R. *Consensus Statement on Concussion in Sport. 3rd International Conference on Concussion in Sport Held in Zurich, November 2008.* Clin J Sport Med 2009; 19: 185-200.

² McCrory P, Johnston K, Meeuwisse W, Aubry M, Cantu R, Dvorak J, Graf-Baumann T, Kelly J, Lovell M, Schamasch P. *Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004.* Br J Sports Med 2005; 39: 196-204.



*National Collaborating Centre
for Acute Care*

Head Injury

Triage, assessment, investigation and early management of head injury in infants, children and adults

METHODS, EVIDENCE & GUIDANCE

SEPTEMBER 2007

Commissioned by the National Institute
for Health and Clinical Excellence

| | | |
|--|--|--|
| | | |
|--|--|--|

**Head Injury: triage, assessment,
investigation and early management of
head injury in infants, children and adults.**

| | |
|--|---|
| | METHODS, EVIDENCE & GUIDANCE |
|--|---|

Published by the National Collaborating Centre for Acute Care at The Royal College of Surgeons of England, 35-43 Lincoln's Inn Fields, London, WC2A 3PE

First published June 2003

© National Collaborating Centre for Acute Care 2007

Apart from any fair dealing for the purposes of research or private study, criticism or review, as permitted under the Copyright, Designs and Patents Act, 1988, no part of this publication may be reproduced, stored or transmitted in any form or by any means, without the prior written permission of the publisher or, in the case of reprographic reproduction, in accordance with the terms of licences issued by the Copyright Licensing Agency in the UK. Enquiries concerning reproduction outside the terms stated here should be sent to the publisher at the UK address printed on this page.

The use of registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant laws and regulations and therefore for general use.

The rights of National Collaborating Centre for Acute Care to be identified as Author of this work have been asserted by them in accordance with the Copyright, Designs and Patents Act, 1988.

ISBN 0-9549760-5-3

Foreword

Updating a document can be more difficult than starting from scratch; certainly we have found incorporation of new evidence into the guideline first published by NICE four years ago to be more complex than initially envisaged. I thank the Guideline Development Group and the team at the National Acute Care Collaboration Centre for their enthusiastic and professional support and advice throughout this process. We have been helped in our task by contributions from patient groups and stakeholders. The final document is undoubtedly richer as a result of the extensive consultations which followed the publication of the first draft.

Perhaps the most important prompt for this update was the publication of validation studies related to the advice on CT imaging; one of the most significant components of the first guidance. New research evidence on the management of paediatric head injuries was also available and this has been particularly useful in clarifying the subtle differences in guidance for adults and children.

Emerging evidence on the value of CT in cervical spine imaging – and the increasing awareness that plain films may not reveal clinically important lesions – has led the Guideline Development Group to recommend greater use of CT in the assessment of the neck in those head injured patients who have impaired consciousness.

The transfer of critically ill or injured patients between hospitals is rarely out of the news and it has been an agenda item at our meetings throughout the update process. There are two issues. Should ambulances “by pass” local hospitals en route from the scene of an incident to reach a specialist centre? Secondly, if all patients continue, as at present, to be transported to the nearest hospital, what are the indications for “secondary transfer”? The evidence in both areas is weak – but there is more than there was four years ago. On balance the Guideline Development Group consider the case for transferring all seriously head injured patients to a specialist neuroscience centre to be sufficiently strong to recommend that “secondary transfer” should be the norm for this group of patients, irrespective of the need for a neurosurgical operation. In contrast, we do not consider the case has been made for “by pass”. Both issues are critically

important; there is an urgent need for a stronger evidence base. We therefore recommend research in this area be given high priority.

The plight of those disabled after brain injury continues to cause concern. Our remit prevented a detailed examination of this important topic but we do comment on the indications for follow up and emphasise the need for further research.

Finally, we have taken the opportunity to review some sections of the previous guideline, addressing issues which have caused concern to users. I hope this update is even more helpful than its predecessor and that it will contribute to the improved care of head injured patients to which we all aspire.

Professor David Yates

Chair, Guideline Development Group

1st June 2007

Contents

| | |
|--|-----------|
| FOREWORD..... | 4 |
| CONTENTS | 6 |
| GUIDELINE DEVELOPMENT GROUP MEMBERSHIP AND ACKNOWLEDGMENTS | 10 |
| STAKEHOLDER INVOLVEMENT | 13 |
| ABBREVIATIONS | 18 |
| GLOSSARY OF TERMS | 19 |
| 1 BACKGROUND AND SCOPE | 30 |
| 1.1 INTRODUCTION | 30 |
| 1.2 UK GUIDELINES | 31 |
| 1.3 ROLE OF CT IMAGING | 32 |
| 1.4 NORTH AMERICAN GUIDELINES | 32 |
| 1.5 THE SKULL RADIOGRAPH | 32 |
| 1.6 ADMISSION | 33 |
| 1.7 MORBIDITY | 34 |
| 1.8 CAUSE OF INJURY | 34 |
| 1.9 SUMMARY OF CURRENT CARE IN THE UK | 35 |
| 1.10 SCOPE | 36 |
| 1.11 POPULATION | 37 |
| 1.12 HEALTHCARE SETTING | 37 |
| 1.13 THE NEED FOR THIS UPDATE GUIDELINE | 37 |
| 1.14 WHAT ARE CLINICAL PRACTICE GUIDELINES? | 38 |
| 1.15 THE NATIONAL COLLABORATING CENTRE FOR ACUTE CARE | 39 |
| 1.16 REMIT OF THE GUIDELINE | 39 |
| 1.17 WHAT THE UPDATE GUIDELINE COVERS | 39 |
| 1.18 WHAT THE GUIDELINE DOES NOT COVER | 40 |
| 1.19 WHO DEVELOPED THIS GUIDELINE? | 40 |
| 2 METHODS | 42 |
| 2.1 GUIDELINE DEVELOPMENT GROUP | 42 |
| 2.2 WORKING PRINCIPLES | 42 |
| 2.3 SYSTEMATIC REVIEWS | 42 |
| 2.4 RESOURCES | 43 |
| 2.5 CONSENSUS METHODS | 44 |
| 2.6 SYSTEMATIC REVIEW OF INDICATIONS FOR CT OF THE HEAD | 45 |
| 2.7 SYSTEMATIC REVIEW OF INDICATIONS FOR IMAGING OF THE CERVICAL SPINE | 45 |
| 2.8 SYSTEMATIC REVIEW OF MEANS OF IDENTIFYING PATIENTS AT HIGH RISK OF LATE SEQUELAE FOLLOWING HEAD INJURY | 46 |
| 2.9 SYSTEMATIC REVIEW OF MEDICAL RADIATION RISKS | 47 |
| 2.10 GUIDELINE UPDATE METHODOLOGY | 47 |
| 2.11 DEVELOPING THE CLINICAL QUESTIONS | 47 |
| 2.12 CLINICAL LITERATURE SEARCH | 47 |
| 2.13 HIERARCHY OF CLINICAL EVIDENCE | 48 |
| 2.14 THE LITERATURE REVIEWING PROCESS | 51 |

| | |
|---|-----------|
| 2.15 HEALTH ECONOMICS METHODS | 51 |
| 2.16 GRADING OF RECOMMENDATIONS | 51 |
| 2.17 RESEARCH RECOMMENDATIONS | 51 |
| 2.18 PRIORITISATION OF RECOMMENDATIONS FOR IMPLEMENTATION | 51 |
| 2.19 VALIDATION OF THE GUIDELINE | 51 |
| 3 SUMMARY OF RECOMMENDATIONS | 52 |
| 3.1 KEY PRIORITIES FOR IMPLEMENTATION | 52 |
| 3.2 THE COMPLETE LIST OF CLINICAL PRACTICE RECOMMENDATIONS | 54 |
| 3.3 PRESENTATION AND REFERRAL | 56 |
| 3.4 TRANSPORT FROM COMMUNITY HEALTH SERVICES AND NHS MINOR INJURY CLINICS AND PRE-HOSPITAL MANAGEMENT | 59 |
| 3.5 ASSESSMENT AND INVESTIGATION IN THE EMERGENCY DEPARTMENT | 60 |
| 3.6 TRANSFER FROM SECONDARY SETTINGS TO A NEUROSCIENCE UNIT | 68 |
| 3.7 OBSERVATION OF ADMITTED PATIENTS | 71 |
| 3.8 DISCHARGE | 72 |
| 3.9 NEW RECOMMENDATIONS | 75 |
| 3.10 RECOMMENDATIONS FOR RESEARCH | 77 |
| 4 PRE-HOSPITAL ASSESSMENT, ADVICE AND REFERRAL TO HOSPITAL ... | 82 |
| 4.1 PREDICTOR VARIABLES | 82 |
| 4.2 LOSS OF CONSCIOUSNESS | 82 |
| 4.3 AMNESIA | 82 |
| 4.4 NEUROLOGICAL SIGNS | 83 |
| 4.5 BLEEDING DISORDERS AND USE OF ANTICOAGULANTS | 83 |
| 4.6 SKULL FRACTURE | 83 |
| 4.7 AGE | 83 |
| 4.8 MECHANISM OF INJURY | 83 |
| 4.9 DRUG OR ALCOHOL INTOXICATION | 84 |
| 4.10 HEADACHE | 84 |
| 4.11 VOMITING | 84 |
| 4.12 IRRITABILITY AND ALTERED BEHAVIOUR | 85 |
| 4.13 HISTORY OF CRANIAL NEUROSURGICAL INTERVENTIONS | 85 |
| 4.14 PUBLIC HEALTH LITERATURE | 85 |
| 4.15 TELEPHONE ADVICE LINES | 85 |
| 4.16 COMMUNITY HEALTH SERVICES AND NHS MINOR INJURY CLINICS | 86 |
| 4.17 TRANSPORT FROM COMMUNITY HEALTH SERVICES AND NHS MINOR INJURY CLINICS AND PRE-HOSPITAL MANAGEMENT | 88 |
| 4.18 TRAINING IN RISK ASSESSMENT | 88 |
| 5 IMMEDIATE MANAGEMENT AT THE SCENE AND TRANSPORT TO HOSPITAL | 89 |
| 5.1 PRE-HOSPITAL MANAGEMENT | 89 |
| 5.2 GLASGOW COMA SCORE | 90 |
| 5.3 GLASGOW COMA SCALE SCORE | 91 |
| 5.4 IMMEDIATE MANAGEMENT OF PATIENTS WITH SEVERE HEAD INJURIES | 91 |
| 5.5 THE BENEFITS OF DIRECT TRANSPORT FROM THE SCENE TO A SPECIALIST NEUROSCIENCES CENTRE COMPARED TO TRANSPORT TO THE NEAREST DISTRICT GENERAL HOSPITAL | 91 |
| 5.6 ADVANCED LIFE SUPPORT TRAINING FOR AMBULANCE CREWS | 95 |
| 5.7 PRIORITY DISPATCH OF EMERGENCY AMBULANCES | 95 |
| 6 ASSESSMENT IN THE EMERGENCY DEPARTMENT | 96 |
| 6.1 FOCUS OF EMERGENCY DEPARTMENT ASSESSMENT IN PATIENTS WITH A HEAD INJURY | 96 |
| 6.2 INVESTIGATION OF CLINICALLY IMPORTANT BRAIN INJURIES | 97 |
| 6.3 WHAT IS THE BEST INITIAL DIAGNOSTIC TECHNIQUE TO DETERMINE WHICH PATIENTS HAVE SUSTAINED DAMAGE TO THE BRAIN AND REQUIRE FURTHER ASSESSMENT OF THE HEAD? | 97 |
| 6.4 WHAT ARE THE EFFECTS ON PATIENT OUTCOMES OF PROVIDING AN IMMEDIATE CT VERSUS OBSERVATION? | |

| | |
|--|-----|
| 6.5 THE BEST CLINICAL PREDICTION RULE FOR SELECTING ADULTS, INFANTS AND CHILDREN WITH HEAD INJURY FOR CT IMAGING OF THE HEAD..... | 100 |
| 6.6 INVESTIGATION OF CERVICAL SPINE INJURIES | 111 |
| 6.7 WHAT IS THE BEST DIAGNOSTIC IMAGING TECHNIQUE TO DETERMINE WHICH PATIENTS HAVE SUSTAINED DAMAGE TO THE CERVICAL SPINE AND REQUIRE FURTHER ASSESSMENT OF CERVICAL SPINE | 113 |
| 6.8 CERVICAL SPINE IMAGING OF INFANTS AND CHILDREN | 116 |
| 6.9 THE BEST CLINICAL PREDICTION RULE FOR SELECTING PATIENTS THAT HAVE SUSTAINED DAMAGE TO THE CERVICAL SPINE FOR THE IMAGING TECHNIQUE SELECTED IN SECTION 6.7?..... | 117 |
| 6.10 USING ADULT RULES WITH INFANTS AND CHILDREN | 123 |
| 6.11 PILOTING THE NEW RULES | 124 |
| 6.12 NON-ACCIDENTAL INJURY IN CHILDREN | 124 |
| 6.13 GOOD PRACTICE IN EMERGENCY DEPARTMENT ASSESSMENT | 124 |

7 IMAGING PRACTICE AND INVOLVEMENT OF THE NEUROSURGICAL DEPARTMENT..... 127

| | |
|---|-----|
| 7.1 GOOD PRACTICE IN IMAGING OF PATIENTS WITH A HEAD INJURY | 127 |
| 7.2 URGENCY IN PERFORMING CT OF THE HEAD..... | 127 |
| 7.3 CERVICAL SPINE IMAGING URGENCY | 128 |
| 7.4 INVOLVING NEUROSURGICAL CARE..... | 129 |
| 7.5 OTHER REASONS FOR DISCUSSING A PATIENT'S CARE WITH A NEUROSURGEON | 130 |
| 7.6 CRITERIA FOR NEUROSURGICAL INTERVENTIONS | 130 |
| 7.7 TRANSFER FROM SECONDARY TO TERTIARY CARE SETTINGS..... | 130 |
| 7.8 WHAT ARE THE BENEFITS FOR PATIENTS OF RECEIVING TREATMENT AT A NEUROSCIENCES CENTRE WHO HAVE SUFFERED A CLINICALLY IMPORTANT BRAIN INJURY THAT DOES NOT REQUIRE SURGICAL INTERVENTION?..... | 131 |
| 7.9 TRANSFER OF CHILDREN | 135 |

8 DISCHARGE AND FOLLOW-UP..... 138

| | |
|--|-----|
| 8.1 INTRODUCTION | 138 |
| 8.2 DISCHARGE OF LOW RISK PATIENTS WITH GCS EQUAL TO 15 | 138 |
| 8.3 DISCHARGE OF PATIENTS WITH NORMAL IMAGING OF THE HEAD..... | 139 |
| 8.4 DISCHARGE OF PATIENTS WITH NORMAL IMAGING OF THE CERVICAL SPINE..... | 139 |
| 8.5 DISCHARGE OF PATIENTS ADMITTED FOR OBSERVATION | 139 |
| 8.6 DISCHARGE OF PATIENTS AT RISK OF NON-ACCIDENTAL INJURY | 139 |
| 8.7 DISCHARGE AND GLASGOW COMA SCALE STATUS | 140 |
| 8.8 DISCHARGE ADVICE | 140 |
| 8.9 DISCHARGE OF PATIENTS WITH NO CARER AT HOME | 140 |
| 8.10 THE BEST TOOL FOR IDENTIFYING THE PATIENTS WHO SHOULD BE REFERRED TO REHABILITATION SERVICES FOLLOWING THE INITIAL MANAGEMENT OF A HEAD INJURY..... | 141 |
| 8.11 OUTPATIENT APPOINTMENTS | 144 |
| 8.12 PROGNOSIS IN SEVERE HEAD INJURY | 144 |
| 8.13 ADVICE ABOUT LONG TERM PROBLEMS AND SUPPORT SERVICES | 145 |
| 8.14 COMMUNICATION WITH COMMUNITY SERVICES..... | 145 |
| 8.15 RE-ATTENDEES..... | 145 |

9 ADMISSION AND OBSERVATION..... 146

| | |
|--|-----|
| 9.1 INTRODUCTION | 146 |
| 9.2 ADMISSION | 146 |
| 9.3 GOOD PRACTICE IN OBSERVATION OF PATIENTS WITH HEAD INJURY | 147 |
| 9.4 MINIMUM DOCUMENTED OBSERVATIONS | 148 |
| 9.5 FREQUENCY OF OBSERVATIONS | 148 |
| 9.6 PATIENT CHANGES REQUIRING REVIEW WHILE UNDER OBSERVATION..... | 148 |
| 9.7 IMAGING FOLLOWING CONFIRMED PATIENT DETERIORATION DURING OBSERVATION | 149 |
| 9.8 FURTHER IMAGING IF GCS EQUAL TO 15 NOT ACHIEVED AT 24 HOURS | 149 |
| 9.9 OBSERVATION OF CHILDREN AND INFANTS..... | 149 |
| 9.10 TRAINING IN OBSERVATION..... | 149 |
| 9.11 SUPPORT FOR FAMILIES AND CARERS | 149 |

10 MEDICAL RADIATION..... 151

| | |
|-------------------------|-----|
| 10.1 INTRODUCTION | 151 |
|-------------------------|-----|

| | |
|--|------------|
| 10.2 PATIENT DOSES FROM HEAD CT | 152 |
| 10.3 PATIENT DOSES FROM CERVICAL SPINE CT | 152 |
| 10.4 SUMMARY OF EFFECTIVE DOSES FROM CT AND CONVENTIONAL X-RAY EXAMINATIONS OF THE HEAD AND CERVICAL SPINE | 153 |
| 10.5 CANCER RISKS | 155 |
| 10.6 RADIATION EXPOSURE MANAGEMENT | 155 |
| 11 ECONOMIC EVALUATION..... | 157 |
| 11.1 INTRODUCTION | 157 |
| 11.2 METHODS | 158 |
| COST PER PATIENT TESTED (2005-6 UK£):* | 162 |
| 11.3 DIAGNOSIS OF INTRACRANIAL HAEMATOMA IN PATIENTS WITH A MINOR/MILD HEAD INJURY | 163 |
| 11.4 IDENTIFYING CERVICAL SPINE DAMAGE IN PATIENTS WITH HEAD INJURY | 172 |
| 11.5 DISCUSSION | 175 |
| 11.6 ADDENDUM 2007 – DIRECT TRANSPORT FROM INJURY SCENE TO A SPECIALIST NEUROSCIENCES CENTRE | 180 |
| Bibliography | 212 |

APPENDICES A-N can be found in a separate document

Guideline Development Group membership and acknowledgements

Guideline Development Group (2003)

Professor David Yates (Chairman and Trauma Audit and Research Network)

Mr Kieran Breen (Child Brain Injury Trust; patient representative)

Dr Patricia Brennan (British Paediatric Accident and Emergency Group)

Dr Niall Cartlidge (Association of British Neurologists)

Professor Helen Carty (Royal College of Radiologists)

Dr Nichola Chater (British Society of Rehabilitation Medicine)

Mr Jack Collin (Association of Surgeons of Great Britain and Ireland)

Mr Roger Evans (British Association for Accident and Emergency Medicine)

Professor Charles Galasko (British Orthopaedic Association)

Ms Gabby Lomas (Royal College of Nursing, Accident and Emergency Association)

Professor David Lloyd (British Association of Paediatric Surgeons)

Mr Tim Lynch (Ambulance Association)

Professor David Mendelow (Society of British Neurological Surgeons)

Dr Edward Moss (Royal College of Anaesthetists)

Dr David Murfin (Royal College of General Practitioners)

Mr Graham Nickson (Headway; patient representative)

Dr Christopher Rowland-Hill (British Society of Neuroradiologists)

Guideline Development Group (2007)

| | |
|-------------------------------|---|
| Professor David Yates (Chair) | UK Trauma Audit and Research Network |
| Dr Nichola Chater | British Society of Rehabilitation Medicine |
| Dr Paul Cooper | Association of British Neurologists |
| Mrs Hilary Dent | College of Radiographers |
| Mr Joel Dunning | Cardiothoracic Specialist Registrar |
| Dr Roger Evans | British Association for Accident & Emergency Medicine |
| Professor David Lloyd | British Association of Paediatric Surgeons |
| Ms Gabrielle Lomas | Royal College of Nursing. Emergency Care Association |
| Dr Ian Maconochie | Association of Paediatric Emergency Medicine |
| Professor David Mendelow | Society of British Neurological Surgeons |
| Professor David Menon | Intensive Care Society |
| Mr Archie Morson | East of England Ambulance NHS Trust |
| Dr Edward Moss | Royal College of Anaesthetists |
| Dr David Murfin | Royal College of General Practitioners |
| Dr Chris Rowland Hill | British Society of Neuroradiologists |
| Mr Paul Sidi | Headway Surrey |

National Collaborating Centre for Acute Care (2003)

Dr John Browne (project manager and systematic reviewer)

Mr Joel Desmond (systematic reviewer)

Dr Jan van der Meulen (statistical advice)

Mr Carlos Sharpin (information science support)

Mr David Wonderling (health economics)

NCC-AC staff on the Guideline Development Group (2007)

| | |
|------------------|---|
| Rifna Aktar | Project Manager |
| David Wonderling | Senior Health Economist |
| Clare Jones | Research Associate |
| Peter B Katz | Information Scientist |
| Elisabetta Fenu | Health Economist |
| Carlos Sharpin | Information Scientist / Research Associate |
| Dr Jennifer Hill | Director |
| Dr John Browne | Methodological Advisor |
| Kathryn Oliver | Research Associate (from Nov 2006-Feb 2007) |
| Ms Susan Murray | Project Manager (from Feb 2006-Apr 2006) |

Conflict of interests (2003 and 2007)

The Guideline Development Group were asked to declare any possible conflict of interest they might have that could interfere with their work on the guideline. No conflicts of interest were declared.

Acknowledgements (2003)

The development of this guideline was greatly assisted by the following people: Professor Nick Black (Consultant on consensus methods), Dr Jacqueline Dutchak, Judith Hayes, Saadia John, Dr Gillian Leng, Laura Price, Christine Sealey, Professor Sir Graham Teasdale, Dr Barry Wall, Sally Williams, Jennifer Wood.

Acknowledgements (2007)

The development of this guideline was greatly assisted by the following people: Linda Brittain; Kelly Dickinson; Nishanthi Talawila; Caroline Lawson, Dr Barry Wall, Matt Stevenson.

Stakeholder involvement

The following stakeholders commented on draft versions of these guidelines (2003):

Brain and Spine Foundation
British Association of Oral and Maxillofacial Surgeons
British Dietetic Association
British Medical Association
British Orthopaedic Association
British Paediatric Neurology Association
British Psychological Society, The
British Society of Rehabilitation Medicine
Department of Health and Welsh Assembly Government
Faculty of Public Health Medicine
Headway - The Brain Injury Association
Independent Healthcare Association
Leeds General Infirmary
Patient Involvement Unit
Royal College of Anaesthetists
Royal College of General Practitioners
Royal College of Nursing
Royal College of Ophthalmologists
Royal College of Paediatrics and Child Health
Royal College of Physicians
Royal College of Psychiatrists
Royal College of Speech and Language Therapists
Society of British Neurological Surgeons
Staffordshire Ambulance HQ
Victim Support
Walton Centre for Neurology and Neurosurgery NHS Trust
Welsh Ambulance Trust Headquarters
Wessex Neurological Centre

Stakeholder Involvement

(2007)

The following stakeholders registered with NICE and were invited to comment on draft versions of these guidelines (2007):

- 5 Boroughs Partnership NHS Trust
- Acute Care Collaborating Centre
- Addenbrooke's NHS Trust
- Adults Strategy and Commissioning Unit
- Aintree Hospitals NHS Trust
- Association for Spina Bifida & Hydrocephalus (ASBAH)
- Association of British Neurologists
- Association of the British Pharmaceuticals Industry,(ABPI)
- Barnsley Acute Trust
- Barnsley PCT
- Biophausia AB
- Bradford & Airedale Primary Care Trust
- British and Irish Orthoptic Society
- British Association for Counselling and Psychotherapy (BACP)
- British Association of Neuroscience Nurses
- British Dietetic Association
- British National Formulary (BNF)
- British Paediatric Mental Health Group of the Royal College of Paediatrics and Child Health
- British Paediatric Neurology Association
- British Paramedic Association
- British Psychological Society
- British Society of Interventional Radiology
- British Society of Neuroradiologists
- British Society of Rehabilitation Medicine
- Calderdale and Huddersfield Acute Trust
- CASPE Research
- Chartered Society of Physiotherapy (CSP)
- Childrens Acute Transport Service
- Chronic Conditions Collaborating Centre
- Clinical Effectiveness Committee
- Clinovia Ltd
- College of Emergency Medicine
- College of Occupational Therapists
- Commission for Social Care Inspection
- Community Practitioners and Health Visitors Association
- Connecting for Health
- Conwy & Denbighshire Acute Trust
- Cornwall Acute Trust
- Cyrenians
- Department for Education and Skills
- Department of Health

- Derbyshire Mental Health Trust
- Dudley Group of Hospitals NHS Trust
- East and North Herts NHS Trust
- Eaton Foundation
- Faculty of Dental Surgery
- Gloucestershire Partnership NHS Trust
- Good Hope Hospitals NHS Trust
- Great Ormond Street Hospital for Children NHS Trust
- Hampshire PCT
- Harrogate and District NHS Foundation Trust
- Headway - The Brain Injury Association
- Health and Safety Executive
- Health Commission Wales
- Healthcare Commission
- Heart of England NHS Foundation Trust
- Help the Hospices
- Hertfordshire Partnership NHS Trust
- Huntleigh Healthcare
- Institute of Physics and Engineering in Medicine
- King's College Acute Trust
- Kingston PCT
- Leeds Teaching Hospitals NHS Trust
- Liverpool PCT
- Luton and Dunstable Hospital NHS Trust
- Maidstone and Tunbridge Wells NHS Trust
- Medicines and Healthcare Products Regulatory Agency (MHRA)
- Mental Health Act Commission
- Mental Health Collaborating Centre
- Mental Health Nurses Association
- National Institute for Mental Health in England (NIMHE)
- National Patient Safety Agency
- National Public Health Service - Wales
- National Treatment Agency for Substance Misuse
- NCC for Cancer
- NCCHTA
- NCEPOD
- NHS Direct
- NHS Health and Social Care Information Centre
- NHS Pathways
- NHS Plus
- NHS Quality Improvement Scotland
- North Cumbria Acute Hospitals NHS Trust
- North Staffordshire Combined Healthcare NHS Trust
- Northwest London Hospitals NHS Trust
- Nottingham City PCT
- Novo Nordisk Limited
- Nursing & Supportive Care Collaborating Centre
- Nutricia Ltd (UK)
- Oxfordshire & Buckinghamshire Mental Health Trust
- Patient and Public Involvement Programme for NICE
- PERIGON (formerly The NHS Modernisation Agency)
- Primary Care Collaborating Centre
- Primary Care Neurology Society
- Regional Public Health Group - London
- Royal College of General Practitioners
- Royal College of Nursing

- Royal College of Paediatrics and Child Health
- Royal College of Pathologists
- Royal College of Physicians of London
- Royal College of Radiologists
- Royal College of Speech and Language Therapists
- Royal National Hospital For Rheumatic Diseases
- Royal United Hospital Bath NHS Trust
- Saracen Care Services
- Scottish Intercollegiate Guidelines Network (SIGN)
- Sheffield Children's Hospital Trust
- Sheffield PCT
- Sheffield Teaching Hospitals NHS Foundation Trust
- Society of British Neurological Surgeons
- South Manchester University Hospitals NHS Trust
- St George's Healthcare NHS Trust
- Staffordshire Ambulance HQ
- Staffordshire Ambulance Service NHS Trust
- Staffordshire Moorlands PCT
- Stockport PCT
- Tameside and Glossop Acute Trust
- The Association of the British Pharmaceutical Industry (ABPI)
- The British Psychological Society
- The Chartered Society of Physiotherapy
- The Confidential Enquiry into Maternal & Child Health (CEMACH)
- The David Lewis Centre
- The North West London Hospitals NHS Trust
- The Robert Jones & Agnes Hunt Orthopaedic & District Hospital NHS Trust
- The Royal Society of Medicine
- The Stroke Association
- Tissue Viability Nurses Association
- UK Specialised Services Public Health Network
- University College London Hospitals (UCLH) Acute Trust
- University Hospital Birmingham NHS Trust
- Vitaline Pharmaceuticals UK Ltd
- Walsall PCT
- Walton Centre for Neurology and Neurosurgery NHS Trust
- Welsh Assembly Government
- Welsh Scientific Advisory Committee (WSAC)
- Wessex Neurological Centre
- Wirral Hospital Acute Trust
- Withybush Hospital
- Women's & Children's Collaborating Centre

Guideline Review Panel (2007)

The Guideline Review Panel is an independent panel that oversees the development of the guideline and takes responsibility for monitoring its quality. The members of the Guideline Review Panel were as follows:

Mr Peter Robb

Consultant ENT Surgeon, Epsom and St Helier University Hospitals and The Royal Surrey County NHS Trusts

Dr Christine Hine

Consultant in Public Health (Acute Commissioning), Bristol and South Gloucestershire PCTs

Mr Mike Baldwin

Project Development Manager, Cardiff Research Consortium

Mr John Seddon

Patient representative

Mrs Jill Freer

Acting Director of Provider Services, NHS Warwickshire

Abbreviations

| | |
|-------------------|---|
| ABC | Airways, breathing, circulation. |
| ALS | Advanced Life Support |
| APLS | Advanced Paediatric Life Support |
| ARR | Absolute risk reduction |
| ATLS | Advanced trauma life support |
| AVPU | AVPU score |
| BLS | Basic Life Support |
| CT | Computed tomography |
| CC | Cerebral Contusions |
| CCR | Canadian Cervical Spine Rule |
| ED | Emergency Department |
| EMD | Emergency Medical Dispatch |
| EPLS | European Paediatric Life Support |
| GCS | Glasgow Coma Scale or Score |
| GCS(Paed) | Paediatric version of the GCS |
| GDG | Guideline Development Group |
| GOS | Glasgow Outcome Scale |
| HTA | Health Technology Assessment |
| ICH | Intracranial Haematoma |
| JRCALC | Joint Royal Colleges Ambulance Liaison Committee |
| ITLS | International Trauma Life Support |
| LOC | Level of Consciousness |
| MRI | Magnetic Resonance Imaging |
| NEXUS | National Emergency X-Radiography Utilization Study |
| NHS | National Health Service |
| NICE | National Institute for Health and Clinical Excellence |
| NAI | Non-accidental injury |
| NRPB | National Radiological Protection Board |
| QALY | Quality Adjusted Life Year |
| PEPP | Paediatric Education for Pre-hospital Professionals |
| PHPLS | Pre-hospital Paediatric Life Support course |
| PHTLS | Pre-hospital Trauma Life Support course |
| PRCT | Prospective Randomised Controlled Trial |
| TBI | Traumatic Brain Injury |
| TICH | Traumatic Intracerebral Haemorrhage |
| SICH | Spontaneous Intracerebral Haemorrhage |
| STICH | Surgical Trial in Intracerebral Haemorrhage |

Glossary

| | |
|---|--|
| Absolute risk | Measures the probability of an event or outcome occurring (for example, an adverse reaction to the drug being tested) in the group of people under study. Studies that compare two or more groups of patients may report results in terms of the <i>Absolute Risk Reduction</i> . |
| Absolute Risk Reduction (ARR) | The ARR is the difference in the risk of an event occurring between two groups of patients in a study – for example if 6% of patients die after receiving a new experimental drug and 10% of patients die after having the old drug treatment then the ARR is 10% - 6% = 4%. Thus by using the new drug instead of the old drug 4% of patients can be prevented from dying. Here the ARR measures the risk reduction associated with a new treatment. See also <i>Absolute risk</i> . |
| Acute sector | Hospital-based health services which are provided on an in-patient, day case or out-patient basis. |
| Advanced Paediatric Life Support (APLS) course | A course for healthcare professionals run by the Advanced Life Support Group which teaches a practical systematic approach to the management of acutely ill or injured babies and children. (See http://www.alsg.org) |
| Advanced Trauma Life Support (ATLS) course | A course with the aim to teach a simple systematic approach to the management of trauma patients through interactive tutorials, skills teaching and simulated patient management scenarios. (see http://www.rcseng.ac.uk/education/courses/trauma_life_support_advanced.html) |
| Algorithm (in guidelines) | A flow chart of the clinical decision pathway described in the guideline, where decision points are represented with boxes, linked with arrows. |
| Allocation concealment | The process used to prevent advance knowledge of group assignment in a randomised controlled trial (RCT). The allocation process should be impervious to any influence by the individual making the allocation, by being administered by someone who is not responsible for recruiting participants. |
| Amnesia | Partial or total loss of memory, usually resulting from shock, psychological disturbance, brain injury, or illness. |
| Applicability | The extent to which the results of a study or review can be applied to the target population for a clinical guideline. |
| Appraisal of evidence | Formal assessment of the quality of research evidence and its relevance to the clinical question or guideline under consideration, according to predetermined criteria. |
| ARR | See <i>Absolute Risk Reduction</i> . |
| Basal skull fracture | A fracture involving the base of the cranium. |
| Battle's sign | Bruising which sometimes occurs behind the ear in cases of fracture of the base of the skull (basal skull fracture). |
| Best available evidence | The strongest research evidence available to support a particular guideline recommendation. |
| Bias | Influences on a study that can lead to invalid conclusions about a treatment or intervention. Bias in research can make a treatment look better or worse than it really is. Bias can even make it look as if the treatment works when it actually doesn't. Bias can occur by chance or as a result of <i>systematic</i> errors in the design and execution of a study. Bias can occur at different stages in the research process, for example, in the collection, analysis, interpretation, publication or review of research data. For examples see <i>Selection bias</i> , <i>Performance bias</i> , <i>Information bias</i> , <i>Confounding</i> , <i>Publication bias</i> . |
| Blinding or masking | The practice of keeping the investigators or subjects of a study ignorant of the group to which a subject has been assigned. For example, a clinical trial in which the participating patients or their doctors are unaware of whether they (the |

| | |
|------------------------------------|--|
| | patients) are taking the experimental drug or a placebo (dummy treatment). The purpose of 'blinding' or 'masking' is to protect against <i>bias</i> . See also <i>Double blind study</i> , <i>Single blind study</i> , <i>Triple blind study</i> . |
| C-spine | Cervical spine or bony part of the neck |
| Case-control study | A study that starts with the identification of a group of individuals sharing the same characteristics (for example, people with a particular disease) and a suitable comparison (control) group (for example, people without the disease). All subjects are then assessed with respect to things that happened to them in the past, for example, things that might be related to getting the disease under investigation. Such studies are also called <i>retrospective</i> as they look back in time from the outcome to the possible causes. |
| Case report (or case study) | Detailed report on one patient (or case), usually covering the course of that person's disease and their response to treatment. |
| Case series | Description of several cases of a given disease, usually covering the course of the disease and the response to treatment. There is no comparison (<i>control</i>) group of patients. |
| Causal relationship | Describes the relationship between two <i>variables</i> whenever it can be established that one causes the other. For example there is a causal relationship between a treatment and a disease if it can be shown that the treatment changes the course or outcome of the disease. Usually <i>randomised controlled trials</i> are needed to ascertain causality. Proving cause and effect is much more difficult than just showing an association between two variables. For example, if it happened that everyone who had eaten a particular food became sick, and everyone who avoided that food remained well, then the food would clearly be associated with the sickness. However, even if leftovers were found to be contaminated, it could not be proved that the food caused the sickness – unless all other possible causes (for example, environmental factors) had been ruled out. |
| Cerebrospinal fluid (CSF) | Clear fluid which is continuously being produced and absorbed by and in the brain, flowing in the ventricles (cavities) within the brain and around the surface of the brain and spinal cord |
| CSF otorrhea | Escape of CSF from the brain into the ear canal |
| Cervical spine | The cervical spine is the area of the vertebral column commonly referred to as the neck. The cervical spine is made up of seven vertebrae, referred to by 'C', appended with an identifying number. The number indicates the level of the spine in which the particular vertebra is located. The top vertebra is C1, the lowest C7 |
| Cervico-dorsal junction | The junction between the bottom of the cervical spine and the top of the dorsal (or <i>thoracic</i>) spine. |
| Clinical audit | A <i>systematic</i> process for setting and monitoring standards of clinical care. Whereas 'guidelines' define what the best clinical practice should be, 'audit' investigates whether best practice is being carried out. Clinical audit can be described as a cycle or spiral. Within the cycle there are stages that follow a systematic process of establishing best practice, measuring care against specific criteria, taking action to improve care, and monitoring to sustain improvement. The spiral suggests that as the process continues, each cycle aspires to a higher level of quality. |
| Clinical decision rule | A clinical decision rule/clinical prediction rule is generated by initially examining, and ultimately combining, a number of variables to predict the likelihood of a current diagnosis of a future event. Sometimes, if the likelihood is sufficiently high or low, the rule generates a suggested course of action ¹ . |
| Clinical effectiveness | The extent to which a specific treatment or intervention, when used under <u>usual or everyday conditions</u> , has a beneficial effect on the course or outcome of disease compared to no treatment or other routine care. (Clinical trials that assess effectiveness are sometimes called management trials.) Clinical 'effectiveness' is not the same as <i>efficacy</i> . |
| Clinical impact | The effect that a guideline recommendation is likely to have on the treatment, or treatment outcomes, of the target population. |

| | |
|----------------------------------|--|
| Clinical question | This term is sometimes used in guideline development work to refer to the questions about treatment and care that are formulated in order to guide the search for research evidence. When a clinical question is formulated in a precise way, it is called a <i>focused question</i> . |
| Clinical trial | A research study conducted with patients which tests out a drug or other intervention to assess its effectiveness and safety. Each trial is designed to answer scientific questions and to find better ways to treat individuals with a specific disease. This general term encompasses <i>controlled clinical trials</i> and <i>randomised controlled trials</i> . |
| Clinician | A healthcare professional providing patient care, for example, doctor, nurse, physiotherapist. |
| Closed head injury | A blow to the head or a severe shaking causing tearing, shearing or stretching of the nerves at the base of the brain, blood clots in or around the brain or oedema (swelling) of the brain. There is no penetration of the skull or brain tissue by an object; the skull may be fractured but this does not result in a direct connection between the brain and the outside. (see Penetrating Brain Injury) |
| Cluster randomisation | A study in which groups of individuals (for example, patients in a General Practitioner surgery or on a hospital ward) are randomly allocated to treatment groups. Take, for example, a smoking cessation study of two different interventions – leaflets and teaching sessions. Each General Practitioner surgery within the study would be randomly allocated to administer one of the two interventions. See also <i>Cluster</i> , <i>Cluster design</i> . |
| Coagulopathy | A condition affecting the blood's ability to form a clot. |
| Cochrane Collaboration | An international organisation in which people find, appraise and review specific types of studies called <i>randomised controlled trials</i> . The Cochrane Database of Systematic Reviews contains regularly updated reviews on a variety of health issues and is available electronically as part of the <i>Cochrane Library</i> . |
| Cochrane Library | The Cochrane Library consists of a regularly updated collection of evidence-based medicine databases including the Cochrane Database of Systematic Reviews (reviews of <i>randomised controlled trials</i> prepared by the Cochrane Collaboration). The Cochrane Library is available on CD-ROM and the Internet. |
| Cohort | A group of people sharing some common characteristic (for example, patients with the same disease), followed up in a research study for a specified period of time. |
| Cohort study | An observational study that takes a group (cohort) of patients and follows their progress over time in order to measure outcomes such as disease or mortality rates and make comparisons according to the treatments or interventions that patients received. Thus within the study group, subgroups of patients are identified (from information collected about patients) and these groups are compared with respect to outcome, for example, comparing mortality between one group that received a specific treatment and one group which did not (or between two groups that received different levels of treatment). Cohorts can be assembled in the present and followed into the future (a 'concurrent' or 'prospective' cohort study) or identified from past records and followed forward from that time up to the present (a 'historical' or 'retrospective' cohort study). Because patients are not randomly allocated to subgroups, these subgroups may be quite different in their characteristics and some adjustment must be made when analysing the results to ensure that the comparison between groups is as fair as possible. |
| Coma | A sleep-like state in which a person is not conscious. |
| Co-morbidity | Co-existence of a disease or diseases in the people being studied in addition to the health problem that is the subject of the study. |
| Community health services | General Practice, ambulance crews, NHS walk-in centres and dental practitioners. |
| Concussion | The common result of a blow to the head or sudden deceleration usually causing an altered mental state, either temporary or prolonged. Physiological and/or anatomical disruption of connections between some nerve cells in the brain may occur. Often used by the public to refer to a brief loss of consciousness. |
| Confidence interval | A way of expressing certainty about the findings from a study or group of studies, using statistical techniques. A confidence interval describes a range of possible effects (of a treatment or intervention) that are consistent with the results of a study or group of studies. A wide confidence interval indicates a lack of certainty or precision about the true size of the clinical effect and is seen in studies with too few patients. Where confidence intervals are narrow they indicate more precise estimates of effects and a larger sample of patients studied. It is usual to interpret a '95%' confidence interval as the range of effects within which we are 95% |

| | |
|---|---|
| | confident that the true effect lies. |
| Confounder or confounding factor | Something that influences a study and can contribute to misleading findings if it is not understood or appropriately dealt with. For example, if a group of people exercising regularly and a group of people who do not exercise have an important age difference then any difference found in outcomes about heart disease could well be due to one group being older than the other rather than due to the exercising. Age is the confounding factor here and the effect of exercising on heart disease cannot be assessed without adjusting for age differences in some way. |
| Consciousness | An alert cognitive state in which you are aware of yourself and your situation |
| Consensus development conference | A technique used for the purpose of reaching an agreement on a particular issue. It involves bringing together a group of about 10 people who are presented with evidence by various interest groups or experts who are not part of the decision making group. The group then retires to consider the questions in the light of the evidence presented and attempts to reach a consensus. See also <i>Consensus methods</i> . |
| Consensus methods | A variety of techniques that aim to reach an agreement on a particular issue. Formal consensus methods include <i>Delphi</i> and <i>nominal group</i> techniques, and <i>consensus development conferences</i> . In the development of clinical guidelines, consensus methods may be used where there is a lack of strong research evidence on a particular topic. |
| Consistency | The extent to which the conclusions of a collection of studies used to support a guideline recommendation are in agreement with each other. See also <i>Homogeneity</i> . |
| Control group | A group of patients recruited into a study that receives no treatment, a treatment of known effect, or a placebo (dummy treatment) - in order to provide a comparison for a group receiving an experimental treatment, such as a new drug. |
| Controlled clinical trial (CCT) | A study testing a specific drug or other treatment involving two (or more) groups of patients with the same disease. One (the experimental group) receives the treatment that is being tested, and the other (the comparison or control group) receives an alternative treatment, a placebo (dummy treatment) or no treatment. The two groups are followed up to compare differences in outcomes to see how effective the experimental treatment was. A CCT where patients are randomly allocated to treatment and comparison groups is called a <i>randomised controlled trial</i> . |
| Cost benefit analysis | A type of <i>economic evaluation</i> where both costs and benefits of healthcare treatment are measured in the same monetary units. If benefits exceed costs, the evaluation would recommend providing the treatment. |
| Cost effectiveness | A type of <i>economic evaluation</i> that assesses the additional costs and benefits of doing something different. In cost effectiveness analysis, the costs and benefits of different treatments are compared. When a new treatment is compared with current care, its additional costs divided by its additional benefits is called the cost effectiveness ratio. Benefits are measured in natural units, for example, cost per additional heart attack prevented. |
| Cost utility analysis | A special form of <i>cost effectiveness</i> analysis where benefit is measured in <i>quality adjusted life years</i> . A treatment is assessed in terms of its ability to extend or improve the quality of life. |
| Cranial | Pertaining to the cranium. |
| Craniocervical junction | The junction between the base of the skull and the top of the cervical spine. |
| Crossover study design | A study comparing two or more interventions in which the participants, upon completion of the course of one treatment, are switched to another. For example, for a comparison of treatments A and B, half the participants are randomly allocated to receive them in the order A, B and half to receive them in the order B, A. A problem with this study design is that the effects of the first treatment may carry over into the period when the second is given. Therefore a crossover study should include an adequate 'wash-out' period, which means allowing sufficient time between stopping one treatment and starting another so that the first treatment has time to wash out of the patient's system. |
| Cross-sectional study | The observation of a defined set of people at a single point in time or time period – a snapshot. (This type of study contrasts with a <i>longitudinal study</i> which follows a set of people over a period of time.) |
| Data set | A list of required information relating to a specific disease. |
| Decision analysis | A systematic way of reaching decisions, based on evidence from research. This evidence is translated into probabilities, and then into diagrams or decision trees |

| | |
|---|--|
| | which direct the clinician through a succession of possible scenarios, actions and outcomes. |
| Diagnostic study | A study to assess the effectiveness of a test or measurement in terms of its ability to accurately detect or exclude a specific disease. |
| Double blind study | A study in which neither the subject (patient) nor the observer (investigator/clinician) is aware of which treatment or intervention the subject is receiving. The purpose of blinding is to protect against bias. |
| Drowsiness | A state of impaired awareness associated with a desire or inclination to sleep. |
| Dura Mater | The thick lining of the brain and spinal cord |
| Economic evaluation | Comparative analysis of alternative courses of action in terms of both their costs and consequences. |
| Effectiveness | See <i>Clinical effectiveness</i> . |
| Efficacy | The extent to which a specific treatment or intervention, under <u>ideally controlled conditions</u> (for example, in a laboratory), has a beneficial effect on the course or outcome of disease compared to no treatment or other routine care. |
| Elective | Name for clinical procedures that are regarded as advantageous to the patient but not urgent. |
| Emergency Department (ED or A&E) | A clinical department in a district general or teaching hospital which has trained staff and equipment able to receive, resuscitate, investigate and initially manage the full spectrum of emergencies. Most units accept patients of all ages, some are restricted to adults, others to children. All should be open at all times and all its facilities should be available at all times. |
| Emergency Department Clinician | A medically qualified member of an emergency department or an appropriately trained nurse working in an emergency department. |
| Empirical | Based directly on experience (observation or experiment) rather than on reasoning alone. |
| Epidemiology | Study of diseases within a population, covering the causes and means of prevention. |
| European Paediatric Life Support course (EPLS) | The EPLS provider course is intended to provide training for multi-disciplinary healthcare professionals in the early recognition of the child in respiratory or circulatory failure and the development of the knowledge and core skills required to intervene to prevent further deterioration towards respiratory or cardiorespiratory arrest. (see http://www.resus.org.uk) |
| Event rate | The proportion of patients in a group for whom a specified health event or outcome is observed. Thus, if out of 100 patients, the event is observed in 27, the event rate is 0.27 or 27%. Control Event Rate (CER) and Experimental Event Rate (EER) are the terms used in <i>control</i> and <i>experimental</i> groups of patients respectively. |
| Evidence based clinical practice | Evidence based clinical practice involves making decisions about the care of individual patients based on the best research evidence available rather than basing decisions on personal opinions or common practice (which may not always be evidence based). Evidence based clinical practice therefore involves integrating individual clinical expertise and patient preferences with the best available evidence from research |
| Evidence table | A table summarising the results of a collection of studies which, taken together, represent the evidence supporting a particular recommendation or series of recommendations in a guideline. |
| Exclusion criteria | See <i>Selection criteria</i> . |
| Experimental study | A research study designed to test if a treatment or intervention has an effect on the course or outcome of a condition or disease - where the conditions of testing are to some extent under the control of the investigator. <i>Controlled clinical trial</i> and <i>randomised controlled trial</i> are examples of experimental studies. |
| Experimental treatment | A treatment or intervention (for example, a new drug) being studied to see if it has an effect on the course or outcome of a condition or disease. |
| External validity | The degree to which the results of a study hold true in non-study situations, for example, in routine clinical practice. May also be referred to as the <i>generalisability</i> of study results to non-study patients or populations. |
| Extradural (or epidural) | A collection of blood between the skull inner surface and the dura mater caused by damage to the blood vessels running on the surface of the dura mater – often |

| | |
|------------------------------------|--|
| haemorrhage | associated with a fracture of the skull. The underlying brain injury may not be severe initially but the increasing pressure caused by the bleeding inflicts further damage. |
| Extradural space | The space on the outer side of the dura mater. |
| Extrapolation | The application of research evidence based on studies of a specific population to another population with similar characteristics. |
| Focal Neurological Deficit | A neurological deficit restricted to a particular part of the body or a particular activity |
| Forest plot | A graphical display of results from individual studies on a common scale, allowing visual comparison of results and examination of the degree of <i>heterogeneity</i> between studies. |
| Funnel plot | Funnel plots are simple scatter plots on a graph. They show the treatment effects estimated from separate studies on the horizontal axis against a measure of sample size on the vertical axis. <i>Publication bias</i> may lead to asymmetry in funnel plots. |
| Generalisability | The extent to which the results of a study hold true for a population of patients beyond those who participated in the research. See also <i>External validity</i> . |
| Glasgow Coma Scale | A standardised system used to assess the degree of brain impairment and to identify the seriousness of injury in relation to outcome. The system involves three determinants: eye opening, verbal responses and motor response all of which are evaluated independently according to a numerical value that indicates the level of consciousness and degree of dysfunction. |
| Gold standard | A method, procedure or measurement that is widely accepted as being the best available. |
| Haematoma | An accumulation of blood in or under the tissues. |
| Haemotympanum | A collection of blood in the middle ear space |
| Health economics | A field of conventional economics which examines the benefits of healthcare interventions (for example, medicines) compared with their financial costs. |
| Heterogeneity | Or lack of <i>homogeneity</i> . The term is used in <i>meta-analyses</i> and <i>systematic reviews</i> when the results or estimates of effects of treatment from separate studies seem to be very different – in terms of the size of treatment effects or even to the extent that some indicate beneficial and others suggest adverse treatment effects. Such results may occur as a result of differences between studies in terms of the patient populations, outcome measures, definition of <i>variables</i> or duration of follow-up. |
| Hierarchy of evidence | An established hierarchy of study types, based on the degree of certainty that can be attributed to the conclusions that can be drawn from a well conducted study. Well-conducted <i>randomised controlled trials</i> (RCTs) are at the top of this hierarchy. (Several large statistically significant RCTs which are in agreement represent stronger evidence than say one small RCT.) Well-conducted studies of patients' views and experiences would appear at a lower level in the hierarchy of evidence. |
| Homogeneity | This means that the results of studies included in a <i>systematic review</i> or <i>meta analysis</i> are similar and there is no evidence of <i>heterogeneity</i> . Results are usually regarded as homogeneous when differences between studies could reasonably be expected to occur by chance. See also <i>Consistency</i> . |
| Hyperventilation | Abnormally rapid breathing. Hyperventilation results in excessive intake of oxygen and increased elimination of carbon dioxide, which may eventually lead to a disturbance in the blood chemistry. |
| Hypoglycaemia | Abnormally low levels of glucose in the blood, leading to muscular weakness, confusion, sweating and, in severe cases, coma. Hypoglycaemia is a complication of many anti-diabetic treatments. |
| Inclusion criteria | See <i>Selection criteria</i> . |
| Infant | Aged under 1 year. |
| Intention to treat analysis | An analysis of a clinical trial where patients are analysed according to the group to which they were initially randomly allocated, regardless of whether or not they had dropped out, fully complied with the treatment, or crossed over and received the |

| | |
|-------------------------------------|--|
| | alternative treatment. Intention-to-treat analyses are favoured in assessments of clinical effectiveness as they mirror the non-compliance and treatment changes that are likely to occur when the treatment is used in practice. |
| Internal validity | Refers to the integrity of the study design. |
| Intervention | Healthcare action intended to benefit the patient, for example, drug treatment, surgical procedure, psychological therapy, etc. |
| Interventional procedure | A procedure used for diagnosis or treatment that involves making a cut or hole in the patient's body, entry into a body cavity or using electromagnetic radiation (including X-rays or lasers). The National Institute for Health and Clinical Excellence (NICE) has the task of producing guidance about whether specific interventional procedures are safe enough and work well enough for routine use. |
| Intracranial | Originating within the cranial (brain) cavity. |
| Intracranial haematoma | A collection of blood inside the cranium caused by damage to brain tissue or the rupture of a blood vessel. The resulting swelling can compress the brain. |
| Intracerebral haemorrhage | A bleed inside the brain tissue. |
| Intracranial lesion | A lesion of the brain. |
| Literature review | A process of collecting, reading and assessing the quality of published (and unpublished) articles on a given topic. |
| Longitudinal study | A study of the same group of people at more than one point in time. (This type of study contrasts with a <i>cross sectional study</i> which observes a defined set of people at a single point in time.) |
| Mandible | The lower jaw as a functional unit, regardless of which bones or cartilage make up the lower jaw in a particular organism. |
| Meningism | Stiffness of the neck associated with backwards extension of the cervical spine. |
| Meta analysis | Results from a collection of independent studies (investigating the same treatment) are pooled, using statistical techniques to synthesise their findings into a single estimate of a treatment effect. Where studies are not compatible for example, because of differences in the study populations or in the outcomes measured, it may be inappropriate or even misleading to statistically pool results in this way. See also <i>Systematic review & Heterogeneity</i> . |
| Methodology | The overall approach of a research project, for example, the study will be a <i>randomised controlled trial</i> , of 200 people, over one year. |
| Methodological quality | The extent to which a study has conformed to recognised good practice in the design and execution of its research methods. |
| Monte Carlo simulation | A modelling technique that uses random numbers to capture the effects of uncertainty. Multiple simulations are run (usually somewhere between 1,000 and 10,000). For each simulation, the value of each uncertain variable in the analysis is selected at random from a probability distribution for the value of that variable. The simulation results are compiled, providing a probability distribution for the overall result. |
| Motor response | Movement in response to an external stimulus |
| Multicentre study | A study where subjects were selected from different locations or populations, for example, a co-operative study between different hospitals; an international collaboration involving patients from more than one country. |
| Negative predictive value | The proportion of individuals with a negative test result who do NOT have the disease. |
| Neurorehabilitation services | A programme of clinical and vocational services with the goal of returning brain injured patients to a satisfying occupation. |
| Neurosurgery | A surgical specialty for the treatment of diseases and disorders of the brain, spinal cord and nerves. |
| Non-experimental study | A study based on subjects selected on the basis of their availability, with no attempt having been made to avoid problems of bias. |
| Non-systematic review | See Review. |
| Objective measure | A measurement that follows a standardised procedure which is less open to subjective interpretation by potentially biased observers and study participants. |
| Observational study | In research about diseases or treatments, this refers to a study in which nature is allowed to take its course. Changes or differences in one characteristic (for example, whether or not people received a specific treatment or intervention) are studied in relation to changes or differences in other(s) (for example, whether or not they died), without the intervention of the investigator. There is a greater risk of |

| | |
|----------------------------------|---|
| | <i>selection bias</i> than in <i>experimental studies</i> . |
| Occipital condyle | The articulation point between the skull and the first cervical vertebra. |
| Odds ratio | Odds are a way of representing probability, especially familiar for betting. In recent years odds ratios have become widely used in reports of clinical studies. They provide an estimate (usually with a <i>confidence interval</i>) for the effect of a treatment. Odds are used to convey the idea of 'risk' and an odds ratio of 1 between two treatment groups would imply that the risks of an adverse outcome were the same in each group. For rare events the odds ratio and the <i>relative risk</i> (which uses actual risks and not odds) will be very similar. See also <i>Relative risk</i> , <i>Risk ratio</i> . |
| Outcome | The end result of care and treatment and/ or rehabilitation. In other words, the change in health, functional ability, symptoms or situation of a person, which can be used to measure the effectiveness of care/ treatment/ rehabilitation. Researchers should decide what outcomes to measure before a study begins; outcomes are then assessed at the end of the study. |
| Paediatric | Pertaining to children and infants |
| Paraesthesia | Abnormal sensation such as burning or tingling due to a disorder of the sensory nervous system. |
| Penetrating head injury | Head injury where an object penetrates the scalp and skull and enters the brain or its lining. |
| Performance bias | Systematic differences in care provided apart from the intervention being evaluated. For example, if study participants know they are in the <i>control group</i> they may be more likely to use other forms of care; people who know they are in the experimental group may experience <i>placebo effects</i> , and care providers may treat patients differently according to what group they are in. Masking (<i>blinding</i>) of both the recipients and providers of care is used to protect against performance bias. |
| Periorbital haematoma | Bleeding around or behind the eyes. |
| Pilot study | A small scale 'test' of the research instrument. For example, testing out (piloting) a new questionnaire with people who are similar to the population of the study, in order to highlight any problems or areas of concern, which can then be addressed before the full scale study begins. |
| Placebo | Placebos are fake or inactive treatments received by participants allocated to the <i>control group</i> in a clinical trial which are indistinguishable from the active treatments being given in the experimental group. They are used so that participants are ignorant of their treatment allocation in order to be able to quantify the effect of the experimental treatment over and above any <i>placebo effect</i> due to receiving care or attention. |
| Placebo effect | A beneficial (or adverse) effect produced by a <i>placebo</i> and not due to any property of the <i>placebo</i> itself. |
| Positive predictive value | The proportion of individuals with a positive test result who actually have the disease. |
| Power | See <i>Statistical power</i> . |
| Primary care | Healthcare delivered to patients outside hospitals. Primary care covers a range of services provided by General Practitioners, nurses and other healthcare professionals, dentists, pharmacists and opticians. |
| Probability | How likely an event is to occur, for example, how likely a treatment or intervention will alleviate a symptom. |
| Prognostic factor | Patient or disease characteristics, for example, age or <i>co-morbidity</i> , which influence the course of the disease under study. In a randomised trial to compare two treatments, chance imbalances in <i>variables</i> (prognostic factors) that influence patient outcome are possible, especially if the size of the study is fairly small. In terms of analysis these prognostic factors become <i>confounding factors</i> . See also <i>Prognostic marker</i> . |
| Prognostic marker | A <i>prognostic factor</i> used to assign patients to categories for a specified purpose – for example, for treatment, or as part of a clinical trial, according to the likely progression of the disease. For example, the purpose of randomisation in a clinical trial is to produce similar treatment groups with respect to important <i>prognostic factors</i> . This can often be achieved more efficiently if randomisation takes place within subgroups defined by the most important prognostic factors. Thus if age was very much related to patient outcome then separate randomisation schemes would |

| | |
|--|---|
| | be used for different age groups. This process is known as stratified random allocation. |
| Prospective study | A study in which people are entered into the research and then followed up over a period of time with future events recorded as they happen. This contrasts with studies that are <i>retrospective</i> . |
| Publication bias | Studies with statistically significant results are more likely to get published than those with non-significant results. <i>Meta-analyses</i> that are exclusively based on published literature may therefore produce biased results. This type of bias can be assessed by a <i>funnel plot</i> . |
| P value | If a study is done to compare two treatments then the <i>P</i> value is the probability of obtaining the results of that study, or something more extreme, if there really was no difference between treatments. (The assumption that there really is no difference between treatments is called the 'null hypothesis'.) Suppose the <i>P</i> -value was $P=0.03$. What this means is that if there really was no difference between treatments then there would only be a 3% chance of getting the kind of results obtained. Since this chance seems quite low we should question the validity of the assumption that there really is no difference between treatments. We would conclude that there probably is a difference between treatments. By convention, where the value of <i>P</i> is below 0.05 (that is, less than 5%) the result is seen as statistically significant. Where the value of <i>P</i> is 0.001 or less, the result is seen as highly significant. <i>P</i> values just tell us whether an effect can be regarded as statistically significant or not. In no way do they relate to how big the effect might be, for which we need the <i>confidence interval</i> . |
| Qualitative research | Qualitative research is used to explore and understand people's beliefs, experiences, attitudes, behaviour and interactions. It generates non-numerical data, for example, a patient's description of their pain rather than a measure of pain. In healthcare, qualitative techniques have been commonly used in research documenting the experience of chronic illness and in studies about the functioning of organisations. Qualitative research techniques such as <i>focus groups</i> and <i>in depth interviews</i> have been used in one-off projects commissioned by guideline development groups to find out more about the views and experiences of patients and carers. |
| Quality adjusted life years (QALYS) | A measure of health outcome. QALYS are calculated by estimating the total life-years gained from a treatment and weighting each year with a quality of life score. |
| Quantitative research | Research that generates numerical data or data that can be converted into numbers, for example clinical trials or the national Census which counts people and households. |
| Quasi experimental study | A study designed to test if a treatment or intervention has an effect on the course or outcome of disease. It differs from a <i>controlled clinical trial</i> and a <i>randomised controlled trial</i> in that: a) the assignment of patients to treatment and comparison groups is not done randomly, or patients are not given equal probabilities of selection, or b) the investigator does not have full control over the allocation and/or timing of the intervention, but nonetheless conducts the study as if it were an experiment, allocating subjects to treatment and comparison groups. |
| Random allocation or Randomisation | A method that uses the play of chance to assign participants to comparison groups in a research study, for example, by using a random numbers table or a computer-generated random sequence. Random allocation implies that each individual (or each unit in the case of <i>cluster randomisation</i>) being entered into a study has the same chance of receiving each of the possible interventions. |
| Randomised controlled trial | A study to test a specific drug or other treatment in which people are randomly assigned to two (or more) groups: one (the experimental group) receiving the treatment that is being tested, and the other (the comparison or control group) receiving an alternative treatment, a placebo (dummy treatment) or no treatment. The two groups are followed up to compare differences in outcomes to see how effective the experimental treatment was. (Through randomisation, the groups should be similar in all aspects apart from the treatment they receive during the study.) |
| Rehabilitation | A programme of clinical and vocational services with the goal of returning patients |

| | |
|----------------------------------|--|
| services | to a satisfying occupation. |
| Relative risk | A summary measure which represents the ratio of the risk of a given event or outcome (for example, an adverse reaction to the drug being tested) in one group of subjects compared to another group. When the 'risk' of the event is the same in the two groups the relative risk is 1. In a study comparing two treatments, a relative risk of 2 would indicate that patients receiving one of the treatments had twice the risk of an undesirable outcome than those receiving the other treatment. Relative risk is sometimes used as a synonym for <i>risk ratio</i> . |
| Reliability | Reliability refers to a method of measurement that consistently gives the same results. For example someone who has a high score on one occasion tends to have a high score if measured on another occasion very soon afterwards. With physical assessments it is possible for different clinicians to make independent assessments in quick succession – and if their assessments tend to agree then the method of assessment is said to be reliable. |
| Retrospective study | A retrospective study deals with the present/ past and does not involve studying future events. This contrasts with studies that are <i>prospective</i> . |
| Review | Summary of the main points and trends in the research literature on a specified topic. A review is considered non-systematic unless an extensive literature search has been carried out to ensure that all aspects of the topic are covered and an objective appraisal made of the quality of the studies. |
| Risk ratio | Ratio of the risk of an undesirable event or outcome occurring in a group of patients receiving experimental treatment compared with a comparison (control) group. The term <i>relative risk</i> is sometimes used as a synonym of risk ratio. |
| Sample | A part of the study's target population from which the subjects of the study will be recruited. If subjects are drawn in an unbiased way from a particular population, the results can be generalised from the sample to the population as a whole. |
| Sampling | Refers to the way participants are selected for inclusion in a study. |
| Sampling frame | A list or register of names which is used to recruit participants to a study. |
| Secondary care | Care provided in hospitals. |
| Seizure | An uncontrolled discharge of nerve impulses which may spread throughout the brain. It usually lasts only a few minutes. It may be associated with loss of consciousness or loss of bowel and bladder control. |
| Selection bias | Selection bias has occurred if: the characteristics of the <i>sample</i> differ from those of the wider population from which the sample has been drawn OR there are systematic differences between comparison groups of patients in a study in terms of prognosis or responsiveness to treatment. |
| Selection criteria | Explicit standards used by guideline development groups to decide which studies should be included and excluded from consideration as potential sources of evidence. |
| Semi-structured interview | Structured interviews involve asking people pre-set questions. A semi-structured interview allows more flexibility than a structured interview. The interviewer asks a number of open-ended questions, following up areas of interest in response to the information given by the respondent. |
| Sensitivity | In diagnostic testing, it refers to the chance of having a positive test result given that you have the disease. 100% sensitivity means that all those with the disease will test positive, but this is not the same the other way around. A patient could have a positive test result but not have the disease – this is called a 'false positive'. The sensitivity of a test is also related to its 'negative predictive value' (true negatives) – a test with a sensitivity of 100% means that all those who get a negative test result do not have the disease. To fully judge the accuracy of a test, its <i>Specificity</i> must also be considered. |
| Sequelae | Plural of sequela, which is any abnormal condition that occurs subsequent to and/or is caused by disease, injury, or treatment. |
| Single blind study | A study in which <u>either</u> the subject (patient/participant) <u>or</u> the observer (clinician/investigator) is not aware of which treatment or intervention the subject is receiving. |
| Specific indication | When a drug or a device has a specific remit to treat a specific condition and is not licensed for use in treating other conditions or diseases. |
| Specificity | In diagnostic testing, it refers to the chance of having a negative test result given that you do not have the disease. 100% specificity means that all those without the disease will test negative, but this is not the same the other way around. A patient |

| | |
|--|--|
| | could have a negative test result yet still have the disease – this is called a ‘false negative’. The specificity of a test is also related to its ‘positive predictive value’ (true positives) – a test with a specificity of 100% means that all those who get a positive test result definitely have the disease. To fully judge the accuracy of a test, its <i>Sensitivity</i> must also be considered. |
| Standard deviation | A measure of the spread, scatter or variability of a set of measurements. Usually used with the mean (average) to describe numerical data. |
| Stand by call | Contact between a paramedic or other healthcare worker and an emergency department, by telephone or radio, to alert the department to the impending arrival of a seriously ill or injured patient who will require immediate resuscitation. |
| Statistical power | The ability of a study to demonstrate an association or causal relationship between two <i>variables</i> , given that an association exists. For example, 80% power in a clinical trial means that the study has a 80% chance of ending up with a <i>P</i> value of less than 5% in a statistical test (that is, a statistically significant treatment effect) if there really was an important difference (for example, 10% versus 5% mortality) between treatments. If the statistical power of a study is low, the study results will be questionable (the study might have been too small to detect any differences). By convention, 80% is an acceptable level of power. See also <i>P</i> value. |
| Structured interview | A research technique where the interviewer controls the interview by adhering strictly to a questionnaire or interview schedule with pre-set questions. |
| Study checklist | A list of questions addressing the key aspects of the research methodology that must be in place if a study is to be accepted as valid. A different checklist is required for each study type. These checklists are used to ensure a degree of consistency in the way that studies are evaluated. |
| Study population | People who have been identified as the subjects of a study. |
| Study quality | See <i>Methodological quality</i> . |
| Study type | The kind of design used for a study. <i>Randomised controlled trial</i> , <i>case-control study</i> , <i>cohort study</i> are all examples of study types. |
| Sub-group analysis | An analysis in which the intervention effect is evaluated in a defined subset of the participants in the trial, or in complementary subsets, such as by sex or in age categories. |
| Subdural space | The space beneath the dura mater, between it and the much thinner <i>arachnoid mater</i> . This is often the area of rupture of delicate thin-walled veins following head injuries. |
| Subdural haematoma (or haemorrhage) | A collection of blood between the dura mater and the arachnoid mater caused by traumatic damage to the associated brain and blood vessels. The rise in pressure caused by such bleeding can cause further significant damage |
| Subject | A person who takes part in an experiment or research study. |
| Subluxation | A partial dislocation of a joint in which the joint surfaces remain in contact, albeit out of alignment. |
| Survey | A study in which information is systematically collected from people (usually from a sample within a defined population). |
| Systematic | Methodical, according to plan; not random. |
| Systematic error | Refers to the various errors or biases inherent in a study. See also <i>Bias</i> . |
| Systematic review | A review in which evidence from scientific studies has been identified, appraised and synthesised in a methodical way according to predetermined criteria. May or may not include a <i>meta-analysis</i> . |
| Systemic | Involving the whole body. |
| Target population | The people to whom guideline recommendations are intended to apply. Recommendations may be less valid if applied to a population with different characteristics from the participants in the research study – for example, in terms of age, disease state, social background. |
| Tertiary centre | A specialist medical centre providing complex treatments which receives referrals from both primary and secondary care. Sometimes called a tertiary referral centre. See also <i>Primary care</i> and <i>Secondary care</i> . |
| Torticollis | Involuntary spasms of the musculature in the neck. |
| Triangulation | Use of three or more different research methods in combination; principally used as a check of validity. The more the different methods produce similar results, the more valid the findings. |

| | |
|---------------------------|--|
| Triple blind study | A study in which the statistical analysis is carried out without knowing which treatment patients received, in addition to the patients and investigators/clinicians being unaware which treatment patients were getting. |
| Unconsciousness | A temporary or prolonged loss of awareness of self and of surroundings |
| Validity | Assessment of how well a tool or instrument measures what it is intended to measure. See also <i>External validity</i> , <i>Internal validity</i> . |
| Variable | A measurement that can vary within a study, for example, the age of participants. Variability is present when differences can be seen between different people or within the same person over time, with respect to any characteristic or feature which can be assessed or measured. |

1 Background and scope

1.1 Introduction

This guideline was first published in June 2003. The present guideline is a partial update of only some areas where new evidence has been published since the publication of the original guideline (see CG4 website

<http://guidance.nice.org.uk/cg41/niceguidance/word/English>). This guideline incorporates both the original and the updated sections. All updated sections of the guideline are not shaded in grey to allow easy identification by the reader. All shaded sections have not been updated and is the original guideline. In this update, there are new recommendations in the sections on pre-hospital management, emergency department assessment, investigations for clinically important brain injuries, investigation for non-accidental injury in children, and transfer from secondary settings. These are highlighted in the document as 'New'. A number of amendments have been made to other recommendations from the initial guideline, and these are highlighted in the document as 'Amended'. Hospital Episode Statistics data for the 2000/2001 annual dataset indicate that there were 112,978 admissions to hospitals in England with a primary diagnosis of head injury (ICD10 codes S00-S09). Seventy-two per cent of these

were male admissions and 30% were children under 15 years of age.^{2,3}

Extrapolating on the basis of relative population size gives an estimate of a further 6,700 head injury admissions in Wales. There are no reliable up to date figures for the total denominator of attenders with a head injury at emergency departments. A figure of one million emergency department attenders for the United Kingdom as a whole is often quoted but this is based on figures from the late 1970s.⁴ It is estimated that head injury admissions represent around 20% of all head injury attenders,⁵ which would imply around 600,000 patients per annum attending emergency departments in England and Wales with a head injury. The true emergency department attendance rate may be closer to 700,000 patients however, as it is likely that the proportion of patients with head injury admitted to hospital has fallen below 20% in recent years. The poor quality of information regarding head injury attenders should improve as the use of a common emergency department dataset increases.

The number of patients who undergo neurosurgery each year following a head injury is also unclear. A figure of around 4,000 patients per year for the

UK as a whole has been quoted⁶ but this may be slightly higher than is the case. Hospital Episode Statistics data for the 2000/2001 annual dataset indicate that 398 patients in England underwent an operation to drain the extradural space (OPCS code A40) and 2,048 patients underwent an operation to drain the subdural space (OPCS code A41)⁷. These figures do not include a small number of other neurosurgical procedures possible after head injury, and include some patients with a non-head injury diagnosis. Thus, the routine data available does not allow for a precise estimate of neurosurgical volume after head injury for England and Wales, but points to a figure in the low thousands.

Although the incidence of head injury is high, the incidence of death from head injury is low (6-10 per 100,000 population per annum).⁵ As few as 0.2% of all patients attending emergency departments with a head injury will die as a result of this injury.^{7,8} Ninety per cent of all people who have sustained a head injury will present with a minor or mild injury (Glasgow Coma Scale [GCS] greater than 12) but the majority of fatal outcomes will be in the moderate (GCS of 9 to 12) or severe (GCS less than or equal to 8) head injury groups which account for only 10% of attenders.⁹ Therefore emergency departments are required to see a large number of patients with a minor/mild head injury, and identify the very small number of these that will go on to have serious acute intracranial complications.

1.2 UK Guidelines

The first UK-wide guidelines on identifying patients who were at high risk of intracranial complications following a head injury were drawn up by a Working Party of Neurosurgeons in 1984.¹⁰ They were used in the UK for over 15 years and relied on various clinical factors, particularly the level of consciousness, to place patients with a head injury into different risk categories. The main investigation incorporated into these guidelines was skull radiography, reflecting the importance of skull fracture as a risk factor for intracranial complications. Modifications to this guideline have since been published by the Society of British Neurological Surgeons in 1998, the Royal College of Surgeons of England in 1999 and by the Scottish Intercollegiate Guidelines Network in 2000.¹¹⁻¹³ The assessment and imaging of patients who have sustained a head injury is also addressed by guidelines from the Royal College of Radiologists.¹⁴

The recent recommendations of the Scottish Intercollegiate Guidelines Network centre around the identification of patients with a high (for example, over 10%) risk of intracranial complications using the GCS, the presence of a skull fracture and various other clinical variables. These high-risk patients are recommended for computed tomography (CT) scanning. Admission for observation was considered a tool for patients with a 'medium-risk' of intracranial complications¹³ but the value of this in terms of sensitivity and

specificity in the detection of haematomas was not determined.

1.3 **Role of CT imaging**

An enhanced role for CT imaging after head injury was advocated by Neurosurgeons in 1990¹⁵ and 1998¹¹, the 1999 guidelines from the Royal College of Surgeons of England and the 2000 guidelines from the Scottish Intercollegiate Guidelines Network. These statements recommended a more liberal CT scanning policy, while still adhering to the skull X-ray as the first line investigation in the majority of minor/mild head injuries.

This change in emphasis is reflected in an observed increase in CT scanning in the UK. Between 2002 and 2004 the number of CT brain scans requested in UK hospitals has more than doubled¹⁶. This move to CT reflects a general consensus that earlier definitive imaging is associated with improved outcomes.^{15,17}

1.4 **North American guidelines**

Prior to the first edition of the NICE head injury guidelines, the UK used *level of consciousness and skull X-ray* as primary assessment tools, coupled with *observation* for patients with 'medium-risk' and CT for the highest risk groups. This translates to a CT scan rate of about 32% of all patients attending the emergency department with a head injury¹⁸⁻²¹. In contrast, rates of CT scanning in the USA at this time were between 75% to 100% of all patients with normal GCS and some previous loss of consciousness following a head injury.²²

In the UK, controversy over guidelines for head injury centres on whether increased CT scanning is feasible or advisable, but in the USA the discussion is exactly the reverse. Research in the USA is directed towards attempts to reduce the very large numbers of CT scans being performed.²³⁻²⁵

1.5 **The skull radiograph**

Historically, in the absence of readily available CT scanning resources, skull X-ray was used to categorise patients with minor/mild head injuries into high and low risk groups. Previously in the UK up to 74% of all patients attending emergency departments with a head injury received a skull X-ray, although only about 2% of these X-rays will show a fracture^{26,27}.

An elevation of risk following positive skull X-ray is widely acknowledged and supported by UK evidence.¹⁷ A recent meta-analysis of thirteen studies where at least 50% of the sample underwent CT was performed. The meta-analysis contained almost 13,000 patients who had recently sustained a head injury. A weighted mean prevalence of intracranial haemorrhage of 0.083 (95% CI: 0.03-0.13) was observed. The meta-analysis found that the sensitivity and specificity of a skull X-ray for predicting the presence of intracranial haemorrhage were 38% and 95% respectively.²³ The equivalent predictive values were 0.41 (positive predictive value) and 0.94 (negative predictive value). These figures imply that if there is a skull fracture diagnosed on radiography, the risk of an intracranial haemorrhage is elevated (about 4.9

times higher than before testing) but one cannot rule out an intracranial haemorrhage in patients for whom a skull X-ray does not show a skull fracture.

One reason for the low sensitivity of skull X-ray in predicting an intracranial haemorrhage is the reliability of radiographic interpretation. It has been consistently shown that clinically competent emergency department clinicians will miss between 13% and 23% of all skull fractures that are detected when radiographs are subsequently reviewed by a radiologist.^{20,27,28}

As CT scanning has both sensitivities and specificities approaching 100% for detecting and locating a surgically significant focal intracranial lesion, it has been established as the definitive diagnostic investigation in patients who have sustained a head injury. The relatively low ordering rate for CT in the UK has historically been a function of availability. However, there has been a substantial investment in CT scanners in England and Wales over the last decade, increasing the capacity of modern scanners within the NHS considerably. In addition, CT technology has advanced considerably in recent years (for example, multisection helical CT), reducing the duration of an examination, improving the imaging output and reducing radiation exposure. The new scanners have greatly reduced the need for general anaesthesia and reduced the sedation rate in infants and patients rendered combative by their injuries.^{29,30} Nevertheless, anaesthesia

and ventilation may still be necessary in restless patients and young children.

1.6 Admission

Acute head injury admissions account for 320,900 bed days in hospitals in England (plus a further 19,000 in Wales by population extrapolation) representing 0.64% of all NHS bed days.^{2,3} This represents a significant resource burden on the NHS. However only 1-3% of admitted patients actually go on to develop life-threatening intracranial pathology, with the remainder going home within 48 hours, having had no intervention other than observation.^{7,8,20}

Also of concern is the quality of the observation that patients receive while in hospital. In a recent retrospective survey of 200,000 children in the North-East of England, only 14 children who presented with a minor head injury required neurosurgery. However, the recognition of secondary deterioration was delayed in all 14 patients, with documented routine neurological observations in only one child. Diagnosis of an intracranial haematoma was made between 6 hours and 14 days after the head injury, with a median delay of 18 hours.³¹

This is not a problem unique to the UK. In the USA it has been found that only 50% of patients admitted with a minor head injury had documentation of neurological observations and for the majority of these, the frequency of observations was not sufficient to detect early neurological deterioration.³² In the UK, patients with head injury have historically been observed on non-

specialist wards by nurses and doctors not experienced in neurological observation. In 1999 The Royal College of Surgeons of England surveyed General Surgeons in the UK and found that although 56% of Consultants observed patients with head injury on their wards, only 48% had any neurological experience and 34% were dissatisfied with this referral process. The Royal College advised that patients with head injury should not be observed in non-specialist wards,¹² but it is unclear whether this has resulted in an increased proportion of patients with head injury being observed in appropriately staffed wards.

1.7 Morbidity

The incidence of morbidity after head injury is higher than had been previously appreciated³³ and far exceeds the capacity of UK neurorehabilitation services. In a study of head injury admissions in 1995/96 in Glasgow, 47% of patients followed up for one year after discharge had survived with some form of restriction to lifestyle. Surprisingly, the proportion of patients experiencing the most serious sequelae (that is, moderate or severe), did not vary according to the severity of the initial injury. The study found that 47% of patients admitted with apparently minor/mild head injuries experienced significant sequelae on follow-up, compared to 45% of patients admitted for moderate head injury, and 48% of patients admitted for severe head injury. Only 47% of survivors with sequelae were seen in hospital after discharge and only 28% received some

input from rehabilitation services. A second large UK study examined the outcome of patients attending a minor head injury clinic³⁴. They saw 639 patients who had originally presented with a minor head injury. Fifty-six per cent were not back to work at 2 weeks, and 12% had not returned to work at 6 weeks. In addition at 6 weeks many had persisting symptoms including headache (13%), memory loss (15%) and concentration problems (14%). These data have been reproduced in other countries.^{35,36}

1.8 Cause of injury

In the UK 70-88% of all people that sustain a head injury are male, 10-19% are aged greater than or equal to 65 years and 40-50% are children. Falls (22-43%) and assaults (30-50%) are the most common cause of a minor head injury in the UK, followed by road traffic accidents (~25%). Alcohol may be involved in up to 65% of adult head injuries. Of note, road traffic accidents account for a far greater proportion of moderate to severe head injuries. Also there are marked regional variations, especially in assaults and the involvement of alcohol, but the incidence of penetrating head trauma remains low. The incidence of death due to head injury in the UK is 6-10 per 100,000 per annum.^{2-5,7}

In the USA 65-75% of people that sustain a head injury are male. The USA has a higher rate of road traffic accidents (~50%) and a lower rate of falls (20%-30%) than the UK, reflecting the difference in car usage in the two countries. Assaults account for around

20% of injuries although again there are regional differences. Alcohol is associated with around 50% of all adult head injuries: the alcohol may have been consumed by either the injured person or the person causing the incident. Firearm trauma to the head surpassed motor vehicles as the single largest cause of death from traumatic head injury in 1990 in the USA. However, gunshot trauma to the head is not a common cause for attendance to hospital. This is largely due to the fact that 90% of gunshot wounds to the head are fatal and that two-thirds of people injured in this way will not reach hospital. The prevalence of death due to any traumatic head injury is 20 per 100,000 in the USA, which is double the rate in the UK. Firearm-related deaths account for 8 per 100,000 of these deaths.^{19,22,37-40}

Comparisons with a Canadian population are important at this stage because of the importance of Canadian evidence to these guidelines. A large Canadian study on people with GCS greater than 12 following a head injury found that 31% of these people had sustained falls (comparable with UK estimates) and 43% had been in some form of road traffic accident (higher than the estimate of 25% for the UK). Assaults, by contrast, accounted for only 11% of the Canadian sample, compared to estimates of 30-50% for the UK. The proportion of males in this study was similar to that observed in the UK (69%).²⁵ The Guideline Development Group is of the opinion that a head injury episode is more likely to have

alcohol involvement in the UK than in Canada.

1.9 Summary of current care in the UK

For 15 years, the UK followed guidelines for minor/mild head injuries based on consciousness level, with skull X-ray as the primary investigation, and admission for observation of most patients considered to be at risk for intracranial complications. CT scanning was generally reserved for patients with moderate or severe head injuries (GCS less than 13). CT scanning of patients who have sustained a head injury has gradually increased in recent years, since the first edition of the NICE guidelines for head injury. However, there are still differences between the protocols being used in North America and the UK.

Only 1-3% of patients with head injury who are admitted to hospital in the UK for observation will go on to require neurosurgery, with the remainder being discharged. Even a small reduction in the proportion of patients requiring admission would have a substantial beneficial impact on hospital resources.

There is evidence that outcomes for severely injured patients in England and Wales, as measured by severity adjusted odds of death, improved steadily up to the mid-1990s, but have not improved since. There is also indirect evidence that trauma care for patients with severe head injury in England and Wales is delivering a lower proportion of expected survivors when compared to trauma care in the United States, although these data are confounded by

case mix issues, especially the older age profile of patients with head injury in England and Wales.⁴¹ A sub-group analysis performed by the authors of this paper found that since 1989 there has been no improvement in the age and severity adjusted odds of death for patients with severe head injury in England and Wales (Lecky F, personal communication).

The supply of emergency neurosurgical beds in the UK is limited. A recent survey revealed only 43 neurosurgical intensive care beds available for an overall estimated population of 63.6 million.⁴² This shortfall can lead to delays in patient transfer, and is symptomatic of larger resource and workload issues for neurosurgery in the UK.⁴³ These larger resource problems have many implications for head injury care, including delays obtaining a neurosurgical opinion at night or at the weekend.

Finally there is increasing awareness of a high level of disability following minor/mild head injury. The provision of diagnostic and treatment services could bring great benefits to patients who would otherwise spend prolonged periods off work or dependent on others. Unfortunately, neurorehabilitation services in England and Wales do not have the capacity to provide the volume of services currently required.

1.10 Scope

The National Institute for Health and Clinical Excellence (NICE) originally commissioned the National Collaborating Centre for Acute Care

(NCC-AC) to produce a clinical guideline for patients and clinicians on the early management of head injury, beginning in December 2001. The guideline published in June 2003. The guideline provided advice on effective care using the best possible research evidence. The guideline was based on a scope and commissioning brief received from NICE. These documents reflected a NICE consultation with relevant stakeholders. The clinical areas outlined in the scope were as follows:

- pre-hospital management including assessment, airway management and ventilation, cervical spine protection and appropriate transfer;
- indications for referral to hospital from pre-hospital care;
- secondary care with the aim of early detection of intracranial complications, including admission for observation, skull X-ray and other imaging procedures, notably CT scanning and nuclear magnetic resonance;
- criteria for transfer and discharge including circumstances when patients should be admitted to a neurosurgical unit, admitted for a short period of observation or discharged home;
- criteria for surgical intervention;
- information for patients and their carer/s prior to and during hospital admission;
- management at home of patients who are discharged within 48 hours of admission including advice to primary

care and emergency department staff on the management of patients who re-present with suspicious symptoms;

- guidance on appropriate handover arrangements;
- information for patients and carers.

1.11 Population

The guideline offered best practice for the care of all patients who presented with a suspected or confirmed traumatic head injury with or without other major trauma. Separate advice was provided for adults and children (including infants) where different practices were indicated. It offered advice on the management of patients with a suspected or confirmed head injury who may have been unaware that they had sustained a head injury because of intoxication or other causes. The guideline did not provide advice on the management of patients with other traumatic injury to the head (for example, to the eye or face). It does not address the rehabilitation or long term care of patients with a head injury but the guideline does explore possible criteria for the early identification of patients who require rehabilitation.

1.12 Healthcare setting

The guideline covers the care received from NHS advice sources (for example, NHS Direct, emergency department helplines), primary care, ambulance, and hospital staff who have direct contact with and make decisions concerning the care of patients who present with suspected or confirmed head injury. It recognises the need for care to be

integrated between the primary, secondary and tertiary sectors, and the need to ensure that none of these sectors is unnecessarily overburdened. It addresses the management of patients in primary care, pre-hospital, in emergency departments or similar units, and in the different hospital settings to which they may be transferred where observation for possible deterioration is indicated.

The guideline does not address management within the intensive care or neurosurgical unit, but provides guidance on the appropriate circumstances in which to request a neurosurgical opinion.

Service configuration, competencies, skill mix and training requirements of staff are outside the scope of the guidelines, as they are the remit of the NHS Modernisation Agency, but good practice points on these matters are introduced in places.

1.13

The need for this update guideline

Up to 2 years after publication of all NICE guidelines any new evidence is considered for relevance and importance. The original guideline was produced in June 2003 and this current version is the 2 year partial update of the previous guideline. Since the Head Injury guideline was published there have been new studies with some changes in criteria with respect to CT scanning. This was identified as an area of concern at the time of the initial publication. In addition, a variety of comments have been received post publication on the following areas: guidance for CT scanning, issues relating

to the Glasgow Coma Scale (GCS), competencies and settings with particular respect to Emergency Department, Minor Injuries Unit and the community. There was sufficient new evidence to prompt an update. This update affects a few recommendations within the original guideline.

New evidence has been incorporated using the latest version of the NICE technical manual (April 2007). The original guideline was produced using standard methodology between 2001-03 prior to the first version of the NICE technical manual. In this update we have not sought to revisit previously reviewed literature and recommendations except in the areas that we are updating. The write up of sections that we have not updated has not been amended and we have added sections only where an update was needed. A guideline review is carried out at 2 years and a proposal will be put forward to the Guidelines Executive at NICE based on this review.

1.14 What are clinical practice guidelines?

NICE clinical guidelines are recommendations for the care of individuals in specific clinical conditions or circumstances within the NHS – from prevention and self-care through primary and secondary care to more specialised services. We base our clinical guidelines on the best available research evidence, with the aim of improving the quality of healthcare. We use predetermined and systematic methods to identify and evaluate the evidence relating to specific clinical questions.

Clinical guidelines:

- provide recommendations for the treatment and care of people by healthcare professionals
- are used to develop standards to assess the clinical practice of individual health professionals
- are used in the education and training of health professionals to help patients, carers and clinicians to make informed decisions
- improve communication between patients and health professionals

While guidelines assist the practice of healthcare professionals, they do not replace their knowledge and skills. NICE produce guidelines using the following steps⁴⁴:

- Guideline topic is referred to NICE from the Department of Health (except guideline updates)
- Stakeholders register an interest in the guideline and are consulted throughout the development process.
- The scope is prepared by the National Collaborating Centre for Acute Care. The update scope is based on the previous guideline.
- The National Collaborating Centre for Acute Care establish a guideline development group
- A draft guideline is produced after the group assesses the available evidence and makes recommendations

- There is a consultation on the draft guideline.
- The final guideline is produced.

The National Collaborating Centre for Acute Care and NICE produce a number of versions of this guideline:

- the full guideline contains all the recommendations, plus details of the methods used and the underpinning evidence
- the NICE guideline presents the recommendations from the full version in a format suited to implementation by health professionals and NHS bodies
- the quick reference guide presents recommendations in a suitable format for health professionals
- information for the public (Understanding NICE Guidance) is written using suitable language for people without specialist medical knowledge.

This version is the full version. The other versions can be downloaded from our website at www.rcseng.ac.uk/surgical_research_units/nccac/ or are available from NICE www.NICE.org.uk.

1.15 The National Collaborating Centre for Acute Care

This guideline was commissioned by NICE and developed by the National Collaborating Centre for Acute Care (NCC-AC). The centre is one of seven national collaborating centres funded by NICE and comprises a partnership

between a variety of academic, professional and patient-based organisations. As a multidisciplinary centre we draw upon the expertise of the healthcare professions and academics and ensure the involvement of patients in our work. Further information on the centre and our partner organisations can be found at our website.

(www.rcseng.ac.uk/surgical_research_units/nccac/)

1.16 Remit of the Guideline

The remit (Appendix A) was received from the Department of Health and the National Assembly for Wales in October 2001 as part of NICE's 2nd wave programme of work. This remit and scope have not been altered for this update.

1.17 What the update guideline covers

The guideline covers best practice advice on the care of adults, children (aged 1-15 years) and infants (under one year) who present with a suspected or confirmed traumatic head injury with or without other major trauma. In certain circumstances, the age group 'infants and young children' (that is, those aged under 5 years) is used. Cut-off points of 10 years and 12 years are also used. The guideline will offer advice on the management of patients with a suspected or confirmed head injury who may be unaware that they have sustained a head injury because of intoxication or other causes. The primary patient outcome of concern throughout the guideline is 'clinically important brain or cervical spine injury'. For the purposes

of this guideline, clinically important brain or cervical spine injury is defined as any acute condition that has been identified by imaging or by assessment of risk factors.

This update covers the following;

- The benefits of transporting patients with head injuries to a neurosciences unit compared to an emergency department.
- The benefits of secondary transfer of patients.
- The best imaging tool for identifying patients with head and cervical spine injuries
- The best clinical prediction rule for selecting patients with head and cervical spine injuries for the imaging tool selected.
- Evidence on harm associated with radiation to the head and/or spine.
- Identification of patients who should be referred to rehabilitation services following the initial management of a head injury

Only 8 clinical questions (Appendix C) are covered within this partial update; all other criteria set in the scope (Appendix A) were adhered to in this update. This guideline incorporates both the original and the updated sections. All updated sections of the guideline are not shaded in grey to allow easy identification by the reader. Shaded sections have not been updated and are parts of the original guideline. All recommendations are in bold within each

section for reader ease, as well as a full list of recommendations at the beginning of the guideline. All recommendations are clearly stated whether they are 'new' or 'amended' recommendations.

1.18

What the guideline does not cover

The guideline does not provide advice on the management of patients with other traumatic injury to the head (for example, to the eye or face). The guideline will not address the rehabilitation or long term care of patients with a head injury but will provide criteria for the early identification of patients who would benefit from rehabilitation.

Areas outside the inclusion criteria for each clinical question are not covered within this partial update. All criteria set in the scope (Appendix A) were adhered to in this update.

1.19 ***Who developed this guideline?***

A multidisciplinary Guideline Development Group (GDG) comprising professional group members and consumer representatives of the main stakeholders developed this guideline (see section on Guideline Development Group Membership and acknowledgements).

The National Institute for Health and Clinical Excellence (NICE) funds the National Collaborating Centre for Acute Care and thus supported the development of this guideline. The GDG was convened by the NCC-AC and chaired by Professor David Yates in accordance with guidance from NICE. A

few new members were involved in this update where the Chair and NCC felt those clinical specialties would be useful.

The group met every 6-8 weeks during the development of the guideline. At the start of the guideline development process all GDG members declared interests including consultancies, fee-paid work, share-holdings, fellowships and support from the healthcare industry. At all subsequent GDG meetings, members declared arising conflicts of interest, which were also recorded (Appendix B). Members are either required to withdraw completely or for part of the discussion if their declared interest makes it appropriate, however this was not deemed necessary for any group members on this guideline.

Staff from the NCC-AC provided methodological support and guidance for the development process. They undertook systematic searches, retrieval and appraisal of the evidence and drafted the guideline. The glossary to the guideline contains definitions of terms used by staff and the GDG.

2 Methods

2.1 *Guideline development group*

A Guideline Development Group (GDG) representing all relevant professional and patient parties was formed in December 2001, under the Chairmanship of Professor David Yates from the Trauma Audit and Research Network.

2.2 *Working principles*

It was decided by the GDG to focus the full systematic reviewing methods used in these guidelines on the selection of which patients who have sustained a head injury should be referred for imaging of the head and cervical spine, given that these issues are at the heart of acute management of head injuries. It was agreed that brief literature reviews and formal consensus methods would be used to deal with the remaining topics.

For the purposes of the guidelines it was agreed that 'infants' are aged under 1 year, 'children' are 1-15 year olds and 'adults' are aged 16 years or more. In certain circumstances, the age group 'infants and young children' (that is, aged under 5 years) is used. Cut-off points of 10 years and 12 years are also used where appropriate. 'Head injury' for the purposes of the guidelines is defined as any trauma to the head, other than superficial injuries to the face.

It was also agreed that the primary patient outcome of concern throughout

the guideline development process would be defined as 'clinically important brain injury'. It was agreed that need for neurosurgery was too limited a definition, given that operation is not appropriate for some patients and the guideline scope calls for some means for the early identification of those patients that might benefit from neurorehabilitation. This deliberately broad definition of outcome also reflects the heterogeneity of brain injuries that may be experienced following head trauma.

2.3 *Systematic reviews*

The systematic reviews performed for these guidelines were designed to identify different types of clinical decision rule. The studies reviewed included derivation designs (usually cohort studies where the predictive power of a number of prognostic variables were explored) and validation designs (where the sensitivity and specificity of previously defined rules were examined). Data collection may have been prospective or retrospective. The follow-up rate for important outcomes was also recorded: a standard of at least 80% follow-up is often stated for studies on the development of clinical decision rules. The use of multivariate statistics to identify the independent contribution of each variable to the rules

was also an important determinant of study quality. Systematic reviews of studies on the development of clinical decision studies and/or prognostic variables in head injury were also sought.

The Guideline Development Group agreed to use classifications adapted from the Oxford Centre for Evidence-based Medicine Levels of Evidence (May 2001), to summarise the evidence levels for reviewed studies. These differ from the levels of evidence normally used by NICE, as the NICE classification is not suitable for certain study designs.

The levels of evidence used for studies on the development of clinical decision rules were as follows:

1. Cohort study with consecutive patients and good reference standards, used to validate clinical decision rules;
2. Cohort study with consecutive patients and good reference standards used to derive clinical decision rules (or validated on split samples only);
3. Non-consecutive study or without consistently applied reference standards;
4. Case-control study, poor or non-independent reference standard;
5. Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

The levels of evidence used for systematic reviews were as follows:

1. Systematic review (with homogeneity) of mostly Level 1 studies
2. Systematic review (with homogeneity) of mostly Level 2 studies
3. Systematic review (with homogeneity) of mostly Level 3 studies

It was also agreed to adopt the Oxford Centre for Evidence-based Medicine classification for grade of recommendations (May 2001). This was used so that consistency with the levels of evidence classification could be achieved.

The grades of recommendation used in this guideline are as follows:

- A. Consistent level 1 studies
- B. Consistent level 2 or 3 studies or extrapolations from level 1 studies
- C. Level 4 studies or extrapolations from level 2 or 3 studies
- D. Level 5 evidence or troublingly inconsistent or inconclusive studies of any level

2.4 Resources

The following databases were searched for literature for the period 1990 to 2002:

- Medline
- Embase
- The Cochrane Library – this includes:
 - Cochrane Database of Systematic Reviews (CDSR)

- Database of Abstracts of Reviews of Effectiveness (DARE)
- Cochrane Controlled Trials Register (CCTR)
- Health Technology Assessment (HTA) Database
- NHS Economic Evaluations Database (NHS-EED)
- System for Information on Grey Literature in Europe (SIGLE)
- Health Management Information Consortium (HMIC)

In addition, reference lists of previous guidelines and key papers were used to identify other key references, including pre-1990 literature. Experts were contacted to identify other key literature. Grey literature was identified using NICE stakeholder contacts. The following web sites were also searched:

- Agency for Healthcare Research and Quality (AHRQ)
- Brain Trauma Foundation
- CMA Infobase – clinical practice guidelines
- Department of Health
- <http://www.google.com>
- National Guideline Clearing House (USA)
- National Research Register (NRR)

- Organising Medical Networked Information (OMNI)
- Scottish Intercollegiate Guideline Network
- Turning Research into Practice (TRIP) Database

No useful additional papers (that is, in addition to the grey literature already in our possession and the documents found during the database searches) were found using these methods, apart from a small number of documents of interest to the systematic review on radiation risks and CT of the head.

2.5

Consensus methods

Formal consensus methods were used to generate agreement regarding the recommendations for these guidelines. Consensus was used for all grades of recommendation, even those based on level one evidence, to ensure complete 'sign-up' by all GDG members to the final guidelines. An initial set of recommendations was circulated in questionnaire format, and GDG members rated their agreement with each recommendation on a nine point scale (strongly disagree to strongly agree). Separate ratings were made where relevant for infants, children and adults. A meeting was then held on July 25th 2002 to discuss the recommendations in the light of GDG responses to the questionnaire. A revised set of recommendations was drawn up following the meeting and again circulated to GDG members for their appraisal. At this stage there was near complete agreement with all

recommendations, and only minor revisions in wording were required. The recommendations presented in this guideline are the result of the consensus exercise.

2.6 Systematic review of indications for CT of the head

This systematic review aimed to identify highly sensitive and specific clinical decision rules which could be used to select patients who are at high risk of clinically important brain injury, and who therefore should have CT imaging of the head.

This search produced 1454 abstracts in MEDLINE and 680 abstracts in EMBASE (after duplicates with MEDLINE were excluded). An initial screen for relevance was carried out by one systematic reviewer, which reduced the number of abstracts to 174 in MEDLINE and 68 in EMBASE. These abstracts were then independently read by two reviewers to identify those papers that should be obtained and read in full. At this point the only criteria used was the likelihood that the paper described a rule for the diagnosis of intracranial haematoma (ICH), clinically important brain injury or need for a neurosurgical intervention in patients who have recently sustained a head injury, and produced some data on the likely sensitivity and specificity of the rule. Both derivation and validation papers were selected.

The independent reviewing process produced 72 papers in MEDLINE and 20 papers in EMBASE. In total 92 papers were deemed worthy of review.

A brief description of the rule proposed was extracted. Many papers do not provide explicit description of the diagnostic strategies, inclusion criteria, or post-diagnosis management strategies (for example, eligibility for early discharge). The participant descriptions extracted were GCS levels, age, prevalence of important outcomes (especially intracranial haemorrhage) and the main inclusion and exclusion criteria. If a non-consecutive sample was described (for example, selection criteria was CT imaging where 100% CT imaging was not the rule being tested) this was noted. The outcomes extracted included the need for neurosurgery, ICH, intracranial injury and clinically important brain injury and CT ordering rate. Data on specificity and sensitivity were recorded where possible; 95% confidence intervals were also recorded or calculated if possible.

2.7 Systematic review of indications for imaging of the cervical spine

The systematic review aimed to identify clinical decision rules which could be used to select patients who are at high risk of clinically important cervical spine fracture, and who therefore should have three-view plain radiography followed by other imaging if these prove inadequate.

This search produced 863 abstracts in MEDLINE and 268 in EMBASE (after duplicates had been removed). An initial screen for relevance was carried out by one systematic reviewer, which reduced the number of abstracts to 142 papers in MEDLINE and 10 papers in EMBASE. These abstracts were then independently

read by two reviewers to identify those papers that should be obtained and read in full. At this point the only criteria used was the likelihood that the paper described a rule for the diagnosis of cervical fracture, and produced some data on the likely sensitivity and specificity of the rule. Both derivation and validation papers were selected.

The independent reviewing process produced 78 papers in MEDLINE and 7 papers in EMBASE. In total 85 papers were deemed worthy of review.

A brief description of the rule proposed was extracted. Many papers did not provide an explicit description of the diagnostic strategies, inclusion criteria, or post-diagnosis management strategies (for example, eligibility for early discharge).

Participant details extracted included symptom status, alertness, age, number of centres, prevalence of important outcomes, the country of study and the main inclusion and exclusion criteria. The outcomes that the rule is intended to detect were noted. These included clinically important cervical fracture, unimportant cervical spine fracture, need for surgery and internal or external fixation. The radiography ordering rate was also noted as an outcome. Data on specificity and sensitivity were recorded where possible; 95% confidence intervals were also recorded or calculated if possible.

2.8 Systematic review of means of identifying patients at high risk of late sequelae following head injury

This systematic review aimed to identify clinical decision rules that could be used to select patients who are at high risk of late sequelae following head injury, and who therefore should be followed up so that potential long term problems can be identified.

The original search for CT algorithms for the identification of prognostic variables for intracranial haematoma produced 1454 abstracts in MEDLINE and 680 abstracts in EMBASE (after duplicates with MEDLINE were excluded). This full abstract list was reviewed to look for papers that may be of relevance to disability. After this a search was performed on Medline and Embase, listed in Appendix 1 for prognosis of minor/mild head injury. Experts were also contacted for relevant papers. The search of the 1454 abstracts revealed 152 potentially interesting papers. The additional MEDLINE and EMBASE search revealed 48 papers not previously seen of which eight abstracts looked to be of relevance. Experts provided three useful papers. These abstracts were then independently read by two reviewers to identify those papers that should be obtained and read in full. At this point the only criteria used was the likelihood that the paper might describe a rule or provide factors in the acute assessment of the patient that might predict post-concussional syndrome. After this assessment 23 papers were selected for review

A brief description of the rule proposed was extracted. Only one paper actually proposed a rule. Participant description focused on GCS levels, age, and the main inclusion and exclusion criteria. The outcome measures used were extracted. The definitions of long term disability or post-concussive were heterogeneous. Data on specificity and sensitivity were recorded where possible. As only one paper provided a rule, these figures could only be calculated for this one paper. The prevalence of important outcomes was also recorded. A previous systematic review was also available to the project team and this informed the review.

2.9 Systematic review of medical radiation risks

This review aimed to provide simple estimates of the radiation risks associated with CT of the head. The search produced 654 abstracts in MEDLINE and 260 in EMBASE (after duplicates had been removed). A search using the Google search engine revealed useful documents from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the National Radiological Protection Board (NRPB). Personal communications with the National Radiological Protection Board also provided papers and data which contributed to the review. Following abstract review and including the papers supplied by experts, 80 full articles were obtained and were reviewed to determine relevance. This identified 16 documents considered of

relevance and these contributed to the text of this guideline.

2.10 Guideline update methodology

The guideline update was commissioned by NICE and developed in accordance with the guideline development process outlined in 'The guidelines manual' updated in April 2006⁴⁵ and 2007⁴⁴.

2.11 Developing the clinical questions

Clinical questions were developed to guide the literature searching process and to facilitate the development of recommendations by the GDG. The clinical questions were initially drafted by the review team and were refined and validated by the GDG. The questions were based on the scope (Appendix A).

2.12 Clinical literature search

The aim of the literature search was to identify relevant evidence within the published literature, in order to answer the clinical questions identified. Searches of clinical databases were performed using generic and specific filters, relevant medical subject heading terms and free-text terms. Non-English studies and abstracts were not included. Each database was searched up to 8 January 2007. Papers identified after this date were not routinely considered. Search strategies can be found in Appendix D. The following databases were included in the literature search to identify relevant journal articles:

- Medline (Dialog Datastar) 1951-2006
- Embase (Dialog Datastar) 1974-2006

- PsycINFO 1806-2006

- Health Economic and Evaluations Database (HEED)

- NHS Economic Evaluation Database (NHSEED)

Bibliographies of identified reports and guidelines were also checked to identify relevant literature. The internet was searched to identify guidelines and reports. The following web sites were used to help identify these:

- Members of the Guidelines International Network's web sites (<http://www.g-i-n.net>)
- National Institute for Health and Clinical Excellence (NICE) (www.nice.org.uk)
- National electronic Library for Health (NeLH) (<http://www.nelh.nhs.uk>)
- Scottish Intercollegiate Guideline Network (SIGN) (www.sign.ac.uk)
- US National Guideline Clearing House (www.guidelines.gov)
- CMA Infobase (<http://mdm.ca/cpgsnew/cpgs/>)
- NIH Consensus Development Program (<http://consensus.nih.gov>)
- New Zealand Guidelines Group (<http://www.nzgg.org.nz>)

2.13

Hierarchy of clinical evidence

There are many different methods of ranking the evidence and there has been considerable debate about which system is best. The system used for the update was the one developed by the Scottish Intercollegiate Guidelines Network (SIGN), shown in Table 1.

Table 1: Levels of evidence for intervention studies (reproduced with permission of the Scottish Intercollegiate Guidelines Network)

| Level of evidence | Type of evidence |
|-------------------|--|
| 1++ | High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias |
| 1+ | Well-conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias |
| 1- | Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias |
| 2++ | High quality systematic reviews of case-control or cohort studies High quality case-control or cohort studies with a very low risk of confounding, bias, or chance and a high probability that the relationship is causal |
| 2+ | Well-conducted case-control or cohort studies with a low risk of confounding, bias, or chance and a moderate probability that the relationship is causal |
| 2- | Case-control or cohort studies with a high risk of confounding bias, or chance and a significant risk that the relationship is not causal |
| 3 | Non-analytic studies (For example, case reports, case series) |
| 4 | Expert opinion |

For each clinical question the highest level of evidence was sought. Where an appropriate systematic review, meta-analysis or randomised controlled trial was identified, we did not search for studies of a weaker design.

Table 2: Levels of evidence for studies of the accuracy of diagnostic tests. Adapted from 'The Oxford Centre for Evidence-based Medicine Levels of Evidence' (2001) and the Centre for Reviews and Dissemination 'Report Number 4' (2001).

| Levels of evidence | Type of evidence |
|---|--|
| Ia | Systematic review (with homogeneity) ^a of level-1 studies ^b |
| Ib | Level-1 studies ^b |
| II | Level-2 studies ^c Systematic reviews of level-2 studies |
| III | Level-3 studies ^d Systematic reviews of level-3 studies |
| IV | Consensus, expert committee reports or opinions and/or clinical experience without explicit critical appraisal; or based on physiology, bench research or 'first principles' |
| <p>^a Homogeneity means there are no or minor variations in the directions and degrees of results between individual studies that are included in the systematic review.</p> <p>^b Level-1 studies are studies:</p> <ul style="list-style-type: none"> • that use a blind comparison of the test with a validated reference standard (gold standard) • in a sample of patients that reflects the population to whom the test would apply. <p>^c Level-2 studies are studies that have only one of the following:</p> <ul style="list-style-type: none"> • narrow population (the sample does not reflect the population to whom the test would apply) • a poor reference standard (defined as that where the 'test' is included in the 'reference', or where the 'testing' affects the 'reference') • a comparison between the test and reference standard that is not blind • case-control design. <p>^d Level-3 studies are studies that have at least two or three of the features listed for level-2 studies.</p> | |

2.14 *The literature reviewing process*

References identified by the systematic literature search were screened for appropriateness by title and abstract by an information scientist and systematic reviewer. The GDG also suggested further references and these were assessed in the same way.

Selected studies were ordered and assessed in full by the NCC-AC team using agreed inclusion/ exclusion criteria specific to the guideline topic, and using NICE methodology quality assessment checklists appropriate to the study design⁴⁵.

2.15 *Health economics methods*

See chapter 11.

2.16 *Grading of recommendations*

Following a public consultation in April 2006 NICE is no longer publishing grades alongside recommendations contained within its guidance. This full version will only contain the recommendation grading for the original sections that have not been updated.

2.17 *Research recommendations*

When areas were identified where there was a lack of evidence, the GDG considered making recommendations for future research. Decisions about inclusion were based on factors such as the importance to patients or the population, national priorities, and the potential impact on the NHS and future NICE guidance.

2.18 *Prioritisation of recommendations for implementation*

To assist users of the guideline in deciding the order in which to implement the recommendations, the GDG identified up to ten key priorities for implementation. The decision was made after discussion and voting by the GDG. They selected recommendations that would:

- Have a high impact on patient outcomes, including mortality and morbidity
- Have a high impact on reducing variation
- Lead to a more efficient use of NHS resources
- Mean patients reach critical points in the care pathways more quickly

2.19 *Validation of the guideline*

Registered stakeholders were given the opportunity to comment on the draft guideline, which was posted on the NICE website. A Guideline Review Panel also reviewed the guideline and checked that stakeholders' comments had been addressed.

3 Summary of recommendations

Below are the recommendations that the GDG selected as the key priorities for implementation followed by the full list of recommendations.

3.1 Key Priorities for Implementation

3.1.1 Initial assessment in the emergency department

All patients presenting to an emergency department with a head injury should be assessed by a trained member of staff within a maximum of 15 minutes of arrival at hospital. Part of this assessment should establish whether they are high risk or low risk for clinically important brain injury and/or cervical spine injury, using the guidance on patient selection and urgency for imaging (head and cervical spine).

3.1.2 Urgency of imaging

[Amended] Computed tomography (CT) imaging of the head should be

performed (that is, imaging carried out and results analysed) within 1 hour of the request having been received by the radiology department in those patients where imaging is requested because of any of the risk factors:

- GCS less than 13 on initial assessment in the emergency department.
- GCS less than 15 at 2 hours after the injury.
- Suspected open or depressed skull fracture.
- Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).
- More than one episode of vomiting in adults; three or more episodes of vomiting in children.
- Post-traumatic seizure.
- Coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin) providing that some loss of consciousness or amnesia has been experienced; patients receiving antiplatelet therapy may be at increased risk of intracranial bleeding, though this is currently unquantified –

clinical judgement should be used to assess the need for an urgent scan in these patients.

- Focal neurological deficit.

[Amended] Patients who have any of the following risk factors:

- Amnesia for events more than 30 minutes before impact (the assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years).
- Age 65 years or older, providing that some loss of consciousness or amnesia has been experienced.
- Dangerous mechanism of injury (a pedestrian struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs) providing that some loss of consciousness or amnesia has been experienced.

and none of the following risk factors:

- GCS less than 13 on initial assessment in the emergency department.
- GCS less than 15 at 2 hours after the injury.
- Suspected open or depressed skull fracture.
- Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).

- More than one episode of vomiting in adults; three or more episodes of vomiting in children.

- Post-traumatic seizure.

- Coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin) providing that some loss of consciousness or amnesia has been experienced; patients receiving antiplatelet therapy may be at increased risk of intracranial bleeding, though this is currently unquantified – clinical judgement should be used to assess the need for an urgent scan in these patients.

- Focal neurological deficit.

should have CT imaging of the head performed within 8 hours of the injury (imaging should be performed immediately in these patients if they present 8 hours or more after their injury).

| | | |
|-------|--|---|
| | <p>[New] Children under 10 years of age with a Glasgow Coma Score (GCS) of 8 or less should have CT imaging of the cervical spine within 1 hour of presentation or when they are sufficiently stable.</p> | |
| | <p>[Amended] Imaging of the cervical spine should be performed within 1 hour of a request having been received by the radiology department or when the patient is sufficiently stable. Where a request for urgent CT imaging of the head (that is, within 1 hour) has also been received, the cervical spine imaging should be carried out simultaneously.</p> | |
| 3.1.3 | <p>Admission</p> <p>[Amended] In circumstances where a patient with a head injury requires hospital admission, it is recommended that the patient be admitted only under the care of a team led by a consultant who has been trained in the management of this condition during his/her higher specialist training. The consultant and his/her team should have competence (defined by local agreement with the neuroscience unit) in assessment, observation and indications for imaging (see recommendations in 3.7); inpatient management; indications for transfer to a neuroscience unit (see recommendations in 3.6); and hospital discharge and follow-up (see recommendations in 3.8).</p> | <p>3.1.4 Organisation of transfer of patients between referring hospital and neuroscience unit</p> <p>[Amended] Local guidelines on the transfer of patients with head injuries should be drawn up between the referring hospital trusts, the neuroscience unit and the local ambulance service, and should recognise that:</p> <ul style="list-style-type: none"> - transfer would benefit all patients with serious head injuries (GCS \leq 8), irrespective of the need for neurosurgery - if transfer of those who do not require neurosurgery is not possible, ongoing liaison with the neuroscience unit over clinical management is essential. <p>3.1.5 Advice about long-term problems and support services</p> <p>[Amended] All patients and their carers should be made aware of the possibility of long-term symptoms and disabilities following head injury and should be made aware of the existence of services that they could contact should they experience long-term problems. Details of support services should be included on patient discharge advice cards.</p> |
| | | <p>3.2 The complete list of clinical practice recommendations</p> <p>3.2.1 Glasgow Coma Scale</p> <p>The assessment and classification of patients who have sustained a head injury should be guided primarily by the adult and paediatric versions of the</p> |

Glasgow Coma Scale and its derivative the Glasgow Coma Score (GCS). Recommended versions are shown in Appendix M and Appendix N. Good practice in the use of the Glasgow Coma Scale and Score should be adhered to at all times, following the principles below.

- 3.2.1.1 Monitoring and exchange of information about individual patients should be based on the three separate responses on the Glasgow Coma Score (for example, a patient scoring 13 based on scores of 4 on eye-opening, 4 on verbal response and 5 on motor response should be communicated as E4, V4, M5). (D)**
- 3.2.1.2 If a total score is recorded or communicated, it should be based on a sum of 15, and to avoid confusion this denominator should be specified (for example, 13/15). (D)**
- 3.2.1.3 The individual components of the GCS should be described in all communications and every note and should always accompany the total score. (D)**
- 3.2.1.4 The paediatric version of the Glasgow Coma Score should include a 'grimace' alternative to the verbal score to facilitate scoring in pre-verbal or intubated patients. (D)**
- 3.2.1.5 Best practice in paediatric coma observation and recording as detailed by the National Paediatric Neuroscience Benchmarking Group should be followed at all times. (these principles are detailed in Appendix N). (D)**

3.2.2 Public health literature

- 3.2.2.1 Public health literature and other non-medical sources of advice (for example, St John Ambulance, police officers) should encourage people who have any concerns following a head injury to themselves or to another person, regardless of the injury severity, to seek immediate medical advice. (D)**

3.2.3 Training in risk assessment

- 3.2.3.1 [Amended] It is recommended that General Practitioners, nurses, dentists and ambulance crews should receive training, as necessary, to ensure that they are capable of assessing the presence or absence of the risk factors listed in recommendations 3.3.2. (D)**

3.2.4 Support for families and carers

- 3.2.4.1 There should be a protocol for all staff to introduce themselves to family members or carers and briefly explain what they are doing. In addition a photographic board with the names and titles of personnel in the hospital departments caring for patients with head injury can be helpful. (D)**
- 3.2.4.2 Information sheets detailing the nature of head injury and any investigations likely to be used should be available in the emergency department. The patient version of these NICE guidelines may be helpful. (D)**
- 3.2.4.3 Staff should consider how best to share information with children and introduce them to the possibility of long term complex changes in their parent or sibling. Literature produced**

| | | |
|---------|---|---|
| | by patient support groups may be helpful. (D) | - Unconsciousness, or lack of full consciousness (for example, problems keeping eyes open). |
| 3.2.4.4 | [Amended] Healthcare professionals should encourage carers and relatives to talk and make physical contact (for example, holding hands) with the patient. However, it is important that relatives and friends do not feel obliged to spend long periods at the bedside. If they wish to stay with the patient, they should be encouraged to take regular breaks. (D) | - Any focal (that is, restricted to a particular part of the body or a particular activity) neurological deficit since the injury (examples include problems understanding, speaking, reading or writing; loss of feeling in part of the body; problems balancing; general weakness; any changes in eyesight; and problems walking). |
| 3.2.4.5 | There should be a board or area displaying leaflets or contact details for patient support organisations either locally or nationally to enable family members to gather further information. (D) | - Any suspicion of a skull fracture or penetrating head injury (for example, clear fluid running from the ears or nose, black eye with no associated damage around the eye, bleeding from one or both ears, new deafness in one or both ears, bruising behind one or both ears, penetrating injury signs, visible trauma to the scalp or skull). |
| 3.3 | <i>Presentation and referral</i> | - Any seizure ('convulsion' or 'fit') since the injury. |
| | A person with a head injury may present via a telephone advice service or to a community health service or minor injury clinic. The following recommendations apply in these settings. | - A high-energy head injury (for example, pedestrian struck by motor vehicle, occupant ejected from motor vehicle, a fall from a height of greater than 1 metre or more than five stairs, diving accident, high-speed motor vehicle collision, rollover motor accident, accident involving motorized recreational vehicles, bicycle collision, or any other potentially high-energy mechanism). |
| 3.3.1 | Telephone advice lines | - The injured person or their carer is incapable of transporting the injured person safely to the hospital emergency department without the use |
| 3.3.1.1 | [Amended] Telephone advice services (for example, NHS Direct, emergency department helplines) should refer people who have sustained a head injury to the emergency ambulance services (that is, 999) for emergency transport to the emergency department if they have experienced any of the following (alternative terms to facilitate communication are in parenthesis): | |

of ambulance services (providing any other risk factor indicating emergency department referral is present). (D)

3.3.1.2 Telephone advice services (for example, NHS Direct, emergency department helplines) should refer people who have sustained a head injury to a hospital emergency department if the history related indicates the presence of any of the following risk factors (alternative terms to facilitate communication are in parenthesis):

- Any previous loss of consciousness ('knocked out') as a result of the injury, from which the injured person has now recovered.
- Amnesia for events before or after the injury ('problems with memory'). The assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years.
- Persistent headache since the injury.
- Any vomiting episodes since the injury.
- Any previous cranial neurosurgical interventions ('brain surgery').
- History of bleeding or clotting disorder.
- Current anticoagulant therapy such as warfarin.
- Current drug or alcohol intoxication.
- Age 65 years or older.

- Suspicion of non-accidental injury.
- Irritability or altered behaviour ('easily distracted' 'not themselves' 'no concentration' 'no interest in things around them') particularly in infants and young children (that is, aged under 5 years).
- Continuing concern by the helpline personnel about the diagnosis. (D)

3.3.1.3 In the absence of any of the factors listed in 3.3.1.1 and 3.3.1.2, the helpline should advise the injured person to seek medical advice from community services (for example, general practice) if any of the following factors are present:

- Adverse social factors (for example, no-one able to supervise the injured person at home).
- Continuing concern by the injured person or their carer about the diagnosis. (D)

3.3.2 Community health services and NHS minor injury clinics

3.3.2.1 [Amended] Community health services (general practice, ambulance crews, NHS walk-in centres, dental practitioners) and NHS minor injury clinics should refer patients who have sustained a head injury to a hospital emergency department, using the ambulance service if deemed necessary (see section 3.4.1.1); if any of the following are present.

- GCS less than 15 on initial assessment.

- Any loss of consciousness as a result of the injury.
 - Any focal neurological deficit since the injury (examples include problems understanding, speaking, reading or writing; decreased sensation; loss of balance; general weakness; visual changes; abnormal reflexes; and problems walking).
 - Any suspicion of a skull fracture or penetrating head injury since the injury (for example, clear fluid running from the ears or nose, black eye with no associated damage around the eyes, bleeding from one or both ears, new deafness in one or both ears, bruising behind one or both ears, penetrating injury signs, visible trauma to the scalp or skull of concern to the professional).
 - Amnesia for events before or after the injury. The assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years.
 - Persistent headache since the injury.
 - Any vomiting episodes since the injury.
 - Any seizure since the injury.
 - Any previous cranial neurosurgical interventions.
 - A high-energy head injury (for example, pedestrian struck by motor vehicle, occupant ejected from motor vehicle, fall from a height of greater than 1 metre or more than five stairs, diving accident, high-speed motor vehicle collision, rollover motor accident, accident involving motorized recreational vehicles, bicycle collision, or any other potentially high-energy mechanism).
 - History of bleeding or clotting disorder.
 - Current anticoagulant therapy such as warfarin.
 - Current drug or alcohol intoxication.
 - Age 65 years or older.
 - Suspicion of non-accidental injury.
 - Continuing concern by the professional about the diagnosis. (D)
- 3.3.2.2** In the absence of any the factors listed in 3.3.2.1, the professional should consider referral to an emergency department if any of the following factors are present depending on their own judgement of severity.
- Irritability or altered behaviour, particularly in infants and young children (that is, aged under 5 years).
 - Visible trauma to the head not covered above but still of concern to the professional.
 - Adverse social factors (for example, no-one able to supervise the injured person at home).
 - Continuing concern by the injured person or their carer about the diagnosis. (D)

| | |
|----------------|--|
| 3.4 | <i>Transport from community health services and NHS minor injury clinics and pre-hospital management</i> |
| 3.4.1 | Transport to the emergency department |
| 3.4.1.1 | Patients referred from community health services and NHS minor injury clinics should be accompanied by a competent adult during transport to the emergency department. (D) |
| 3.4.1.2 | The referring professional should determine if an ambulance is required, based on the patient's clinical condition. If an ambulance is deemed not required, public transport and car are appropriate means of transport providing the patient is accompanied. (D) |
| 3.4.1.3 | The referring professional should inform the destination hospital (by phone) of the impending transfer and in non-emergencies a letter summarising signs and symptoms should be sent with the patient. (D) |
| 3.4.2 | Pre-hospital management |
| | The following principles should be adhered to in the immediate care of patients who have sustained a head injury. |

- 3.4.2.1** [Amended] Adults who have sustained a head injury should initially be assessed and their care managed according to clear principles and standard practice, as embodied in: the Advanced Trauma Life Support (ATLS) course/European Trauma course; the International Trauma Life Support (ITLS) course; the Pre-hospital Trauma Life Support (PHTLS) course;

the Advanced Trauma Nurse Course (ATNC); the Trauma Nursing Core Course (TNCC); and the Joint Royal Colleges Ambulance Service Liaison Committee (JRCALC) Clinical Practice Guidelines for Head Trauma. For children, clear principles are outlined in the Advanced Paediatric Life Support (APLS)/European Paediatric Life Support (EPLS) course, the Pre-hospital Paediatric Life Support (PHPLS) course and the Paediatric Education for Pre-hospital Professionals (PEPP) course. (D)

| | |
|----------------|--|
| 3.4.2.2 | Ambulance crews should be fully trained in the use of the adult and paediatric versions of the Glasgow Coma Scale. (D) |
| 3.4.2.3 | Ambulance crews should be trained in the detection of non-accidental injury and should pass information to emergency department personnel when the relevant signs and symptoms arise. (D) |
| 3.4.2.4 | The priority for those administering immediate care is to treat first the greatest threat to life and avoid further harm. (D) |

- 3.4.2.5** [Amended] Patients who have sustained a head injury should be transported directly to a facility that has been identified as having the resources necessary to resuscitate, investigate and initially manage any patient with multiple injuries. It is expected that all acute hospitals and all neuroscience units accepting patients directly from an incident will have these resources, and that these

| | | |
|---------|---|---|
| | resources will be appropriate for a patient's age. (D) | bladder will reduce irritability. |
| 3.4.2.6 | [Amended] Patients who have sustained a head injury and present with any of the following risk factors should have full cervical spine immobilisation attempted unless other factors prevent this: <ul style="list-style-type: none"> - GCS less than 15 on initial assessment by the healthcare professional - neck pain or tenderness - focal neurological deficit - paraesthesia in the extremities - any other clinical suspicion of cervical spine injury. (D) | Analgesia as described in 3.5.1.9 should be given only under the direction of a doctor. |
| 3.4.2.7 | [Amended] Cervical spine immobilisation should be maintained until full risk assessment including clinical assessment (and imaging if deemed necessary) indicates it is safe to remove the immobilisation device. (D) | |
| 3.4.2.8 | Standby calls to the destination emergency department should be made for all patients with a GCS less than or equal to 8, to ensure appropriately experienced professionals are available for their treatment and to prepare for imaging. (D) | |
| 3.4.2.9 | [New] Pain should be managed effectively because it can lead to a rise in intracranial pressure. Reassurance and splintage of limb fractures are helpful; catheterisation of a full | |
| 3.5 | Assessment and investigation in the emergency department | |
| 3.5.1 | Good practice in emergency department assessment | |
| | The main focus of emergency department assessment for patients who have sustained a head injury should be the risk of clinically important brain injuries and injuries to the cervical spine and the consequent need for imaging. Due attention should also be paid to co-existing injuries and to other concerns the clinician may have (for example, non-accidental injury, possible non-traumatic aetiology such as seizure). Early imaging, rather than admission and observation for neurological deterioration, will reduce the time to detection of life-threatening complications and is associated with better outcomes. | |
| 3.5.1.1 | The priority for all emergency department patients is the stabilisation of airway, breathing and circulation (ABC) before attention to other injuries. (D) | |
| 3.5.1.2 | Depressed conscious level should be ascribed to intoxication only after a significant brain injury has been excluded.(D) | |
| 3.5.1.3 | All emergency department clinicians involved in the assessment of patients | |

- with a head injury should be capable of assessing the presence or absence of the risk factors in the guidance on patient selection and urgency for imaging (head and cervical spine – see later recommendations). Training should be available as required to ensure that this is the case. (D)
- 3.5.1.4** Patients presenting to the emergency department with impaired consciousness (GCS less than 15) should be assessed immediately by a trained member of staff. (D)
- 3.5.1.5** In patients with a GCS less than or equal to 8 there should be early involvement of an anaesthetist or critical care physician to provide appropriate airway management, as described in recommendations 3.6.1.7 and 3.6.1.8 to assist with resuscitation. (D)
- 3.5.1.6** All patients presenting to an emergency department with a head injury should be assessed by a trained member of staff within a maximum of 15 minutes of arrival at hospital. Part of this assessment should establish whether they are high risk or low risk for clinically important brain injury and/or cervical spine injury, using the guidance on patient selection and urgency for imaging (head and cervical spine – see later recommendations). (D)
- 3.5.1.7** [Amended] In patients considered to be at high risk for clinically important brain injury and/or cervical spine injury, assessment should be extended to full clinical examination to establish the need to request CT imaging of the head and/or imaging of the cervical spine. The guidance on patient selection and urgency for imaging (head and cervical spine) should form the basis for the final decision on imaging after discussion with the radiology department. See recommendations 3.5.3.1 to 3.5.4.2 (imaging of the head) and 3.5.5.1 to 3.5.7.2 (imaging of the cervical spine). (D)
- 3.5.1.8** [Amended] Patients who, on initial assessment, are considered to be at low risk for clinically important brain injury and/or cervical spine injury should be re-examined within a further hour by an emergency department clinician. Part of this assessment should fully establish the need to request CT imaging of the head and/or imaging of the cervical spine. The guidance on patient selection and urgency for imaging (head and cervical spine) should again form the basis for the final decision on imaging after discussion with the radiology department. See recommendations 3.5.3.1 to 3.5.4.2 (imaging of the head) and 3.5.5.1 to 3.5.7.2 (imaging of the cervical spine). (D)
- 3.5.1.9** [NEW] Pain should be managed effectively because it can lead to a rise in intracranial pressure. Reassurance and splintage of limb fractures are helpful; catheterisation of a full bladder will reduce irritability. Significant pain should be treated with small doses of intravenous opioids titrated against clinical response and

| | | | |
|----------|--|---------|--|
| | baseline cardiorespiratory measurements. | | clinically important brain injuries is CT imaging of the head. (A) |
| 3.5.1.10 | [Amended] Throughout the hospital episode, all healthcare professionals should use a standard head injury proforma in their documentation when assessing and observing patients with head injury. This form should be of a consistent format across all clinical departments and hospitals in which a patient might be treated. A separate proforma for those under 16 years should be used. Areas to allow extra documentation should be included (for example, in cases of non-accidental injury). (Examples of proformas that should be used in patients with head injury are provided in Appendices J, K1 and K2). (D) | 3.5.2.2 | For safety, logistic and resource reasons, magnetic resonance imaging (MRI) scanning is not currently indicated as the primary investigation for clinically important brain injury in patients who have sustained a head injury, although it is recognised that additional information of importance to the patient's prognosis can sometimes be detected using MRI. (D) |
| | | 3.5.2.3 | MRI is contraindicated in both head and cervical spine investigations unless there is absolute certainty that the patient does not harbour an incompatible device, implant or foreign body. (D) |
| 3.5.1.11 | It is recommended that in-hospital observation of patients with a head injury, including all emergency department observation, should only be conducted by professionals competent in the assessment of head injury. (D) | 3.5.2.4 | There should be appropriate equipment for maintaining and monitoring the patient within the MRI environment and all staff involved should be aware of the dangers and necessary precautions for working near an MRI scanner. (D) |
| 3.5.1.12 | Patients who returned to an emergency department within 48 hours of discharge with any persistent complaint relating to the initial head injury should be seen by or discussed with a senior clinician experienced in head injuries, and considered for a CT scan. (B) | 3.5.2.5 | [NEW] Plain X-rays of the skull should not be used to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury. |
| 3.5.2 | Investigations for clinically important brain injuries | 3.5.2.6 | [NEW] Unless the CT result is required within 1 hour, it is acceptable to admit a patient for effective overnight observation and delay the CT scan until the next morning if the patient presents out of hours and any of the following risk factors are present in |
| 3.5.2.1 | The current primary investigation of choice for the detection of acute | | |

| | | |
|---------|--|---|
| | <p>addition to a period of loss of consciousness or amnesia:</p> <ul style="list-style-type: none"> - age 65 years or older - amnesia for events more than 30 minutes before impact - dangerous mechanism of injury (a pedestrian or cyclist struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs). | <ul style="list-style-type: none"> - Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign). - Post-traumatic seizure. - Focal neurological deficit. - More than one episode of vomiting. - Amnesia for events more than 30 minutes before impact. (B) |
| 3.5.2.7 | [NEW] If CT imaging is unavailable because of equipment failure, patients with GCS 15 may be admitted for observation. Arrangements should be in place for urgent transfer to a centre with CT scanning available should there be a clinical deterioration that indicates immediate CT scanning is necessary. | 3.5.3.2 CT should also be requested immediately in patients with any of the following risk factors, provided they have experienced some loss of consciousness or amnesia since the injury: |
| 3.5.3 | Selection of patients for CT imaging of the head | |
| | <u>For adults</u> | |
| 3.5.3.1 | <p>[Amended] Adult patients who have sustained a head injury and present with any one of the following risk factors should have CT scanning of the head requested immediately:</p> <ul style="list-style-type: none"> - GCS less than 13 on initial assessment in the emergency department. - GCS less than 15 at 2 hours after the injury on assessment in the emergency department. - Suspected open or depressed skull fracture. | <ul style="list-style-type: none"> - Age 65 years or older. - Coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin). - Dangerous mechanism of injury (a pedestrian or cyclist struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs). (B) <p><u>For children</u></p> |
| | | 3.5.3.3 [NEW] Children (under 16 years) who have sustained a head injury and present with any one of the following risk factors should have CT scanning of the head requested immediately: |
| | | <ul style="list-style-type: none"> - Loss of consciousness lasting more than 5 minutes (witnessed). |

| | | |
|---------|---|--|
| | <ul style="list-style-type: none"> - Amnesia (antegrade or retrograde) lasting more than 5 minutes. - Abnormal drowsiness. - Three or more discrete episodes of vomiting. - Clinical suspicion of non-accidental injury. - Post-traumatic seizure but no history of epilepsy. - GCS less than 14, or for a baby under 1 year GCS (paediatric) less than 15, on assessment in the emergency department. - Suspicion of open or depressed skull injury or tense fontanelle. - Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign). - Focal neurological deficit. - If under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head. - Dangerous mechanism of injury (high-speed road traffic accident either as pedestrian, cyclist or vehicle occupant, fall from a height of greater than 3 metres, high-speed injury from a projectile or an object). | <p>within 1 hour of the request having been received by the radiology department in those patients where imaging is requested because of any of the following risk factors:</p> <ul style="list-style-type: none"> - GCS less than 13 on initial assessment in the emergency department. - GCS less than 15 at 2 hours after the injury. - Suspected open or depressed skull fracture. - Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign). - More than one episode of vomiting in adults; three or more episodes of vomiting in children. - Post-traumatic seizure. - Coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin) providing that some loss of consciousness or amnesia has been experienced; patients receiving antiplatelet therapy may be at increased risk of intracranial bleeding, though this is currently unquantified – clinical judgement should be used to assess the need for an urgent scan in these patients. - Focal neurological deficit. (B) |
| 3.5.4 | Urgency in performing CT imaging of the head | |
| 3.5.4.1 | [Amended] CT imaging of the head should be performed (that is, imaging carried out and results analysed) | 3.5.4.2 [Amended] Patients who have any of the following risk factors and none of the risk factors in 3.5.4.1 should have |

their CT imaging performed within 8 hours of the injury (imaging should be performed immediately in these patients if they present 8 hours or more after their injury):

- Amnesia for events more than 30 minutes before impact (the assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years).

- Age 65 years or older providing that some loss of consciousness or amnesia has been experienced.

- Dangerous mechanism of injury (a pedestrian struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs) providing that some loss of consciousness or amnesia has been experienced. (B)

3.5.5 Investigation for injuries to the cervical spine

3.5.5.1 [Amended] The current initial investigation of choice for the detection of injuries to the cervical spine is the plain radiograph. Three views should be obtained and be of sufficient quality for reliable interpretation. However, in certain circumstances CT is preferred. (B)

3.5.5.2 As a minimum, CT should cover any areas of concern or uncertainty on plain film or clinical grounds. (B)

3.5.5.3 With modern multislice scanners the whole cervical spine can be scanned at high resolution with ease and

multiplanar reformatted images generated rapidly. Facilities for multiplanar reformatting and interactive viewing should be available. (B)

3.5.5.4 MRI is indicated in the presence of neurological signs and symptoms referable to the cervical spine and if there is suspicion of vascular injury (for example, subluxation or displacement of the spinal column, fracture through foramen transversarium or lateral processes, posterior circulation syndromes). (B)

3.5.5.5 MRI may add important information about soft tissue injuries associated with bony injuries demonstrated by plain films and/or CT. (B)

3.5.5.6 MRI has a role in the assessment of ligamentous and disc injuries suggested by plain films, CT or clinical findings. (B)

3.5.5.7 In CT, the occipital condyle region should be routinely reviewed on 'bone windows' for patients who have sustained a head injury. Reconstruction of standard head images onto a high resolution bony algorithm is readily achieved with modern CT scanners.(B)

3.5.5.8 In patients who have sustained high energy trauma or are showing signs of lower cranial nerve palsy, particular attention should be paid to the region of the foramen magnum. If necessary, additional high resolution imaging for coronal and sagittal reformatting should be performed while the patient is on the scanner table.(B)

3.5.6 Selection of patients for imaging of the cervical spine

3.5.6.1 [Amended] Adult patients should have three-view radiographic imaging of the cervical spine requested immediately if any of the following points apply:

- There is neck pain or midline tenderness with:
 - Age 65 years or older, or
 - dangerous mechanism of injury (fall from greater than 1 metre or five stairs; axial load to head for example, diving; high-speed motor vehicle collision; rollover motor accident; ejection from a motor vehicle; accident involving motorized recreational vehicles; bicycle collision).
- It is not considered safe to assess the range of movement in the neck for reasons other than those above.
- It is considered safe to assess the range of movement in the neck and, on assessment, the patient cannot actively rotate the neck to 45 degrees to the left and right; safe assessment can be carried out if the patient:
 - was involved in a simple rear-end motor vehicle collision
 - is comfortable in a sitting position in the emergency department
 - has been ambulatory at any time since injury with no midline cervical spine tenderness

- presents with delayed onset of neck pain.

- A definitive diagnosis of cervical spine injury is required urgently (for example, before surgery). (A)

3.5.6.2 [NEW] Adult patients who have any of the following risk factors should have CT imaging of the cervical spine requested immediately:

- GCS below 13 on initial assessment
- Has been intubated
- Plain film series is technically inadequate (for example, desired view unavailable), suspicious or definitely abnormal
- Continued clinical suspicion of injury despite a normal X ray.
- The patient is being scanned for multi-region trauma.

3.5.6.3 Children aged 10 years or more can be treated as adults for the purposes of cervical spine imaging. (D)

3.5.6.4 Children under 10 years should receive anterior/posterior and lateral plain films without an anterior/posterior peg view. (D)

3.5.6.5 [NEW] In children under 10 years, because of the increased risks associated with irradiation, particularly to the thyroid gland, and the generally lower risk of significant spinal injury, CT of the cervical spine should be used only in cases where patients have a severe head injury (GCS \leq 8), or where there is a strong

| | | |
|---------|--|---|
| | clinical suspicion of injury despite normal plain films (for example, focal neurological signs or paraesthesia in the extremities), or where plain films are technically difficult or inadequate. | minimise radiation dose during imaging of the head and cervical spine, while ensuring that image quality and coverage is sufficient to achieve an adequate diagnostic study. (D) |
| 3.5.7 | Urgency in performing cervical spine imaging | 3.5.10 Involving the neurosurgeon |
| 3.5.7.1 | [NEW] Children under 10 years of age with GCS of 8 or less should have CT imaging of the cervical spine within 1 hour of presentation or when they are sufficiently stable. | 3.5.10.1 The care of all patients with new, surgically significant abnormalities on imaging should be discussed with a neurosurgeon. The definition of 'surgically significant' should be developed by local neurosurgical centres and agreed with referring hospitals. An example of a neurosurgical referral letter is shown in Appendix L. (D) |
| 3.5.7.2 | [Amended] Imaging of the cervical spine should be performed within 1 hour of a request having been received by the radiology department or when the patient is sufficiently stable. Where a request for urgent CT imaging of the head (that is, within 1 hour) has also been received, the cervical spine imaging should be carried out simultaneously. (D) | 3.5.10.2 Regardless of imaging, other reasons for discussing a patient's care plan with a neurosurgeon include: |
| 3.5.8 | Investigations of non-accidental injury in children | <ul style="list-style-type: none"> - persisting coma (GCS \leq 8) after initial resuscitation. - unexplained confusion which persists for more than 4 hours - deterioration in GCS after admission (greater attention should be paid to motor response deterioration) - progressive focal neurological signs - a seizure without full recovery - definite or suspected penetrating injury - a cerebrospinal fluid leak. (D) |
| 3.5.8.1 | [Amended] A clinician with expertise in non-accidental injuries in children should be involved in any suspected case of non-accidental injury in a child. Examinations/investigations that should be considered include: skull X-ray as part of a skeletal survey, ophthalmoscopic examination for retinal haemorrhage, and examination for pallor, anaemia, and tense fontanelle or other suggestive features. Other imaging such as CT and MRI may be required to define injuries. | |
| 3.5.9 | Radiation exposure management | |
| 3.5.9.1 | In line with good radiation exposure practice every effort should be made to | |

3.5.11 Admission**3.5.11.1 The following patients meet the criteria for admission to hospital following a head injury.**

- Patients with new, clinically significant abnormalities on imaging.
- Patients who have not returned to GCS 15 after imaging, regardless of the imaging results.
- When a patient fulfils the criteria for CT scanning but this cannot be done within the appropriate period, either because CT is not available or because the patient is not sufficiently cooperative to allow scanning.
- Continuing worrying signs (for example, persistent vomiting, severe headaches) of concern to the clinician.
- Other sources of concern to the clinician (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak). (D)

3.5.11.2 [Amended] Some patients may require an extended period in a recovery setting because of the use of general anaesthesia during CT imaging. (D)

3.5.11.3 Patients with multiple injuries should be admitted under the care of the team that is trained to deal with their most severe and urgent problem. (D)

3.5.11.4 [Amended] In circumstances where a patient with a head injury requires

hospital admission, it is recommended that the patient be admitted only under the care of a team led by a consultant who has been trained in the management of this condition during his/her higher specialist training. The consultant and his/her team should have competence (defined by local agreement with the neuroscience unit) in assessment, observation and indications for imaging (see recommendations 3.7); inpatient management; indications for transfer to a neuroscience unit (see recommendations 3.6); and hospital discharge and follow up (see recommendations 3.8). (D)

3.5.11.5 It is recommended that in-hospital observation of patients with a head injury should only be conducted by professionals competent in the assessment of head injury. (D)

3.6 *Transfer from secondary settings to a neuroscience unit***3.6.1 Transfer of adults**

3.6.1.1 [Amended] Local guidelines on the transfer of patients with head injuries should be drawn up between the referring hospital trusts, the neuroscience unit and the local ambulance service, and should recognise that:

- transfer would benefit all patients with serious head injuries (GCS \leq 8), irrespective of the need for neurosurgery
- if transfer of those who do not require neurosurgery is not possible,

- ongoing liaison with the neuroscience unit over clinical management is essential. (D)
- 3.6.1.2** [NEW] The possibility of occult extracranial injuries should be considered for the multiply injured adult, and he or she should not be transferred to a service that is unable to deal with other aspects of trauma.
- 3.6.1.3** There should be a designated consultant in the referring hospital with responsibility for establishing arrangements for the transfer of patients with head injuries to a neuroscience unit and another consultant at the neuroscience unit with responsibility for establishing arrangements for communication with referring hospitals and for receipt of patients transferred. (D)
- 3.6.1.4** [Amended] Patients with head injuries requiring emergency transfer to a neuroscience unit should be accompanied by a doctor with appropriate training and experience in the transfer of patients with acute brain injury. The doctor should be familiar with the pathophysiology of head injury, the drugs and equipment they will use and with working in the confines of an ambulance (or helicopter if appropriate). They should have a dedicated and adequately trained assistant. They should be provided with appropriate clothing for the transfer, medical indemnity and personal accident insurance. Patients requiring non-emergency transfer should be accompanied by appropriate clinical staff. (D)
- 3.6.1.5** The transfer team should be provided with a means of communication with their base hospital and the neurosurgical unit during the transfer. A portable phone may be suitable providing it is not used in close proximity (that is, within 1 metre) of medical equipment prone to electrical interference (for example, infusion pumps). (D)
- 3.6.1.6** [Amended] Although it is understood that transfer is often urgent, initial resuscitation and stabilisation of the patient should be completed and comprehensive monitoring established before transfer to avoid complications during the journey. A patient who is persistently hypotensive, despite resuscitation, should not be transported until the cause of the hypotension has been identified and the patient stabilised. (D)
- 3.6.1.7** All patients with a GCS less than or equal to 8 requiring transfer to a neurosurgical unit should be intubated and ventilated as should any patients with the indications detailed in recommendation 3.6.1.8. (D)
- 3.6.1.8** [Amended] Intubation and ventilation should be used immediately in the following circumstances:
- Coma – not obeying commands, not speaking, not eye opening (that is, $GCS \leq 8$).
 - Loss of protective laryngeal reflexes.
 - Ventilatory insufficiency as judged by blood gases: hypoxaemia ($PaO_2 < 13$ kPa on oxygen) or hypercarbia ($PaCO_2 > 6$ kPa).

- Spontaneous hyperventilation causing $\text{PaCO}_2 < 4 \text{ kPa}$.
 - Irregular respirations. (D).
- 3.6.1.9** [Amended] Intubation and ventilation should be used before the start of the journey in the following circumstances:
- Significantly deteriorating conscious level (one or more points on the motor score), even if not coma.
 - Unstable fractures of the facial skeleton.
 - Copious bleeding into mouth (for example, from skull base fracture).
 - Seizures. (D)
- 3.6.1.10** [Amended] An intubated patient should be ventilated with muscle relaxation and appropriate short-acting sedation and analgesia. Aim for a PaO_2 greater than 13 kPa , PaCO_2 4.5 to 5.0 kPa unless there is clinical or radiological evidence of raised intracranial pressure, in which case more aggressive hyperventilation is justified. If hyperventilation is used, the inspired oxygen concentration should be increased. The mean arterial pressure should be maintained at 80 mmHg or more by infusion of fluid and vasopressors as indicated. In children, blood pressure should be maintained at a level appropriate for the child's age. (D)
- 3.6.1.11** Education, training and audit are crucial to improving standards of transfer; appropriate time and funding for these activities should be provided. (D)
- 3.6.1.12** Carers and relatives should have as much access to the patient as is practical during transfer and be fully informed on the reasons for transfer and the transfer process. (D)
- 3.6.2** Transfer of children
- 3.6.2.1** The recommendations in section 3.6.1 were written for adults but the principles apply equally to children and infants, providing that the paediatric modification of the Glasgow Coma Scale is used. (D)
- 3.6.2.2** Service provision in the area of paediatric transfer to tertiary care should also follow the principles outlined in the National Service Framework for Paediatric Intensive Care. These do not conflict with the principles outlined in 3.6.1. (D)
- 3.6.2.3** [NEW] The possibility of occult extracranial injuries should be considered for the multiply injured child, and he or she should not be transferred to a service that is unable to deal with other aspects of trauma.
- 3.6.2.4** Transfer of a child or infant to a specialist neurosurgical unit should be undertaken by staff experienced in the transfer of critically ill children. (D)
- 3.6.2.5** Families should have as much access to their child as is practical during transfer and be fully informed on the reasons for transfer and the transfer process. (D)

3.7 Observation of admitted patients**3.7.1 Training in observation**

3.7.1.1 Medical, nursing and other staff caring for patients with head injury admitted for observation should all be capable of performing the observations listed in 3.7.2 and 3.7.5.

3.7.1.2 The acquisition and maintenance of observation and recording skills require dedicated training and this should be available to all relevant staff.

3.7.1.3 Specific training is required for the observation of infants and young children. (D)

3.7.2 Minimum documented observations

3.7.2.1 For patients admitted for head injury observation the minimum acceptable documented neurological observations are: GCS; pupil size and reactivity; limb movements; respiratory rate; heart rate; blood pressure; temperature; blood oxygen saturation. (D)

3.7.3 Frequency of observations

3.7.3.1 Observations should be performed and recorded on a half-hourly basis until GCS equal to 15 has been achieved. The minimum frequency of observations for patients with GCS equal to 15 should be as follows, starting after the initial assessment in the emergency department:

- half-hourly for 2 hours
- then 1-hourly for 4 hours
- then 2-hourly thereafter.

3.7.3.2 Should a patient with GCS equal to 15 deteriorate at any time after the initial 2-hour period, observations should revert to half-hourly and follow the original frequency schedule. (D)

3.7.4 Observation of children and infants

3.7.4.1 Observation of infants and young children (that is, aged under 5 years) is a difficult exercise and therefore should only be performed by units with staff experienced in the observation of infants and young children with a head injury. Infants and young children may be observed in normal paediatric observation settings, as long as staff have the appropriate experience. (D)

3.7.5 Patients changes requiring review while under observation

3.7.5.1 [Amended] Any of the following examples of neurological deterioration should prompt urgent reappraisal by the supervising doctor:

- Development of agitation or abnormal behaviour.
- A sustained (that is, for at least 30 minutes) drop of one point in GCS (greater weight should be given to a drop of one point in the motor response score of the Glasgow Coma Scale).
- Any drop of three or more points in the eye-opening or verbal response scores of the Glasgow Coma Scale, or two or more points in the motor response score.

| | |
|--|--|
| <ul style="list-style-type: none"> - Development of severe or increasing headache or persisting vomiting. - New or evolving neurological symptoms or signs such as pupil inequality or asymmetry of limb or facial movement. (D) | 3.8 Discharge |
| 3.7.5.2 To reduce inter-observer variability and unnecessary referrals, a second member of staff competent to perform observation should confirm deterioration before involving the supervising doctor. This confirmation should be carried out immediately. Where a confirmation cannot be performed immediately (for example, no staff member available to perform the second observation) the supervising doctor should be contacted without the confirmation being performed. (D) | <u>General:</u> |
| 3.7.6 Imaging following confirmed patient deterioration 3.7.6.1 [Amended] If any of the changes noted in 1.7.5.1 above are confirmed, an immediate CT scan should be considered, and the patient's clinical condition should be re-assessed and managed appropriately. (D) | 3.8.1 Discharge and Glasgow Coma Scale status 3.8.1.1 No patients presenting with head injury should be discharged until they have achieved GCS equal to 15, or normal consciousness in infants and young children as assessed by the paediatric version of the Glasgow Coma Scale. (D) 3.8.2 Discharge advice 3.8.2.1 All patients with any degree of head injury who are deemed safe for appropriate discharge from an emergency department or the observation ward should receive verbal advice and a written head injury advice card. The details of the card should be discussed with the patients and their carers. If necessary (for example, patients with literacy problems, visual impairment or speaking languages without a written format), other formats (for example, tapes) should be used to communicate this information. Communication in languages other than English should also be facilitated. (D) |
| 3.7.7 Further imaging if GCS equal to 15 not achieved at 24 hours 3.7.7.1 In the case of a patient who has had a normal CT scan but who has not achieved GCS 15 after 24 hours' observation, a further CT scan or MRI scanning should be considered and discussed with the radiology department. (D) | 3.8.2.2 The risk factors outlined in the card should be the same as those used in the initial community setting to advise patients on emergency department attendance. Patients and carers should also be alerted to the possibility that some patients may make a quick recovery, but go on to experience delayed complications. Instructions should be included on contacting |

community services in the event of delayed complications. (D)

3.8.2.3 Patients who presented to the emergency department with drug or alcohol intoxication and are now fit for discharge should receive information and advice on alcohol or drug misuse. (D)

Suggested written advice cards for patients and carers are provided in Appendices E, F and G.

3.8.3 Discharge of patients with no carer at home

3.8.3.1 All patients with any degree of head injury should only be transferred to their home if it is certain that there is somebody suitable at home to supervise the patient. Patients with no carer at home should only be discharged if suitable supervision arrangements have been organised, or when the risk of late complications is deemed negligible.(D)

Discharge of specific patient groups:

3.8.4 Low-risk patients with GCS equal to 15

3.8.4.1 If CT is not indicated on the basis of history and examination the clinician may conclude that the risk of clinically important brain injury to the patient is low enough to warrant transfer to the community, as long as no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe

discharge and for subsequent care (for example, competent supervision at home). (D)

3.8.5 Patients with normal imaging of the head

3.8.5.1 After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant discharge, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe discharge and for subsequent care (for example, competent supervision at home). (D)

3.8.6 Patients with normal imaging of the cervical spine

3.8.6.1 After normal imaging of the cervical spine the clinician may conclude that the risk of injury to the cervical spine is low enough to warrant discharge, as long as the patient has returned to GCS equal to 15 and their clinical examination is normal, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe discharge and for subsequent care (for example, competent supervision at home). (D)

3.8.7 Patients admitted for observation

3.8.7.1 Patients admitted after a head injury may be discharged after resolution of all significant symptoms and signs providing they have suitable supervision arrangements at home (see also recommendation 3.5.2.6 for those admitted out of hours but who require a CT scan). (D)

3.8.8 Patients at risk of non-accidental injury

3.8.8.1 No infants or children presenting with head injuries that require imaging of the head or cervical spine should be discharged until assessed by a clinician experienced in the detection of non-accidental injury. (D)

3.8.8.2 It is expected that all personnel involved in the assessment of infants and children with head injury should have training in the detection of non-accidental injury. (D)

3.8.9 Outpatient appointments

3.8.9.1 Every patient who has undergone imaging of their head and/or been admitted to hospital (that is, those initially deemed to be at high risk for clinically important brain injury) should be routinely referred to their General Practitioner for follow-up within a week after discharge. (D)

3.8.9.2 When a person who has undergone imaging of the head and/or been admitted to hospital experiences persisting problems, there should be an opportunity available for referral from primary care to an out-patient appointment with a professional trained in assessment and management of sequelae of brain

injury (for example, clinical psychologist, neurologist, neurosurgeon, specialist in rehabilitation medicine). (D)

3.8.10 Advice about long-term problems and support services

3.8.10.1 [Amended] All patients and their carers should be made aware of the possibility of long-term symptoms and disabilities following head injury and should be made aware of the existence of services that they could contact if they experience long-term problems. Details of support services should be included on patient discharge advice cards. (D)

3.8.11 Communication with community services

3.8.11.1 A communication (letter or email) should be generated for all patients who have attended the emergency department with a head injury, and sent to the patient's GP within 1 week of the end of the hospital episode. This letter should include details of the clinical history and examination. This letter should be open to the person or their carer, or a copy should be given to them. (D)

3.8.11.2 [Amended] A communication (letter or email) should be generated for all school-aged children who received head or cervical spine imaging, and sent to the relevant GP and school nurse within 1 week of the end of the hospital episode. This letter should include details of the clinical history and examination. (D)

3.8.11.3 [Amended] A communication (letter or email) should be generated for all pre-school children who received head or cervical spine imaging, and sent to the GP and health visitor within 1 week of the end of the hospital episode. This letter should include details of the clinical history and examination. (D)

3.9 New Recommendations

3.9.1 Pre-hospital management

3.9.1.1 Pain should be managed effectively because it can lead to a rise in intracranial pressure. Reassurance and splintage of limb fractures are helpful; catheterisation of a full bladder will reduce irritability. Analgesia as described in 3.5.1.9 should be given only under the direction of a doctor.

3.9.2 Investigations for clinically important brain injuries

3.9.2.1 Plain X-rays of the skull should not be used to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury.

3.9.2.2 Unless the CT result is required within 1 hour, it is acceptable to admit a patient for effective overnight observation and delay the CT scan until the next morning if the patient presents out of hours and any of the following risk factors are present in addition to a period of loss of consciousness or amnesia:

- age 65 years or older

- amnesia for events more than 30 minutes before impact
- dangerous mechanism of injury (a pedestrian or cyclist struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs).

3.9.2.3 If CT imaging is unavailable because of equipment failure, patients with GCS 15 may be admitted for observation. Arrangements should be in place for urgent transfer to a centre with CT scanning available should there be a clinical deterioration that indicates immediate CT scanning is necessary.

3.9.3 Selection of patients for CT imaging of the head

3.9.3.1 Children (under 16 years) who have sustained a head injury and present with any one of the following risk factors should have CT scanning of the head requested immediately:

- Loss of consciousness lasting more than 5 minutes (witnessed).
- Amnesia (antegrade or retrograde) lasting more than 5 minutes.
- Abnormal drowsiness.
- Three or more discrete episodes of vomiting.
- Clinical suspicion of non-accidental injury.
- Post-traumatic seizure but no history of epilepsy.
- GCS less than 14, or for a baby under 1 year GCS (paediatric) less than

15, on assessment in the emergency department.

- Suspicion of open or depressed skull injury or tense fontanelle.
- Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).
- Focal neurological deficit.
- If under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head.
- Dangerous mechanism of injury (high-speed road traffic accident either as pedestrian, cyclist or vehicle occupant, fall from a height of greater than 3 metres, high-speed injury from a projectile or an object).

3.9.4 Selection of patients for imaging of the cervical spine

- 3.9.4.1** Adult patients who have any of the following risk factors should have CT imaging of the cervical spine requested immediately:

- GCS below 13 on initial assessment
- Has been intubated
- Plain film series is technically inadequate (for example, desired view unavailable), suspicious or definitely abnormal
- Continued clinical suspicion of injury despite a normal X ray.
- The patient is being scanned for multi-region trauma.

3.9.5 Selection of patients for imaging of the cervical spine

- 3.9.5.1** In children under 10 years, because of the increased risks associated with irradiation, particularly to the thyroid gland, and the generally lower risk of significant spinal injury, CT of the cervical spine should be used only in cases where patients have a severe head injury (GCS \leq 8), or where there is a strong clinical suspicion of injury despite normal plain films (for example, focal neurological signs or paraesthesia in the extremities), or where plain films are technically difficult or inadequate.

3.9.6 Urgency in performing cervical spine imaging

- 3.9.6.1** Children under 10 years of age with GCS of 8 or less should have CT imaging of the cervical spine within 1 hour of presentation or when they are sufficiently stable.

3.9.7 Urgency in performing cervical spine imaging

- 3.9.7.1** Children under 10 years with GCS of 8 or less should have CT imaging of the cervical spine within 1 hour of

- presentation or when they are sufficiently stable.
- 3.9.8 Transfer of adults**
- 3.9.8.1** The possibility of occult extracranial injuries should be considered for the multiply injured adult, and he or she should not be transferred to a service that is unable to deal with other aspects of trauma.
- 3.10 Recommendations for research**
- The GDG identified the following priority area for research.
- 3.10.1 Is the clinical outcome of head injury patients with a reduced level of consciousness improved by direct transport from the scene of injury to a tertiary centre with neurosciences facilities compared with the outcome of those who are transported initially to the nearest hospital without neurosurgical facilities?**
- The aim of this study is to conduct a comparison in patient outcome (mortality/morbidity) for those head injured patients that are transported directly to a centre with neurosciences facilities with the outcomes of those who are transported to the nearest hospital without neurosciences facilities, possibly necessitating a secondary transfer. Patients suffering from serious head injuries with a reduced level of consciousness are currently transported to the nearest hospital by land ambulance or helicopter. The nearest hospital may not have the resources or expertise to provide definitive care for these patients. Patients should be followed as they pass through the care system with mortality and morbidity outcomes collected. These should be compared to allow, using sub-group analysis, the identification of patients for whom direct transfer is most beneficial.
- 3.10.1.1 Why this research is important**
- Limited evidence in this area has shown that patients do better in terms of outcome if they are transported directly to a neurosciences centre when compared to those who are taken to the nearest district general hospital. This evidence however does not appear to have influenced current practice. For people working in the prehospital arena, it is important to define which patients who have sustained a head injury would do better by being transported directly to a neurosciences centre.
- Currently patients are either always transported to the nearest district general hospital as is the case in most land vehicle deployment or in some organisations especially those involving helicopter emergency medical services the decision is left to the judgement of the clinicians at the scene. Those patients transported to the nearest district general hospital may suffer a significant delay in receiving definitive treatment for their head injury. Information from such research can help to define which patients should be transported direct to a neurosciences centre bypassing the nearest hospital.
- Guidance will be required to define the patient population for example, researchers may focus on isolated

injuries or head injuries associated with multi trauma. Further specification about what level of consciousness would be suitable for primary transfer to a neurosciences unit would be required. Researchers should look at the impact of the duration of transport on study outcome. So for a journey time to the neurosciences unit of less than 20 minutes, direct transport might improve outcomes, (as concluded by the London Severe Injury Working Group) but beyond this time, direct transport might worsen outcomes.

In addition to measuring changes in morbidity and mortality, the cost-effectiveness of direct transport should be modelled in terms of the cost per quality-adjusted life-year gained. A prototype model was produced for the 2007 update of this guideline (1.1.1).

from the UK with good sensitivity and specificity.

However, clinical decision rules often provide an overestimate of their performance when applied to new populations. We now recommend the usage of the CHALICE rule for children suffering a head injury in the UK, with the caveat that a validation of the rule in a new population of head injured UK patients be urgently undertaken to ensure its reliability and reproducibility.

Such a study is now essential and performing a validation of the CHALICE study in a novel UK population may easily be performed in a 1-2 year timeframe with acceptable costs, and considerable benefits in terms of assuring clinicians as to the safety of this novel rule.

3.10.2 Research is needed to establish the validity of previously derived clinical decision rules on the selection of head injured infants and children for CT scanning to exclude significant brain injury.

3.10.2.1 Why this research is important

The 2002 NICE guidelines recommended that children be selected for CT scanning on the basis of the Canadian Head CT rule, a clinical decision rule derived and validated in adults. This was due to the absence of such a rule derived in children. However since this date the CHALICE rule has been published which presents a clinical decision rule derived in a large group of children and infants

3.10.3 Research is needed to develop consensus on criteria for lesions not currently considered to be surgically significant following imaging of a patient with head injury.

Although most neurosurgeons agree about which extradural and subdural haematomas should be removed, there is controversy about whether or not to remove traumatic intracerebral haemorrhage (TICH) and cerebral contusions (CC). A prospective randomised controlled trial (PRCT) should be set up to discover if early surgery improves the outcome in these lesions compared to initial conservative treatment.

3.10.3.1 Why this research is important

One option in the management of traumatic intracerebral haemorrhage (TICH) and cerebral contusions (CC) is to monitor the patient clinically or with Intracranial Pressure Monitoring and other forms of brain tissue monitoring such as brain tissue oxygen (BtO₂) or microdialysis. When the patient deteriorates, he or she is rushed to the operating theatre. The problem is that this approach has never been validated in a prospective randomised controlled trial (PRCT). Waiting until there is deterioration in the level of consciousness (LOC) or until there is deterioration in the monitoring parameters builds delay into the management and results in secondary brain damage occurring and becoming established before surgery in all such cases. The principle of early surgical evacuation of spontaneous intracerebral haemorrhage (SICH) has been investigated in the surgical trial in intracerebral haemorrhage (STICH) and reported in the Lancet (2005). The results of such a PRCT in TICH would fundamentally alter the recommendations made by NICE, in terms of which patients should be referred to neurosurgery and, more importantly, how their care should be managed there. There is no level 1 evidence about what to do with these patients and the need for such a PRCT in head injured patients is urgent. This research question should immediately be put to UK research funding bodies.

3.10.4 Do patients with significant traumatic brain injury who do not require operative neurosurgical intervention at

presentation, but are still cared for in specialist neurosciences centres, have improved clinical outcomes when compared to similar patients who are treated in non-specialist centres?

3.10.4.1 Why this research is important

Traumatic brain injury (TBI) is amongst the most important causes of death in young adults, with an overall mortality for severe TBI of over 50%. TBI care consumes one million acute hospital bed-days, and over 15,000 ICU bed-days annually, and patients who do survive significant TBI experience an enormous burden of long term physical disability, neurocognitive deficits, and neuropsychiatric sequelae. The financial impact is significant: the NHS spends over £1 billion on just the acute hospital care of the 10,000 patients with significant TBI. The costs of rehabilitation and community care are difficult to estimate, but probably total many multiples of the figure provided for acute care. These considerations make TBI a national healthcare priority and its outcome impact is consistent with its inclusion in the National Service Framework for Long Term Neurological Conditions.

Current referral of patients with acute traumatic brain injury practice is still dominated in many parts of the United Kingdom by the need for operative neurosurgical intervention at presentation. This may be inappropriate, since many patients with severe head injury have evidence of raised intracranial pressure in the absence of surgical lesions, and suffer morbidity and mortality equal to those with

surgical lesions. Further, several studies provide strong circumstantial evidence that managing such “non-surgical” patients in specialist neurosciences centres may result in substantial improvements in mortality and functional outcome, probably due to specialist expertise in areas of non-operative management, such as neurocritical care. However, these results may be confounded by case-mix effects and referral bias, and the cost-effectiveness of such specialist management remains uncertain. There is a strong case to address this question in the context of a formal study, since a change in practice could have a major impact on death and disability in a condition that is a major contributor to mortality in healthy young adults. Importantly, the results of such a study could fundamentally alter the recommendations made by NICE, in terms of where patients with head injury are treated within the healthcare system, and result in better optimised (and potentially more cost-effective) patient flows within the NHS.

The available evidence in this area has been addressed in the systematic review that contributed to the revision of NICE Guidelines on the early management of head injury. This review could find no high quality clinical evidence on the topic. This is unsurprising, since any study that addressed these issues would have to be undertaken within the context of a healthcare system and include ambulance services, district general hospitals and neuroscience referral centres. Such a study would therefore require the organisational backing of a body such as NICE and careful design to

account for confounds and biases.

However, we believe that given careful design, such a study would be both ethically and logistically feasible. The patient group is well defined, and adequate numbers would be available to provide a definitive result within a reasonable time frame. While circumstantial evidence may support transfer of such patients to neurosciences centres, current practice is not influenced by this view in many regions, and many would argue that there is still clinical equipoise in this area. There are clear risks from transfer, and there could be clear harm, both in terms of clinical outcome and health economics, if the anticipated benefits were not realised. On the other hand, if the benefits from observational studies were confirmed by the trial, the resulting changes in management could potentially reduce case-mix adjusted mortality by 26% and increase the incidence of favourable outcome in survivors by nearly 20%.

3.10.5 Research is needed to summarise and identify the optimal predictor variables for long term sequelae following mild traumatic brain injury.

A systematic review of the literature could be used to derive a clinical decision rule to identify, at the time of injury, relevant patients. This would in turn lay the foundation for a derivation cohort study.

3.10.5.1 Why this research is important

We performed a review of the literature in this area, repeated in this update process. While 394 studies were

identified that attempted to use a wide range of variables and tests to predict a range of longer term outcome measures, no robust clinical decision tool has successfully been derived and validated to identify patients at the time of injury who could be considered for follow-up due to a higher risk of long term sequelae. A systematic review of the literature would summarise and identify the optimal predictor variables for such a clinical decision rule and also identify the optimal outcome variables, thus laying the foundation for a derivation cohort study.

The derivation cohort study to create this clinical decision rule could potentially be conducted in conjunction with the validation of the CHALICE rule, with follow up of patients involved in this study at 6mths-1 yr. This would ensure optimal value for money for funders and ensure good results in a large cohort of patients. Separate studies could also be performed in adults but the initial study may in fact be more urgent in the childhood population.

Identification of patients likely to suffer from long term sequelae will allow targeted research regarding responsiveness to, or effectiveness of focused rehabilitation programmes. Preventative action could potentially be taken, thus reducing the strain on resources further down the care pathway. Furthermore, patient outcomes could potentially be improved by early identification and treatment (both curative and preventive) of problems. However, further research is required before we can be certain that a robust

framework exists with which to cope with individuals identified by the clinical prediction rule proposed above.

4 Pre-hospital assessment, advice and referral to hospital

4.1 *Predictor variables*

A large number of people sustain head injuries each year many of which are sufficiently minor to not require medical attention. Advice to the public and community services should focus on the variables known to elevate the risk of clinically important brain injury or another head wound that may require surgical repair. A large number of variables have been identified as elevating the risk of these outcomes after head injury.

4.2 *Loss of consciousness*

A history of altered consciousness after a head injury increases the risk of intracranial complications although the absolute risk remains low.^{15,46} There is controversy regarding the importance of momentary loss of consciousness, and the variable is, by definition, difficult to measure when no independent observer is available. There is evidence that intracranial complications can occur even

when no loss of consciousness has occurred, but most studies in this area exclude patients who have not experienced a loss of consciousness,

resulting in a paucity of literature on this aspect of risk.

4.3 *Amnesia*

Amnesia after head injury increases the risk of intracranial complications, although the length and type of amnesia are controversial.^{15,46} Amnesia is usually defined as post-traumatic (anterograde – for events after the trauma) in the literature but a recent important study has suggested that retrograde amnesia (**that is**, for memories before the

trauma) is a more important risk factor.²⁵ Amnesia is a less useful predictor variable in infants and young children, simply because it is difficult to measure.

4.4 Neurological signs

Post-traumatic neurological signs such as focal neurological deficits or seizure are highly associated with the risk of an intracranial complication⁴⁷ and the risk is so large that these patients are commonly excluded from studies developing clinical decision rules for the management of acute head injury.

4.5 Bleeding disorders and use of anticoagulants

Patients with coagulopathy have an elevated risk of intracranial complications but the exact strength of this relationship has not been established.^{48,49}

4.6 Skull fracture

It is accepted that the risk of intracranial complications is higher in patients with a diagnosis of skull fracture. It can be estimated that the risk of developing an intracranial haematoma is about 12 times higher in patients with a radiographically detected skull fracture than in patients without this diagnosis, based on an estimate of 38% sensitivity and 95% specificity produced by a meta-analysis of the value of the radiological diagnosis of skull fracture.²³ There is variation in diagnostic practice for skull fracture. Some guidelines advocate the use of skull X-ray in the diagnosis of skull fracture,¹³ while others advocate the use of signs alone (for example, cerebrospinal fluid leak,

periorbital haematoma, depressed or open skull injury, penetrating injury).²⁵

4.7 Age

An exact age threshold for identifying patients at high risk of intracranial complications following a head injury has not been identified, but it is clear that increasing age is associated with an increased risk and a poorer prognosis.⁵⁰ Commonly used thresholds are 60 years^{19,51} and 65 years^{25,50}. To avoid confusion, the GDG chose to adopt a standard age threshold throughout these guidelines of greater than or equal to 65 years. An odds ratio of 4.1 (95% CI: 2.8-6.1) for clinically important brain injury has been quoted with this threshold, providing the patient has experienced loss of consciousness or amnesia.²⁵

There is evidence that the prevalence of intracranial complications in children and infants is much lower than in adults. However, this should be weighed against the fact that an unknown, but significant, proportion of head injuries in children are non-accidental. These injuries may result in a different pattern of morbidity to that seen in adults, and obviously require investigation regardless of cause.

4.8 Mechanism of injury

High energy injury mechanisms have an intuitive appeal in determining the risk of intracranial complications but there are difficulties with providing an exact definition of 'high energy'. Terms such as 'assault' or 'road traffic accident' cover a great heterogeneity of circumstance. A recent level two study has proposed the

following criteria as high risk factors for clinically important brain injuries after head injury: pedestrian struck by motor vehicle, occupant ejected from motor vehicle, or a fall from a height of greater than three feet or more than five stairs²⁵. A further study has defined 'axial load to head' as a high risk factor for cervical spine injury after an accident^{19,52}. This covers the following areas: diving; high-speed motor vehicle collision; rollover motor accident; ejection from a motor vehicle; accident involving motorized recreational vehicles; bicycle collision. In addition, there are many other high energy mechanism injuries which cannot be covered in an exhaustive list (for example, the variety of blunt instruments that could be used in a violent assault) which were considered to be important by the GDG.

UPDATE 2007:

The height threshold for a high-risk fall is sometimes defined as greater than three feet, and sometimes as greater than 1 metre. For the sake of consistency, this guideline will use the term '1 metre'. The recent CHALICE⁵³ rule recognises falls of greater than 3 metres were highly associated with the development of intracranial lesions.

4.9 Drug or alcohol intoxication

Drug or alcohol intoxication can result in signs and symptoms which are risk factors for intracranial complications (for example, vomiting, headache, amnesia, impaired consciousness) but have also been identified as independent risk factors following head injury, making a

differential diagnosis difficult.^{19,54} In addition, alcohol abuse can lead to hypoglycaemia, which can in turn lead to impaired consciousness. This may lead to the incorrect diagnosis of a developing intracranial trauma complication.

4.10 Headache

Headache is a controversial variable in the evaluation of risk for intracranial complications. In some studies the variable has been an important predictor^{19,55} but not in others.^{25,56} Headache can be difficult to define both in terms of duration and severity, particularly in infants and young children.

4.11 Vomiting

Vomiting is consistently identified as a high risk variable, but there is some controversy regarding the number of episodes required to qualify as high-risk.^{19,25,55,56} Vomiting is also quite common in infants and children and its predictive power is controversial in this age group. It has been estimated that around 16% of infants and children aged 12 years or less vomit after minor head injury, and the cause of vomiting often seems to be related to individual intrinsic factors (for example, previous tendency to vomit) rather than specific features of the head injury⁵⁷. There are inconsistencies between the various pre-hospital advice services in their choice of the timescales and number of vomits which would arouse concern in children. This is a reflection of the lack of evidence on which to make a judgment. The GDG considered that in a child under 12 years who has sustained a

head injury 3 vomits within a 4 hour period should be cause for concern even when there are no other signs or symptoms.

4.12 Irritability and altered behaviour

Irritability and altered behaviour are non-specific terms which are sometimes used in clinical guidelines for acute head injury management with little empirical evidence to support their use.¹³

However, they may be an important sign in the pre-verbal child, where other problems like amnesia or headaches cannot be detected.

4.13 History of cranial neurosurgical interventions

Previous cranial neurosurgical interventions have an intuitive relationship with risk of intracranial complications and were considered worthy of inclusion by the GDG despite a dearth of empirical evidence on the variable.

4.14 Public health literature

Public health literature and other non-medical sources of advice (for example, St John Ambulance, police officers) should encourage people who have any concerns following a head injury to themselves or to another person, regardless of the injury severity, to seek immediate medical advice.

This is a grade D recommendation based on evidence level five.

4.15 Telephone advice lines

[Amended] Telephone advice services (for example, NHS Direct, emergency

department helplines) should refer people who have sustained a head injury to the emergency ambulance services (that is, 999) for emergency transport to the emergency departments if they have experienced any of the following (alternative terms to facilitate communication are in parenthesis).

- **Unconsciousness, or lack of full consciousness (for example, problems keeping eyes open).**
- **Any focal (that is, restricted to a particular part of the body or a particular activity) neurological deficit since the injury (examples include problems understanding, speaking, reading or writing; loss of feeling in part of the body; problems balancing; general weakness; any changes in eyesight; and problems walking).**
- **Any suspicion of a skull fracture or penetrating head injury (for example, clear fluid running from the ears or nose, black eye with no associated damage around the eye, bleeding from one or both ears, new deafness in one or both ears, bruising behind one or both ears, penetrating injury signs, visible trauma to the scalp or skull).**
- **Any seizure ('convulsion' or 'fit') since the injury.**
- **A high-energy head injury (for example, pedestrian struck by motor vehicle, occupant ejected from motor vehicle, a fall from a height of greater than 1 metre or more than five stairs, diving accident, high-speed motor**

vehicle collision, rollover motor accident, accident involving motorized recreational vehicles, bicycle collision, or any other potentially high-energy mechanism).

- The injured person or their carer is incapable of transporting the injured person safely to the hospital emergency department without the use of ambulance services (providing any other risk factors indicating emergency department referral are present).

Telephone advice services (for example, NHS Direct, emergency department helplines) should refer people who have sustained a head injury to a hospital emergency department if the history related indicates the presence of any of the following risk factors (alternative terms to facilitate communication are in parenthesis):

- Any previous loss of consciousness ('knocked out') as a result of the injury, from which the injured person has now recovered.
- Amnesia for events before or after the injury ('problems with memory'). The assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years.
- Persistent headache since the injury.
- Any vomiting episodes since the injury.
- Any previous cranial neurosurgical interventions ('brain surgery').

- History of bleeding or clotting disorder.
- Current anticoagulant therapy such as warfarin.
- Current drug or alcohol intoxication.
- Age \geq 65 years.
- Suspicion of non-accidental injury.
- Irritability or altered behaviour ('easily distracted' 'not themselves' 'no concentration' 'no interest in things around them') particularly in infants and young children (that is, aged under 5 years).

- Continuing concern by the helpline personnel about the diagnosis.

In the absence of any of the above factors, the helpline should advise the injured person to seek medical advice from community services (for example, general practice) if any of the following factors are present:

- Adverse social factors (for example, no-one able to supervise the injured person at home).
- Continuing concern by the injured person or their carer about the diagnosis.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

4.16

Community health services and NHS minor injury clinics

[Amended] Community health services (general practice, ambulance crews,

NHS walk-in centres, dental practitioners) and NHS minor injury clinics should refer patients who have sustained a head injury to a hospital emergency department, using the ambulance service if deemed necessary (see section 4.17), if any of the following are present:

- **GCS less than 15 on initial assessment.**
- **Any loss of consciousness as a result of the injury.**
- **Any focal neurological deficit since the injury (examples include problems understanding, speaking, reading or writing; decreased sensation; loss of balance; general weakness; visual changes; abnormal reflexes; and problems walking).**
- **Any suspicion of a skull fracture or penetrating head injury since the injury (for example, clear fluid running from the ears or nose, black eye with no associated damage around the eyes, bleeding from one or both ears, new deafness in one or both ears, bruising behind one or both ears, penetrating injury signs, visible trauma to the scalp or skull of concern to the professional).**
- **Amnesia for events before or after the injury. The assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years.**
- **Persistent headache since the injury.**

- **Any vomiting episodes since the injury.**
- **Any seizure since the injury.**
- **Any previous cranial neurosurgical interventions.**
- **A high-energy head injury (for example, pedestrian struck by motor vehicle, occupant ejected from motor vehicle, fall from a height of greater than 1 metre or more than five stairs, diving accident, high-speed motor vehicle collision, rollover motor accident, accident involving motorized recreational vehicles, bicycle collision, or any other potentially high-energy mechanism).**
- **History of bleeding or clotting disorder.**
- **Current anticoagulant therapy such as warfarin.**
- **Current drug or alcohol intoxication.**
- **Age 65 years or older.**
- **Suspicion of non-accidental injury.**
- **Continuing concern by the professional about the diagnosis.**

In the absence of any the above factors, the professional should consider referral to an emergency department if any of the following factors are present depending on their own judgement of severity.

- **Irritability or altered behaviour, particularly in infants and young children (that is, aged under 5 years).**

- **Visible trauma to the head not covered above but still of concern to the professional.**
- **Adverse social factors (for example, no-one able to supervise the injured person at home).**
- **Continuing concern by the injured person or their carer about the diagnosis.**

These recommendations are based on level five evidence and are considered to be grade D recommendations.

4.17 *Transport from community health services and NHS minor injury clinics and pre-hospital management*

- **Patients referred from community health services and NHS minor injury clinics should be accompanied by a competent adult during transport to the emergency department.**
- **The referring professional should determine if an ambulance is required, based on the patient's clinical condition. If an ambulance is deemed not required, public transport and car are appropriate means of transport providing the patient is accompanied.**
- **The referring professional should inform the destination hospital (by phone) of the impending transfer and in non-emergencies a letter summarising signs and symptoms should be sent with the patient.**

These recommendations are based on level five evidence and are considered to be grade D recommendations.

4.18 *Training in risk assessment*

There is some evidence that ambulance crews using written triage guidelines in a United States context may fall short of acceptable levels of triage accuracy.⁵⁸ The GDG is under the impression that the triage skills of other community professionals may sometimes be below a desirable standard.

[Amended] It is recommended that General Practitioners, nurses, dentists and ambulance crews should receive training, as necessary, to ensure that they are capable of assessing the presence or absence of the risk factors listed in section 4.16.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

5 Immediate management at the scene and transport to hospital

5.1 *Pre-hospital management*

The following principles should be adhered to in the immediate care of patients who have sustained a head injury.

- [Amended] Adults who have sustained a head injury should initially be assessed and their care managed according to clear principles and standard practice, as embodied in: the Advanced Trauma Life Support (ATLS) course/European Trauma course; the International Trauma Life Support (ITLS) course; the Pre-hospital Trauma Life Support (PHTLS) course; the Advanced Trauma Nurse Course (ATNC); the Trauma Nursing Core Course (TNCC); and the Joint Royal Colleges Ambulance Service Liaison Committee (JRCALC) Clinical Practice Guidelines for Head Trauma. For children, clear principles are outlined in the Advanced Paediatric Life Support (APLS)/European Paediatric Life Support (EPLS) course, the Pre-hospital Paediatric Life Support

(PHPLS) course and the Paediatric Education for Pre-hospital Professionals (PEPP) course materials.

- Ambulance crews should be fully trained in the use of the adult and paediatric versions of the GCS.
- Ambulance crews should be trained in the detection of non-accidental injury and should pass information to emergency department personnel when the relevant signs and symptoms arise.
- The priority for those administering immediate care is to treat first the greatest threat to life and avoid further harm.
- [Amended] Patients who have sustained a head injury should be transported directly to a facility that has been identified as having the resources necessary to resuscitate, investigate and initially manage any patient with multiple injuries. It is expected that all acute hospitals and all neuroscience units accepting patients directly from an incident will

have these resources, and that these resources will be appropriate for a patient's age.

- [Amended] Patients who have sustained a head injury and present with any of the following risk factors should have full cervical spine immobilisation attempted unless other factors prevent this:

- GCS less than 15 on initial assessment by the healthcare professional

- neck pain or tenderness

- focal neurological deficit

- paraesthesia in the extremities

- any other clinical suspicion of cervical spine injury.

- [Amended] Cervical spine immobilisation should be maintained until full risk assessment including clinical assessment (and imaging if deemed necessary) indicates it is safe to remove the immobilisation device.

- Standby calls to the destination emergency department should be made for all patients with a GCS less than or equal to 8, to ensure appropriately experienced professionals are available for their treatment and to prepare for imaging.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

- [New] Pain should be managed effectively because it can lead to a rise

in intracranial pressure. Reassurance and splintage of limb fractures are helpful; catheterisation of a full bladder will reduce irritability. Analgesia as described in 6.13 should be given only under the direction of a doctor.

5.2 Glasgow Coma Score

The Glasgow Coma Scale and its derivative the Glasgow Coma Score are widely used in the assessment and monitoring of patients who have sustained a head injury^{59,60}.

The assessment and classification of patients who have sustained a head injury should be guided primarily by the adult and paediatric versions of the Glasgow Coma Scale and its derivative the Glasgow Coma Score^{47,61,62}.

Recommended versions are shown in Appendix M and Appendix N. Good practice in the use of the Glasgow Coma Scale and Score should be adhered to at all times, following the principles below.

- Monitoring and exchange of information about individual patients should be based on the three separate responses on the GCS (for example, a patient scoring 13 based on scores of 4 on eye-opening, 4 on verbal response and 5 on motor response should be communicated as E4, V4, M5).

- If a total score is recorded or communicated, it should be based on a sum of 15, and to avoid confusion this denominator should be specified (for example, 13/15).

- **The individual components of the GCS should be described in all communications and every note and should always accompany the total score.**
 - **The paediatric version of the GCS should include a 'grimace' alternative to the verbal score to facilitate scoring in pre-verbal or intubated patients.**
 - **Best practice in paediatric coma observation and recording as detailed by the National Paediatric Neuroscience Benchmarking Group should be followed at all times. These principles are detailed in Appendix N.**
- These recommendations are based on level five evidence and are considered to be grade D recommendations.**

5.3 Glasgow Coma Scale score

It is well established that the risk of intracranial complications and of subsequent need for surgery increases as GCS score declines.^{15,25,46} A recent study estimated that the rate of clinically important brain injury in hospital attenders who had experienced some loss of consciousness and/or amnesia since their head injury increased from 5% with an initial GCS equal to 15, to 17% for GCS equal to 14, and to 41% for GCS equal to 13.⁶² A further study on paediatric head injury found that a GCS less than 13 was a significant predictor of an abnormal CT scan in children with head injury aged 14 years or younger.⁶³

5.4 Immediate management of patients with severe head injuries

There are specific questions regarding the early management of patients with severe head injuries (that is, GCS less than or equal to 8). Exhaustive systematic reviews have examined evidence on the management of severe traumatic brain injury.^{64,65} These reviews found evidence for only a small number of "standards" (that is, recommendations generally based on class one evidence or strong class two evidence of therapeutic effectiveness) and concluded that there was a paucity of well designed studies examining the efficacy of pre-hospital interventions in severe head injury.

Given these findings, no changes to current practice were recommended in the pre-hospital management of patients who have sustained a severe head injury.

5.5 The benefits of direct transport from the scene to a specialist neurosciences centre compared to transport to the nearest district general hospital

5.5.1 Introduction and rationale for the clinical question

This question has been included in this update because many healthcare professionals, especially ambulance staff, may be uncertain when deciding on the most appropriate destination for a patient with severe head injury. This is pertinent as the severity of head injury may not be known at the scene and the nearest neuroscience unit may be further

away than the emergency department. There is also some confusion amongst hospital staff with regards to interhospital transfer of head injured patients. This is because patients who do not require surgery but do require neurosurgical care may remain in the district general hospital (DGH) and receive treatment there, when they actually require specialist treatment at a neuroscience unit. For interhospital transfers please see Chapter 7.

An emergency department is described as a local, regional DGH with no neurosciences unit or a non specialist centre whereas a neurosciences unit is described as a specialist centre or a unit that has neurosurgical and neurointensive care facilities.

The outcome measures for including studies for this review were mortality, neurological outcome, disability and hospital duration. Studies were excluded where;

- data on head injury patients was not provided,
- the patient group was less than 50% head injured patients,
- intervention was pre hospital care rather than transfer and
- the outcomes reported only duration of transfer and no other outcomes.

5.5.2 Clinical evidence

The first study⁶⁶ was a retrospective observational cohort study (evidence level 2+), that obtained data from the New York State Trauma Registry from

1996-1998. This study examined patients who were transported to a regional/area trauma centre compared with patients transferred to non trauma centre. The patients in the latter group were assessed via the American Triage system (pre hospital care) and referred directly to a non trauma centre. The population were adults (over 13 years) with a GCS less than 14. Sub group data of 2763 head injured patients from a data set of 5419 trauma patients were analysed. Group 1 (n=2272 (82.2%)) patients were transported to regional/area trauma centre. These patients were assessed via American Triage system (pre hospital care) and referred directly to the emergency department of either a regional or area trauma centre. Group 2 (n=491 (17.8%)) patients were assessed via American Triage system (pre hospital care) and referred directly to a non trauma centre. The limitations of this study were that patients were categorised as head injured from data reported in trauma registry however the extent of head injury was unknown, because the GCS was classified as less than 14. The results of this study⁶⁶ showed that the mortality rate of immediate transfer to a neurosciences centre versus transfer to a non trauma centre were in favour of transfer to neuroscience centre with an odds ratio 0.88, CI (0.64-1.22) which did not reach statistical significance.

The second study⁶⁷ (evidence level 2+) described a cohort of paediatric patients aged under 20 years old using a large national US paediatric trauma registry, admitted to one of ninety

paediatric hospitals or trauma centres. The cohort compared 3 sub groups defined by the site of intubation; in the field, in the trauma centre (n=1874) or in a non-trauma centre (n=1647). Taking the data from the latter two branches, risk stratification was performed in patients whose degree of head injury was measured using the New Injury Severity Score (NISS), and the Relative Head Injury Severity Scale (RHIS). The main outcomes were unadjusted mortality rates and functional outcomes. Patients who were assessed using the different scales had no significant differences in outcome or the place of intubation. Mortality (observed vs expected) rate in group 1 was 16.5% and in group 2 was 13.3%. Stratification of injury by NISS or degree of head injury showed that higher mortality rates were not only observed in the severely head injured patients who were intubated in a non trauma but also the mild and moderate head injured patients. Some doubt remains over the definition of head injured patients as it is unclear if these were isolated injury or part of a multiple trauma. This affects the conclusions one can draw from this study.

5.5.3 Economics Evidence from 2007 update

See economics chapter 11.6

5.5.4 Summary of evidence from 2007 update

With one study⁶⁷ it is difficult to draw rational conclusions as to the benefits of direct transport of patients from the scene to either a neurosciences unit or a DGH as there is doubt over the

definition of head injured patients. The other study⁶⁶ showed that the mortality rate of immediate transfer to a neurosciences centre versus DGH were in favour of transport to a neuroscience centre. From this evidence review there is limited evidence for direct transport of head injured patients from the scene to a neurosciences unit being beneficial.

A simulation model⁶⁸ showed improved survival from directly transporting patients to a neurosciences hospital. However, a number of parameters were based on expert judgement rather than strong evidence. A cost-effectiveness analysis based on this model showed that direct transport is likely to be cost-effective.

5.5.5 Rationale behind recommendation

There is no strong evidence to suggest a change in the previous recommendation (see bullet 5 within section 5.1). The GDG recognises that the transported patients with head injury directly to a neuroscience unit rather than a DGH would require a major shift of resources of between an additional 84,000 and 105,000 bed days to neurosurgery from the existing general surgical, orthopaedic, emergency department, paediatric and geriatric services that currently care for these patients. The GDG recognize that further research is needed in this area in order to identify benefits in transporting patients with head injury to a neuroscience unit or a district general hospital. Therefore the GDG propose a research recommendation for this question (see section 5.5.7).

5.5.6 Recommendation

[Amended] Patients who have sustained a head injury should be transported directly to a facility that has been identified as having the resources necessary to resuscitate, investigate and initially manage any patient with multiple injuries. It is expected that all acute hospitals and all neuroscience units accepting patients directly from an incident will have these resources, and that these resources will be appropriate for a patient's age. (Same as the recommendation in section 5.1)

5.5.7 Recommendations for research

The GDG identified the following priority area for research.

5.5.7.1 Research Question

Is the clinical outcome of head injury patients with a reduced level of consciousness improved by direct transport from the scene of injury to a tertiary centre with neurosciences facilities compared with the outcome of those who are transported initially to the nearest hospital without neurosurgical facilities?

The aim of this study is to conduct a comparison of patient outcomes (mortality/morbidity) for those head injured patients that are transported directly to a centre with neurosciences facilities with the outcomes of those who are transported to the nearest hospital without neurosciences facilities, possibly necessitating a secondary transfer. Patients suffering from serious head injuries with a reduced level of

consciousness are currently transported to the nearest hospital by land ambulance or helicopter. The nearest hospital may not have the resources or expertise to provide definitive care for these patients. Patients should be followed as they pass through the care system with mortality and morbidity outcomes collected. These should be compared to allow, using sub-group analysis, the identification of patients for whom direct transfer is most beneficial.

5.5.7.2 Why this research is important

Limited evidence in this area has shown that patients do better in terms of outcome if they are transported directly to a neurosciences centre when compared to those who are taken to the nearest DGH. This evidence however does not appear to have influenced current practice. For people working in the prehospital arena, it is important to define which patients who have sustained a head injury would do better by being transported directly to a neurosciences centre.

Currently patients are either always transported to the nearest DGH as is the case in most land vehicle deployment or in some organisations especially those involving helicopter emergency medical services the decision is left to the judgement of the clinicians at the scene. Those patients transported to the nearest DGH may suffer a significant delay in receiving definitive treatment for their head injury. Information from such research can help to define which patients should be transported direct to

a neurosciences centre bypassing the nearest hospital.

Guidance will be required to define the patient population for example, researchers may focus on isolated injuries or head injuries associated with multi trauma. Further specification about what level of consciousness would be suitable for primary transfer to a neurosciences unit would be required. Researchers should look at the impact of the duration of transport on study outcome. So for a journey time to the neurosciences unit of less than 20 minutes, direct transport might improve outcomes, (as concluded by the London Severe Injury Working Group) but beyond this time, direct transport might worsen outcomes.

5.6 Advanced life support training for ambulance crews

The value of advanced life support (ALS) training for ambulance crews over basic life support training (BLS) is controversial. ALS trained ambulance crews receive extra training in endotracheal intubation, intravenous cannulation, the administration of intravenous fluids and the use of selected drugs. A recent Cochrane systematic review concluded that insufficient evidence existed on the effectiveness of ALS training for ambulance crews.⁶⁹

Given this finding no change to current practice in ALS training for ambulance crews is recommended in these guidelines. This stance will be reviewed in forthcoming versions of these

guidelines depending on advances in the literature.

5.7 Priority dispatch of emergency ambulances

The use of an emergency medical dispatch (EMD) system is controversial. The EMD system requires a form of telephone assessment carried out by ambulance dispatchers to determine the urgency of the emergency. A recent systematic review found little evidence on the effectiveness of EMD in terms of improved clinical outcomes.⁷⁰ However, a recent study on the acceptability of EMD in a UK context found increased satisfaction among callers to the 999 service. The amount of first aid advice and general information received by the service users increased while satisfaction with response times was maintained.⁷¹

Given these findings no change to current practice in EMD is recommended in these guidelines. This stance will be reviewed in forthcoming versions of these guidelines depending on advances in the literature.

6 Assessment in the emergency department

UPDATE 2007:

Hospitals designated to accept patients with any severity of head injury should have the following facilities available at all times:

- A communication system with the ambulance service to enable advanced warning to be given of an injured patient.
- A Trauma Response Team (trained to Advanced Trauma Life Support standards) and medical and nursing staff who have the ability to provide a full range of acute resuscitation procedures and who have all necessary equipment for resuscitation and monitoring.
- A clinician trained in the emergency care of head injured children
- Direct access to 24 hour CT scanning on site.
- An effective CT image reporting service and an image transfer facility linked to the regional neuroscience unit
- Head injury management agreements which clearly set out roles and responsibilities of the admitting hospital and the neuroscience unit.
- A patient transfer team trained and equipped to standards described in chapter 7. (NB This refers to the section on inter-hospital transfers)

6.1 *Focus of emergency department assessment in patients with a head injury*

The main risk to patients who have sustained a recent head injury is the development of a clinically important brain injury. Some brain injuries require an early neurosurgical intervention (for example, intracranial haematoma requiring evacuation) but the life threatening nature of the injury makes early detection essential. Other clinically important brain injuries do not provide an immediate threat to the patient and may produce late sequelae. Early identification of these latter injuries may assist in rehabilitation.

The main focus of emergency department assessment for patients

who have sustained a head injury should be the risk of clinically important brain injuries and injuries to the cervical spine and the consequent need for imaging. Due attention should also be paid to co-existing injuries and to other concerns the clinician may have (for example, non-accidental injury, possible non-traumatic aetiology such as seizure). Early imaging, rather than admission and observation for neurological deterioration, will reduce the time to detection for life-threatening complications and is associated with better outcomes^{17,72}.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

6.2 Investigation of clinically important brain injuries

A systematic review of clinical decision rules for the selection of patients who have sustained a head injury for CT imaging of the head was carried out according to the methods outlined in Chapter Two. Six level one studies^{19,22,24,55,73,74} were identified. It was agreed that the review would focus on this evidence, but also give due cognisance to the findings of a level one systematic review examining the prognostic value of a diagnosis of 'skull fracture'²³ and a level two study that reported on the first part of a project likely to produce level one evidence.²⁵

The studies may be divided into contextual information and actual

decision rules. Four studies provide level one evidence on the following important contextual issues. First, skull X-ray is of limited value in assisting the diagnosis of ICH as the sensitivity of a positive finding is only 38%.²³ While it is true that a finding of skull fracture on radiography significantly elevates the risk of ICH one cannot rule out ICH on the basis of a negative radiograph (sensitivity was 0.38, see section 1.5).

Second, patients with a negative CT scan and no other body system injuries or persistent neurological findings can be safely discharged²². The negative predictive power quoted in this study was 99.7%.

Third, a strategy of either 100% CT imaging or high quality in-patient observation for patients who have sustained a minor/mild head injury will be 100% sensitive.^{73,74} The task is therefore to derive a more sophisticated clinical decision rule for patient selection that will improve specificity without impairing sensitivity.

6.3 What is the best initial diagnostic technique to determine which patients have sustained damage to the brain and require further assessment of the head?

6.3.1 Introduction and rationale for the clinical question

In the 2003 guideline the GDG recommended CT imaging for the head as the primary investigation of choice for the detection of acute clinically important brain injuries (see 6.3.6). In this update a review was carried out to ascertain whether CT is still in 2007 the

most accurate tool for use in the initial diagnosis of head injury. This review also investigates whether there are other imaging tools that have been compared to CT and are accurate in identifying head injury. The outcome measures for including studies for this review were sensitivity and specificity of the imaging technique with or without mortality, disability, neurological outcome, hospital duration, and cost.

6.3.2 Clinical evidence

In the earlier version of the head injury guideline no evidence was found that addressed this question. However in this update one study was retrieved⁷⁵ in children and no evidence was retrieved for adults. This study⁷⁵ examined the diagnostic value of physical examination (including neurological exam) for positive CT scan findings in 98 children (2-16 years) children with closed head injury. This prospective diagnostic study (level II evidence) evaluated physical examination using CT as the reference standard. This study was based in San Diego, USA. Halley et al conclude that physical examination cannot identify all cases of brain injury that are demonstrated on CT imaging. Physical examination was demonstrated in this study as having poor sensitivity of 0.69 (CI: 0.42-0.87) and specificity of 0.4 (CI: 0.30-0.51) for identifying patients with brain injury but this presupposes that CT is 100% accurate.

6.3.3 Economics Evidence from 2007 update

See discussion of clinical decision rules (6.5.3 and 6.5.4) and economic section chapter (11.3.7).

6.3.4 Summary of evidence from 2007 update

The evidence is relatively weak as the Halley et al⁷⁵ study included a limited sample size with 9 out of the 98 subjects not being contactable.

A decision model⁷⁶ estimated that CT scanning all patients was more effective and cost saving than x-raying all patients. It also showed that selective CT scanning could be just as effective as routine CT with lower cost (see also 6.5). However, the setting was the USA where costs are quite different to the NHS and the estimates of effectiveness were derived from case series.

6.3.5 Rationale behind recommendation

Generally speaking, CT is more sensitive than x-ray at detecting clinically important lesions, although evidence specific to head trauma was not retrieved. CT is likely to be cost-effective but only if a) the extra lesions found by CT pose a significant health risk, b) identification leads to earlier/better treatment and c) early/modified treatment improves survival. For these variables there is no high quality evidence. However, a decision model⁷⁶ based on case series evidence estimated that CT scanning all patients would be more effective and cost saving than x-raying all patients in a US context.

The GDG felt based on their expertise that CT is the most appropriate tool for diagnosing life-threatening conditions resulting from head injury. The GDG also felt that a recommendation was required to emphasize that x-ray is not

a suitable substitute for CT. However, it was necessary to acknowledge that plain x-rays are useful adjuvant to CT in managing children with suspected non-accidental injury and therefore a new recommendation was developed (see update 2007 recommendation).

6.3.6 Recommendation

The current primary investigation of choice for the detection of acute clinically important brain injuries is CT imaging of the head.

This recommendation is based on level one evidence and is considered to be a grade A recommendation.

For safety, logistic and resource reasons, magnetic resonance imaging (MRI) scanning is not currently indicated as the primary investigation for clinically important brain injury in patients who have sustained a head injury, although it is recognised that additional information of importance to the patient's prognosis can sometimes be detected using MRI.⁷⁷

MRI is contraindicated in both head and cervical spine investigations unless there is absolute certainty that the patient does not harbour an incompatible device, implant or foreign body.

There should be appropriate equipment for maintaining and monitoring the patient within the MRI environment and all staff involved should be aware of the dangers and necessary precautions for working near an MRI scanner. MRI safety,

availability and speed may improve in the future to the point where it becomes a realistic primary investigation option for head injury.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

Update 2007 Recommendation-

[NEW] Plain X-rays of the skull should not be used to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury.

[NEW] Unless the CT result is required within 1 hour, it is acceptable to admit a patient for effective overnight observation and delay the CT scan until the next morning if the patient presents out of hours and any of the following risk factors are present in addition to a period of loss of consciousness or amnesia:

- age 65 years or older
- amnesia for events more than 30 minutes before impact
- dangerous mechanism of injury (a pedestrian or cyclist struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs).

[NEW] If CT imaging is unavailable because of equipment failure, patients with GCS 15 may be admitted for

- observation. Arrangements should be in place for urgent transfer to a centre with CT scanning available should there be a clinical deterioration that indicates immediate CT scanning is necessary.**
- 6.4 What are the effects on patient outcomes of providing an immediate CT versus observation?**
- 6.4.1 Introduction and rationale for the clinical sub question**
- A question that arises from identifying CT as the best initial imaging technique to determine which patients have sustained damage to the head and require care is whether providing an immediate CT yields better patient outcomes compared with observation. A review of the clinical evidence was deemed necessary as a sub-question as a part of the previous clinical question (see 6.3).
- 6.4.2 Clinical evidence**
- One study (level 1++ evidence) was identified⁷⁸ for this review. This recent large, randomised controlled trial⁷⁸ investigated CT compared with admission to hospital for observation. This study included hospital patients aged ≥ 6 years of age with mild head injury within the past 24hrs who attended emergency departments. The main findings from this trial were that at 3 months, 21.4% (275/1316) of patients in the CT group had not recovered completely compared with 24.2% (300/1286) admitted for observation. The difference was found to be not significant in favour of CT (95%CI: -6.1%-0.6%). The worst outcomes like mortality and severe loss of function were similar between the groups. None of the patients with normal findings on immediate CT had complications later.
- 6.4.3 Economics Evidence from 2007 update**
- See economic section chapter 11.3.
- 6.4.4 Summary of evidence from 2007 update**
- The Af Geijerstam study⁷⁸ showed that the use of CT in the management of patients with mild head injury leads to similar clinical outcomes compared with observation in hospital.
- The associated economic evaluation⁷⁹ showed that for these mild head injured patients CT scanning and then discharge after a negative scan was cost saving compared with admission with no adverse effect on health outcome.
- 6.5 The best clinical prediction rule for selecting adults, infants and children with head injury for CT imaging of the head**
- 6.5.1 Introduction and rationale for the clinical question**
- In order to improve the efficiency of the management of minor head injury, clinical prediction rules can be applied. A clinical prediction rule is derived from original research and is defined as a decision making tool that incorporates 3 or more variables from the history, examination or simple tests^{25,80,81}. This review was carried out to examine which

clinical prediction rule was the best for selecting patients for CT imaging who had experienced a minor head injury. This question was deemed important as the current use of CT for minor head injury is increasing rapidly; it is highly variable and may be inefficient. The interventions included within this review were any prediction rule ranging from NEXUS, NOC, CHR and any other new rules. The studies were included if the outcomes included sensitivity and specificity of prediction rules.

6.5.2 Clinical evidence

In the previous guideline, four studies discussed decision rules for selecting patients for CT imaging which attempted to identify those at a high risk for traumatic brain injury (usually ICH).^{19,24,25,55} On examination of these studies it was felt that one study had validated the rules in a population with a much lower prevalence of abnormal CT scans than an average UK population²⁴ and this study was not considered. A second study described a rule that had only a 65% sensitivity for abnormal CT scan results and was also not considered further.⁵⁵ The sensitivity of these rules have been questioned in another study.⁸²

The remaining two sets of rules, the Canadian CT-rules²⁵ and the 'New Orleans' criteria are now considered.¹⁹ Two versions of the Canadian rules are available, a five point version designed to detect 'need for neurological intervention', and a seven point version designed to detect 'clinically important brain injury'. The remit of this guideline is on the latter outcome, and the seven

point rule is therefore the focus of this review. However, it is recognised that the five point rule has some utility in determining the urgency with which CT imaging should be performed.

Both papers present high quality evidence, but strictly the New Orleans criteria represents level one evidence as it has used separate samples for the derivation and validation phases. The Canadian rules represent level two evidence as they have not yet been validated in a separate sample (this study is ongoing and will report in 2003). Both sets of authors caution against adoption of their rules, the Canadians because of the need for validation, and the New Orleans group because their rules were developed in one centre (the Canadian rules were developed in a multi-centre study).

The Canadian sample²⁵ for a derivation sample, was much larger with 3,121 patients than the New Orleans sample¹⁹ with 520 patients in the derivation phase and 909 patients in the validation phase. This led to statistical power problems with certain key variables (for example, coagulopathy) as not enough patients with these risk factors experienced a negative outcome. It should be noted that the Canadian study considered a much broader range of possible predictive variables, and has outlined in great detail the steps taken to ensure the validity and reliability of the data. Both studies used recursive partitioning as the multivariate technique used to derive the rules.

Both studies excluded patients who had experienced no loss of consciousness. The New Orleans study reports an overall abnormal CT rate of 6.5% and a surgical intervention rate of 0.4%, while the Canadian study reports a rate of clinically important brain injury of 8% and a neurosurgical intervention rate of 1%. The Canadian study included only patients with an initial GCS on arrival at hospital of 13 to 15 and assumed that all patients with GCS less than 13 would receive immediate CT. Four per cent of patients in this study had an initial GCS of 13 and 17% had a GCS of 14, with the remaining 79% having a GCS of 15. The New Orleans study focused on patients with GCS equal to 15 in the emergency department (assuming that all patients with GCS less than 15 would receive immediate CT) and therefore had a lower severity sample than was seen in the Canadian sample.

The cohort used for the derivation of the Canadian Head CT rule contained 69% males, 11% greater than or equal to 65 years and 31% patients who had sustained a fall, similar to figures for the UK. However, as noted in section 1.8: cause of injury, the proportion of assaults seen in the Canadian sample (11%) is lower than is usually quoted for the UK (30-50%). By contrast, the proportion of road traffic accidents in the Canadian sample (43% if injuries involving pedestrians and cyclists are included) is higher than estimates of 25% for the UK. It is not clear whether this reflects broad difference in injury patterns between the two countries, or simply reflects the specific group of patients selected for the Canadian study

(that is, hospital attendees that had experienced some loss of consciousness or amnesia).

It is also important to note that the Guideline Development Group is under the impression that head injury episodes are more likely to involve alcohol in the UK than in Canada, although exact data on this variable is not available.

Both studies report 100% sensitivity (95% CI: 92-100) for need for neurosurgical intervention. The New Orleans criteria reports a 100% (95% CI: 95-100) sensitivity for positive CT scans, whereas the Canadian seven point rules are 98% (95% CI: 96-99) sensitive for detecting clinically important brain injury. The New Orleans rules have a 25% (95% CI: 22-28) specificity for detecting positive CT scans whereas the Canadian rules are reported to have a 50% (95% CI: 48-51) specificity rate for detecting clinically important brain injury.

The New Orleans criteria would lead to a 78% CT ordering rate in patients with GCS equal to 15. The Canadian seven point rules would lead to a 54% ordering rate in patients with a GCS of 13 to 15. It is important to note that the New Orleans study reports 100% CT-scanning of the sample, whereas the Canadian study had a scanning rate of only 67%, and the remaining 33% had a proxy outcome assessment via telephone interview. The final sample in the Canadian study does not include some 10% of eligible patients who did not undergo CT and subsequently could not be contacted for follow-up.

The rules have the following similarities. Both suggest that patients with GCS less than 15 on presentation at emergency departments should have immediate CT imaging. The only caveat to this is that the Canadian rules specify GCS less than 15 two hours after injury. However, it should be born in mind that 93% of adults and 96% of children report to emergency departments with GCS equal to 15,¹⁵ implying that CT imaging for those with GCS less than 15 will not greatly impact on resources. The area of controversy is generally accepted to relate to patients with GCS equal to 15.

Neither rule suggests a role for skull X-ray or admission for observation without CT imaging. Both rules agree that vomiting should be included as an indication for imaging, although the Canadian rule specifies more than one episode. Both rules agree that skull fracture (linear, basal, depressed, open, depressed and penetrating) should be an indication for CT imaging but these are defined and dealt with in different ways. In the New Orleans rules this is included as part of a category named 'physical evidence of trauma above the clavicles' which also includes contusions, abrasions and lacerations. Presumably these would include facial surface wounds and not only wounds to the skull. The Canadian rules seem to have considered obvious penetrating skull injury and/or obvious depressed skull fracture as a priori indications for imaging and have also included any sign of basal skull fracture, and any 'suspicion' of open or depressed skull fracture as part of their rules.

Both rules include an age category. The New Orleans rules specify age greater than 60 years, and the Canadian rules specify age greater than or equal to 65 years.

Both rules agree that post-traumatic seizure should be an indication for CT imaging, but the Canadian rules considered this an a priori variable, whereas it is explicitly included in the New Orleans rules.

It is also important to note that coagulopathy is not included in either set of rules but for very different reasons. The Canadian study excluded these patients deliberately, presumably because they were considered a priori candidates for CT imaging. The New Orleans rules included these patients but did not have enough power to detect a significant predictive effect. The New Orleans study explicitly states that this variable was not considered by their study and imply that it should be considered an important predictive variable. A further exclusion from both samples is focal neurological deficit (this is not completely clear from the New Orleans study) again, presumably because CT imaging of the head for these patients was considered non-controversial.

The rules differ in their treatment of amnesia. The Canadian rules include pre-traumatic amnesia (retrograde – for events before the injury) of greater than 30 minutes, whereas the New Orleans rules include post-traumatic 'short-term memory deficits' (anterograde - for events after the injury). The Canadian

rules contain a variable called 'dangerous mechanism' (of injury), which is defined as a pedestrian struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than three feet or five stairs. The New Orleans rules did not consider this variable. The New Orleans rules contain a headache variable, which was dropped from the Canadian rules.

The New Orleans rules contain a variable for drug or alcohol intoxication whereas this is not included in the Canadian rules. The Canadian authors seem to imply that having a variable "GCS less than 15 after 2 hours" will allow the less severe intoxications to resolve and eliminate a corresponding number of unnecessary scans. The Canadian authors measured ethanol levels in a sub-sample and found that it had no predictive power for the outcomes studied.

UPDATE 2007: Adult rules

Three new studies^{81,83,84} were retrieved for this review looking at clinical prediction rules in adults in addition to the studies in the previous guideline (see section 6.5.2).

One of the 3 new studies looking at clinical prediction rules in adults was Stiell et al⁸¹, a prospective cohort validation study (diagnostic study level I evidence) of 1822 blunt head trauma patients in nine Canadian emergency departments. In the previous guideline the derivation study was included. The inclusion criteria were defined as blunt trauma to the head resulting in witnessed

loss of consciousness, definite amnesia or witnessed disorientation, a GCS score of 13 or greater and injury within the previous 24 hours. The Canadian CT head rule (CCHR) was compared to the New Orleans Criteria (NOC). There were 97 patients (5.3%) with clinically important brain injury and 8 patients (0.4%) required neurosurgical intervention. For detecting clinically important brain injury both rules had 100% (95% CI, 96% to 100%) sensitivity but the Canadian CT head rule had a higher specificity of 50.6% (95% CI, 48% to 53%) than NOC 12.7% (95% CI, 11% to 14%). The reference standard was the CT scan.

The second study was a prospective cohort study (diagnostic study level II evidence) by Smits et al⁸⁴ comprising 3181 Dutch patients with blunt head injury and compared the NOC and CCHR rules. The inclusion criteria were patients age older than 16 years, GCS of 13 to 14 and presentation within 24 hours. Patients with a GCS score of 15 were included if they had one of the following risk factors; history of loss of consciousness, short-term memory deficit, amnesia for traumatic event, posttraumatic seizure, vomiting, severe headache, clinical evidence of intoxication, use of anticoagulants, physical evidence of injury above clavicles or neurological deficit.

The prevalence of neurocranial traumatic CT findings was 9.8% and the incidence of neurosurgical intervention was 0.5%. The CT scan was used as the reference standard. For neurosurgical intervention both rules had 100% (95%

CI, 81.6 to 100%) sensitivity and the CCHR had a higher specificity of 37.5% (95% CI, 34.9% to 40.0%) compared to NOC 3.0% (95% CI, 1.2% to 4.8%).

Neurocranial traumatic CT findings and important CT findings reported a higher sensitivity for the NOC rule. Outcomes were also reported on the entire population, which resulted in the authors adapting the rules to their study population. This study has methodological concerns as the rules tested were adapted to fit into their study population.

The final study⁸³ was a prospective cohort derivation study (diagnostic study level II evidence) for the NEXUS II rules by Mower et al which has not yet been validated in a separate sample. This study comprised 13,728 blunt trauma patients in 21 participating centres who had undergone a head CT scan. The prevalence of intracranial injury was 6.7% (917 out of 13,728). The prediction rule had 8 criteria highly associated with intracranial injuries. The rule had a sensitivity of 98.3% (95% CI, 97.2% to 99.0%) and specificity of 13.7% (95% CI, 13.1% to 14.3%).

UPDATE 2007: Child rules

Four new studies in children^{53,85-87} were retrieved in this update.

Oman et al⁸⁵ studied a prospective cohort (diagnostic study level II evidence) of 1666 children (under 18 years) with blunt head trauma. Patients underwent CT scanning from 21 emergency departments in the NEXUS cohort. This study looked at children in

the NEXUS II derivation study to determine if the prediction rule was effective on children. The prevalence of clinically important ICI was 8.3%. The sensitivity was 98.6% (95% CI, 94.9-99.8) and the specificity 15.1% (95% CI, 13.3-16.9). When the sub-group of children under 3 years old was examined the sensitivity was 100% (95% CI, 86.3-100).

The second prospective cohort study (diagnostic study level I evidence) by Haydel et al⁸⁶ comprised 175 children (5-17 years) with minor head injury from trauma centre in US. Minor head injury was defined as blunt head trauma with loss of consciousness and a normal GCS score, or modified coma scale for infants and children and normal brief neurological examination. The reference standard was a CT scan. The NOC prediction rule was applied to the population to determine children with intracranial injury. The prevalence was 8%. The sensitivity was 100% (95% CI, 73-100) and the specificity was 25.5% (95% CI, 19.1-33.0%). The CT ordering rate was reduced by 23.4% (95% CI, 17.7-30.2).

Palchak⁸⁷ reported a prospective cohort study (diagnostic study level II evidence) of 2,043 children (under 18 years) presenting with blunt head trauma of all severities at a paediatric emergency department at a level 1 trauma centre. Significant predictors of traumatic brain injury were determined and the prediction rule was derived using recursive partitioning. The reference standard was CT scanning and clinical follow-up. The prediction rule had a

sensitivity of 100% (95% CI, 97.2% to 100%) and a specificity of 42.7% (95% CI, 40.5% to 44.9%) to identify traumatic brain injury requiring intervention. The prediction rule was used on the sub-group of patients that had a CT scan (n=1271) to identify traumatic brain injury identified on CT. The sensitivity was 99.0% (95% CI 94.4% to 100%) and specificity 25.8% (95% CI 23.3% to 28.4%). This prediction rule missed one patient with a traumatic brain injury identified on CT. This is a derivation study, not yet validated.

Palchak prediction rule:

A CT scan is required if any of the following predictors are present:

- Abnormal mental status
- Clinical signs of skull fracture
- History of vomiting
- Scalp haematoma in children aged 2 years or younger
- Headache

The final study by Dunning⁵³ which is a prospective multi-centre cohort (diagnostic study level II evidence) reported 22,772 children (under 16 years) presenting at ten hospital emergency departments in the North West of England with any severity of head injury. Significant predictors of intracranial haemorrhage were determined and the Children's Head Injury Algorithm to predict Important Clinical Events (CHALICE) prediction rule

was derived using recursive partitioning. The reference standard was CT scanning and clinical follow-up by a multi-modal method of patient monitoring. The CHALICE prediction rule had a sensitivity of 98.6% (95% CI, 96.4% to 99.6%) and a specificity of 86.9% (95% CI, 86.5% to 87.4%). The CT scan ordering rate was 14%. This is a derivation study, not yet validated.

The CHALICE Prediction Rule:

A computed tomography scan is required if any of the following criteria are present.

History

- Witnessed loss of consciousness of more than 5 min duration
- History of amnesia (either antegrade or retrograde) of more than 5 min duration
- Abnormal drowsiness (defined as drowsiness in excess of that expected by the examining clinician)
- 3 or more vomits after head injury (a vomit is defined as a single discrete episode of vomiting)
- Suspicion of non-accidental injury (NAI, defined as any suspicion of NAI by the examining clinician)
- Seizure after head injury in a patient who has no history of epilepsy

Examination

- Glasgow Coma Score (GCS) less than 14, or GCS less than 15 if less than 1 year old

- Suspicion of penetrating or depressed skull injury or tense fontanelle

- Signs of a basal skull fracture (defined as evidence of blood or cerebrospinal fluid from ear or nose, panda eyes, Battle's sign, haemotympanum, facial crepitus or serious facial injury)

- Positive focal neurology (defined as any focal neurology, including motor, sensory, coordination or reflex abnormality)

- Presence of bruise, swelling or laceration more than 5 cm if less than 1 year old

Mechanism

- High-speed road traffic accident either as pedestrian, cyclist or occupant (defined as accident with speed more than 40 m/h)
- Fall of more than 3 m in height
- High-speed injury from a projectile or an object

If none of the above variables are present, the patient is at low risk of intracranial pathology.

6.5.3 Economics Evidence from 2007 update

See economic section chapter 11.3

6.5.4

Summary of evidence from 2007 update

Adult Rule

Three new studies^{81,83,84} were identified for this review which compared different decision rules in adults. One study⁸¹ showed that for patients with minor head injury and GCS score of 15, the Canadian CT head rule had a higher specificity than NOC for clinical important outcomes. This study also showed that the Canadian CT head rule and NOC have equivalent high sensitivities for detecting the need for neurosurgical intervention and clinically important brain injury. The second study⁸⁴ showed that for patients with minor head injury and a GCS score of 13 to 15, the Canadian CT head rule has a lower sensitivity than the NOC for neurocranial traumatic or clinically important CT findings. The final study⁸³ included the NEXUS II rule which had a sensitivity of 98.3% and specificity of 13.7%.

When we updated the unit costs in the guideline's cost analysis, the results were even more favourable towards the Canadian head CT rule, since radiology costs had fallen. Two studies^{16,88} of the impact of our recommendation for head imaging showed opposite results; there is still great uncertainty about the rates of imaging and admission nationally and therefore the overall economic impact of the guideline is unclear. A published economic evaluation⁷⁶ using cohort study evidence suggested that the Canadian head CT rule is more cost-effective in a US context than a number of alternative strategies based on CT, X-ray or

admission. However, none of the economic evidence has taken into account the impact of the increased radiation exposure.

Child Rules

The 4 new studies^{53,85-87} within this review compared different decision rules in children. One study⁸⁵ concluded that the decision rule derived in the large NEXUS II cohort performed with similar high sensitivity among the subgroup of children who were included in this study. The second study⁸⁶ found that CT use in children aged 5 years or older with minor head injury could be safely reduced by 23% by using a clinical decision rule previously validated in adults. The Palchak study⁸⁷ derived a clinical decision rule for the identification of children who should undergo CT after head injury. The final study⁵³ derived a highly sensitive clinical decision rule for the identification of children who should undergo CT scanning after head injury.

We did not find any economic evidence specific to children.

6.5.5 Rationale behind recommendation

Two evidence based decision rules for selection of patients who have sustained a head injury for CT imaging of the head have been described. There is no clear means of choosing one over the other, and the decision on which rule to choose was therefore based on consensus. Based on the Guideline Development Group consensus, it was decided that the seven point Canadian CT head rules should be used to identify

patients who will need CT imaging of the head.

In order to provide guidance that covers all possibilities, the seven point Canadian CT rule has been slightly adapted as follows.

- Patients with post-traumatic seizure, focal neurological deficit or coagulopathy should be included in the rule.
- Patients with non-symptomatic risk factors (that is, age greater than or equal to 65 years, coagulopathy, dangerous mechanism of injury) should at least have had an instance of loss of consciousness or amnesia (that is, the main signs and symptoms used to screen patients for inclusion in the Canadian CT-head rule study) before receiving CT. This is to prevent the possibility of patients with no signs or symptoms receiving a CT.
- As noted above, falls from three feet have been changed to falls from greater than 1 metre, to ensure consistency with other rules adopted by this guideline. A lower threshold for height of falls should be used when dealing with infants and young children (that is, aged under 5 years). See section 4.8.
- Clinical judgement regarding the cause of vomiting in those aged under or equal to 12 years should be used, and this judgement should guide whether imaging is considered necessary.

- The assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years.

The 2003 Guideline Development Group considered these recommendations see below to be interim and dependant on future research which was likely to appear in the literature in time for the update. These include the validation phase of the Canadian CT head rules, and a new clinical decision instrument based upon the NEXUS II study. The latter study recruited approximately 15,000 patients to the overall project (derivation and validation)⁸⁹.

In relation to selection of patients for imaging of the head, a recent level two study has produced a clinical decision rule for use in children aged under 2 years. It is likely that a validation study for this rule will appear in the near future, although methodological concerns will remain about the derivation phase (see Appendix i). A strong predictive power is ascribed to scalp haematoma in young children.⁹⁰

The literature on skull X-ray in children and infants indicates that, as with adults, the specificity of skull X-ray is too low to be the primary investigation (that is, the absence of skull fracture does not predict absence of intra-cranial complications).^{20,91,92} In studies which have included both children and adults, there is evidence that adult rules can be safely applied to children, but these studies have suffered from statistical power problems.⁹³ The evidence

regarding the safety of adult rules with infants is inconclusive.^{19,24,55}

UPDATE 2007: Adult rules

Based on the three adult prediction rule studies^{81,83,84}, the GDG decided that no change in recommendation was required as they felt there was not enough evidence to warrant a change. The case for selective CT scanning was strengthened by a cost-effectiveness model, although it was conducted from a US perspective and the UK evidence showed great variability between centres. One study had drawn attention to difficulties in scanning and discharging patients out of hours¹⁶, in particular, it is often not practical to discharge elderly patients during the night for social reasons. The GDG agreed that patients age 65 years or older presenting out of hours who are fully conscious and have no other indication for an immediate CT can be safely managed by admission for overnight observation without immediate CT. Admitting these patients overnight could be cheaper than out of hours CT scanning, especially as it would not be possible to discharge many of these patients. Furthermore the Af Geijerstam study showed that for head injured patients generally, observation was not associated with a significant increase in morbidity or mortality compared with immediate CT (see 6.4). The GDG also recognize that any centre which receives head injured patients should have 24 hour CT scanner availability however there may be situations where due to failure of CT scanning equipment this may not be possible. It is then important

to make sure that patients are transferred to a centre which does have the relevant equipment (see recommendation 6.5.6).

UPDATE 2007: Child rules

The original recommendation stated that validated adult rules (Canadian head CT rule) on imaging of the head may be safely used in children and infants. However, the GDG decided that a new recommendation was required for clinical prediction rules of the head in children with the emerging evidence in the Dunning study in this update (CHALICE)⁵³.

The CT ordering rates for both rules are similar⁵³ and therefore the rule that is most accurate is likely to be the most cost-effective.

The GDG considers that the CHALICE rule for children is derived from the best current evidence for the treatment of head injuries in children, but the GDG cautions that this rule is a derivation study only and requires prospective validation. Therefore future recommendations will be dependent on future validation studies.

6.5.6 Recommendation

For Adults -

[Amended] Adult patients who have sustained a head injury and present with any one of the following risk factors should have CT scanning of the head requested immediately:

- **GCS less than 13 on initial assessment in the emergency department.**
- **GCS less than 15 at 2 hours after the injury on assessment in the emergency department.**
- **Suspected open or depressed skull fracture.**
- **Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).**
- **Post-traumatic seizure.**
- **Focal neurological deficit.**
- **More than one episode of vomiting.**
- **Amnesia for events more than 30 minutes before impact.**

CT should also be requested immediately in patients with any of the following risk factors, provided they have experienced some loss of consciousness or amnesia since the injury:

- **Age 65 years or older.**
- **Coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin).**
- **Dangerous mechanism of injury (a pedestrian or cyclist struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs).**

These recommendations are based on level two evidence and are considered to be grade B recommendations.

For Children -

[NEW] Children (under 16 years) who have sustained a head injury and present with any one of the following risk factors should have CT scanning of the head requested immediately:

- **Loss of consciousness lasting more than 5 minutes (witnessed).**
- **Amnesia (antegrade or retrograde) lasting more than 5 minutes.**
- **Abnormal drowsiness.**
- **Three or more discrete episodes of vomiting.**
- **Clinical suspicion of non-accidental injury.**
- **Post-traumatic seizure but no history of epilepsy.**
- **GCS less than 14, or for a baby under 1 year GCS (paediatric) less than 15, on assessment in the emergency department.**
- **Suspicion of open or depressed skull injury or tense fontanelle.**
- **Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).**
- **Focal neurological deficit.**
- **If under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head.**
- **Dangerous mechanism of injury (high-speed road traffic accident either as pedestrian, cyclist or vehicle occupant, fall from a height of greater**

than 3 metres, high-speed injury from a projectile or an object).

6.6

Investigation of cervical spine injuries

Patients who have sustained head injury may have co-incidental cervical spine injury. These patients require clinical and radiographic clearance of the cervical spine before removal of an immobilisation device. The major consequence of a missed bony or ligamentous injury is damage to the cervical cord.

6.6.1

Imaging options

There are four options for imaging of the cervical spine. It is recognised that technological advances in imaging modalities may make the following discussion obsolete in the future.

- **Plain films:**
 - cross table lateral
 - 3 film series (with swimmer's view for cervico-dorsal junction if required)
 - 5 film series including 'trauma obliques'.
- **Lateral flexion/extension series – immediate and/or delayed.**
- **CT (localised or whole cervical spine including cervico-dorsal junction).**
- **Magnetic Resonance Imaging.**

6.6.1.1 Plain films

When adequate visualisation of the entire cervical spine is achieved a negative predictive value for a three-

view series has been quoted as between 93-98%.⁹⁴⁻⁹⁶ Sensitivity however varies from 62% to 84% in these high risk populations. It is estimated that in a high risk population one in six cervical spine injuries would be missed relying on an adequate three-view plain film series alone.⁹⁷ If fractures that are clinically important are used as the gold standard then sensitivity is approximately 94%⁹⁸ and overall specificity 96% in a low risk group.⁹⁹

There is evidence that five-view cervical spine radiography does not improve predictive value compared to three-view radiography with CT as the gold standard.¹⁰⁰ The use of a lateral view alone will miss a significant proportion of injuries detected by a three-view series.¹⁰¹

Patients who have sustained major trauma are more difficult to evaluate with plain films and specificity decreases to between 79% and 89%, mainly due to inadequate or incomplete studies. The most common reason for this is poor visualisation of the cervico-dorsal junction.

6.6.1.2 Lateral flexion/extension views

In alert symptomatic patients, lateral flexion/extension views can be safely performed over the pain-free range. Studies have shown significant false positive and false negative rates.¹⁰² Ten per cent of 'normals' may have 'abnormal' flexion/extension views.¹⁰³

There is controversy over the safety of using fluoroscopically guided passive

flexion and extension to assess patients who are not fully conscious.

6.6.1.3 CT imaging of the cervical spine

CT imaging of the cervical spine may be localised (for example, craniocervical or cervico-dorsal to clarify a clinical or plain radiographic area of suspicion), or cover the whole cervical spine. Modern multislice helical CT scanners enable the whole cervical spine to be scanned at high resolution with ease. Multiplanar reformatted images can be generated rapidly on modern workstations. Use of these modern facilities is increasing in the NHS, but total coverage has not yet been achieved.

Several studies report 100% sensitivity for detection of injuries in areas poorly visualised or suspicious on plain films. These studies are flawed however in that they have not used an alternative gold standard.⁹⁷ If CT imaging of the head has been requested the cost of cervical CT is reduced and can be accomplished quickly without patient transfer.

6.6.1.4 Magnetic Resonance Imaging (MRI) of the cervical spine

There is evidence that MRI detects a higher proportion of soft tissue abnormalities when performed within 48 hours of injury than plain film and CT¹⁰⁴ but the clinical significance of these injuries is unclear. MRI is less effective than CT in the detection of bony injury.¹⁰⁵ It has also been demonstrated that MRI can miss ligamentous injuries if delayed.¹⁰⁶ Injuries of the mid-cervical spine, especially subluxation and lateral

fractures are associated with vertebral artery injury which may be detected by MRI.¹⁰⁷

6.6.1.5 Occipital condyle injuries

Occipital condylar fractures are uncommon injuries associated with high energy blunt trauma to the head and/or upper cervical spine. They are difficult to diagnose clinically but should be suspected in patients showing signs of lower cranial nerve palsy after injury. Demonstration on plain films is extremely difficult and radiological diagnosis requires good quality CT.

6.7 *What is the best diagnostic imaging technique to determine which patients have sustained damage to the cervical spine and require further assessment of cervical spine*

6.7.1 Introduction and rationale for the clinical question

Given the potentially devastating consequences of a missed cervical spine injury, timely and accurate diagnosis is essential for optimal management. This review is required to identify which of the currently available tools is best to identify clinically important cervical spine injury.

The population group was patients with head injury and suspected cervical spine injury. The intervention/imaging options were:

- Computed Tomography Scan (CT)
- Magnetic Resonance Imaging (MRI)

- X-rays: cross table lateral, 3 film series, 5 film series, lateral flexion; extension series or swimmer views

- Observation alone

- Physical examination

The outcome measures for included studies for this review were sensitivity and specificity of the imaging technique.

6.7.2 Clinical evidence

We included one meta-analysis¹⁰⁸ which compared plain X-rays with CT. This meta-analysis included seven diagnostic cohort studies. The studies varied in the number of views (3 and 5) and some were retrospective and others prospective. Another prospective diagnostic cohort study¹⁰⁹ was also retrieved comparing 3 view X-ray with CT. The final prospective diagnostic cohort study¹¹⁰ compared helical CT and X-rays (single cross-table lateral). All 3 studies were graded as diagnostic studies level II evidence. All these studies included patients over 16 years of age. We found no studies in children and infants.

A meta-analysis¹⁰⁸ was retrieved which included seven diagnostic cohort studies. This study comprised 3834 patients with blunt trauma events requiring imaging. The reference standard was either CT or all imaging scans and clinical follow-up. CT scans had a higher sensitivity of 98% (95% CI, 96-99) compared to X-rays which were 52% (95% CI, 47-56). The test for heterogeneity for the sensitivity of CT was 0.99 and for X-rays was 0.07. As there was a high variation in

the sensitivities for X-rays we reviewed the seven studies^{95,111-116} individually. The patient populations varied between the studies. Three studies^{95,112,115} selected only the most severely injured patients (altered mental status or those requiring admission to the intensive care unit). One study¹¹⁶ selected only high risk blunt trauma patients. Another study's¹¹³ inclusion criteria was for blunt trauma patients with physical findings of posterior midline neck tenderness, altered mental status or neurological deficit. The final two studies^{111,114} reviewed patients that had suffered a cervical spine fracture or patients that had both CT and X-ray imaging for suspected cervical spine fracture. The later study¹¹¹ reported a prevalence of cervical spine injury of 76% (19 of 25 included patients). The sensitivities in these seven studies ranged from 39 to 76%. The studies varied in the number of X-ray views (3 and 5) and three were retrospective and four prospective. The meta-analysis¹⁰⁸ evidence supports the use of cervical spine CT as the initial screening test in high risk patients.

A prospective cohort study¹⁰⁹ was retrieved. This was a small study (N=34) that selected high risk blunt trauma patients in a US trauma centre. The study used X-rays to identify fractures of the cervical spine and CT scans were used as the reference standard. The sensitivity of X-rays (3 view) was 93.3% and the specificity was 95.0%.

The final prospective cohort study¹¹⁰ comprised 442 unconscious intubated blunt trauma patients in the UK. The reference standard was MRI and/or

clinical outcome. The interventions tested were helical CT (n=381) and X-rays (single cross-table lateral) (n=421). Only 421 patients had a cross table lateral film as 21 patients went straight to CT for clinical reasons. 381 patients had a CT scan that was followed up by MRI or clinical outcome. Cervical spine injuries were found in 14% of the patients. CT scans were more sensitive than X-rays (98.1% vs 72.1% respectively). X-rays had a lower specificity (94.2%) than CT scans (98.8%). Only 200 of the X-rays were adequate.

6.7.3 Economics Evidence from 2007 update

See Economics section in chapter 11.4

6.7.4 Summary of evidence from 2007 update

The meta-analysis¹⁰⁸ found that CT had a higher sensitivity than X-rays. Nygren¹⁰⁹ found that X-rays had a sensitivity of 93.3% in high risk blunt trauma patients (CT was used as the reference standard). Brohi et al¹¹⁰ found that CT scans had a higher sensitivity than X-rays in a group of unconscious intubated blunt trauma patients.

The economic evidence¹¹⁷⁻¹²⁰ suggests that CT scanning of the cervical spine is cost-effective in higher risk groups who are already undergoing head CT. However, the costs and health consequences associated with the increased radiation exposure were not taken into account, and the settings of these studies were outside the UK NHS.

6.7.5 Rationale behind recommendation

There is no evidence at present to suggest that cervical spine CT scanning is required for everyone regardless of head injury severity; the economic evidence suggests that it would not be cost-effective for head injury patients with a low risk of spinal damage. The GDG previously recommended that X-rays should be the initial imaging modality of choice supplemented with CT when appropriate.

The new evidence¹⁰⁸⁻¹¹⁰ indicates that in severely head injured patients, CT is the best initial diagnostic tool for assessment of the cervical spine. The GDG suggested a change in wording of the recommendation to add that patients with head injury ($GCS \leq 13$) and intubated patients should have CT scans of the cervical spine rather than plain radiographs.

If CT detects more unstable fractures then potentially it will lead to health gain and cost savings by averting paralysis. The cost-effectiveness evidence¹¹⁷⁻¹²¹ suggests that CT scanning of the cervical spine is cost-effective in higher risk groups but not in all head injured patients. These studies were conducted from a US perspective and therefore are not directly applicable to the UK NHS. Logically, as long as CT is picking up more unstable fractures, cervical spine CT will be cost-effective for those NHS patients at the very highest risk; the threshold at which it becomes not cost-effective is, however, difficult to determine.

The rationale for this amendment to the previous recommendation is that in this group of head injured patients ($GCS \leq 13$) X-rays are not able to detect all cervical spine injuries and the risk of cervical spine injury is higher than in the less severely head injured patients. The update evidence is level two evidence. The recommendation is based on the evidence retrieved along with the GDG consensus. The GDG agreed that this change to the recommendation could also be applied for children as there is no evidence at present to suggest otherwise.

6.7.6

Recommendation

[Amended] The current initial investigation of choice for the detection of injuries to the cervical spine is the plain radiograph. Three views should be obtained and be of sufficient quality for reliable interpretation. However, in certain circumstances CT is preferred.

[NEW] Adult patients who have any of the following risk factors should have CT imaging of the cervical spine requested immediately:

- **GCS below 13 on initial assessment**
- **Has been intubated**
- **Plain film series is technically inadequate (for example, desired view unavailable), suspicious or definitely abnormal**
- **Continued clinical suspicion of injury despite a normal X ray.**
- **The patient is being scanned for multi-region trauma.**

As a minimum, CT should cover any areas of concern or uncertainty on plain film or clinical grounds.

With modern multislice scanners the whole cervical spine can be scanned at high resolution with ease and multiplanar reformatted images generated rapidly. Facilities for multiplanar reformatting and interactive viewing should be available.

MRI is indicated in the presence of neurological signs and symptoms referable to the cervical spine and if there is suspicion of vascular injury (for example, subluxation or displacement of the spinal column, fracture through foramen transversarium or lateral processes, posterior circulation syndromes).

MRI may add important information about soft tissue injuries associated with bony injuries demonstrated by plain films and/or CT.

MRI has a role in the assessment of ligamentous and disc injuries suggested by plain films, CT or clinical findings.

In CT, the occipital condyle region should be routinely reviewed on 'bone windows' for patients who sustained a head injury. Reconstruction of standard head images onto a high resolution bony algorithm is readily achieved with modern CT scanners.

In patients who have sustained high energy trauma or are showing signs of lower cranial nerve palsy, particular

attention should be paid to the region of the foramen magnum. If necessary, additional high resolution imaging for coronal and sagittal reformatting should be performed while the patient is on the scanner table.

These recommendations are based on level three evidence and are considered to be grade B recommendations.

6.8 *Cervical spine imaging of Infants and children*

6.8.1 Recommendation

Children aged 10 years or more can be treated as adults for the purposes of cervical spine imaging.

It is recognised that physical examination of an immobilised, distressed child can be extremely difficult. Based on consensus the following recommendations were formulated by the Guideline Development Group:

Children under 10 years should receive anterior/posterior and lateral plain films without an anterior/posterior peg view.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

[NEW] In children under 10 years, because of the increased risks associated with irradiation, particularly to the thyroid gland, and the generally lower risk of significant spinal injury, CT of the cervical spine should be used only in cases where

patients have a severe head injury (GCS \leq 8), or where there is a strong clinical suspicion of injury despite normal plain films (for example, focal neurological signs or paraesthesia in the extremities), or where plain films are technically difficult or inadequate.

This recommendation is based on GDG opinion and evidence on risks of irradiation (see 10).

6.9 *The best clinical prediction rule for selecting patients that have sustained damage to the cervical spine for the imaging technique selected in section 6.7?*

6.9.1 Introduction and rationale for the clinical question

In order to improve the efficiency of the management of cervical spine injury, clinical prediction rules can be applied. A clinical prediction rule is derived from original research and is defined as a decisional making tool that incorporates three or more variables from the history, examination or simple tests^{25,80,81}. This review was carried out to examine which clinical prediction rule was the best for determining which patients should undergo CT of the cervical spine. This question was deemed important as emerging evidence shows that the current practice of using plain films is not always reliable in identifying clinically important injuries to the cervical spine. This is particularly true in patients with severe head injury in whom assessment is more difficult. The interventions included within the studies were any prediction rule ranging from NEXUS, NOC, CCR and any other new rules. The outcomes

included sensitivity and specificity of prediction rules.

6.9.2 Clinical evidence

In the 2003 guideline, a systematic review of clinical decision rules for selection of patients who sustained a head injury for imaging of the cervical spine was carried out according to the methods outlined in Chapter Two. Two level one studies were identified.^{52,122} These were the NEXUS study group from America and the Canadian cervical spine rule.

The remaining papers that were reviewed all contained non-level one evidence for a variety of rules and were derived in small cohorts. In addition some papers considered a variety of different aspects of cervical spine imaging. These included studies in patients who are not fully conscious, studies on the utility of flexion-extension views, studies in children and studies on the utility of CT scanning or MRI scanning. These studies are included in the evidence table but contribute little to the decision as to which rule to use to exclude low risk patients from cervical imaging.

The Canadian cervical spine rule involves the following questions.

- Is there any high risk factor present that mandates radiography: age greater than or equal to 65 years, dangerous mechanism, or paraesthesia in the extremities?
- Is there a low risk factor present that allows the safe assessment of range of

motion (that is, simple rear-end motor vehicle collision, sitting position in ED, ambulatory at any time since injury, delayed onset of neck pain, absence of midline cervical spine tenderness?)

- Is the patient able to actively rotate their neck 45 degrees to the left and right?

For the NEXUS rule, absence of five criteria are used to classify the patient as low risk.

- No midline cervical tenderness.
- No focal neurological deficit.
- Normal alertness.
- No intoxication.
- No painful distracting injury.

Both papers present high quality evidence, the NEXUS rule is level one evidence although they validated their rule by asking each doctor whether the patient was high or low risk using the rule rather than compelling the attending physician to follow the rule. The validation phase of the Canadian cervical spine rules has now been completed and successfully validates the rule.

The NEXUS study¹²² collected prospective data on 34,069 patients in twenty-one hospitals in the USA who underwent cervical imaging following blunt trauma. Included were patients at all levels of alertness, and children. The Canadian cervical spine rule studied 8,924 patients in ten large Canadian

community and university hospitals who underwent cervical imaging following blunt trauma. Only adults with a GCS score equal to 15 were included.

The Canadian cervical spine rule excluded patients who were not fully alert at the time of assessment (that is, GCS equal to 15) on the assumption that these patients would automatically receive cervical spine imaging. The NEXUS rule included all levels of alertness. The NEXUS paper reports an overall cervical fracture rate of 2.4% and a clinically significant fracture rate of 1.7%, while the Canadian paper reports an overall fracture rate of 2.0% with a clinically significant cervical spine fracture rate of 1.7%. The NEXUS rule had no age exclusion whereas the Canadian rules were derived and validated only on patients aged over 16 years.

The Canadian cervical spine rule gives a sensitivity of 100% (95% CI: 98-100) and NEXUS gives a sensitivity of 99.6% (95% CI: 98.6-100). The NEXUS rule is not 100% sensitive but of the two clinically significant missed fractures one had an extension-teardrop fracture and self discharged. He was well at six months. One had a fracture of the right lamina of the sixth cervical vertebra requiring open fixation, but may have been incorrectly classified as low risk by the institution as he had loss of consciousness and neurological signs. Of interest, Stiell et al tested the NEXUS rule on the Canadian cervical spine cohort and found that the sensitivity of the NEXUS rule was only 93%. They also criticise the NEXUS rule for the poor

reproducibility of 'presence of intoxication' and 'distracting painful injuries'. These criticisms have not been accepted by the developers of the NEXUS rules, who argued that the data collected by the Canadian group was inadequate to properly test the NEXUS criteria (Hoffman JR, personal communication).

The main difference in the performance of the rules lies in specificity. The NEXUS rule has a specificity of 13% (95% CI: 12.8-13.0) whereas the specificity of the Canadian cervical spine rule is 42% (95% CI: 40-44) for clinically significant injuries. In addition the Canadian cervical spine rule detected 27 out of 28 clinically insignificant spine fractures.

Because of the very large difference in specificity the ordering rate produced by the two rules is also markedly different. The NEXUS rule requires an 87% three-view plain radiography rate, whereas the Canadian cervical spine rule requires a 58% rate. It is important to note that NEXUS only found 498 of the 818 cervical spine abnormalities on plain radiography, as a very high number of plain radiographs were of inadequate quality. Another issue of concern is that 23 of the cervical fractures that were categorised as high risk by the NEXUS rule had plain radiographs that missed the fracture even though they were of good quality. These fractures were only picked up as further imaging was performed. The Canadian cervical spine rule paper did not comment on how many of their plain radiographs were of inadequate quality, and therefore how many

patients had their fracture picked up by additional imaging.

In the Canadian study, 68% of the sample underwent plain radiography. All participants were telephoned at 14 days to assess for any missed injuries, as there was no other universal gold standard imaging applied, but 577 participants originally entered into the study could not be traced by telephone and did not have a cervical spine radiograph and so were later excluded. This is clearly of methodological concern. The NEXUS study performed three-view imaging in 87% of all participants. They had a different follow up protocol in that they set up a surveillance protocol, looking for any missed fractures returning to any of the participating hospitals. None was found.

The two rules overall adopt very different strategies in the generation of their rules in that the NEXUS group has selected clinical correlates from the history and the examination without advising any specific tests in the examination, whereas the Canadian rules have been generated around an interim test of the ability to actively rotate the neck, thereby increasing the specificity markedly. With regard to the similarities of the rules, NEXUS categorises patients who are not alert as high risk, whereas the Canadian rules considers such patients to be at high risk on an a priori basis. Both identify absence of midline tenderness as a means of triaging to low risk. NEXUS immediately puts them at low risk whereas the Canadian rule marks them as low risk if they can also rotate the

neck. NEXUS identifies focal neurology as high risk and the Canadian rule identifies paraesthesia as high risk.

The main difference in the nature of the rules lies in the use of active neck rotation. NEXUS did not consider removal of the collar for examination as a safe procedure prior to imaging, whereas the Canadian rule found low risk criteria for safely performing active neck rotation, a manoeuvre that has an excellent specificity for exclusion of neck fracture. Due to this great difference in ethos, there are many differences in the two rules. The Canadians cite age greater than or equal to 65 years and dangerous mechanism as indications for immediate radiography, whereas these were not identified in the NEXUS rule. The Canadian rule also cites several specific low risk factors for the simple neck rotation test. The NEXUS rule uses painful distracting injury and intoxication to select patients for radiography, whereas the Canadian investigators did not find these as useful as their other high risk factors

The two rules differ greatly in their approach to the assessment of patients at risk for a cervical injury. The NEXUS study is a much larger cohort and includes children and those who had a GCS score of less than 15. The Canadian rule is however much more specific and provides a validated rule that safely excludes 42% of patients who sustained a head injury from radiography. Neither rule however fully describes how to diagnose the fracture once someone has been identified as at high risk, because plain radiography is

often inadequate and is not always 100% sensitive.

6.9.3 Clinical evidence from update 2007

In the update two diagnostic studies^{123,124} were identified (level I evidence) that examined patients with head injury and suspected cervical spine injury.

One prospective cohort study¹²³ comprised 7438 consecutive adult patients in nine Canadian emergency departments with acute trauma to the head or neck who were in a stable and alert (GCS 15) condition. These patients had neck pain or no neck pain but visible injury above the clavicle and were non-ambulatory and had a dangerous mechanism of injury. This study sought to validate the CCR and also compares the outcomes to the NEXUS low risk criteria (NLR). Patients received an X-ray when ordered by the treating physician or were followed up with a structured telephone interview with a nurse to ensure no injuries were missed.

162 patients (2%) had cervical spine injury. The CCR had a higher sensitivity than NLC, which was 99.4% (95% CI, 96-100) compared to 90.7% (95% CI, 85-94) respectively. CCR had a higher specificity (45.1% [95% CI, 44-46]) compared to NLC (36.8% [95% CI, 36-38]). CCR had a lower ordering rate than NLC (55.9% vs 66.6%). The CCR missed one injury compared to NLC which only identified 147 of the 162 cervical spine injuries. There was an

additional 845 patients selected that were excluded for the primary analysis. These patients were excluded as they were not tested on range of motion which is one of the criteria for the CCR prediction rule. Secondary analysis was conducted including these 'indeterminate' patients.

The second prospective cohort study retrieved¹²⁴ compared the CCR and physicians judgement. This study comprised 6265 adult patients in ten Canadian emergency departments who were in a stable and alert (GCS 15) condition and had neck pain or no neck pain but visible injury above the clavicle and were non-ambulatory and had a dangerous mechanism of injury. This population was from Phase 1 of the original derivation study for the CCR. Physician's judgement was assessed to predict at least 0% probability of clinically important cervical spine injury. Patients received X-rays as requested by judgement of the treating physician or were followed up at 14 days by structured telephone interview. There were 64 (1%) clinically important cervical spine injuries detected. CCR had a higher sensitivity of 100% (95% CI, 94-100) compared to physician judgement of 92.2% (95% CI, 94-100). Specificity was 44.0% (95% CI, 43-45) for CCR compared to 53.9% (95% CI, 82-96) for physician judgement.

6.9.4 Economics Evidence from 2007 update

There were no new published economic evidence for this question found in the update. We updated the unit costs in our cost analysis. The cost savings from the Canadian Cervical Spine Rule compared

with the NEXUS rule were still present but were now more modest since radiology costs are lower.

6.9.5 Summary of evidence from 2007 update

The Canadian Cervical Spine Rule had a higher sensitivity than NEXUS low risk criteria and physician judgement. It should be noted that both studies^{123,124} came from the Canadian Cervical Spine Rule group. There is no new evidence to support CT spine for people with mild head injuries.

The Canadian Cervical Spine Rule still appears to be less costly than the NEXUS rule.

6.9.6 Rationale behind recommendation

In the 2003 guideline two evidence based decision rules for selection of patients who sustained a head injury for imaging of the cervical spine have been described. There was no clear means of choosing one over the other, and the choice of rule was therefore based on consensus. Based on the Guideline Development Group 2003 consensus, it was decided that the Canadian cervical spine rules should be used to identify patients who will require imaging of the cervical spine.

In order to provide guidance that covers all possibilities, the Canadian cervical spine rule had been slightly adapted as follows.

- Patients with GCS less than 15 at the time of assessment should have cervical spine imaging.

- Patients with focal neurological deficit should be included in the rule.

- Patients who have non-symptomatic risk factors (that is, are aged greater than or equal to 65 years, or who have had a dangerous mechanism of injury) should have some neck pain or tenderness before receiving cervical spine imaging.

UPDATE 2007:

The GDG decided that no change should be made to the original recommendation that the Canadian Cervical Spine Rule (CCR) should be used for selecting patients with cervical spine damage for the most accurate imaging technique. The GDG agreed that in cases where there is a severe head injury to an adult, a CT cervical spine examination is required. Adults and children age 10 or over should have a CT cervical spine if they are having a CT of the head. CT of all cervical spines is not recommended as there is no evidence to support this practice.

6.9.7 Recommendation For Adults -

[Amended] Adult patients should have three-view radiographic imaging of the cervical spine requested immediately if any of the following points apply:

- There is neck pain or midline tenderness with:

- Age 65 years or older, or

- dangerous mechanism of injury (fall from greater than 1 metre or five stairs; axial load to head for example, diving; high-speed motor vehicle collision; rollover motor accident; ejection from a motor vehicle; accident involving motorized recreational vehicles; bicycle collision).

- It is not considered safe to assess the range of movement in the neck for reasons other than those above.

- It is considered safe to assess the range of movement in the neck and, on assessment, the patient cannot actively rotate the neck to 45 degrees to the left and right; safe assessment can be carried out if the patient:

- was involved in a simple rear-end motor vehicle collision

- is comfortable in a sitting position in the emergency department

- has been ambulatory at any time since injury with no midline cervical spine tenderness

- presents with delayed onset of neck pain.

- A definitive diagnosis of cervical spine injury is required urgently (for example, before surgery).

These recommendations are based on level one evidence and are considered to be grade A recommendations.

The Guideline Development Group 2003 considered this recommendation to be interim and dependant on future research likely to appear in time for the

update guideline specifically the peer reviewed publication of the validation phase of the Canadian cervical spine rules.

For Children -

[NEW] Children under 10 years of age with GCS of 8 or less should have CT imaging of the cervical spine within 1 hour of presentation or when they are sufficiently stable.

The recommendation is based on GDG opinion.

6.10 Using adult rules with infants and children

The literature on cervical spine injury in infants and children has not to date produced highly sensitive and specific clinical decision rules based on level one evidence that can be used to select such patients for imaging cervical spine.

There is evidence that the prevalence of spinal injuries in children and infants with head injury is much lower than in adults but to date no clearly defined rules with acceptable sensitivity and specificity have been produced.^{125,126}

In this update new clinical prediction rules for head imaging have been examined in children and have been recommended for the head. However no studies have investigated clinician prediction rules for the cervical spine in children, therefore no new recommendation is suggested for use in children.

6.10.1 Recommendations for research

The GDG identified the following priority areas for research.

6.10.1.1 Research Question

Research is needed to establish the validity of previously derived clinical decision rules on the selection of head injured infants and children for CT scanning to exclude significant brain injury.

6.10.1.2 Why this research is important

The 2002 NICE guidelines recommended that children be selected for CT scanning on the basis of the Canadian Head CT rule, a clinical decision rule derived and validated in adults. This was due to the absence of such a rule derived in children. However since this date the CHALICE rule has been published which presents a clinical decision rule derived in a large group of children and infants from the UK with good sensitivity and specificity.

However, clinical decision rules often provide an overestimate of their performance when applied to new populations. We now recommend the usage of the CHALICE rule for children suffering a head injury in the UK, with the caveat that a validation of the rule in a new population of head injured UK patients be urgently undertaken to ensure its reliability and reproducibility.

Such a study is now essential and performing a validation of the CHALICE study in a novel UK population may easily be performed in a 1-2 year timeframe with acceptable costs, and

considerable benefits in terms of assuring clinicians as to the safety of this novel rule.

6.11 Piloting the new rules

The process of implementing these guidelines is beyond the Guideline Development Group but it is recommended that the clinical decision rules advocated in this chapter be piloted and their usage and impact on health outcomes analysed at a small number of representative hospitals before being broadly adopted. The Guideline Development Group 2003 were aware that both the head and cervical spine imaging rules advocated were derived from a Canadian sample, where the proportion of head injury episodes involving assaults and the influence of alcohol is apparently much lower, and the proportion involving road traffic accidents much higher, than in the UK. It is unclear how this could impact on CT ordering rates following adoption of the rules in a UK context.

6.12 Non-accidental injury in children

These guidelines are not intended to cover the acute management of non-accidental injury, but it is important that health professionals are aware that the head injury examination is an important opportunity to identify this problem. There is evidence that a distinct pattern of brain injuries is associated with non-accidental injury in children. This results from the different mechanisms of injury in accidental versus non-accidental head injury.

UPDATE 2007:

[Amended] A clinician with expertise in non-accidental injuries in children should be involved in any suspected case of non-accidental injury in a child. Examinations/investigations that should be considered include: skull X-ray as part of a skeletal survey, ophthalmoscopic examination for retinal haemorrhage, and examination for pallor, anaemia, and tense fontanelle or other suggestive features. Other imaging such as CT and MRI may be required to define injuries.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

Work on the derivation of clinical decision rules to predict non-accidental injury based on imaging patterns has recently been begun.¹²⁷ However, the decision rules in this area will require substantial validation before they can inform clinical practice. Future versions of this guideline should determine the status of research in this area.

6.13 Good practice in emergency department assessment

The following should be practised during emergency department assessment.

- **The priority for all emergency department patients is the stabilisation of airway, breathing and circulation (ABC) before attention to other injuries.**
- **Depressed conscious level should be ascribed to intoxication only after a significant brain injury has been excluded.**

- All emergency department clinicians involved in the assessment of patients with a head injury should be capable of assessing the presence or absence of the risk factors in the guidance on patient selection and urgency for imaging (head and cervical spine – see previous recommendations). Training should be available as required to ensure that this is the case.

- Patients presenting to the emergency department with impaired consciousness (GCS less than 15) should be assessed immediately by a trained member of staff.

- In patients with a GCS less than or equal to 8 there should be early involvement of an anaesthetist or critical care physician to provide appropriate airway management, as described in section 7.8.6, and to assist with resuscitation.

- All patients presenting to an emergency departments with a head injury should be assessed by a trained member of staff within a maximum of 15 minutes of arrival at hospital. Part of this assessment should establish whether they are high risk or low risk for clinically important brain injury and/or cervical spine injury, using the guidance on patient selection and urgency for imaging (head and cervical spine – see previous recommendations).

[Amended] In patients considered to be at high risk for clinically important brain injury and/or cervical spine injury, assessment should be extended

to full clinical examination to establish the need to request CT imaging of the head and/or imaging of the cervical spine. The guidance on patient selection and urgency for imaging (head and cervical spine) should form the basis for the final decision on imaging after discussion with the radiology department. See recommendations 3.5.3.1 to 3.5.4.2 (imaging of the head) and 3.5.5.1 to 3.5.7.2 (imaging of the cervical spine).

[Amended] Patients who, on initial assessment, are considered to be at low risk for clinically important brain injury and/or cervical spine injury should be re-examined within a further hour by an emergency department clinician. Part of this assessment should fully establish the need to request CT imaging of the head and/or imaging of the cervical spine. The guidance on patient selection and urgency for imaging (head and cervical spine) should again form the basis for the final decision on imaging after discussion with the radiology department. See recommendations 3.5.3.1 to 3.5.4.2 (imaging of the head) and 3.5.5.1 to 3.5.7.2 (imaging of the cervical spine).

[NEW] Pain should be managed effectively because it can lead to a rise in intracranial pressure. Reassurance and splintage of limb fractures are helpful; catheterisation of a full bladder will reduce irritability. Significant pain should be treated with small doses of intravenous opioids titrated against clinical response and

baseline cardiorespiratory measurements.

[Amended] Throughout the hospital episode, all healthcare professionals should use a standard head injury proforma in their documentation when assessing and observing patients with head injury. This form should be of a consistent format across all clinical departments and hospitals in which a patient might be treated. A separate proforma for those under 16 years should be used. Areas to allow extra documentation should be included (for example, in cases of non-accidental injury). (Examples of proformas that should be used in patients with head injury are provided in Appendices J, K1 and K2).

It is recommended that in-hospital observation of patients with a head injury, including all emergency department observation, should only be conducted by professionals competent in the assessment of head injury.

Patients who returned to an emergency department within 48 hours of discharge with any persistent complaint relating to the initial head injury should be seen by or discussed with a senior clinician experienced in head injuries, and considered for a CT scan.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

7 Imaging practice and involvement of the neurosurgical department

7.1 *Good practice in imaging of patients with a head injury*

It is assumed that general principles of good practice in imaging will be adhered to, as outlined in publications by the Royal College of Radiologists.¹⁴ On the basis of consensus, the Guideline Development Group has made the following recommendations.

- All CT scans of the head should be reviewed by a clinician who has been deemed competent to review such images.
- All plain radiographs of the cervical spine should be reviewed by a clinician who has been deemed competent to review such images.
- Where necessary, transport or transmission of images should be used to ensure that a competent clinician review the images.
- All imaging performed on patients with head injury should have a full or interim written report for the patients'

notes within an hour of the procedure having been performed.

- Imaging of any kind should not delay neurosurgical or anaesthetic referral in patients with severe head injury. (D)

These recommendations are based on level five evidence and are considered to be grade D recommendations.

7.2 *Urgency in performing CT of the head*

Given the demands on CT scanners and radiologists trained in their use it is important to distinguish between those patients for whom CT imaging is required 'urgently' and those where CT can be performed 'within a reasonable period'.

Given that it is proposed that selection for head imaging be based upon the Canadian CT-head rules, it is possible to distinguish between those patients at high risk for neurosurgical intervention (the five point rules) and those at high risk for non-neurosurgical clinically

important brain injuries (the seven point rules). The former set of patients will need CT imaging to be performed urgently (that is, within one hour of the request having been received) whereas the latter patients can wait for a reasonable period (8 hours) before imaging.

[Amended] CT imaging of the head should be performed (that is, imaging carried out and results analysed) within 1 hour of the request having been received by the radiology department in those patients where imaging is requested because of any of the following risk factors:

- GCS less than 13 on initial assessment in the emergency department.
- GCS less than 15 at 2 hours after the injury.
- Suspected open or depressed skull fracture.
- Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).
- More than one episode of vomiting in adults; three or more episodes of vomiting in children.
- Post-traumatic seizure.
- Coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin) providing that some loss of consciousness or amnesia has been experienced; patients receiving antiplatelet therapy may be at increased risk of intracranial bleeding,

though this is currently unquantified – clinical judgement should be used to assess the need for an urgent scan in these patients.

- Focal neurological deficit.

[Amended] Patients who have any of the following risk factors and none of the risk factors above should have their CT imaging performed within 8 hours of the injury (imaging should be performed immediately in these patients if they present 8 hours or more after their injury):

- Amnesia for events more than 30 minutes before impact (the assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years).
- Age 65 years or older, providing that some loss of consciousness or amnesia has been experienced.
- Dangerous mechanism of injury (a pedestrian struck by a motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1 metre or five stairs) providing that some loss of consciousness or amnesia has been experienced.

These recommendations are based on level two evidence and are considered to be grade B recommendations.

7.3 Cervical spine imaging urgency

The demands on X-ray facilities are not as pressing as those on CT facilities and there is no consequent need to discriminate between different

categories of patient requiring cervical spine imaging. Cervical spine imaging if indicated should be carried out urgently as these patients will often need CT of the head once the cervical spine has been cleared.

[Amended] Imaging of the cervical spine should be performed within 1 hour of a request having been received by the radiology department or when the patient is sufficiently stable. Where a request for urgent CT imaging of the head (that is, within 1 hour) has also been received, the cervical spine imaging should be carried out simultaneously.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

7.4 Involving neurosurgical care

The care of all patients with new, surgically significant abnormalities on imaging should be discussed with a neurosurgeon. The definition of 'surgically significant' should be developed by local neurosurgical centres and agreed with referring hospitals. An example of a neurosurgical referral letter is shown in Appendix L .¹³

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

Examples of abnormalities not surgically significant have been produced by a survey of neuroradiologists and emergency physicians in Canada.²⁵ However, these criteria have not to date

been accepted by UK neurosurgeons, and a survey carried out in 2003 by the Society of British Neurological Surgeons found substantial concern about the Canadian criteria. The UK survey was carried out specifically to complement the development of this guideline. It would be desirable if the criteria to be used in this area could be based on the opinion of UK neurosurgeons.

7.4.1 Recommendations for research

The GDG identified the following priority areas for research in the original guideline as well as in this update.

7.4.1.1 Research Question

Research is needed to develop consensus on criteria for lesions not currently considered to be surgically significant following imaging of a patient with head injury.

Although most neurosurgeons agree about which extradural and subdural haematomas should be removed, there is controversy about whether or not to remove traumatic intracerebral haemorrhage (TICH) and cerebral contusions (CC). A prospective randomised controlled trial (PRCT) should be set up to discover if early surgery improves the outcome in these lesions compared to initial conservative treatment.

7.4.1.2 Why this research is important

One option in the management of traumatic intracerebral haemorrhage (TICH) and cerebral contusions (CC) is to

monitor the patient clinically or with intracranial pressure monitoring and other forms of brain tissue monitoring such as brain tissue oxygen (BtO₂) or microdialysis. When the patient deteriorates, he or she is rushed to the operating theatre. The problem is that this approach has never been validated in a prospective randomised controlled trial (PRCT). Waiting until there is deterioration in the level of consciousness (LOC) or until there is deterioration in the monitoring parameters builds delay into the management and results in secondary brain damage occurring and becoming established before surgery in all such cases. The principle of early surgical evacuation of spontaneous intracerebral haemorrhage (SICH) has been investigated in the surgical trial in intracerebral haemorrhage (STICH) and reported in the Lancet (2005). The results of such a PRCT in TICH would fundamentally alter the recommendations made by NICE, in terms of which patients should be referred to neurosurgery and, more importantly, how they should be managed there. There is no level 1 evidence about what to do with these patients and the need for such a PRCT in head injured patients is urgent. This research question should immediately be put to UK Research Funding bodies.

7.5 Other reasons for discussing a patient's care with a neurosurgeon

Other criteria for discussing a patient's care with a neurosurgeon were developed by both Guideline Development Group consensus and

recommendations from previous guidelines.¹³

Regardless of imaging, other reasons for discussing a patient's care plan with a neurosurgeon include:

- **persisting coma (GCS less than or equal to 8) after initial resuscitation.**
- **unexplained confusion which persists for more than 4 hours**
- **deterioration in GCS score after admission (greater attention should be paid to motor response deterioration)**
- **progressive focal neurological signs**
- **a seizure without full recovery**
- **definite or suspected penetrating injury**
- **a cerebrospinal fluid leak.**

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

7.6 Criteria for neurosurgical interventions

These guidelines assume best practice will be followed once neurosurgeons have become involved with a particular patient. The exact nature and timing of the interventions is beyond the scope of the guidelines.

7.7 Transfer from secondary to tertiary care settings

The risk of a further injury to patients during transfer to tertiary care is well established.¹²⁸ In the previous guideline transfer of the patient between a general hospital and a neurosciences unit were advised to follow the principles set out by the Neuroanaesthesia Society of Great

Britain and Ireland and the Association of Anaesthetists of Great Britain and Ireland.¹²⁹ The recommendations are listed below see section 7.9.7 with slight modifications to wording so that they fit the style of these guidelines. The PaCO₂ targets recommended for intubated patients are based on recent literature in this area.¹³⁰⁻¹³² Since the original guideline there has been an update of the guidance from the Association of Anaesthetists¹³³ which has been reviewed in this update and recommendations have been revised accordingly see section 7.8.6.

7.8 *What are the benefits for patients of receiving treatment at a neurosciences centre who have suffered a clinically important brain injury that does not require surgical intervention?*

7.8.1 **Introduction and rationale for the clinical question**

There is no uncertainty about the management of patients with operative lesions; they must be transferred to the neurosciences unit for their operation. However, there is concern that patients who have suffered a clinically important brain injury, who are initially referred to an emergency department but do not have an operable lesion, may have a poorer outcome if they are not referred to a neurosciences centre. The dilemma for hospital staff at the DGH is whether to keep the patients at that location or to transfer them to a neurosciences unit to continue with their treatment. This question is relevant for clinicians at both types of hospitals. It is important to address whether the patient will receive better non – operative treatment if they

are transferred to a specialist neurosciences centre than if they remained at the initial DGH.

An emergency department is described as a local, regional district general hospital with no neurosciences unit or a non specialist centre whereas a neurosciences unit is described as a specialist centre or a unit that has neurosurgical and neurointensive care facilities.

The main outcome measures for including studies in this review were mortality, neurological outcome, disability and hospital duration and at least one of these outcomes were reported in the studies. Studies were excluded where;

- data on head injury patients were not provided,
- the patient group was less than 50% head injured patients,
- intervention was pre hospital care rather than transfer and
- the outcomes reported only duration of transfer and no other outcomes.

7.8.2 **Clinical evidence**

One study¹³⁴ was identified that looked at interhospital transfer (secondary transfer from one hospital to another). Three additional studies^{66,135,136} looked at direct transport from the injury scene to a DGH or transfer to a neurosciences unit from a DGH.

The first study¹³⁴ a prospective observational study (level 2+ evidence) included patients of any age who were injured by blunt trauma between 1996-

2003 (n=6921). These patients were treated by participating hospitals in the Trauma Audit and Research Network (TARN), in the United Kingdom. The intervention group (n=4616) patients received care at a neurosurgical centre (including those who had been transferred which was 53% (2677/4982)). The control group (n=2305) patients received all their care in hospitals without neurosurgical facilities on site. The mortality rate for all patients that were transported to a neurosciences unit was 35% (95% CI, 34-37%) and for those that were transported to the emergency department was 61% (95% CI, 59-63%). The mortality rate for the subgroup (n=894) of patients with isolated, non-surgical severe head injury who were transported to a neurosciences unit was 26%, (95% CI, 22-29%) and for those that were transported to the emergency department the rate was 34% (95% CI, 39-40%), $p=0.005$.

The second study⁶⁶ a retrospective observational cohort study (level 2+ evidence) examined the issue of bypass, which obtained data from the New York State Trauma Registry from 1996-1998. The population consisted of adults more than 13 years of age with a GCS less than 14. A sub group of 2763 head injured patients from the data set of 5419 trauma patients was analysed. The patients in the intervention group (n=1430 (51.8%)) were transported to a regional trauma centre. These patients were assessed via the American Triage system (pre hospital care) and referred directly to the emergency department of a regional centre. The comparison group

(n=1333 (48.2%)) were transferred to an area/non trauma centre. These patients were assessed via the American Triage system (pre hospital care) and referred directly to either an area centre or a non trauma centre. The mortality for transfer to regional centre versus non trauma centre was OR of 0.67 (95% CI, 0.53-0.85).

In another study¹³⁵, a low quality study (level 3 evidence), where patients were directly transported to neurosurgical care or secondarily transferred from a DGH, the population group were neurosurgical unit patients with an extradural haematoma requiring surgery (n=104). Group 1 patients (n=71) had a mean age of 22 years ($\pm 2SE$) were directly transported to a neurosurgical centre. Group 2 patients (n=33) had a mean age 20years ($\pm 3SE$) and were transferred from the DGH to a neurosurgical centre. The results using the Glasgow Outcome Scale (GOS) show that mortality in group 1 was 4% (3/71) and in group 2 was 24% (8/33). The moderate/severe disability in group 1 was 10% (7/71) and group 2 was 27% (9/33). Recovery was good in 86% (61/71) of group 1 patients and 49% (16/33) in group 2, with $p \leq 0.0002$.

The final study¹³⁶ was a well designed cohort study (level 2++ evidence) looking at mortality outcomes between patients directly transferred to a trauma centre and those who were transferred first to a non-trauma centre, and then on to a trauma centre. This cohort study included severely traumatic brain injured patients. The data was collected as part of a multi-centre online database

designed to track pre-hospital and in-hospital severe TBI patient data, called TBI-trac. All patients passing through the trauma centres were included, and selection criteria were applied. Therefore, out of 1449, only 1123 patients were included; the remainder were excluded on the basis of a well-defined criterion, which included the mechanism of injury, death, brain death, or otherwise not benefiting from the care on offer. The authors compared, using a logistic regression model, two-week mortality outcomes between patients directly transferred to a trauma centre (n=864, 77.3%), and those who were transferred first to a non-trauma centre, and then on to a trauma centre (n=254, 22.7%). The model controlled for baseline characteristics and clinical data including hypotension status on day one, if the patient was less than or more than 60 years old, pupil status on day 1, and the initial GCS. Admission time and time by transport status were found to not affect the significance of the results. Patients were found to have a significantly lower chance of mortality with direct transfer with an odds ratio of 1.48 (CI 1.03-2.12) and p=0.04.

7.8.3 Economics Evidence from 2007 update

There was no new economic evidence for this question found in the update.

7.8.4 Summary of evidence from 2007 update

Only one study¹³⁴ provides some good evidence that all patients with severe head injuries (GCS 8 or less) would benefit from receiving treatment in a

neurosurgical unit irrespective of any need for a neurosurgical operation instead of receiving treatment at the emergency department. This study found data which suggests that treatment in a neurosciences centre offers a better strategy for the management of severe head injury. This study did not address direct transfer from the scene, only inter-hospital transfers. There is evidence^{135,136} which suggests good recovery, better mortality and morbidity rates amongst severely injured patients who bypass the DGH and go to the neurosciences unit. However another study⁶⁶ suggests very little difference.

7.8.5 Rationale behind recommendation

A slight amendment to the previous recommendation was required (see 7.8.6). The GDG felt that there is evidence to support a recommendation for severely head injured to receive treatment in a neurosurgical unit irrespective of any need for a neurosurgical operation and have included an amendment to the recommendation below 7.8.6. The GDG agreed that the studies^{66,135,136} did not provide enough evidence for this question to demonstrate that all patients should be sent directly to receive treatment in a neurosurgical unit irrespective of any need for a neurosurgical operation. This is because the GDG recognises that this would require a major shift of resources of between an additional 84,000 and 105,000 bed days to neurosurgery from the existing general surgical, orthopaedic, emergency department, paediatric and geriatric services that

currently care for these patients. The GDG agreed that whilst there are not enough resources for all head injury patients to go to a neurosciences centre, we should aspire to improve the rate of transfer. The GDG opinion therefore is to propose this area for further research (see section 7.9.1).

7.8.6 Recommendation

For adults:

[Amended] Local guidelines on the transfer of patients with head injuries should be drawn up between the referring hospital trusts, the neuroscience unit and the local ambulance service, and should recognise that:

- **transfer would benefit all patients with serious head injuries (GCS \leq 8), irrespective of the need for neurosurgery**
- **if transfer of those who do not require neurosurgery is not possible, ongoing liaison with the neuroscience unit over clinical management is essential.**

[NEW] The possibility of occult extracranial injuries should be considered for the multiply injured adult, and he or she should not be transferred to a service that is unable to deal with other aspects of trauma.

There should be a designated consultant in the referring hospital with responsibility for establishing arrangements for the transfer of patients with head injuries to a

neuroscience unit and another consultant at the neuroscience unit with responsibility for establishing arrangements for communication with referring hospitals and for receipt of patients transferred.

[Amended] Patients with head injuries requiring emergency transfer to a neuroscience unit should be accompanied by a doctor with appropriate training and experience in the transfer of patients with acute brain injury. The doctor should be familiar with the pathophysiology of head injury, the drugs and equipment they will use and with working in the confines of an ambulance (or helicopter if appropriate). They should have a dedicated and adequately trained assistant. They should be provided with appropriate clothing for the transfer, medical indemnity and personal accident insurance. Patients requiring non-emergency transfer should be accompanied by appropriate clinical staff.

The transfer team should be provided with a means of communication with their base hospital and the neurosurgical unit during the transfer. A portable phone may be suitable providing it is not used in close proximity (that is, within 1 metre) of medical equipment prone to electrical interference (for example, infusion pumps).

[Amended] Although it is understood that transfer is often urgent, initial resuscitation and stabilisation of the patient should be completed and

comprehensive monitoring established before transfer to avoid complications during the journey. A who is patient persistently hypotensive, despite resuscitation, should not be transported until the cause of the hypotension has been identified and the patient stabilised.

All patients with a GCS less than or equal to 8 requiring transfer to a neuroscience unit should be intubated and ventilated as should any patients with the indications detailed in the recommendation below.

[Amended] Intubation and ventilation should be used immediately in the following circumstances:

- Coma – not obeying commands, not speaking, not eye opening (that is, $GCS \leq 8$).
- Loss of protective laryngeal reflexes.
- Ventilatory insufficiency as judged by blood gases: hypoxaemia ($PaO_2 < 13$ kPa on oxygen) or hypercarbia ($PaCO_2 > 6$ kPa).
- Spontaneous hyperventilation causing $PaCO_2 < 4$ kPa.
- Irregular respirations.

[Amended] Intubation and ventilation should be used before the start of the journey in the following circumstances:

- Significantly deteriorating conscious level (one or more points on the motor score), even if not coma.
- Unstable fractures of the facial skeleton.

- Copious bleeding into mouth (for example, from skull base fracture).
- Seizures.

[Amended] An intubated patient should be ventilated with muscle relaxation and appropriate short-acting sedation and analgesia. Aim for a PaO_2 greater than 13 kPa, $PaCO_2$ 4.5 to 5.0 kPa unless there is clinical or radiological evidence of raised intracranial pressure, in which case more aggressive hyperventilation is justified. If hyperventilation is used, the inspired oxygen concentration should be increased. The mean arterial pressure should be maintained at 80 mmHg or more by infusion of fluid and vasopressors as indicated. In children, blood pressure should be maintained at a level appropriate for the child's age.

Education, training and audit are crucial to improving standards of transfer; appropriate time and funding for these activities should be provided.

Carers and relatives should have as much access to the patient as is practical during transfer and be fully informed on the reasons for transfer and the transfer process.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

7.9 Transfer of children

The recommendations in section 7.8.6 above were written for adults but the principles apply equally to children

and infants, providing that the paediatric modification of the Glasgow Coma Scale is used.

Service provision in the area of paediatric transfer to tertiary care should also follow the principles outlined in the National Service Framework for Paediatric Intensive Care. These do not conflict with the principles outlined in section 7.5 above¹³⁷.

Transfer of a child or infant to a specialist neurosurgical unit should be undertaken by staff experienced in the transfer of critically ill children.

Families should have as much access to their child as is practical during transfer and be fully informed on the reasons for transfer and the transfer process.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

[NEW] The possibility of occult extracranial injuries should be considered for the multiply injured child, and he or she should not be transferred to a service that is unable to deal with other aspects of trauma.

7.9.1 Recommendations for research

The GDG also identified the following priority areas for research.

7.9.1.1 Research Question

Do patients with significant traumatic brain injury who do not require operative neurosurgical intervention at

presentation, but are still cared for in specialist neurosciences centres, have improved clinical outcomes when compared to similar patients who are treated in non-specialist centres?

7.9.1.2 Why this research is important

Traumatic brain injury (TBI) is amongst the most important causes of death in young adults, with an overall mortality for severe TBI of over 50%. TBI care consumes one million acute hospital bed-days, and over 15,000 ICU bed-days annually, and patients who do survive significant TBI experience an enormous burden of long term physical disability, neurocognitive deficits, and neuropsychiatric sequelae. The financial impact is significant: the NHS spends over £1 billion on just the acute hospital care of the 10,000 patients with significant TBI. The costs of rehabilitation and community care are difficult to estimate, but probably total many multiples of the figure provided for acute care. These considerations make TBI a national healthcare priority and its outcome impact is consistent with its inclusion in the National Service Framework for Long Term Neurological Conditions.

Current referral of patients with acute traumatic brain injury practice is still dominated in many parts of the United Kingdom by the need for operative neurosurgical intervention at presentation. This may be inappropriate, since many patients with severe head injury have evidence of raised intracranial pressure in the absence of

surgical lesions, and suffer morbidity and mortality equal to those with surgical lesions. Further, several studies provide strong circumstantial evidence that managing such “non-surgical” patients in specialist neurosciences centres may result in substantial improvements in mortality and functional outcome, probably due to specialist expertise in areas of non-operative management, such as neurocritical care. However, these results may be confounded by case-mix effects and referral bias, and the cost-effectiveness of such specialist management remains uncertain. There is a strong case to address this question in the context of a formal study, since a change in practice could have a major impact on death and disability in a condition that is a major contributor to mortality in healthy young adults. Importantly, the results of such a study could fundamentally alter the recommendations made by NICE, in terms of where patients with head injury are treated within the healthcare system, and result in better optimised (and potentially more cost-effective) patient flows within the NHS.

The available evidence in this area has been addressed in the systematic review that contributed to the revision of NICE Guidelines on the early management of head injury. This review could find no high quality clinical evidence on the topic. This is unsurprising, since any study that addressed these issues would have to be undertaken within the context of a healthcare system and include ambulance services, district general hospitals and neuroscience referral centres. Such a study would therefore

require the organisational backing of a body such as NICE and careful design to account for confounds and biases.

However, we believe that given careful design, such a study would be both ethically and logistically feasible. The patient group is well defined, and adequate numbers would be available to provide a definitive result within a reasonable time frame. While circumstantial evidence may support transfer of such patients to neurosciences centres, current practice is not influenced by this view in many regions, and many would argue that there is still clinical equipoise in this area. There are clear risks from transfer, and there could be clear harm, both in terms of clinical outcome and health economics, if the anticipated benefits were not realised. On the other hand, if the benefits from observational studies were confirmed by the trial, the resulting changes in management could potentially reduce case-mix adjusted mortality by 26% and increase the incidence of favourable outcome in survivors by nearly 20%.

8 Discharge and follow-up

8.1 Introduction

One consequence of these guidelines will be a tendency to discharge a higher proportion of patients with head injury directly from the emergency department. At the same time it is anticipated that patients admitted for in-hospital observation will on average have sustained a more severe head injury than is currently the case. These changes to current admission practice will increase the need to ensure that patient discharge from hospital is safe and carefully planned. A very small number of patients will develop late complications despite normal CT results and an absence of signs and symptoms. A well designed system of high quality discharge advice and post-discharge observation by a carer is required to ensure that these patients receive appropriate care as soon as possible. The role of carers at home in the early post-discharge observation of patients is important and should be guided by clear and detailed information. There should be clearly defined pathways back to hospital care for patients who

show signs of late complications. There is also a clear need for systematic follow

up of all grades of patient, given the high likelihood of long term disabilities.

8.2 Discharge of low risk patients with GCS equal to 15

If CT is not indicated on the basis of history and examination the clinician may conclude that the risk of clinically important brain injury to the patient is low enough to warrant transfer to the community, as long as no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe discharge and for subsequent care (for example, competent supervision at home).

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

8.3 Discharge of patients with normal imaging of the head

After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant discharge, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe discharge and for subsequent care (for example, competent supervision at home).

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

example, competent supervision at home).

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

8.5 Discharge of patients admitted for observation

Patients admitted after a head injury may be discharged after resolution of all significant symptoms and signs providing they have suitable supervision arrangements at home (see also recommendation 6.3.6 for those admitted out of hours but who require a CT scan).

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

8.4 Discharge of patients with normal imaging of the cervical spine

After normal imaging of the cervical spine the clinician may conclude that the risk of injury to the cervical spine is low enough to warrant discharge, as long as the patient has returned to GCS equal to 15 and their clinical examination is normal, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe discharge and for subsequent care (for

8.6 Discharge of patients at risk of non-accidental injury

No infants or children presenting with head injuries that require imaging of the head or cervical spine should be discharged until assessed by a clinician experienced in the detection of non-accidental injury.

It is expected that all personnel involved in the assessment of infants and children with head injury should have training in the detection of non-accidental injury.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

Guidance on the process of transferring patients of all ages who may have sustained non-accidental injury, including liaison with appropriate community care and legal organisations are contained in a recent Department of Health manual.¹³⁸

8.7 Discharge and Glasgow Coma Scale status

No patients presenting with head injury should be discharged until they have achieved GCS equal to 15, or normal consciousness in infants and young children as assessed by the paediatric version of the Glasgow Coma Scale.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

8.8 Discharge advice

All patients with any degree of head injury who are deemed safe for appropriate discharge from an emergency department or the observation ward should receive verbal advice and a written head injury advice card. The details of the card should be discussed with the patients and their carers. If necessary (for example, patients with literacy problems, visual impairment or speaking languages without a written format), other formats (for example, tapes) should be used to communicate this information. Communication in languages other than English should also be facilitated.

The risk factors outlined in the card should be the same as those used in the initial community setting to advise

patients on emergency department attendance. Patients and carers should also be alerted to the possibility that some patients may make a quick recovery, but go on to experience delayed complications. Instructions should be included on contacting community services in the event of delayed complications.

Patients who presented to the emergency department with drug or alcohol intoxication and are now fit for discharge should receive information and advice on alcohol or drug misuse.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

Suggested written advice cards for patients and carers are provided in Appendices E, F and G.

8.9 Discharge of patients with no carer at home

All patients with any degree of head injury should only be transferred to their home if it is certain that there is somebody suitable at home to supervise the patient. Patients with no carer at home should only be discharged if suitable supervision arrangements have been organised, or when the risk of late complications is deemed negligible.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

8.10 *The best tool for identifying the patients who should be referred to rehabilitation services following the initial management of a head injury*

8.10.1 Introduction and rationale for the clinical question

It is well known that some patients labelled as having had a minor head injury may experience long term disability following discharge from hospital. Symptoms such as headache, dizziness, memory deficits, slowness of thought, poor concentration, communication problems, inability to work and problems with self-care have been described. These patients are categorised by the International Classification of Diseases (ICD-10) as having post-concussional syndrome (PCS).

Five papers were classed as level two evidence due to the quality of the study design in the original guideline.^{33,36,139-141} However from these papers, only one paper¹³⁹ explicitly constructed a decision rule that could be used in the acute setting to identify patients at risk of PCS. This rule identifies a high-risk group that has an 89% risk of PCS and a low risk group with a risk of PCS of 9%. Unfortunately 50% of patients then fall into a medium risk category, where the risk is 47% for PCS. Therefore the only category that may be of use for excluding patients from follow up is the low risk category, but this category was derived from only eleven patients. Therefore this study, although being the only paper to attempt the derivation of a rule is still really only of use to

researchers looking to improve on their findings.

Of the remaining papers: length of post-traumatic amnesia, period of loss of consciousness, abnormal initial GCS, gender, age, positive radiological findings and various neuropsychometric tests have been advocated as being associated with an increased risk of PCS, but there is no data as to how these variables might combine as a decision rule for the safe exclusion of low risk patients from follow-up.

In the original guideline, there was insufficient evidence for the recommendation of any decision rules that can safely exclude a patient from follow up although several high-risk variables have been reported.

UPDATE 2007:

In this update, no clinical evidence review was carried out due to a vast amount of evidence in this area and the limited framework of this update. Therefore a thorough evidence map was conducted to aid future research in this area.

8.10.2 Clinical evidence

A search was developed to identify papers which attempted to develop, compare or validate a clinical prediction rule which would identify those patients, using variables collected during the acute phase of care, who would suffer long term sequelae and who would therefore benefit from rehabilitation. We considered systematic reviews, RCTs,

non-randomised controlled trials, cohort studies, and case series.

In total, 394 relevant studies were included and put through a rigorous coding procedure. The following pieces of information were coded for each study using the abstract:

- Aim of the study – whether explicitly or implicitly about referral for rehabilitation, and also whether it aimed to compare, develop or validate a tool, or attempted to carry out a multivariate analysis and thus infer a referral tool.
- Population – age group, injury severity. Other details were recorded under the variables section. Infants are children less than 1 year, adults are over 18. Injury severity was defined using the GCS system or if the authors used the words 'mild', 'moderate', or 'severe' in the abstract.
- Study design – type of study.
- Variables considered – these were categorised into certain groups. Every piece of information explicitly collected about the patient was categorised and noted. Therefore variables included predictors, outcomes, demographics, classifying information and so on.

Ninety two studies were identified as being explicitly about tools for referral. However, the remaining 302 studies were included as in a complete systematic review they would contain useful information; for example, the authors may have investigated variables which could be used to form a clinical

prediction rule without making this explicit in the abstract.

A wide spread of variables was identified which included; GCS/GOS or other measure of injury severity, S100B, Tau protein, Interleukin, other blood marker, other clinical data, cognitive measure, behavioural measure, disability measure, sensory measure, imaging measure, quality of life measure, social functioning, employment outcomes, length of stay, mortality, motor skills, demographics, psychosocial measure and somatosensory evoked potentials (SEPs)

The population characteristics of age and injury **severity were not reported in the majority of the reports**. However, the most commonly studied populations appeared to be children (93 studies) and severely head injured patients (133 studies).

8.10.3 Economics Evidence from 2007 update

A full literature review for this question was not conducted. However, below is an overview of relevant papers retrieved:

Economic evaluations of early versus late/no rehabilitation:

- 3 studies published since 2002: Berg2004¹⁴², Worthington2006¹⁴³, Hashimoto-Keiji2006¹⁴⁴

- 3 studies found from reviews: Aronow1987¹⁴⁵, Cope1982¹⁴⁶, Wood1999¹⁴⁷

Economic evaluations of intensive versus less intensive rehabilitation

- 1 study published since 2002:

Ponsford2006¹⁴⁸

- 2 studies found from reviews:

Ashley1997¹⁴⁹, Salazar2000¹⁵⁰

Reviews of economic evaluations

- 4 studies published since 2002:

Turner2004¹⁵¹, Berg2004¹⁴²,

Wehman2005¹⁵², Turnerstokes2004¹⁵³

We did not include in this evidence list studies of the following nature:

- Studies costing a single rehabilitation programme, including before and after comparisons
- Other non-comparative studies
- Studies evaluating length of stay and productivity but not cost
- Studies assessing the accuracy of tools in predicting cost

8.10.4 Conclusion

The amount of literature identified by this search and evidence map was too diverse and too great to be systematically reviewed within the framework of this update. Moreover, the GDG felt it would be inappropriate to develop a recommendation about rehabilitation, given that the economic details about rehabilitation are limited. Rehabilitation covers a vast time span after injury and can encompass many different health professionals and is measured using many different types of outcomes. To derive a single rule, given the lack of clear evidence in this field, will be a challenging task. However, the

GDG felt that a rigorous systematic review should be carried out to facilitate the development of the clinical prediction rule. The GDG therefore decided to propose a research recommendation on this topic.

8.10.5 Recommendations for research

The GDG identified the following priority area for research.

8.10.5.1 Research Question

Research is needed to summarise and identify the optimal predictor variables for long term sequelae following mild traumatic brain injury. A systematic review of the literature could be used to derive a clinical decision rule to identify, at the time of injury, relevant patients. This would in turn lay the foundation for a derivation cohort study.

8.10.5.2 Why this research is important

We performed a review of the literature in this area, repeated in this update process. While 394 studies were identified that attempted to use a wide range of variables and tests to predict a range of longer term outcome measures, no robust clinical decision tools has successfully been derived and validated to identify patients at the time of injury who could be considered for follow-up due to a higher risk of long term sequelae. A systematic review of the literature would summarise and identify the optimal predictor variables for such a clinical decision rule and also identify the optimal outcome variables, thus laying the foundation for a derivation cohort study.

The derivation cohort study to create this clinical decision rule could potentially be conducted in conjunction with the validation of the CHALICE rule, with follow up of patients involved in this study at 6mths-1 yr. This would ensure optimal value for money for funders and ensure good results in a large cohort of patients. Separate studies could also be performed in adults but the initial study may in fact be more urgent in the childhood population.

Identification of patients likely to suffer from long term sequelae will allow targeted research regarding responsiveness to, or effectiveness of focused rehabilitation programmes. Preventative action could potentially be taken, thus reducing the strain on resources further down the care pathway. Furthermore, patient outcomes could potentially be improved by early identification and treatment (both curative and preventive) of problems. However, further research is required before we can be certain that a robust framework exists with which to cope with individuals identified by the clinical prediction rule proposed above.

8.11 **Outpatient appointments**

Every patient who has undergone imaging of their head and/or been admitted to hospital (that is, those initially deemed to be at high risk for clinically important brain injury) should be routinely referred to their General Practitioner for follow-up within a week after discharge.

When a person who has undergone imaging of the head and/or been

admitted to hospital experiences persisting problems, there should be an opportunity available for referral from primary care to an out-patient appointment with a professional trained in assessment and management of sequelae of brain injury (for example, clinical psychologist, neurologist, neurosurgeon, specialist in rehabilitation medicine).

These recommendations are based on level five evidence and are considered to be grade D recommendations.

8.12 **Prognosis in severe head injury**

A recent systematic review focusing only on severe head injuries examined evidence on early indicators of prognosis.¹⁵⁴ The review found that certain variables had a high positive predictive value for poor prognosis. While this level one evidence is useful in identifying patients at highest risk for poor outcome, it is unclear what course of action should be pursued with these patients. Guidelines on the rehabilitation of adults following traumatic brain injury have been prepared by the British Society of Rehabilitation Medicine. These are based on a full systematic review of the literature as well as drawing on the recommendations of existing consensus documents. The guidelines were published in December 2003¹⁵⁵ and include information on the rehabilitation of patients following acquired brain injury. The contents of this guideline are therefore beyond the scope of this guideline.

8.13 Advice about long term problems and support services

[Amended] All patients and their carers should be made aware of the possibility of long-term symptoms and disabilities following head injury and should be made aware of the existence of services that they could contact if they experience long-term problems. Details of support services should be included on patient discharge advice cards.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

8.14 Communication with community services

A communication (letter or email) should be generated for all patients who have attended the emergency department with a head injury, and sent to the patient's GP within 1 week of the end of the hospital episode. This letter should include details of the clinical history and examination. This letter should be open to the person or their carer, or a copy should be given to them.

[Amended] A communication (letter or email) should be generated for all school-aged children who received head or cervical spine imaging, and sent to the relevant GP and school nurse within 1 week of the end of the hospital episode. This letter should include details of the clinical history and examination.

[Amended] A communication (letter or email) should be generated for all pre-school children who received head or

cervical spine imaging, and sent to the GP and health visitor within 1 week of the end of the hospital episode. This letter should include details of the clinical history and examination.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

8.15 Re-attendees

There is evidence that patients who re-attend in the days immediately after head injury are a high risk group for intracranial complications.¹⁵⁶

Patients who returned to an emergency department within 48 hours of discharge with any persistent complaint relating to the initial head injury should be seen by or discussed with a senior clinician experienced in head injuries, and considered for a CT scan.

This recommendation is based on level two evidence and is considered a grade B recommendation.

9 Admission and observation

9.1 Introduction

These guidelines place the emphasis on the early diagnosis of clinically important brain and cervical spine injuries, using a sensitive and specific clinical decision rule with early imaging. Admission to hospital is intrinsically linked to imaging results, on the basis that patients who do not require imaging are safe for discharge to the community (given that no other reasons for admission exist) and those who do require imaging can be discharged following negative imaging (again, given that no other reasons for admission exist). However, observation of patients will still form an important part of the acute management phase, for patients with abnormal CT results that do not require surgery and/or for patients with unresolved neurological signs. Observation should occur throughout the patient's hospital episode, whether in the emergency department or after admission following abnormal imaging results. As noted above, all care professionals should use a standard head injury proforma in their documentation when assessing and observing patients with head injury. Separate adult, and child/infant specific proformas should be used. Again, the

adult and paediatric GCS and derived scores should form the basis of observation, supplemented by other important observations.

An important result of these guidelines will be that the typical patient admitted for in hospital observation after head injury will have a more severe profile. It is presumed that the guidelines will lead to a substantially lower number of patients requiring admission, but these patients will have either confirmed abnormal imaging, have failed to return to normal consciousness or have other continuing signs and symptoms of concern to the clinician. The emphasis will shift therefore from vigilance for possible deterioration, to active care of patients where an ongoing head injury complication has been confirmed.

9.2 Admission

The following patients meet the criteria for admission to hospital following a head injury:

- **Patients with new, clinically significant abnormalities on imaging.**
- **Patients who have not returned to GCS equal to 15 after imaging, regardless of the imaging results.**
- **When a patient fulfils the criteria for CT scanning but this cannot be done within the appropriate period, either because CT is not available or because the patient is not sufficiently cooperative to allow scanning.**
- **Continuing worrying signs (for example, persistent vomiting, severe headaches) of concern to the clinician.**
- **Other sources of concern to the clinician (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak).**

[Amended] Some patients may require an extended period in a recovery setting because of the use of general anaesthesia during CT imaging.

Patients with multiple injuries should be admitted under the care of the team that is trained to deal with their most severe and urgent problem.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

9.3 *Good practice in observation of patients with head injury*

There is some evidence that Emergency Department observation wards are more efficient than general acute wards at dealing with short stay observation

patients, with more senior supervision, fewer tests and shorter stays.¹⁵⁷ There have also been concerns about the experience and skills of staff on general and orthopaedic acute wards in head injury care.¹² This led to a recommendation by the Royal College of Surgeons of England in 1999 that adult patients needing a period of observation should be admitted to a dedicated observation ward within or adjacent to an emergency department.¹²

[Amended] In circumstances where a patient with a head injury requires hospital admission, it is recommended that the patient be admitted only under the care of a team led by a consultant who has been trained in the management of this condition during his/her higher specialist training. The consultant and his/her team should have competence (defined by local agreement with the neuroscience unit) in assessment, observation and indications for imaging (see recommendations 3.7); inpatient management; indications for transfer to a neuroscience unit (see recommendations 3.6); and hospital discharge and follow up (see recommendations 3.8).

It is recommended that in-hospital observation of patients with a head injury should only be conducted by professionals competent in the assessment of head injury.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

The service configuration and training arrangements required to ensure this occurs are beyond the scope of these guidelines but it is hoped that this issue will be addressed by future NHS policy guidance.

9.4 Minimum documented observations

For patients admitted for head injury observation the minimum acceptable documented neurological observations are: GCS; pupil size and reactivity; limb movements; respiratory rate; heart rate; blood pressure; temperature; blood oxygen saturation.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

9.5 Frequency of observations

As the risk of an intracranial complication is highest in the first 6 hours after a head injury, observations should have greatest frequency in this period.¹⁵⁸

Observations should be performed and recorded on a half-hourly basis until GCS equal to 15 has been achieved. The minimum frequency of observations for patients with GCS equal to 15 should be as follows, starting after the initial assessment in the emergency department:

- half-hourly for 2 hours;
- then 1-hourly for 4 hours;
- then 2-hourly thereafter.

Should a patient with GCS equal to 15 deteriorate at any time after the initial

2-hour period, observations should revert to half-hourly and follow the original frequency schedule.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

9.6 Patient changes requiring review while under observation

[Amended] Any of the following examples of neurological deterioration should prompt urgent reappraisal by the supervising doctor:

- Development of agitation or abnormal behaviour.
- A sustained (that is, for at least 30 minutes) drop of one point in GCS (greater weight should be given to a drop of one point in the motor response score of the Glasgow Coma Scale).
- Any drop of three or more points in the eye-opening or verbal response scores of the Glasgow Coma Scale, or two or more points in the motor response score.
- Development of severe or increasing headache or persisting vomiting.
- New or evolving neurological symptoms or signs such as pupil inequality or asymmetry of limb or facial movement.

To reduce inter-observer variability and unnecessary referrals, a second member of staff competent to perform observation should confirm deterioration before involving the

supervising doctor. This confirmation should be carried out immediately. Where a confirmation cannot be performed immediately (for example, no staff member available to perform the second observation) the supervising doctor should be contacted without the confirmation being performed.

These recommendations are based on level five evidence and are considered to be a grade D recommendation.

9.7 *Imaging following confirmed patient deterioration during observation*

[Amended] If any of the changes noted in recommendation 1.7.5.1 are confirmed, an immediate CT scan should be considered, and the patient's clinical condition should be re-assessed and managed appropriately.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

9.8 *Further imaging if GCS equal to 15 not achieved at 24 hours*

In the case of a patient who has had a normal CT scan but who has not achieved GCS equal to 15 after 24 hours observation, a further CT scan or MRI scanning should be considered and discussed with the radiology department.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

9.9 *Observation of children and infants*

Observation of infants and young children (that is, aged under 5 years) is a difficult exercise and therefore should only be performed by units with staff experienced in the observation of infants and young children with a head injury. Infants and young children may be observed in normal paediatric observation settings, as long as staff have the appropriate experience.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

9.10 *Training in observation*

Medical, nursing and other staff caring for patients with head injury admitted for observation should all be capable of performing the observations listed in 9.4 and 9.6 above.

The acquisition and maintenance of observation and recording skills require dedicated training and this should be available to all relevant staff.

Specific training is required for the observation of infants and young children.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

9.11 *Support for families and carers*

Early support can help the patient's family or carer(s) prepare for the effects of head injury. This support can reduce the psychological sequelae

experienced by the family or carer and result in better long term outcomes for both the patient and their family.

Patient's family members can find the hospital acute care setting overwhelming and this can cause additional tension or stress. It can be a particularly traumatic experience for a child visiting a sibling or parent with a head injury.

There should be a protocol for all staff to introduce themselves to family members or carers and briefly explain what they are doing. In addition a photographic board with the names and titles of personnel in the hospital departments caring for patients with head injury can be helpful.

Information sheets detailing the nature of head injury and any investigations likely to be used should be available in the emergency department. The patient version of these NICE guidelines may be helpful.

Staff should consider how best to share information with children and introduce them to the possibility of long term complex changes in their parent or sibling. Literature produced by patient support groups may be helpful.

These recommendations are based on level five evidence and are considered to be grade D recommendations.

The presence of familiar friends and relatives at the early stage following admission can be very helpful. The patient recovering consciousness can easily be confused by strange faces and the strange environment in which they

find themselves. Relatives or carers are often willing to assist with simple tasks which, as well as helping nursing staff, helps families to be part of the recovery process rather than just an observer.

[Amended] Healthcare professionals should encourage carers and relatives to talk and make physical contact (for example, holding hands) with the patient. However, it is important that relatives and friends do not feel obliged to spend long periods at the bedside. If they wish to stay with the patient, they should be encouraged to take regular breaks.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

Voluntary support groups can speak from experience about the real life impact post head injury and can offer support following discharge from hospital. This is particularly important where statutory services are lacking.

There should be a board or area displaying leaflets or contact details for patient support organisations either locally or nationally to enable family members to gather further information.

This recommendation is based on level five evidence and is considered to be a grade D recommendation.

10 Medical radiation

10.1 Introduction

The medical use of radiation for diagnosis and therapy is the largest source of radiation exposure to humans outside natural background radiation. The main diagnostic sources of radiation are X-ray examinations, particularly those involving CT. Magnetic Resonance Imaging does not involve ionising radiation. Recent advances in CT technology, particularly the advent of multislice helical CT, have led to dramatic improvements in image quality and speed of acquisition. These have resulted in more clinical applications for CT imaging and an explosive growth in the number of CT examinations performed in countries that have access to this technology. The radiation doses received by the patient remain considerably larger for CT compared to conventional X-ray imaging, but dose-saving features introduced into the latest scanners and the adoption of more optimised scanning protocols have led to small reductions in patient dose for some CT examinations over the past few years. In 1998 CT examinations accounted for 4% of all X-ray imaging procedures in the UK and contributed

40% of the collective dose to the population.¹⁵⁹ By 2002 these figures had risen to 7% and 47% respectively.¹⁶⁰

National patient dose surveys for CT examinations have been carried out in the UK in 1989¹⁶¹ and in 2003¹⁶². Both surveys show significant variations in patient dose across the country for the same CT examination, by factors of 10 to 40, due to differences in scanner design and institutional-specific examination techniques. There consequently still appears to be considerable scope for standardising examination techniques to protect the patient from unnecessary exposure without reduction in image quality.

Patient doses were generally lower by 10-40% in the 2003 survey compared to 1989. Lowering patient dose is possible with adjustments of scan technique, tube current and filtration factors, alterations in pitch, and image reconstruction parameters¹⁶³⁻¹⁶⁵. Increased awareness of these dose-reduction techniques has probably led to better-optimised scan protocols being used in the later survey. Automatic tube

current modulation according to the thickness and density of the part of the patient being scanned, is also helping to reduce doses in the latest CT scanners.

10.2 *Patient doses from head CT*

Specific dosimetry techniques and dose quantities have been developed for measuring patient radiation exposure. To relate the exposures to the risk of radiation-induced cancer (or deleterious hereditary effects), an estimate of the absorbed dose to a number of radiosensitive organs or tissues in the body is required.

The absorbed dose to an organ or tissue dose, usually expressed in milligray (mGy), reflects the energy deposited by X-rays per gram of irradiated body tissue, averaged over the particular organ or tissue.

The effective dose, usually expressed in millisieverts (mSv), is a calculated weighted sum of organ doses that takes into account organ differences in radio-sensitivity and is a useful comparative index related to the total radiation-induced cancer risks from varying radiological procedures.

The latest UK CT patient dose survey¹⁶² shows the typical effective dose from a routine head CT examination on adults to be 1.5 mSv. This remains much the same for examinations on 10 year old and 5 year old children but rises to about 2.5 mSv for examinations on babies (0-1 years old). In comparison to conventional X-ray examinations of the skull with a typical effective dose of 0.06 mSv¹⁶⁶, CT head examinations

involve about 25 times more radiation exposure. In the 1998 UK survey, the eyes, thyroid and breasts typically received doses of about 50 mGy, 2 mGy and 0.03 mGy, respectively, from a head CT scan¹⁶¹. Since the effective dose for a CT head scan has come down by about 20% between the 1989 and 2003 surveys, these organ doses have probably seen a similar reduction.

For comparison, the average natural background radiation level in the UK gives rise to an annual effective dose of 2.2 mSv, with regional averages ranging from 1.5 mSv to 7.5 mSv per year.

10.3 *Patient doses from cervical spine CT*

A small proportion of patients are currently deemed suitable for CT examination of the cervical spine, usually carried out in conjunction with CT of the head. Unfortunately cervical spine scans were not included in the 2003 patient dose survey but the mean value for the effective dose on adult patients receiving CT of the cervical spine in the 1989 UK national survey¹⁶¹ was 2.6 mSv. This compares to 1.8 mSv for CT of the head alone in the 1989 survey. The effective dose for cervical spine CT is higher because the thyroid is directly irradiated (mean thyroid dose equal to 44 mGy). NRPB models¹⁶⁷ indicate that the effective dose received by children and infants from head and neck CT scans is higher, if the scan parameters are unchanged from those used on adult patients. The increase amounts to a factor of 2.3 for newborns, a factor of 1.5 for 5 year olds and a factor of 1.2 for 10 year olds. These factors emphasise the need to match the scan

parameters to the size of the patient.

The doses involved for all age groups may now be smaller due to increased awareness of this need and the introduction of multislice helical CT, as has been seen for CT head scans.

10.4 Summary of effective doses from CT and conventional X-ray examinations of the head and cervical spine

A summary of estimates of the effective doses received by adults, children and infants from CT and conventional radiographic examinations of the head and cervical spine are detailed in Table 9.1 below. The estimates for CT head examinations are based on the 2003 survey¹⁶¹ and reflect UK practice at that time for selecting CT scan parameters for adult and paediatric patients. The estimates for CT cervical spine examinations are based on the 1989 survey for adult patients and paediatric enhancement factors that assume that the same CT technique parameters are used for children and adults (which has been common practice until recently). They consequently are likely to overestimate patient doses from current practice.

The estimates for conventional radiographic examinations are based on typical effective doses for adults in a further NRPB survey¹⁶⁶.

Effective doses for children from these radiographic examinations have been assumed to be the same as those for adults, since the technique parameters are usually adapted to the size of the patient.

Table 10.4.1 Effective radiation doses for different imaging techniques by age group.

| Patient Age (y) | Effective dose (mSv) | | | |
|-----------------|----------------------|-----|----------------|-----|
| | Head | | Cervical spine | |
| | Radiographs* | CT | Radiographs** | CT |
| 0-1 | 0.06 | 2.5 | 0.07 | 6.0 |
| 5 | 0.06 | 1.5 | 0.07 | 3.9 |
| 10 | 0.06 | 1.6 | 0.07 | 3.1 |
| Adult | 0.06 | 1.5 | 0.07 | 2.6 |

* assumes 1 PA + 1 AP + 1 lateral radiograph per examination

** assumes 1 AP + 1 lateral radiograph per examination

10.5

Cancer risks

The risk of radiation-induced malignancies from a single CT exposure is difficult to assess. There have been no published epidemiological studies of increased incidence of cancer among CT exposed patients. Current estimates of the risks from medical X-rays are based on the long term follow up of populations exposed to large doses of radiation.¹⁶⁸ The 1990 recommendations of the International Commission on Radiological Protection (ICRP) report a nominal probability coefficient of 5% per Sv effective dose for the lifetime risk of fatal cancer in a population of all ages and both sexes exposed to radiation at the relatively low doses used in CT examinations.¹⁶⁹

The lifetime fatal cancer risk will vary with age at exposure and sex and the way that it does so varies from organ to organ. As a rough guide, assuming uniform whole body irradiation, the NRPB estimates that the lifetime risk for radiation-induced cancer per unit dose is about twice as high in children (0-15 years old) than in adults (20-60 years old)¹⁷⁰. This would put the lifetime risk of fatal cancer following exposures in childhood at about 10% per Sv effective dose, compared to about 5% per Sv for exposures to adults between 20 and 60 years old. The risks drop dramatically at ages above 60 years due mostly to the reduced lifetime available in which these delayed effects of radiation can occur.

More specifically, Brenner et al estimated that the lifetime cancer

mortality risks from CT examinations on a one-year-old child are approximately an order of magnitude higher than the risks for CT-scanned adults.¹⁷¹ This is due to both an increased dose for children having CT scans in the USA at the time (2001) compared to adults, and an estimated increase in risk per unit dose of about a factor of 3 for a one year old child. While this paper calculates a projected 500 additional cancer deaths per year in the USA from the number of paediatric CT examinations performed in 2001, this only represents a 0.35% increase in the background cancer death rate.

In summary, the best available evidence suggests that paediatric CT will result in increased lifetime risks of cancer compared to adult CT due to both the higher radiation doses currently delivered to children and their increased sensitivity to radiation-induced cancer over a longer life span.

10.6 Radiation exposure management

In line with good radiation exposure practice every effort should be made to minimise radiation dose during imaging of the head and cervical spine, while ensuring that image quality and coverage is sufficient to achieve an adequate diagnostic study.

In spite of the potential risks of increased radiation exposure as a result of these guidelines, the consensus opinion of the Guideline Development Group is that this is justified by the increased effectiveness in identifying and managing patients with significant brain injuries.

These recommendations are based on level five evidence and are considered to be grade D recommendations

11 Economic evaluation

11.1 Introduction

The explicit use of economic evaluation in clinical guideline development is a recent but international phenomenon. In the USA, the Committee on Clinical Practice Guidelines has recommended that every clinical guideline include cost information for alternative patient management strategies.¹⁷² In the UK, the remit of NICE is to produce national clinical guidelines that address cost-effectiveness as well as clinical effectiveness.

The reasoning behind the application of economic criteria to clinical guidelines is that no health system anywhere in the world has enough resources to provide every potentially beneficial preventative, diagnostic, curative and palliative procedure. Therefore, there is a need to re-deploy resources to those procedures where the potential health gain is greatest. This requires abandoning practices that are relatively poor value for money.

There is a well-developed methodological literature for assessing the relative cost-effectiveness (value for money) of different healthcare

procedures.¹⁷³⁻¹⁷⁵ There is still some debate over some of the specific methods of economic evaluation in healthcare but essentially there are six steps to evaluating the relative efficiency of any procedure.

1. Identify the target group (for example, patients attending emergency departments with GCS greater than 12), the procedure to be evaluated (for example, head CT scanning) and its alternative strategy (for example, skull X-ray).

2. Identify all the important health and resource outcomes that are likely to differ between the procedure and its alternative.

3. Measure the differences in identified health and resource outcomes.

4. Estimate the value of the health gain and the value of the resource use. (Resource use is valued in terms of its monetary value, its economic cost.

Health gain is sometimes valued in monetary terms but more often a non-pecuniary measure such as the quality-adjusted life-year, QALY, is used).

5. Estimate the ratio of net health gain to net resource cost (for example, the cost per QALY gained) and compare this with the ratios estimated for other commonly used health programmes to assess its relative efficiency. The estimation of net health gain and net cost requires some kind of model (such as a decision analysis) to combine probability and outcome information.

6. Consider the robustness of the cost-effectiveness estimate in terms of statistical precision and generalisability to other settings.

Ideally one would repeat each of these steps for each procedure considered within the guideline (and within each procedure, for each relevant patient subgroup). This would allow us to see for which group of patients the procedure is good value for money. In practice we are limited by the availability of data.

11.2 Methods

The guideline development group identified two main areas where the potential impact of alternative strategies could be substantial.

- Diagnosis of life-threatening important brain injuries in patients with minor head injury
- Identifying cervical spine damage in patients with head injury.

A third area, identification of patients most likely to experience long term sequelae, was also considered for economic evaluation. However, the lack of satisfactory clinical decision rules in this area means that this area remains

an issue only on the research agenda at this time.

UPDATE 2007:

For both of the identified areas, a review of the literature was conducted followed by simple economic modelling of the cost-effectiveness in England and Wales of different strategies. The costs in these models were updated to 2005-6 prices for the 2007 update and the evidence summaries were modified accordingly.

A full literature review for the rehabilitation question was not conducted during the 2007 update either. The list of the relevant papers retrieved can be found in 8.10.3

A fourth area was added during the 2007 update – the issue of which patients can bypass the nearest emergency department and go straight to a neurosciences centre from the scene of injury – see 11.6.

11.2.1 Literature review

Using the same search strategy as for the main systematic reviews but with an additional filter to locate costing information, a search (Appendix 1) was performed of:

- Medline (PubMed)
- Embase
- Health Economic Evaluations Database (HHED) - <http://www.ohe-heed.com>.

- NHS Economic Evaluations Database (NHS EED) -

<http://nhsdhp.york.ac.uk/nhsdhp.htm>.

These strategies were designed to find any economic study related to head injury. Abstracts and database reviews of papers found were reviewed by the health economist and were discarded if they appeared not to contain any economic data or if the focus of the paper was not imaging after trauma. Relevant references in the bibliographies of reviewed papers were also identified and reviewed.

greater access to CT scanning. Patients with a negative CT scan would be discharged. The fourth strategy is comprehensive scanning and admission of all patients, essentially what happens in the US system.

11.2.2 Modelling of cost-effectiveness – intracranial haematoma

A cost analysis was performed for the use of CT scanning on patients who have minor/mild head injury (that is, GCS greater than 12) but some loss of consciousness or amnesia at the time of the impact or thereafter. The reason for selecting this group is that it is assumed that those patients with a more significant loss of consciousness receive CT scanning automatically or are referred to neurosurgery. It is assumed that those who do not experience loss of consciousness or amnesia will not receive CT scanning. These assumptions mirror the methods used to derive the Canadian CT-head rule.

Four alternative strategies were selected for the model (Table 11.1). The first is an approximation of the current (pre-2003) UK system, based on skull X-ray for patients who have experienced loss of consciousness or amnesia. The second and third are the Canadian head rules, which avoid skull X-ray, but allow

Table 11.1 - Description of different strategies for the target group

| | Indications for test | | |
|--|----------------------|---|---|
| | Skull X-ray | 24 hour admission | CT |
| 1. Current (pre-2003) UK system ¹⁷⁶ | All | headache, vomiting or other neurological indication | skull fracture or deterioration in 24 hours |
| 2. Canadian CT Head 5-rule ²⁵ | None | +ve CT scan | suspected fracture (open, depressed, basal), age greater than or equal to 65 years, GCS of 13 or 14 at 2 hours, 2 or more vomiting episodes |
| 3. Canadian CT Head 7-rule ²⁵ | None | +ve CT scan | As for 5-rule but also CT if pre-impact amnesia greater than 30mins or dangerous mechanism |
| 4. 4. US system | None | All | All |

The cost per patient for each strategy was calculated on the basis of the expected usage of skull X-ray, head CT scan and 24 hour observation. It was not possible to quantify differences in health outcomes and other cost outcomes (Table 11.2, outcomes 4-10).

Table 11.2 - Health and resource consequences of Canadian CT head rule versus current (pre-2003) UK system

| Outcome | Net social effect |
|--|-------------------|
| Definite or likely outcomes | |
| 1. Reduced use of skull X-ray | +ve |
| 2. Increased use of CT scanning | -ve |
| 3. Reduced inpatient stay | +ve |
| Possible outcomes | |
| 4. Improved neurosurgical outcomes | +ve |
| 5. Increased incidence of cancer as a result of increased radiation exposure | -ve |
| 6. Change in health service resource use as a result of 4 and 5. | +ve/-ve |
| 7. Change in patient/family resource use as a result of 3 | +ve/-ve |
| 8. Change in patient/family resource use as a result of 4 and 5 | +ve/-ve |
| 9. Reduction in litigation costs | +ve |
| 10. Change in primary care use as a result of 3, 4 and 5 | +ve/-ve |

NB – Any increase in resource use has a negative effect for society because those resources can't then be used for some other beneficial purpose.

Usage figures were derived from Nee et al ¹⁷⁶ for the current (pre-2003) UK system and from Stiell et al ²⁵ for the Canadian rules (Table 11.3). For the US model, usage was determined by the model definition.

Table 11.3 – Proportion of target group receiving each test

| | Proportion of target group | | |
|--|----------------------------|-------------------|-------------------|
| | Skull X-ray | 24 hour admission | CT |
| 1. Current (pre-2003) UK system ¹⁷⁶ | 100% | 26% (24%, 27%) | 4% (3%, 5%) |
| 2. Canadian CT Head 5-rule ²⁵ | 0% | 9%* (8%, 10%) | 32% (30%, 34%) |
| 3. Canadian CT Head 7-rule ²⁵ | 0% | 9%* (8%, 10%) | 54% (52%, 56%) |
| 4. US system | 0% | 100% | 100% |

* Stiell et al²⁵ propose discharging patients that have a negative CT scan, although they are only half way through their validation study, which applies this strategy. This figure is based on their prevalence of complications.

Stiell et al have not yet put their model into practice; therefore the admission rate figure is provisional. For this model it was assumed that only those with a positive CT scan (ICH or other complication) would be admitted. Another problem was that Stiell et al had already excluded patients without any loss of consciousness or amnesia, whereas the UK paper had not. This problem was tackled by assuming that patients in the UK study who were discharged without a skull X-ray or CT scan were also very low risk (that is, had no loss of consciousness or amnesia).

11.2.3 Modelling of cost-effectiveness – cervical spine injuries

We compared the cost of the two alternative strategies identified as being derived using relatively high quality methods:

- NEXUS study rule ¹²²
- Canadian cervical spine rule ⁵²

These systems evaluate all patients with head trauma, the same cohort as for the intracranial haematoma model.

The expected cost for each strategy was calculated on the basis of the expected usage of cervical spine X-ray, and cervical spine CT scan. It was not possible to quantify differences in health outcomes and other cost outcomes (Table 11.4, outcomes 3-8). Usage figures were derived from the original studies. In the case of the Canadian cervical spine rule, there has not been a validation study hence the figures are from the original derivation study. It was assumed that, for both strategies, 39% of X-rays are inadequate ¹²² and that these are followed up with a CT scan.

Table 11.4 - Outcomes from cervical spine scanning

| |
|---|
| 1. Use of cervical spine X-ray |
| 2. Use of cervical spine CT scanning |
| 3. Number of surgical interventions resulting from detection of fractures |
| 4. Incidence of paralysis |
| 5. Incidence of cancer as a result of radiation exposure |
| 6. Change in health service resource use as a result of 4 and 5. |
| 7. Change in patient/family resource use as a result of 4 and 5 |
| 8. Change in litigation costs |

11.2.4 Unit costs

Average unit costs for X-ray, CT scan and 24 hour observation were taken from the NHS Reference Costs 2005-6¹⁷⁷. A unit cost of 24-hour observation was estimated approximately using the median cost of an excess bed day for a 'Head injury without significant brain injury: uncomplicated'.

Table 11.5 - Unit cost estimates for the UK NHS (updated in 2007)

| | Cost per patient tested (2005-6 UK£):* | | |
|-----------------------|--|-----|-------|
| | Lower | Mid | Upper |
| X-ray | 15 | 19 | 23 |
| CT scan | 62 | 77 | 100 |
| 24 hour observation** | 183 | 224 | 277 |

*NHS Reference costs 2005-6¹⁷⁷ 25th, 50th and 75th centiles. Costs include staff time, equipment cost and consumable cost and overheads.

** Cost per day of an inpatient stay for a 'Head injury without significant brain injury: uncomplicated' (n=1563 excess bed days).

The NHS reference cost database contains accounting cost data from every NHS hospital trust. Each trust reports an average cost per hospital episode, categorised by type of visit (for example, out-patient, elective in-patient, etc) clinical specialty and Healthcare Resource Group (HRG). Accounting practices do vary between hospitals but the costs should reflect the full cost of the service (including direct, indirect and overhead costs), as described in the NHS Costing Manual.

Sensitivity analyses were conducted to test the sensitivity of the results to the model parameters:

- for the unit costs, the inter-quartile range was used,
- for the probabilities, the confidence intervals were used.

11.3 ***Diagnosis of intracranial haematoma in patients with a minor/mild head injury***

CT represents the gold standard in the diagnosis of intracranial haematoma following head injury. However, the number of CT scanners and trained staff in the NHS is limited and the cost of testing substantial. Therefore CT scanning in the NHS is currently restricted mainly to those with significant loss of consciousness (either on arrival or after deterioration) and those with a skull fracture, as diagnosed through skull X-ray. The question arises as to whether CT scanning would be cost-effective (that is, value for money) if extended to a larger group of patients.

11.3.1 **Literature review**

Six studies have evaluated the overall impact of different diagnostic testing strategies for patients with minor/mild head injury. The UK studies date back to the early 1980s (pre-CT scanning) and advocate that both skull X-ray and in-patient observation be reduced to save costs.¹⁷⁸⁻¹⁸⁰

Three overseas studies have compared CT scanning with alternative strategies. Ingebrigtsen and Romner¹⁸¹ found that in-patient observation was not necessary with CT. Therefore CT screening was less costly than skull X-ray screening in Norway because it reduced in-patient stays. Shackford et al¹⁸² and Stein et al¹⁸³ had already come to the same conclusion for the USA. However, Stein et al also considered the potential use of X-ray screening without in-patient observation and not surprisingly found this to be the least costly strategy.

Essentially all three studies have concluded that a system of CT scanning high risk patients followed by discharge after a negative CT scan is less costly than skull X-ray and admission for all of these patients. However, this comparison is not strictly relevant to the context of England and Wales because the current system does not admit all patients.

The published evidence from the six studies is not ideal because:

- the resource use and cost for CT scanning is not specific to the UK NHS context or is dated; and

- they have sought to quantify and cost outcomes 1-3 only. For example, the studies did not measure the cost savings and health gain associated with early diagnosis. Stein et al suggested that for those patients who are not diagnosed early there are lost wages and increased costs relating to in-patient stay, rehabilitation, treatment, medication and orthotic devices.

Additional evidence retrieved in 2007 can be found below in 11.3.7.

11.3.2 Cost-effectiveness model – imaging of the head

Using the unit costs and frequencies of testing, the cost per patient of each strategy is shown in Table 11.6. The least cost strategy is the 5-point Canadian CT Head rule. Although the cost of CT scanning is higher than for the current (pre-2003) UK system, the extra cost is more than offset by the reduction in skull X-rays and admissions.

Table 11.6 – Cost per patient for each strategy

| | Component costs (£) | | | Total cost (£) |
|--------------------------------------|---------------------|-------------------|----|----------------|
| | Skull X-ray | 24 hour admission | CT | |
| 1. Current (pre-2003) UK system | 19 | 57 | 3 | 79 |
| 2. Canadian CT Head five point rule | 0 | 20 | 25 | 45 |
| 3. Canadian CT Head seven point rule | 0 | 20 | 42 | 62 |
| 4. US system | 0 | 224 | 77 | 301 |

Both Canadian rules could save the NHS money. It would require investment in additional CT scanning facilities but these costs would, be offset by the freeing up of ward space and X-ray capacity.

These results were largely insensitive to the unit costs and probabilities used (Table 11.7). Only when both costs and probabilities were set to favour the current (pre-2003) UK system was the Canadian seven point rule more costly.

Table 11.7 - Sensitivity analysis for head CT scanning rules

| | Additional cost per patient (£) - Canadian seven point rule compared with current (pre-2003) UK system |
|---|--|
| Baseline | -17.72 |
| Sensitivity to unit costs* | -38.05, 4.62 |
| Sensitivity to proportion of patients scanned** | -25.55, -9.89 |
| Sensitivity to both unit costs and proportions | -46.89, 11.96 |

* Lower limit: High skull X-ray cost, High admission cost, Low CT cost. Upper limit: Low skull X-ray cost, Low admission cost, High CT cost (see table 11.5)

** Lower limit: using confidence limits that favour the Canadian seven point rule. Upper limit: using confidence limits that favour the UK system (see Table 11.3).

This cost analysis was limited because the frequency of testing and admission for each strategy could only be estimated approximately given the currently available data. The Canadian head rule is less costly than the current (pre-2003) UK system because it is assumed that it reduces the number of admissions. In fact Stiell et al ²⁵ have not yet put their model into practice, therefore the admission rate figure is provisional. For this model it was assumed that only those with a positive CT scan (ICH or other complication) would be admitted. If the number of admissions were somewhat higher then this strategy would not be the least cost strategy. Assuming all other parameters in the model remain the same, the five point Canadian head rule is least cost if it reduces in-patient admissions by at least 37%. The seven point Canadian head rule appears to be more expensive even if admissions were entirely eliminated.

Another model parameter which was estimated very approximately was the level of CT use in the current system, because CT scanning use was lower during the Nee et al (1993) study than in the present UK system.

The sensitivity of the results to these particular assumptions is presented in a two-way sensitivity analysis (Table 11.8).

Table 11.8 Additional cost per patient (£) - Canadian seven point rule compared with current (pre-2003) UK system - two-way sensitivity analysis. (Updated 2007)

| Reduction in admissions | CT Scanning rate in current (pre-2003) UK system | | | | | | | |
|-------------------------|--|--------|--------|--------|--------|--------|--------|--------|
| | 0% | 2.5% | 5%* | 10% | 20% | 40% | 60% | 80% |
| 0% | 22.82 | 20.89 | 18.97 | 15.12 | 7.42 | -7.98 | -23.38 | -38.78 |
| 2.5% | 21.39 | 19.46 | 17.54 | 13.69 | 5.99 | -9.41 | -24.81 | -40.21 |
| 5% | 19.96 | 18.04 | 16.11 | 12.26 | 4.56 | -10.84 | -26.24 | -41.64 |
| 10% | 17.10 | 15.18 | 13.25 | 9.40 | 1.70 | -13.70 | -29.10 | -44.50 |
| 20% | 11.39 | 9.47 | 7.54 | 3.69 | -4.01 | -19.41 | -34.81 | -50.21 |
| 40% | -0.03 | -1.96 | -3.88 | -7.73 | -15.43 | -30.83 | -46.23 | -61.63 |
| 60%* | -11.46 | -13.38 | -15.31 | -19.16 | -26.86 | -42.26 | -57.66 | -73.06 |
| 80% | -22.88 | -24.81 | -26.73 | -30.58 | -38.28 | -53.68 | -69.08 | -84.48 |

* This scenario most closely approximates to the model's base case.

Another problem was that the study that presented data on the Canadian rules had already excluded patients without loss of consciousness or amnesia, whereas the UK paper had not – this problem was tackled by assuming that patients who were discharged did not receive a skull X-ray. Furthermore the analysis did not include outcomes 4-10 from Table 11.2.

Evidence retrieved in 2007 provides real data on the impact of the Canadian head CT rule on the NHS - see below in 11.3.7.

11.3.3 Health outcomes (4 and 5, see Table 11.2)

A strategy that increases NHS costs would be economically justified if there were associated health gains. Intuitively, we might expect surgical outcomes to improve if intracranial haematomas (ICHs) are detected earlier. There is no direct evidence that a strategy of CT scanning can improve neurosurgical outcomes although there is some evidence that outcomes have been improved in patients with more serious head injuries.¹⁸⁴

UPDATE 2007:

However, there is cohort study evidence suggesting reduced mortality associated with prompt surgery^{185,186}. A paper retrieved during the 2007 update⁷⁶ had estimated the quality-adjusted life-years (QALYs) gained from prompt surgery by comparing the recovery and mortality rates in different case series (see 11.3.7 below).

Any health gains associated with detection could be partially offset by increased cancer risk. There is no direct evidence that exposure to medical X-rays does increase the incidence of cancer, however, there is a general association between radiation and genetic mutation and it is clear that the exposure level is considerably higher with CT scanning than with skull X-ray (see Chapter 10).

11.3.4 Other health service costs (6, see Table 11.2)

The change in health outcomes just mentioned would lead to considerable

changes in health service resource use for the particular patients affected. However in both cases the net change in health service costs could go up or down. For example, if an improvement in neurosurgical outcome leads to more patients surviving but those that survive require long term care for chronic brain injury then costs would increase. Alternatively if both mortality and disability were reduced then long term costs are likely to be reduced. However, whichever direction the change is in, the average change in costs per patient scanned is likely to be small given the low likelihood of a change in health outcome.

11.3.5 Patient costs (7&8, see Table 11.2)

The costs (time, lost income, medication purchased, etc) to patients and their families associated with changes in health outcome could be considerable. As with health service costs we could not be certain what the net effect would be for the family. Again when averaged across all patients these cost changes could be quite small because the incidence of these changes in outcomes will be small.

There may be substantial costs associated with the decision to admit but these are likely to differ according to the situation of the family. For example, if a parent is admitted then there might be a need for child-minders but on the other hand the act of regular observation at home is costly in itself and families might find it easier if this burden were undertaken by the hospital.

11.3.6 Litigation costs (9, see Table 11.2)

It has been suggested that litigation might be reduced if more patients were scanned. However, Bramley et al¹⁸⁷ have estimated that only one in 10,000 patients subsequently turn out to have an intracranial haematoma after being discharged without a CT. Therefore the potential costs saved per patient screened are likely to be small. It should also be born in mind that successful litigation usually arises out of organisations not abiding by guidelines.

11.3.7 Update 2007

We found three new studies that evaluated diagnostic tools: a decision analysis¹⁸⁸ and an RCT⁷⁹ were comparing admission with CT scanning, and a case series¹⁸⁹ was evaluating the use of head MRI as an addition to CT.

A further three new studies evaluated diagnostic decision rules. We found two studies evaluating the implementation of the head CT rule recommended in the original edition of this guideline. A third study compared the Canadian Head CT Rule with various imaging strategies.

A decision analysis¹⁸⁸ compared CT scanning (and discharge after a negative scan) with admission in head injury patients with a GCS of 15 (mild head injury). They found the CT strategy to be cost saving compared with admission. The same team confirmed the results of this study with a randomised controlled trial of 2600 mild head injury patients⁷⁹. Outcomes were followed up for three months. There were no differences in clinical outcomes (survival and extended Glasgow Outcome scale

GOS) but costs were £133 less per patient in the CT arm.

A retrospective case series of 40 patients¹⁸⁹ was used to evaluate the addition of an MRI to CT scanning in patients with traumatic brain injury. The number of lesions diagnosed by CT but not by MRI was 9 out of 40, while the lesions detected by MRI but not by CT were 24 out of 40. The addition of MRI cost more than £1,500 in additional charges per extra lesion diagnosed. However the identification of the additional lesions did not lead to a change in the treatment path and therefore the addition of MRI to CT was neither effective nor cost-effective. However, the cohort was small for estimating the effectiveness with any precision.

A UK cohort study¹⁶ evaluated the consequences of implementing the NICE guideline. The X-ray and admission-based practice was replaced with the Canadian CT head rule. Cases of head injury were followed up in a regional neurosciences hospital and in a district general hospital for one month, six months before and for one month after the guideline implementation. In the case of the neurosciences hospital the cost per patient was reduced by £34 and it was reduced by £3 per patient at the general hospital. In contrast in a similar cohort study⁸⁸ of 992 patients, costs were found to increase by £77 per patient. Table 1 shows the resource use observed in both studies compared with the predictions in the original edition of this guideline. The evidence from the cohorts suggests that compared with our

predictions there was a more modest increase in CT and a more modest decrease in X-ray.

The variation in impact between centres could be due to a number of factors including variation in the baseline position and completeness of adherence to the NICE guideline in the after period of the studies. In the centre that showed an increase in cost, X-rays were very low in number to start with and therefore there was less scope for cost savings; furthermore admissions had inexplicably increased slightly compared with the reductions seen at the other centres. The large amount of variation between centres means that the impact of our recommendations at a national level remains uncertain.

Table 11.9: Resource use before and after implementation of NICE head CT rule

| | NCC-AC2003 Model | | Shravat2006 DGH | |
|------------------|-----------------------------|-------|----------------------------|-------|
| | Before | After | Before | After |
| CT | 2% | 29% | 2% | 8% |
| SXR | 54% | 0% | 11% | 0% |
| admission | 14% | 4% | 8% | 9% |

| | Hassan2005 Neurosciences | | Hassan2005 DGH | |
|------------------|-------------------------------------|-------|---------------------------|-------|
| | Before | After | Before | After |
| CT | 3% | 18% | 1% | 9% |
| SXR | 37% | 4% | 19% | 1% |
| admission | 9% | 4% | 7% | 5% |

One of the centres in the Hassan study¹⁶ had modified the protocol so that elderly patients with a GCS of 15 seen out of hours could be admitted instead of getting urgent CT. The reasoning involves a combination of factors: a) the cost of out-of-hours radiology was relatively high, b) the elderly represent quite a large group and there are often difficulties in trying to discharge them over night. Hence, the modification is lower cost since out-of-hours radiology is avoided and most would need admission anyway. We don't have evidence of effectiveness for this specific patient group but the randomised evidence for the general population showed no difference in outcomes between observation and CT scan⁷⁹. The GDG agreed that this was an acceptable deviation from the head rule and the guideline recommendations were modified accordingly.

A decision analysis⁷⁶ compared the Canadian head CT rule with several strategies including 'CT all', 'admit all', 'discharge all' and 'X-ray all' in a US context. Quality-adjusted life-years (QALYs) and costs were estimated for both prompt and delayed surgery by comparing the mortality and recovery rates in different case series. The Canadian rule dominated the other strategies, that is to say it gave the highest number of QALYs and the lowest cost. However, the study did not evaluate the earlier UK guidelines based on skull X-ray and admission. The CT all strategy was just as clinically effective but more costly. The results were sensitive to the probability that

prompt surgery leads to a good outcome.

11.4 *Identifying cervical spine damage in patients with head injury*

Table 11.4 identifies the resource and health outcomes that could differ between different diagnostic strategies.

11.4.1 Literature review

There are three cost-effectiveness studies in this area:

- Kaneriyā et al ¹⁹⁰ estimated that five view X-ray could save \$24 per patient scanned compared with three-view because it reduced the number of subsequent CTs associated with inadequate X-rays by 48%.
- Tan et al ¹⁹¹ estimated the cost-effectiveness of CT scan after inadequate X-ray. They found a cost of \$16,900 per potentially (or definitely) unstable fracture and \$50,600 per definitely unstable fracture. This is cost-effective given the consequences of paralysis.
- Blackmore et al ¹²¹, using test sensitivities pooled from the published literature, compared CT scanning of the cervical spine with conventional cervical spine X-ray. Using their own risk rating scale, they found CT scanning to be a cost-effective strategy (\$16,000 per quality-adjusted life-year gained) for the 'high' and 'moderate' risk groups (high energy mechanism and age under 50 or moderate energy mechanism and age greater than 50) but not for the low risk group (\$84,000 per QALY gained). Unlike the other studies, incorporated into these figures are the costs and morbidity associated with paralysis.
- In addition, two more studies estimated the costs that could be saved by moving from current practice at a particular institution to a particular scanning protocol.^{122,192}

The above studies are not strictly relevant to the context of England and Wales, not least because the unit costs and the patient groups used in the studies are not from the UK. Furthermore they only attempted to include outcomes 1 and 2 (and in the case of Blackmore et al 4 and 6 as well) and crucially do not address the long term effects of medical radiation, which are likely to be greater in CT scanning of the neck than in CT scanning of the head (see Chapter 10).

The Blackmore analysis suggests for a patient group that is at particularly high risk of paralysis, cervical spine CT could be preferable to X-ray by both improving health outcomes and lowering costs. However, they do not take into account the impact of the large radiation dose received by the thyroid from a cervical spine CT scan. This would be very difficult to model given the lack of empirical evidence on the long term effects of this medical radiation. It was the consensus of the Guideline Development Group that the benefits from CT scanning of the cervical spine do not obviously outweigh the risks.

In light of the review of new clinical and cost-effectiveness evidence, the GDG modified its position to recommend CT scanning in high risk patients. Additional cost-effectiveness evidence retrieved in 2007 can be found below in 11.4.3.

11.4.2 Cost-effectiveness model – imaging of the cervical spine

We conducted our own tentative cost analysis comparing the NEXUS and the Canadian cervical spine rules. We estimated that the Canadian rule could save about £14 per patient (Table 11.10).

Table 11.10 – Comparison of the Canadian and NEXUS cervical spine rules (Updated 2007)

| Strategy | Proportion of patients receiving test | | Cost of testing (£) per patient | | |
|-----------|---------------------------------------|-------|---------------------------------|-------|-------|
| | X-ray | CT | X-ray | CT | Total |
| Canadian | 58.2% | 22.8% | 11.05 | 17.53 | 28.58 |
| NEXUS | 87.4% | 34.2% | 16.60 | 26.31 | 42.91 |
| Increment | | | | | 14.33 |

The assumption that a CT scan will be performed after all inadequate X-rays may over-estimate the actual cost savings; if we omit them then the cost-savings are £4 per patient scanned.

Sensitivity ranges are presented in Table 11.11.

Table 11.11 - Sensitivity analysis for cervical spine scanning rules

| | Incremental cost per patient (£) of NEXUS rule compared with Canadian cervical spine rule | |
|--|---|-------------------|
| | X-ray costs only | X-ray and CT cost |
| Baseline estimate | 5.54 | 14.33 |
| Sensitivity to unit costs | 4.38, 6.71 | 11.45, 18.12 |
| Sensitivity to proportions tested | 5.28, 5.80 | 13.65, 15.01 |
| Sensitivity to both unit costs and proportions | 4.17, 7.02 | 10.91, 18.95 |

The Canadian cervical spine rule could save valuable health service resources but it is yet to be validated and if it was found to be less sensitive it might not be the most cost-effective strategy due to the morbidity and high costs associated with paralysis. This cost analysis was limited because of the use of overseas data and the simplified assumptions regarding dealing with inadequate X-rays. Furthermore the analysis did not include outcomes 3-8 from Table 11.4.

11.4.3 Update 2007

Five new studies were found: a non-randomised controlled trial¹¹⁷, two cohort studies^{118,193}, a case series¹¹⁹ and a decision model¹²⁰. One study¹⁹³ was evaluating the role of MRI scanning in children, another study¹¹⁷ was comparing helical CT scanning with X-ray in children, and the rest were comparing CT scanning with X-ray in adults.

A non-RCT¹¹⁷ compared the costs of helical CT with those of X-ray in a population of 136 children who required cervical spine radiography in addition to cranial CT. The imaging costs including follow-up tests were £100 and £130 respectively for the radiography and CT diagnostic strategies (significance not reported).

A retrospective cohort study¹¹⁸ based on an adult population of 573 trauma patients undergoing spinal imaging (the proportion with head injury was not reported) compared the costs of helical CT with X-ray. Unlike the non-RCT, this study found the cost of CT was no greater than X-ray (£36 vs £35) due to

the staff time involved with CT being substantially less.

In a case series study¹¹⁹, 407 adult patients in a trauma centre underwent both X-ray and helical CT (again the proportion with head injury was not reported). The reference standard was represented by two radiologists independently reviewing both the HCT and plain X-ray results together with hospital case notes. The sensitivity yielded by X-ray was 45% while the sensitivity yielded by the helical CT intervention was 98%. The helical CT strategy was more costly than a strategy of helical CT after inadequate X-ray. From their figures, we calculate that this strategy costs an extra £7,300 per fracture detected. Using the model by Blackmore and colleagues¹²¹, as follows, we can see that this is highly cost-effective. The model estimated that 5% of fractures would lead to paralysis and that paralysis is associated with 16 QALYs lost. Hence £7,300 per fracture detected would translate to only £9,125 per QALY gained and that is without taking in to account the considerable cost savings from averting paralysis.

The decision analysis of helical CT vs X-ray of the cervical spine in patients undergoing cranial CT for head injury by Grogan et al¹²⁰ was based on an earlier model by Blackmore and colleagues¹²¹ looking at conventional CT vs X-ray. It considered only patients at medium and high risk:

- Focal neuro-deficit or severe head injury or high energy impact, or

- Moderate energy impact and age more than 50

Helical CT cost an additional £37,000 per paralysis averted in this group. This would imply that the helical CT strategy is cost saving when the very high cost of treating paralysis is taken into account.

A retrospective cohort study with a historical control published in 2002¹⁹³ evaluated a protocol of MRI scanning patients whose cervical spine had not been cleared within 72 hours. The control strategy was not clearly defined. This study was conducted in a specific population of patients consisting of 102 children (age 0 to 17) who were intubated at the time of hospital admission and who remained in the intensive care unit for at least 3 days. Among the 51 patients in the control group, 19 underwent MRI, whereas it was required for 31 patients in the post-protocol group.

The MRI group had reduced hospital charges (£18,000 vs £24,000; significance not reported) attributable to reduced stay in hospital and in intensive care. However, sample variation and a general trend over time towards reduced stay might explain this difference.

11.5

Discussion

A simple cost model demonstrates that some strategies that increase head CT scanning could potentially reduce costs if patients that have a negative scan are discharged without admission. However, there are health outcomes and some additional changes to resource use that

cannot be quantified using currently available data – notably those associated with the impact of radiation exposure.

Table 11.12 (below) summarises the estimated changes in imaging and admission volumes and cost in England and Wales as a result of these guidelines. This is based on Tables 11.3, 11.6 and 11.10 and assumes an incidence of 700,000 head injury attendees to emergency departments per year.

We would like to emphasise the tentativeness of these estimates. There is uncertainty over these figures for a number of reasons. Data were taken from four different sources to estimate the number of scans (currently and with the new system).^{25,52,122,176} Various assumptions had to be made to make the denominator of the estimates from these studies comparable. Some of the evidence was not from a UK population. Empirical studies found in the 2007 update (Table 11.9) show great variation between centres and therefore help little to reduce the uncertainty about the numbers of each scan before and after the guideline.

The reduction in skull X-rays is likely to be an overestimate, as some skull X-rays may still have to take place for non-accidental injuries and other reasons. The reduction in in-patient observation is also uncertain. This assumes that clinicians are able to discharge patients who have had a negative CT scan. This will not be the case for patients who

have other comorbid traumatic
symptoms.

Table 11.12 – Imaging and admission volumes and costs England and Wales associated with different clinical decision rules (updated 2007)

| | Number per year (000) | | | Cost per year (£m) | | |
|-----------------------|-----------------------|-----------------|--------|--------------------|-----------------|--------|
| | Current (pre-2003) | New (post-2003) | Change | Current (pre-2003) | New (post-2003) | Change |
| <i>Head</i> | | | | | | |
| Skull X-ray | 378 | 0 | -378 | 7.2 | 0.0 | -7.2 |
| Head CT | 16 | 205 | 189 | 1.2 | 15.8 | 14.6 |
| 24-hr Obs | 96 | 33 | -63 | 21.6 | 7.5 | -14.1 |
| | | | | | | |
| <i>Cervical spine</i> | | | | | | |
| X-ray | 330 | 220 | -110 | 6.3 | 4.2 | -2.1 |
| CT | 129 | 86 | -43* | 10.0 | 6.6 | -3.3 |
| | | | | | | |
| <i>All</i> | | | | 46.2 | 34.1 | -12.1 |

* Note that the 2003 recommendations should lead to reduced spine imaging generally (including CT), as given here. However the 2007 update should lead to increased CT scanning compared with the 2003 recommendations (figures not given).

The Canadian head CT rule, adopted by the consensus of the Guideline Development Group is expected to reduce costs. There are also likely to be improvements in quality of care. In the short term this will mean fewer patients being diagnosed on 'deterioration', patients getting reassurance sooner rather than later and hopefully improvements in long term outcomes (although this is not based on high quality evidence). If patient outcomes are improved then this in turn might lead to additional cost-savings. It was the decision of the Guideline Development Group that the potential benefits of adopting this rule are likely to outweigh the potential costs.

The NEXUS cervical spine rule and the Royal College of Radiologists guidelines appear to be almost identical. Given this, on the basis of a simple cost model, the adoption of the Canadian cervical spine rule could save valuable health service resources. This rule is yet to be validated, however, and if it was found to be less sensitive it might not be the most cost-effective strategy due to the morbidity and high costs associated with paralysis. On the other hand, the thyroid is known to be susceptible to radiation damage and strategies that reduce the need for radiological examination of the neck may reduce subsequent morbidity and health service cost.

Our simple analyses estimated an additional scanning cost of £17 per head trauma patient associated with adopting the Canadian head CT and a cost saving of £14 associated with adopting the Canadian cervical spine

rule. This suggests a combined impact of £31 saved per patient. For England and Wales, assuming an incidence of head injury of around 700,000 cases a year, of which 54% satisfy the criteria for scanning, a modest saving of £12.1m that could be reinvested in the health service would result. However, we should be very cautious about this figure. The longer term impact of changing imaging strategies on health outcomes and health service costs is even less certain. Staff shortages in radiology mean that implementation of these changes could take some time or else use up extra resources. Another reason why these cost savings might not be realised in the short term is that they are likely to require investment in new CT scanning equipment.

It is probable that we have not taken into account fully the implementation costs of the guideline. To some extent this is true, as our remit does not include the details of implementation. For example, we acknowledge that full implementation of the guideline will require staff training, the cost of which we have not been in a position to quantify.

It is also possible that the costs incorporated into our cost analyses do not reflect the real costs of the services. For example, the increased utilisation of CT scanners may necessitate the purchase of additional scanners, although the capital cost of CT scanners should be incorporated into the unit costs that we have used in our cost-effectiveness model. There is also a possibility of the expansion of out of

hours practice, which may push up the unit cost of scanning. The shortage of radiology and radiography staff, especially those with appropriate experience in CT scanning of the head, may again mean that the real cost of increasing CT scanning is greater than our calculations would suggest or at least that implementation will have to be delayed.

One issue raised throughout the guideline consensus process was the need for additional staff training at many levels. Achieving this goal, nationally, could require substantial resources, especially when shortages in specialist staff (for example, radiographers) are already constraining the system.¹⁹⁴

We have suggested a number of reasons in the guideline document why the cost savings we have predicted might not occur. These include:

- in-patient observation may not be reduced despite the increase in CT scanning (evidence since 2003 is mixed – see Table 11.9);
- cervical spine CT might be quite rare at present and therefore the reductions won't take place;
- some skull X-rays will still have to take place for penetrating injury and other reasons (for example, suspected non-accidental injury);
- we have postulated that the similarity between the NEXUS guidelines and those of the RCR suggests that the NEXUS study represents current practice

for cervical spine imaging in the UK. If this is not the case then a move to the Canadian cervical spine rule might not lead to cost savings.

It is clear that the long term morbidity associated with injury to the head and cervical spine and the lack of evidence concerning suitable rehabilitation are a major problem. Not only does it reduce the quality of life for these individuals and their carers but also it places a substantial burden on society in general through time off work and social security payments.¹⁹⁵ Hence the development of effective rehabilitation programmes should be placed high up the research agenda.

The other elements of the guideline are probably more conservative and therefore the overall impact on health service resources is probably small although it remains uncertain.

11.5.1 Conclusions from the 2007 update

A randomised controlled trial has confirmed that to discharge patients with mild head injury (GCS15) after a negative CT scan, as recommended in this guideline, is both safe and cost saving.

The impact of the Canadian CT rule as advocated in the original edition of this guideline has varied considerably but reassuringly in some centres it has reduced costs. A published model that took into account long term treatment costs and health consequences indicated that the Canadian head CT rule is more cost-effective than a number of alternative strategies based on CT, X-

ray or admission. However, none of the evidence has taken into account the impact of the increased radiation exposure.

Updating the costs to 2005-6 prices makes the Canadian CT head rule even more cost-effective, since the cost of imaging has fallen.

A modification of the rule so that elderly patients with a GCS of 15 seen out of hours could be admitted instead of getting urgent CT is a safe strategy and could be cost saving for services where out of hours radiography costs are prohibitively high.

The new studies add to existing evidence, in suggesting that CT scanning of the cervical spine is cost-effective in higher risk groups who are already undergoing head CT. However, none of these studies have taken into account the costs and health consequences associated with the increased radiation exposure – it is possible that CT is no longer cost-effective when these are taken into account. It is difficult to model the impact of radiation exposure on cost-effectiveness since there are a large number of uncertainties: a) the amount of radiation received at different parts of the body, b) the relationship between exposure and cancer, c) the types of cancer caused, d) the pattern of resource use in the diagnosis and treatment of the cancer, and e) the timing of cancer, treatment and death. Another limitation with regard to cervical spine imaging is that all the studies were conducted in the USA; the observed healthcare costs and

savings might not be transferable to a UK NHS setting. As the cost of CT scanning, as with most medical care, is lower in the UK, if it is cost-effective in the USA then it is likely to be cost-effective for the NHS. However, the cost savings from paralysis care averted are also likely to be lower.

11.6 Addendum 2007 – Direct transport from injury scene to a specialist neurosciences centre

11.6.1 Literature review

We did not find any cost-effectiveness evidence for this question but we did find two simulation models, which we will refer to as the London and Staffordshire models. We have reviewed these models in some detail, as follows.

11.6.2 London model

The report¹⁹⁶ summarises the findings of a review conducted by the London Severe Injury Working Group focusing on the Trauma services provided in London, including care, treatment and transfer of severely injured patients. Severe injury was defined as the need for Intensive Care.

The analysis of the current service highlights some key issues:

- high secondary referral rate (two thirds of the severely injured patients group),
- evidence of problems associated with such transfers (adverse clinical events during transfer, delay to definitive intervention, low level of staff and standard of care), and

- difficulties for hospitals in transferring patients for specialist care, especially for neurosurgery (stabilisation of patient first, co-ordination between the first hospital and the specialist hospital and consequent long delays).

Methods

A modelling of the flow of trauma patients was carried out to determine the best trauma service configuration for adult trauma patients with severe injury in the London area. The model was designed to estimate the time from injury to:

- Critical Intervention (urgent life saving interventions such as intubation); these interventions are crucial for all trauma patients
- Definitive Intervention (specialist interventions such as neurosurgery); these interventions vary according to the site of the trauma

The specific aims of the modelling exercise were to evaluate the effect on time to intervention of:

- (a) different bypass strategies
- (b) improving the current system by reducing time taken in pre-hospital and in-hospital trauma management.
- (c) a doctor in the pre-hospital phase provided by the London Helicopter Emergency Medical Service (HEMS).

The model simulated results based on about 10,000 actual severe injuries from the London region. Of these 33% had isolated head injury and a further 18% had non-isolated head injury.

The model estimates time to intervention using flow charts. Figure 1 **Error!**

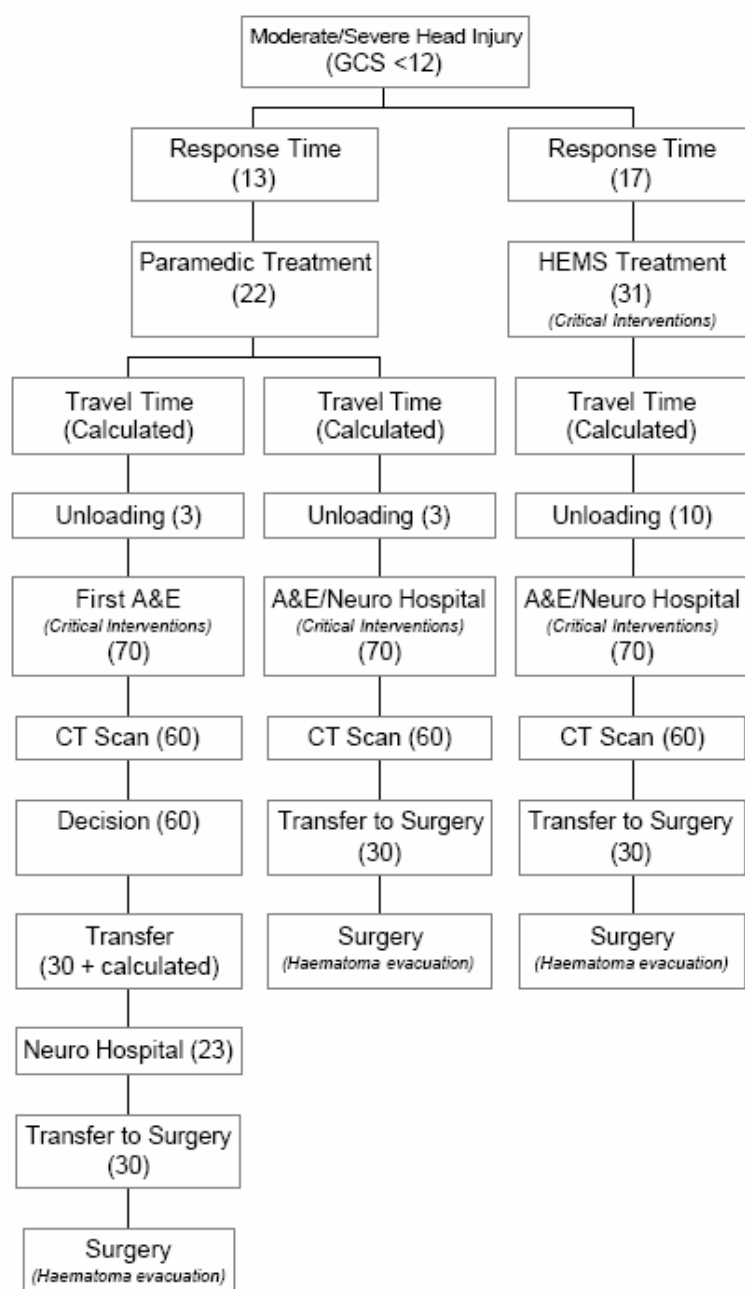
Reference source not found. shows the flowchart for an isolated head injury patient with the average times based on current practice. Similar flowcharts were devised for the different types of trauma. The timings were based on ambulance service records and expert opinion.

For each type of injury, a group of clinical experts decided on a target time for intervention. For head injury, it was considered that it was crucial to carry out neurosurgery within 4 hours of the injury, based on some evidence¹⁸⁶. For each service configuration scenario, the primary outcomes were:

- the median times to critical and definitive interventions.
- the proportion of patients receiving critical and definitive interventions within the relevant time target.

Figure 1: London Model flowchart for isolated head injury patients (figures in parentheses are average time in minutes)

1. Head Injury Needing Neurosurgery (33.2%)



Notes:

- a. The 'Decision' box includes decision, communication, obtaining specialist opinion, finding a bed and arranging the transfer.

Table 11.13: London Model: Median time (hours) to critical/definitive interventions, by bypass strategy

| | Current timings | | | Timings improved at LAS* & hospitals | | |
|---|-----------------|-----|-----|--------------------------------------|-----|------|
| | none | 15 | 20 | none | 15 | 20 |
| <i>Bypass strategy</i> | | | | | | |
| critical intervention (minutes) | 41 | 43 | 45 | 32 | 34 | 36 |
| head injury | 4.8 | 3.7 | 3.4 | 3.8 | 2.9 | 2.7 |
| head and chest injury | 4.9 | 3.8 | 3.5 | 3.9 | 3.0 | 2.7 |
| head, chest and orthopaedic injury | 6.9 | 5.9 | 5.6 | 6.0 | 5.2 | 4.9 |
| chest injury | 4.6 | 3.8 | 3.4 | 3.7 | 3.0 | 2.7 |
| orthopaedic injury | 2.2 | 2.3 | 2.3 | 1.7 | 1.7 | 1.7 |
| head and orthopaedic injury | 6.8 | 5.8 | 5.5 | 5.8 | 5.1 | 4.8 |
| chest and orthopaedic injury | 6.7 | 5.9 | 5.5 | 5.7 | 5.1 | 4.8 |
| head, chest and abdominal injury | 7.0 | 5.9 | 5.6 | 6.0 | 5.2 | 4.9 |
| chest and abdominal injury | 6.6 | 5.9 | 5.5 | 5.7 | 5.1 | 4.8 |
| orthopaedic and abdominal injury | 3.2 | 3.2 | 3.2 | 2.5 | 2.5 | 2.6 |
| abdominal injury | 3.2 | 3.2 | 3.2 | 2.5 | 2.5 | 2.6 |
| facial injury | 3.8 | 3.8 | 3.5 | 3.0 | 3.0 | 2.7 |
| head and facial injury | 4.8 | 3.8 | 3.5 | 3.8 | 3.0 | 2.7 |
| spinal injury | 5.7 | 4.8 | 4.4 | 4.6 | 4.0 | 3.6 |
| head and spinal injury | 4.8 | 3.8 | 3.4 | 3.8 | 3.0 | 2.7 |
| head, orthopaedic and abdominal injury | 6.8 | 5.8 | 5.5 | 5.8 | 5.1 | 44.8 |
| orthopaedic and vascular injury | 6.9 | 5.9 | 5.6 | 5.9 | 5.2 | 4.9 |
| traumatic amputation | 4.7 | 3.8 | 3.5 | 3.7 | 3.0 | 2.7 |

* LAS=London Ambulance Service

Table 11.14: London Model: Proportion of patients receiving critical/definitive interventions within target time, by bypass strategy

| | Current timings | | | Timings improved at LAS* & hospitals | | |
|--|-----------------|-----|-----|--------------------------------------|-----|-----|
| | none | 15 | 20 | none | 15 | 20 |
| <i>Bypass strategy</i> | | | | | | |
| critical intervention (within 60 minutes) | 91% | 88% | 84% | 98% | 97% | 96% |
| head injury (within 4hs) | 23% | 60% | 74% | 63% | 81% | 90% |
| head and chest injury (within 2hs) | 0% | 0% | 0% | 2% | 4% | 5% |
| head, chest and orthopaedic injury (within 2hs) | 0% | 0% | 0% | 0% | 0% | 0% |
| chest injury (within 2hs) | 0% | 0% | 1% | 3% | 6% | 8% |
| orthopaedic injury (within 2hs) | 30% | 27% | 25% | 84% | 82% | 79% |
| head and orthopaedic injury (within 4hs) | 0% | 1% | 1% | 3% | 8% | 10% |
| chest and orthopaedic injury (within 2hs) | 0% | 0% | 0% | 0% | 0% | 0% |
| head, chest and abdominal injury (within 2hs) | 0% | 0% | 0% | 0% | 0% | 0% |
| chest and abdominal injury (within 2hs) | 0% | 0% | 0% | 0% | 0% | 0% |
| orthopaedic and abdominal injury (within 2hs) | 1% | 0% | 0% | 9% | 8% | 7% |
| abdominal injury (within 2hs) | 1% | 0% | 0% | 9% | 8% | 7% |
| facial injury (within 3hs) | 23% | 22% | 27% | 49% | 50% | 63% |
| head and facial injury (within 3hs) | 9% | 22% | 27% | 19% | 50% | 63% |
| spinal injury (within 6hs) | 62% | 79% | 88% | 93% | 96% | 97% |
| head and spinal injury (within 4hs) | 21% | 55% | 70% | 61% | 78% | 88% |
| head, orthopaedic and abdominal injury (within 2hs) | 0% | 0% | 0% | 0% | 0% | 0% |
| orthopaedic and vascular injury (within 4hs) | 0% | 1% | 1% | 3% | 7% | 9% |
| traumatic amputation (within 4 hs) | 30% | 55% | 70% | 66% | 78% | 87% |

* LAS=London Ambulance Service

Model Results

11.13 shows the median time to critical/definitive intervention by type of injury and by bypass strategy used. On the left side of the table the results are based on current timings. On the right hand side the results are based on improved timings. In the case of the isolated head injury patient the median time to neurosurgery is 4.8 hours currently but would fall to 3.4 hours when bypassing patients who are less than 20 minutes from a specialist centre. Table 11.14 shows the proportion of patients that receive interventions within the target time. In the case of the isolated head injury patient the number receiving neurosurgery within 4 hours would increase from 23% with no bypass to 74% with bypassing patients who are less than 20 minutes from a specialist centre. However, on the negative side with this bypass strategy only 84% (compared with 91%) would receive critical intervention within 60 minutes. The group that is made worse off by bypass is those patients with isolated orthopaedic injury: only 25% would receive their definitive intervention within their 2 hour target (compared with 30% without bypass).

For the injuries that can be treated in every hospital the most rapid movement to Definitive Intervention was achieved by the models without bypass, and with improvement in hospital times.

For injuries requiring specialist management the best models for providing early Definitive Intervention included 20 minutes bypass,

improvement in hospital times and use of the London HEMS.

Report conclusions

The bypass protocol proposed is based on the 20 minutes of distance from a Multi-Specialty Centre, as this time gives the best trade-off between longer time to Critical Interventions, and shorter time to Definitive Intervention. However, the best balance between these opposing effects had to be struck by clinical judgement, as little evidence was available.

The report recommended that within a 20 minute drive time of an appropriate specialist unit, a patient should be driven directly to the specialist unit rather than to the local hospital, and that a triage system for London should be gradually introduced, allowing training of pre-hospital personnel and evaluation of the effectiveness of each of the triage criteria. For head injury the initial criterion could be based on GCS and additional criteria could then be added. This would avoid the flooding of Multi-Specialty Centres.

Review

The report has a number of limitations:

- The model, especially the target times, was based more on expert judgement than hard evidence of clinical effectiveness.
- In reality there will be a continuum of risk rather than a time cut-off.
- The model assumes that the specialist hospital has a range of different

specialist services in addition to neurosciences.

- The trade-off between the need for immediate access to critical interventions (e.g. intubation) and the need for faster access to definitive interventions (e.g. surgery) was made on the basis of expert judgement rather than health outcomes.

11.6.3 Staffordshire model

The link between time and health outcomes missed by the London model was captured to some extent in the Staffordshire model⁶⁸.

It evaluated the impact of 10 different transport strategies on survival of patients with serious or worse HI (AIS more than 2). In the model, survival was determined by a number of variables including: a) head AIS score, b) non-head AIS score, c) time to surgery, d) grade of staff during transfer, e) incidence of hypoxia and hypotension, g) distance from hospitals. Some of these variables are patient-specific (a,b,g), some are service-specific (d) and some are determined by the transport strategy (c,e). The data used in the model came from a variety of sources including a large trauma database, the published literature and expert opinion. Monte Carlo simulation (that is repeatedly generating new results by simultaneously drawing at random from the distribution of each model parameter) was used to simulate 10,000 head injury patients and their outcomes under each strategy.

Table 11.15 shows the results for each strategy. All direct transport strategies

had higher expected survival than a strategy of sending all patients to the nearest emergency department but strategies 2-6 were the most effective. Among these strategies, strategy 4 (direct transport of patients with critical head injury, AIS=5) required the least number of patients being diverted to specialist centres. The results were not sensitive to the parameters that were determined by expert opinion.

An important limitation that was acknowledged by the authors was that AIS score is determined after treatment and therefore assessment of patients at the scene of the injury is less accurate. The implication is that the survival gain observed in this model is probably larger than can be achieved in reality, although the pattern should be the same. There are different costs associated with each strategy and therefore a cost-effectiveness analysis is needed to assess which of the 10 strategies is the most cost-effective.

In conclusion, the simulation study shows that survival of severe head injury patients could be substantially improved by transporting patients directly from the injury scene to a hospital with a specialist neurosciences centre. Cost-effectiveness of these strategies was determined as described in 11.6.4.

Comparison with the London model

The Staffordshire model went a step further than the London model by estimating the impact of different strategies on survival (as well as time) in order to trade-off the different outcomes.

Both models rely on evidence combined with expert opinion to estimate the time to intervention. For the Staffordshire model, expert opinion is also used to estimate the survival rates. For the London model, expert opinion is also used to estimate the target times. Thus there must still be uncertainty around the results of both studies as they are not based on hard evidence.

Both research teams recommend bypass if the specialist hospital is ≤ 20 minutes from the injury scene. The Staffordshire model estimated substantial survival gains from bypass even if the specialist hospital is much further away (53 minutes). There are no obvious contradictions between the two models but the authors of the London report have been more cautious in recommending bypass over longer distances.

Table 11.15: Stevenson's Transport model - results

| Criteria for transporting patients directly to Neurosciences Hospital | Percentage of patients bypassing DGH | Survival gain vs 1) (Neurosciences Hospital far) | Survival gain vs 1) (Neurosciences Hospital near) |
|---|--------------------------------------|--|---|
| 1) None | 0% | 0.00% | 0.00% |
| 2) HI AIS>2 | 100% | 3.40% | 4.50% |
| 3) HI AIS>3 | 78% | 3.50% | 4.60% |
| 4) HI AIS=5 | 44% | 3.40% | 4.30% |
| 5) Non-HI AIS<4 | 89% | 3.30% | 4.00% |
| 6) Non-HI AIS<5 | 95% | 3.40% | 4.50% |
| 7) Isolated head injury | 75% | 2.80% | 3.60% |
| 8) Intubated pre-hospital | 20% | 1.70% | 1.90% |
| 9): 7) and 8) | 5% | 1.30% | 1.50% |
| 10) Out of hours | 40% | 1.50% | 2.00% |

11.6.4 Cost-effectiveness model – Direct transport

We conducted a cost-effectiveness analysis of transporting patients with serious head injury directly from the injury scene to a specialist neurosciences hospital (NSH). This was compared to initially transporting such patients to the nearest emergency department and then later transferring them to the NSH after stabilising the patient.

The following general principles were adhered to:

- The GDG was consulted during the construction and interpretation of the models.
- The sources of data are published studies and expert opinion.
- Model assumptions were reported fully and transparently.
- The results were subject to sensitivity analysis and limitations were discussed.
- We followed the methods of the NICE reference case. Therefore costs were calculated from a health services perspective. Health gain was measured in terms of quality-adjusted life-years (QALYs) gained.

11.6.4.1 General method

The model is represented by a decision tree (Fig.2): once the ambulance crews arrive at the accident scene, the patient can be transported either to the nearest District General Hospital (DGH) or to a

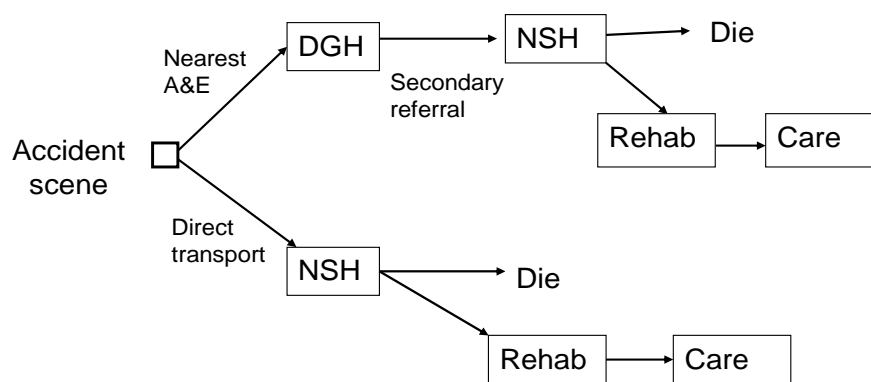
Neurosciences Hospital (NSH). Severe head injury patients initially admitted to the DGH will be subsequently referred to the NSH. Patients that survive will require rehabilitation and frequently some kind of long term care. The number of survivors is different in the different strategies.

To assess the cost-effectiveness of direct transport we need to assess not just changes to ambulance and emergency department costs associated with each strategy but also any changes in rehabilitation and long term care costs arising from the different strategies. These have to be balanced against the health gain.

We could not find evidence of effectiveness that perfectly suits this question. We therefore constructed two similar models based on different empirical studies:

Model A: We based this model on the only study in the clinical literature review that reported both mortality and health status (Glasgow Outcome Scale, GOS) in head injury patients— Poon et al 1991¹³⁵. This study compared a cohort of patients that had been directly transported to NSH to another cohort that were transferred from DGH. This study allows us to estimate both the QALYs gained and the cost savings attributable to improved care status in patients being directly transported. However, there was concern that this study was biased, since case-mix was not properly controlled for. For this reason we developed a more conservative model.

Model B, a conservative model, calculates only the health gain attributable to those patients who survive with direct transport but would not survive with a secondary transfer strategy. The number of these extra survivors is estimated using the results of a decision model that was explicitly answering our question – Stevenson et al 2001⁶⁸ (see 11.6.3). Model B does not take into account health gain for patients who survive under both strategies but have an improved health status with the direct transport strategy.

Fig.2: Transport model decision tree

Each model has advantages and limitations (Table 11.16).

Table 11.16: Summary of the models

| | Description | Advantages | Limitations |
|---------|---|---|---|
| Model A | Mortality & GOS: Cohort study - NSH direct vs NSH secondary referral (Poon 1991). | Both mortality and health state outcomes considered. Data coming from the same study. | Poon data seems overly optimistic and did not control for case-mix. |
| Model B | Mortality: Simulation study – NSH direct vs DGH (Stevenson 2001) GOS: retrospective cohort study (Patel 2002). | More conservative and hopefully less biased than Poon data. | Outcomes include only mortality, not differences in health status. |

For each strategy in both models, the expected healthcare costs and the expected QALYs were calculated by estimating the costs and QALYs for each GOS state and then multiplying them by the proportion of patients that would be in that state as determined by the strategy taken. Health state defined by the GOS state was assumed to be fixed over the lifetime.

The base case models assume that only patients with serious head injury would be transported. A concern is the ability of ambulance crews to determine the severity of the head injury at the scene. There might be a risk of overestimating the number of severely injured patients and therefore of sending too many patients to the NSH, which would mean that cost-effectiveness is reduced and would be risky for patients with multiple trauma. For this purpose, we conducted a sensitivity analysis on the number of false positives (patients erroneously deemed having a serious head injury) that would be transported to the specialist centre without requiring neurosurgical care.

11.6.4.2 Methods: Effectiveness

In Model A, the mortality rate together with the outcomes were derived from a study by Poon et al¹³⁵ in which a group of patients having an extradural haematoma was directly transported to the NSH while another group was only secondarily transferred there (Table 11.17). The mortality and the outcomes were assessed six months after the injury.

Table 11.17: GOS score and death rate after neurosurgical care in a NSH (Model A)

| GOS | % DGH then NSH patients 6 months after injury Poon 1991 | % NSH patients 6 months after injury Poon 1991 |
|--|--|---|
| Good Recovery | 49% | 86% |
| Moderate Disability/Severe Disability | 27% | 10% |
| Death | 24% | 4% |

The survival gain in Model B was derived from the results of a simulation model by Stevenson et al⁶⁸, where the target patient population were adults with a serious head injury (AIS of 3 or more) – see 11.6.3.

The model evaluated 10 different strategies of transporting patients directly to the NSH, which selected patients by different criteria (relating to level of AIS score, presence of multiple injuries, possibility of pre-hospital intubation, out of hours). Directly transporting all serious head injury patients to the NSH led to an estimated increase in survival of 4.5% for injury scenes near to the NSH and 3.4% for more distant injury scenes.

Stevenson et al estimated only mortality and not health status. We assumed that health status in the additional survivors would be similar to the general population of patients with serious head

injury treated in a NSH. We used 6-month GOS data from the surviving patients in a UK study, Patel 2002¹⁹⁷ (Table 11.18). The study population had all had a severe head injury (GCS 8 or less) and had been treated in a Neurosciences Critical Care Unit.

Table 11.18: GOS score after neurosurgical care in a NSH (Model B)

| GOS | % NSH patients 6 months after injury Patel 2002 |
|--------------------------------|--|
| Good Recovery | 49.6% |
| Moderate Disability | 27.1% |
| Severe Disability | 20.3% |
| Vegetative State | 3.0% |

We estimated the health loss associated with false positives. In fact, for these patients the longer the journey from the accident scene to the hospital, the higher is the risk of death from hypotension. In the case of a distant NSH (53 minutes, as reported in Stevenson's model), the mortality increases by 0.05%, while it increases by 0.03% if the NSH is near (20 minutes). These figures derived from the calculation of the probability of death based on clinical estimates (see 11.6.4.7).

11.6.4.3 Methods: Estimating QALYs

For each health state we estimated QALYs (Quality-Adjusted Life Years) by multiplying the discounted life expectancy by the utility score associated with each state. The expected QALYs for each strategy are then estimated by summing up the QALYs for each state weighted by the proportion of patients in that state.

In order to calculate the QALYs we combined data on life expectancy with data on quality of life.

Life expectancy

The life expectancy of patients in a vegetative state (VS) was assumed to be 10 years^{198,199}. In the case of a 60 year old patient in a VS, the life expectancy would be shorter and was assumed to be the same as for a patient in the severe disability state (see below).

To calculate the life expectancy for health states other than VS, we applied the standardised mortality rate (SMR), reported for 2,320 traumatic brain

injured patients in Shavelle 2001²⁰⁰, to the general population of England and Wales, using the Life Tables. According to Shavelle, the SMR decreases during the first 4 years post-injury but remains constant afterwards. In Shavelle 2001 the SMR was distinguished according to three levels of ambulation: a) none, b) some, c) stairs, which we matched approximately to the levels of disability of the GOS (a=SD, b=MD and c=GR).

Life expectancy was discounted at a rate of 3.5% per year, as required by NICE.

For our base case analysis we estimated life expectancy for men aged 40 (the average age of a patient in the Stevenson study). For our sensitivity analysis, we also calculated life-years for patients aged 20 and 60.

Quality of life

The utility scores in Table 11.19 are a measure of the quality of life associated with each of the health states on a scale from 0 (death) to 1 (perfect health). For the good recovery (GR) outcome, we used the EQ-5D score of 0.83 reported for the United Kingdom population²⁰¹. The other utility scores were taken from a decision analysis, Aoki 1998²⁰². The mean utilities for each GOS score were elicited from a sample of 140 subjects with a clinical background using the standard-gamble method. The GOS states in this study were expressed as the degree of disability due to brain damage caused by subarachnoid haemorrhage.

The Poon et al study (Model A) did not distinguish between patients that were severely disabled (SD) and those that were moderately disabled (MD). For these patients we used the simple average of the two SMRs and the simple average of the two utilities.

Another study was found, Tsauo 1999²⁰³, which reported the utility scores associated with each GOS score obtained from health professionals in the UK using the standard gamble method. We did not use this study in our base case model for the following reasons:

- scores were presented for a number of time points and there seemed to be inconsistency between the estimates
- the figures were skewed towards high values (i.e. the utility associated with a moderate disability was higher than the average EQ5D utility score for the general population in the UK²⁰¹)
- the value for the vegetative state was missing
- the number of the health professionals interviewed for the elicitation of the utility scores was not reported.

Therefore, we used this study only for the purpose of sensitivity analysis.

Table 11.19: Health Utilities by Glasgow Outcome Scale (GOS) state

| GOS | Utility score (base case analysis) | Source | Utility score (sensitivity analysis) Tsauo 1999 |
|--|---|--|--|
| <u>Model A</u> | | | |
| Good Recovery | 0.83 | ,Kind 1998 (UK general population) | 0.931 |
| Moderate Disability/Severe Disability | 0.45 | Aoki 1998 (mean of two states) | 0.788 |
| Death | 0 | | 0 |
| <u>Model B</u> | | | |
| Good Recovery | 0.83 | Kind 1998 (average utility in the UK) | 0.931 |
| Moderate Disability | 0.63 | Aoki 1998 | 0.908 |
| Severe Disability | 0.26 | Aoki 1998 | 0.668 |
| Vegetative State | 0.08 | Aoki 1998 | 0.08 |
| Death | 0 | | 0 |

In the sensitivity analysis on the assessment at the scene, we assumed that the false positives, if they survive the longer transport, would have had the same expected QALYs as the good recovery (GR) patient.

Calculating QALYs gained

For Model A, the QALYs gained are calculated as follows:

QALYs gained = $Q_1 - Q_0$

$Q_i = (P_{iGR} \times LE_{GR} \times U_{GR}) + (P_{iD} \times LE_D \times U_D)$

where

Q_i = the expected QALYs per patient ($i=1$: with bypass, $i=0$: without bypass)

P_{iGR}, P_{iD} = proportion of patients in each of the GOS states at 6 months by strategy (where D is both mild disability and severe disability combined).

LE_{GR}, LE_D = the discounted life expectancy of patients by GOS states at 6 months

U_{GR}, U_D = the utility score for each GOS state.

For Model B, the QALYs gained are calculated as follows:

QALYs gained = $Q_i - Q_0 = ES_i \times (P_{GR} \times LE_{GR} \times U_{GR}) + (P_{MD} \times LE_{MD} \times U_{MD}) + (P_{SD} \times LE_{SD} \times U_{SD}) + (P_{VS} \times LE_{VS} \times U_{VS})$

where

Q_i = the expected QALYs per patient associated with bypass strategy i ,
 Q_0 = the expected QALYs per patient associated with no bypass,
 ES_i = extra survivors = the proportion of patients surviving under strategy i that would not have survived under the no bypass strategy

$P_{GR}, P_{MD}, P_{SD}, P_{VS}$ = the proportion of extra survivors in each of the GOS states at 6 months

$LE_{GR}, LE_{MD}, LE_{SD}, LE_{VS}$ = the discounted life expectancy of patients by GOS states at 6 months

$U_{GR}, U_{MD}, U_{SD}, U_{VS}$ = the utility score for each GOS state.

with secondary referral. While the cost of the primary transport to the DGH or to the NSH is similar, an inter-hospital transfer would be more costly than transport from the injury scene because it requires additional staff and tasks. In fact, an anaesthetist and a nurse would always accompany a patient who required urgent transfer, which constitutes 90% of the transfers for head injury. The GDG experts estimated the total cost of the transfer as equal to three-hour time of a nurse and an anaesthetist, given the time necessary to activate a secondary transfer team at the DGH, the time spent in stabilising the patient, and the actual transfer time.

Moreover, on arrival at the NSH the patient would need other treatment for complications due to the transfer. With the average cost of a nurse at £19 per hour, and the cost of an anaesthetist (specialist registrar) of £34 per hour²⁰⁴, the total cost per patient transferred was estimated to be £159.

The cost of patient management at the Emergency Department in the two hospitals was not expected to be different, according to the GDG experts' estimates, since the staff grades would not be different.

All the cost figures are expressed in 2006 Pound Sterling. Costs related to previous years were inflated using the Hospital and Community Health Services Prices Index²⁰⁴.

We have not calculated transportation and emergency department costs in much detail but would argue that this is not a major flaw since these costs are

11.6.4.4 Methods: Ambulance and emergency department costs

Emergency department costs in our models are the staff costs associated

small compared with the additional rehabilitation and care costs incurred by survivors.

We calculated the increased transport cost associated with false positives, as they will be transported to a more distant hospital. The cost was obtained from the unit cost of an ambulance per minute, £6.50²⁰⁴, multiplied by the distance of the accident scene to the hospital, which was 20 minutes (near) or 53 minutes (far) in the simulation study⁶⁸.

11.6.4.5 Methods: Rehabilitation and care costs

We derived the cost of rehabilitation from two UK studies: one, Wood 1999¹⁴⁷, applicable to the severely disabled patients and the other one, Nyein 1999²⁰⁵, applicable to the moderately disabled patients (Table 11.20). The length of rehabilitation for the severely disabled group was 14 months, while it was 75 days for the moderately disabled group. We assumed patients who had a good recovery to undergo the same intensity of rehabilitation as the moderately disabled group, given the fact that the good outcome was assessed six months post-injury. Patients in a vegetative state were assumed not to receive any specific rehabilitative therapy. If any rehabilitation service was provided to them, its cost was assumed to be incorporated in to the cost of long term care.

The same two UK studies were used to calculate the annual care costs (Tab.11.20); in the case of severely

disabled patients, the long term care was the community care support required after rehabilitation and it was based on the cost of a support worker. Similarly, the long term annual cost for the moderate disability group was calculated from the weekly cost of care three months after discharge from the rehabilitation. Patients having a good recovery were assumed not to incur any long term costs. Patients in a vegetative state were assumed to have the same annual care costs as those who are in the severe disability state.

Care costs were discounted at a rate of 3.5% per year, as required by NICE.

Table 11.20: Cost of rehabilitation and long term care

| | total cost of rehabilitation | annual care costs |
|----|---------------------------------|----------------------|
| GR | 19,575 | 0 |
| MD | 19,575 | 7,472 |
| SD | 108,874 | 45,450 |
| VS | 0 | 45,450 |

Thus the model takes into account the increased costs of rehabilitation and care due to people surviving under direct transport, who would not survive under the current system. It could be that costs of neurosurgery and intensive care are also increased if patients are now making it to the NSH who would have died in transit. Since we do not have data on the timing of deaths, we have not included such costs in the base case. However, for a sensitivity analysis we added on the cost of 3 days of level 3 neurosurgical intensive care for each additional survivor. The costs of care in an ICU were calculated from the NHS Reference Costs 2005-2006¹⁷⁷ at £1,338 per day.

Calculating incremental cost

For Model A the incremental cost is calculated as follows:

$$\begin{aligned} \text{Incremental cost} &= \text{Cost}_{\text{NSU}} - \text{Cost}_{\text{DGH}} \\ \text{Cost}_{\text{NSU}} &= (\text{P}_{\text{NSU}_{\text{GR}}} \times (\text{RH}_{\text{GR}} + \text{LE}_{\text{GR}} \times \text{ACC}_{\text{GR}})) \\ &\quad + (\text{P}_{\text{NSU}_{\text{D}}} \times (\text{RH}_{\text{D}} + \text{LE}_{\text{D}} \times \text{ACC}_{\text{D}})) \\ \text{Cost}_{\text{DGH}} &= (\text{P}_{\text{DGH}_{\text{GR}}} \times (\text{RH}_{\text{GR}} + (\text{LE}_{\text{GR}} \times \text{ACC}_{\text{GR}}))) \\ &\quad + (\text{P}_{\text{DGH}_{\text{D}}} \times (\text{RH}_{\text{D}} + (\text{LE}_{\text{D}} \times \text{ACC}_{\text{D}}))) \\ &\quad + \text{TC} \end{aligned}$$

where

Cost_{NSU} = the expected cost per patient associated with direct transport to the NSU

Cost_{DGH} = the expected cost per patient associated with a secondary referral to the NSU from a DGH

$\text{P}_{\text{NSU}_{\text{GR}}}$, $\text{P}_{\text{NSU}_{\text{D}}}$ = the proportion of survivors in good recovery or mild/severe disability at 6 months with direct transport to the NSU

$\text{P}_{\text{DGH}_{\text{GR}}}$, $\text{P}_{\text{DGH}_{\text{D}}}$ = the proportion of survivors in good recovery or mild/severe disability at 6 months with a secondary referral

RH_{GR} , RH_{D} = the cost of rehabilitation by GOS state at 6 months (where D is both mild disability and severe disability combined)

LE_{GR} , LE_{D} = the discounted life expectancy of patients by GOS state at 6 months

ACC_{GR} , ACC_{D} = annual care cost by GOS state at 6 months
TC = cost of transport in secondary referral

For Model B the incremental cost is calculated as follows:

$$\begin{aligned} \text{Incremental cost} &= \text{Cost}_i - \text{Cost}_0 \\ &= \text{ES}_i \times ((\text{P}_{\text{GR}} \times (\text{RH}_{\text{GR}} + (\text{LE}_{\text{GR}} \times \text{ACC}_{\text{GR}}))) \\ &\quad + (\text{P}_{\text{MD}} \times (\text{RH}_{\text{MD}} + (\text{LE}_{\text{MD}} \times \text{ACC}_{\text{MD}}))) \\ &\quad + (\text{P}_{\text{SD}} \times (\text{RH}_{\text{SD}} + (\text{LE}_{\text{SD}} \times \text{ACC}_{\text{SD}}))) + (\text{P}_{\text{VS}} \\ &\quad \times (\text{RH}_{\text{VS}} + (\text{LE}_{\text{VS}} \times \text{ACC}_{\text{VS}})))) \\ &\quad - (\text{TC} \times \text{P}_{\text{DT}}) \end{aligned}$$

where

Cost_i = the expected cost per patient associated with bypass strategy i

Cost_0 = the expected cost per patient associated with secondary referral

ES_i = the proportion of patients surviving under strategy i that would not have survived under the no bypass strategy

P_{GR} , P_{MD} , P_{SD} , P_{VS} = the proportion of extra survivors in each of the GOS states at 6 months

RH_{GR} , RH_{MD} , RH_{SD} , RH_{VS} = the cost of rehabilitation by GOS states at 6 months

LE_{GR} , LE_{MD} , LE_{SD} , LE_{VS} = the discounted life expectancy of patients by GOS states at 6 months

ACC_{GR} , ACC_{MD} , ACC_{SD} , ACC_{VS} = annual care cost by GOS states at 6 months
TC = cost of transport in secondary referral

P_{DT} = proportion of patients directly transported to the NSU

11.6.4.6 Probabilistic sensitivity analysis

A probabilistic sensitivity analysis was performed to assess the robustness of the model results to plausible variations in the model parameters.

This analysis was applied exclusively to the strategy of transporting all patients to the NSU (strategy 2) compared no bypass in the conservative model B.

Probability distributions were assigned to each model parameter, where there was some measure of parameter variability (11.21). We then re-estimated the main results 5000 times,

each time each of the model parameters were set simultaneously selecting from the respective parameter distribution at random.

Table 11.21: Parameters used in the probabilistic sensitivity analysis

| Description of variable | Mean value | Probability distribution | Parameters | Source |
|---|------------|--------------------------|--|---------------|
| Percentage of patients with good recovery at 6 months | 49.6% | Dirichlet | | Patel 2002 |
| Percentage of patients with mild disability at 6 months | 27.1% | Dirichlet | 44, 24, 18,3 where each parameter refers to the number of people in each category | Patel 2002 |
| Percentage of patients with severe disability at 6 months | 20.3% | Dirichlet | | Patel 2002 |
| Percentage of patients in a vegetative state at 6 months | 3.0% | Dirichlet | | Patel 2002 |
| SMR up to 4 years post-injury (GR) | 1.5 | Lognormal | SE = 0.402 | Shavelle 2001 |
| SMR up to 4 years post-injury (MD) | 4.5 | Lognormal | SE= 0.254 | Shavelle 2001 |
| SMR up to 4 years post-injury (SD) | 16.4 | Lognormal | SE= 0.249 | Shavelle 2001 |
| SMR up to 4 years post-injury (VS) | 16.4 | Lognormal | SE= 0.249 | Shavelle 2001 |
| SMR after 4 years (GR) | 1.3 | Lognormal | SE= 0.245 | Shavelle 2001 |
| SMR after 4 years (MD) | 2.4 | Lognormal | SE= 0.178 | Shavelle 2001 |
| SMR after 4 years (SD) | 6.4 | Lognormal | SE= 0.168 | Shavelle 2001 |
| SMR after 4 years (VS) | 6.4 | Lognormal | SE= 0.168 | Shavelle 2001 |
| Utility value of GR | 0.83 | none | | Aoki1999 |
| Utility value of MD | 0.63 | Gamma of 1-U | SE= 0.27, $\alpha = 1.878$, $\beta = 0.197$ | Aoki1999 |
| Utility value of SD | 0.26 | Gamma of 1-U | SE= 0.25, $\alpha = 8.762$, $\beta = 0.084$ | Aoki1999 |
| Utility value of VS | 0.08 | Gamma of 1-U | SE= 0.16, $\alpha = 33.063$, $\beta = 0.028$ | Aoki1999 |

| | | | | |
|---|---------|-------|--|-------------------|
| Cost of rehabilitation (GR) | 19,575 | Gamma | SE= 7986, α = 6.01, β = 3258 | Nyein 1999 |
| Cost of rehabilitation (MD) | 19,575 | Gamma | SE= 7986, α = 6.01, β = 3258 | Nyein 2000 |
| Cost of rehabilitation (SD) | 108,874 | none | | Wood 1999 |
| Cost of rehabilitation (VS) | 0 | none | | |
| Annual care costs (GR) | - | none | | |
| Annual care costs (MD) | 7,472 | Gamma | SE= 12347, α = 0.37, β = 20402 | Nyein 1999 |
| Annual care costs (SD) | 45,450 | none | | Wood 1999 |
| Annual care costs (VS) | 45,450 | none | | Wood 1999 |
| Survival gain (all patients taken to the NSU if within 20minutes) | 4.50% | Gamma | SE= 0.32%, α = 198, β = 0.0002 | Stevenson's model |

11.6.4.7 Results of the cost-effectiveness analysis

According to Model A there are large QALY gains and large cost savings associated with direct transport to the NSH – direct transport is dominant (Table 11.22). With Model B – the conservative model - the QALYs gained are smaller and costs are not decreased overall (Table 11.23 and Table 11.24). However, even with this conservative model, direct transport is cost-effective (below £20,000 per QALY gained).

We chose the group of patients who were 40 years old at the time of injury to represent the results (Table 11.22, Table 11.23 and Table 11.24). In the tables we report the results for the groups of patients of 20 and 60 of age as well. In these cases, direct transport was the dominant strategy in Model A and the incremental cost-effectiveness ratio was still below the threshold of £20,000 per QALY in Model B.

After running the Model B 5,000 times, the probability that directly transporting all the patients to the NSU is cost-effective (i.e. probability that the cost-effectiveness ratio is below £20,000 per QALY gained) is 73% when the NSU near the incident scene (within 20 minutes). In the cases of a patient aged 20 or 60, the probability falls to 66%.

For Model B, we performed a sensitivity analysis on the length of stay in the ICU: assuming that the most costly level 3 of care applies to all the outcome grades, the analysis shows that the direct transport would still be cost-effective as long as the increased length of stay

does not exceed 3 days per additional survivor. Furthermore, even if the LOS were longer than this, these costs could be counteracted by additional complications in those patients who are secondarily transported to the NSH and had delayed surgery.

Table 11.22: Results - Model A.

| | Mean cost | QALYs | Incremental cost per QALY gained vs 1) |
|---------------------------|-----------|-------|--|
| <i>Base case – Age 40</i> | | | |
| 1) First to DGH | 225,109 | 9.99 | - |
| 2) Direct to NSH | 93,422 | 14.99 | NSH dominates DGH |
| <i>Age 20</i> | | | |
| 1) First to DGH | 297,236 | 13.06 | - |
| 2) Direct to NSH | 120,136 | 18.35 | NSH dominates DGH |
| <i>Age 60</i> | | | |
| 1) First to DGH | 76,069 | 3.02 | - |
| 2) Direct to NSH | 38,222 | 4.76 | NSH dominates DGH |

Table 11.23: Results - Model B – Far from NSU

| | Incremental cost | QALYs gained | Incremental cost per QALY gained |
|---|------------------|--------------|----------------------------------|
| Direct to NSH vs First to DGH (base case age 40) | 7,058 | 0.41 | 17,228 |
| Direct to NSH vs First to DGH (age 20) | 9,382 | 0.51 | 18,343 |
| Direct to NSH vs First to DGH (age 60) | 2,259 | 0.12 | 18,367 |

Table 11.24: Results - Model B - Near NSU

| | Incremental cost | QALYs gained | Incremental cost per QALY gained |
|---|------------------|--------------|----------------------------------|
| Direct to NSH vs First to DGH (base case age 40) | 9,393 | 0.54 | 17,323 |
| Direct to NSH vs First to DGH (age 20) | 12,469 | 0.68 | 18,419 |

| | | | |
|---|-------|------|--------|
| Direct to NSH vs First to DGH (age 60) | 3,041 | 0.16 | 18,683 |
|---|-------|------|--------|

Using model B, we conducted a threshold sensitivity analysis to take into account the negative effects of overestimating the number of patients to be taken to the NSH. We define the positive predictive value as the proportion of patients transported directly to the NSH who are correctly diagnosed with a severe head injury. It is the number of true positives divided by the sum of both the true positives and false positives. In the case that the NSH is far from the accident scene (53 minutes), the strategy of taking all the patients directly to the NSH is cost-effective as long as the positive predictive value is more than 28%. If the NSH is near the accident scene (20 minutes), the direct transport to the NSH is marginally cost-effective strategy even if the positive predictive value is as low as 10%.

Using model B we performed a sensitivity analysis by using an alternative set of utility scores. The result was that direct transport strategy proved to be even more cost-effective than in the original model (Table 11.25).

Table 11.25: Results of the sensitivity analysis on the utility – Model B

| | Incremental cost | QALYs gained | Incremental cost per QALY gained |
|--|-----------------------------|-------------------------|---|
| Far NSU – Direct to NSH vs First to DGH (base case age 40) | 7,058 | 0.53 | 13,369 |
| Near NSU – Direct to NSH vs First to DGH (base case age 40) | 9,393 | 0.70 | 13,442 |

11.6.4.8 Discussion

We found that direct transport is potentially cost saving if the health status of patients are substantially improved as was indicated by the Poon study. Even in our conservative model we find that direct transport is cost-effective. But our analysis is limited for a number of reasons.

First, some of our assumptions regarding cost and survival were based on proxies or were extrapolated in to the long term.

Our conservative model, Model B, was based on the mortality results of a previous simulation model. Some of the parameters in the simulation model were based on expert judgement (those listed in Table 11.26). The main clinical outcomes from which the probability of death derives were estimated by experts. In particular, experts were asked to estimate the number of patients that would have survived assuming they received the appropriate care (critical intervention or neurosurgery) at time zero. The actual time elapsed since the accident and its related probability

of death was taken from the database. Having these two points on the probability of death graph, a straight line was drawn. The authors found that the results were not sensitive to the slope of the line. However, the curve representing the real relationship between time to intervention and probability of death could have a different shape.

Table 11.26: Parameters for which the value was estimated by clinicians.

| |
|--|
| Deaths from injuries in areas excluding the head if medical intervention could be given immediately |
| Deaths from a head injury that required neurosurgery if neurosurgical intervention could be given immediately |
| Deaths from a head injury that did not require neurosurgery if medical intervention could be given immediately |
| Reduction in transfer deterioration due to staff expertise |
| Delays administering intubation and delay before making a neurosurgical decision (according to the level of staff expertise) |
| Increased mortality risk due to a secondary referral |
| Extra risk of mortality if the patient suffers hypotension or full hypoxia |

For simplicity, neither model considers the change in health status during the patient's lifetime - they assume that the GOS score (assessed six months after the head injury) remains constant. If instead patients continue to improve after 6 months then our conservative model is underestimating the health gain and cost-effectiveness associated with direct transport. Likewise, our assumption that mortality is increased compared with the general population for survivors over their entire lifetime is a conservative one.

We have probably underestimated the cost savings attributable to direct transport because we included only hospital personnel (one anaesthetist and a nurse), omitting for the costs of drugs, equipment and ambulance. However, we have also omitted additional acute costs associated with direct transport in the treatment of complications such as hypoxia and hypotension, which are less likely if the patient has been stabilised earlier. This would require additional treatments such as volume replacement, blood transfusion, and in some extreme cases they would require surgery or ventilatory support for weeks.

A strategy of direct transport from the injury scene to an NSH will inevitably mean that the unit sees more patients than previously, even though many patients currently being taken to the nearest emergency department are subsequently transferred to the NSH. From the viewpoint of the NSH there will be a substantial cost impact in particular in terms of ITU beds.

In the long-term, this should not represent an increase in cost to the NHS since patients and their treatment costs are merely being shifted from one hospital to another. Furthermore we have no reason to believe that ITU costs are higher at the NSH; indeed according to the 2006 Reference Costs¹⁷⁷, the cost of a bed in a neurosurgical ITU is lower than the cost of a bed in a general ITU. Hence we did not include ITU costs in our base case analysis.

In the short-term, the resource impact is less clear and will depend on local circumstances. A DGH might not achieve the full cost savings from seeing fewer patients as typically it would be losing only 1/4 of an ITU bed. However, staff costs and consumables would be re-deployed almost immediately. The bed could also be re-deployed if there is currently under-capacity. If so more patients would be treated in ITU as a result of the increased capacity at DGHs but this would not necessarily produce a reduction in costs to the Trust. However, this increase in ITU capacity could lead to cost savings from reduced transfers.

To implement a direct transport strategy, NSH units will need to invest in extra ITU beds. This will be offset by cost savings at DGHs. However the cost savings will not necessarily offset the cost fully in the short-term. The implementation costs associated with shifting patients will have to be taken in to account in any cost impact analysis conducted for the purposes of implementation.

A US study²⁰⁶ reports a successful rate of GCS assessment (410/412 patients)

by ambulance crews at the incident site, after an 8-hour training course. Hence, training for ambulance staff in the assessment of head injury patients would be necessary to safeguard the effectiveness and cost-effectiveness of the direct transport strategy.

Since we do not have survival outcomes for the other simulation model based in London (see 11.6.2) we could not use it to estimate cost-effectiveness. However, there is no reason to believe that it would effect our conclusions for near hospitals: if the specialist hospital is ≤ 20 minutes from the injury scene then direct transport is likely to be cost-effective. For distances greater than 20 minutes, the authors of the London model have erred on the side of caution by not recommending bypass. It seems logical that the further away is the specialist hospital the more risky is direct transport. Given the uncertainty of the evidence in this area, if we are to recommend direct transport at all then it probably is better to use some kind of cut-off but it is unclear how the authors of the London model made this decision since analyses based on transport times longer than 20 minutes are not present in the report.

The London model assumed that not just neurosciences but also other specialist services were available at the specialist centres. If specialist centres contain the whole range of services then the issue of whether ambulance crews can diagnose isolated head injury becomes less of an issue (this problem had been raised by several stakeholders), as long as specialist hospitals have adequate

provision of beds, etc. Perhaps we should be recommending that bypass strategies are developed at a regional level to take into account local service configurations.

11.6.4.9 Direct transport model: Conclusions

- A simulation model and some empirical studies have shown reduced mortality associated with directly transporting patients with serious head injury to an NSH.
- If ambulance crews can assess patients accurately then a policy of direct transport to an NSH is likely to produce a net cost saving to emergency department services (because of the resources involved with stabilising and transferring patients).
- Long term care costs might increase or decrease depending on the extent that health status (quality of life) is improved by direct transport.
- We found that even with conservative estimates about long term care costs, direct transport is likely to be cost-effective in spite of the very high costs of caring for patients with severe disability.
- If ambulance crews (unintentionally) overestimate the number of patients to be treated in the Neurosciences Centre, some patients will experience journeys that are longer than necessary and may incur complications— in which case health gain might be decreased and costs increased for these patients.

Nevertheless, a sensitivity analysis showed that the number of overestimated patients would have to be quite high for the direct transport strategy to be no longer cost-effective.

Bibliography

1. Guyatt GH, Rennie D. Users' guides to the medical literature: a manual for evidence-based clinical practice. Chicago: American Medical Association, 2002.
2. Department of Health. (2001) Hospital episode statistics 2000-2001. London: Department of Health.
3. Department of Health. (2001) Hospital episode statistics 1999-2000. London: Department of Health.
4. Jennett B. Epidemiology of head injury. *Archives of Disease in Childhood* 1998, **78**(5):403-6.
5. Kay A, Teasdale G. Head injury in the United Kingdom. *World Journal of Surgery* 2001, **25**(9):1210-20.
6. Society of British Neurological Surgeons. (1999) Safe Neurosurgery 2000. London: Society of British Neurological Surgeons.
7. Swann IJ, MacMillan R, Strong I. Head injuries at an inner city accident and emergency department. *Injury* 1981, **12**(4):274-8.
8. Johnstone AJ, Zuberi SH, Scobie WG. Skull fractures in children: a population study. *Journal of Accident and Emergency Medicine* 1996, **13**(6):386-9.
9. Swann IJ, Teasdale GM. Current concepts in the management of patients with so-called 'minor' or 'mild' head injury. *Trauma* 1999, **1**(2):143-55.
10. Briggs M, Clarke P, Crockard A, Cummins B, Galbraith S, Garfield J *et al.* Guidelines for initial management after head injury in adults. Suggestions from a group of neurosurgeons. *BMJ* 1984, **288**(6422):983-5.
11. Bartlett J, Kett-White R, Mendelow AD, Miller JD, Pickard J, Teasdale G. Guidelines for the initial management of head injuries. Recommendations from the Society of British Neurological Surgeons. *British Journal of Neurosurgery* 1998, **12**(4):349-52.
12. Royal College of Surgeons of England. (1999) Report of the working party on the management of patients with head injuries. London: Royal College of Surgeons of England.
13. Scottish Intercollegiate Guidelines Network. (2000) Early management of patients with a head injury. Edinburgh: Scottish Intercollegiate Guidelines Network.
14. Royal College of Radiologists. (1998) Making the best use of a Department of Clinical Radiology : guidelines for doctors. London: Royal College of Radiologists.
15. Teasdale GM, Murray G, Anderson E, Mendelow AD, MacMillan R, Jennett B *et al.* Risks of acute traumatic intracranial haematoma in children and adults: implications for managing head injuries. *BMJ* 1990, **300**(6721):363-7.
16. Hassan Z, Smith M, Littlewood S, Bouamra O, Hughes D, Biggin C *et al.* Head injuries: a study evaluating the impact of the NICE head injury guidelines. *Emergency Medicine Journal: EMJ* 2005, **22**(12):845-9.
17. Miller JD, Tocher JL, Jones PA. Extradural haematoma--earlier detection, better results. *Brain Injury* 1988, **2**(2):83-6.
18. Desmond J. A multicentre study to develop a set of clinical decision rules for the management of head injury in

- children. 2001. University of Manchester.
19. Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PM. Indications for computed tomography in patients with minor head injury. *New England Journal of Medicine* 2000, **343**(2):100-5.
 20. Lloyd DA, Carty H, Patterson M, Butcher CK, Roe D. Predictive value of skull radiography for intracranial injury in children with blunt head injury. *Lancet* 1997, **349**(9055):821-4.
 21. Nee PA, Hadfield JM, Yates DW, Faragher EB. Significance of vomiting after head injury. *Journal of Neurology, Neurosurgery and Psychiatry* 1999, **66**(4):470-3.
 22. Livingston DH, Lavery RF, Passannante MR, Skurnick JH, Baker S, Fabian TC *et al.* Emergency department discharge of patients with a negative cranial computed tomography scan after minimal head injury. *Annals of Surgery* 2000, **232**(1):126-32.
 23. Hofman PA, Nelemans P, Kemerink GJ, Wilmink JT. Value of radiological diagnosis of skull fracture in the management of mild head injury: meta-analysis. *Journal of Neurology, Neurosurgery and Psychiatry* 2000, **68**(4):416-22.
 24. Richless LK, English K, Heller MB, Rachlin J, McClean P, Auble TE. A prospective evaluation of radiologic criteria for head injury patients in a community emergency department. *American Journal of Emergency Medicine* 1993, **11**(4):327-30.
 25. Stiell IG, Wells GA, Vandemheen K, Clement C, Lesiuk H, Laupacis A *et al.* The Canadian CT Head Rule for patients with minor head injury. *Lancet* 2001, **357**(9266):1391-6.
 26. de Lacey G, McCabe M, Constant O, Welch T, Spinks C, McNally E. Testing a policy for skull radiography (and admission) following mild head injury. *British Journal of Radiology* 1990, **63**(745):14-8.
 27. Gorman DF. The utility of post-traumatic skull X-rays. *Archives of Emergency Medicine* 1987, **4**(3):141-50.
 28. Thillainayagam K, MacMillan R, Mendelow AD, Brookes MT, Mowat W, Jennett B. How accurately are fractures of the skull diagnosed in an accident and emergency department. *Injury* 1987, **18**(5):319-21.
 29. Kaste SC, Young CW, Holmes TP, Baker DK. Effect of helical CT on the frequency of sedation in pediatric patients. *AJR American Journal of Roentgenology* 1997, **168**(4):1001-3.
 30. Pappas JN, Donnelly LF, Frush DP. Reduced frequency of sedation of young children with multisection helical CT. *Radiology* 2000, **215**(3):897-9.
 31. Pickthall C, White S, Eyre JA. Retrospective study of children with minor head injury in the North-East of England [In preparation]. [unpublished data] 2002.
 32. Livingston DH, Loder PA, Hunt CD. Minimal head injury: is admission necessary? *American Surgeon* 1991, **57**(1):14-7.
 33. Thornhill S, Teasdale GM, Murray GD, McEwen J, Roy CW, Penny KI. Disability in young people and adults one year after head injury: prospective cohort study. *BMJ* 2000, **320**(7250):1631-5.
 34. Haboubi NH, Long J, Koshy M, Ward AB. Short-term sequelae of minor head injury (6 years experience of minor head injury clinic). *Disability and Rehabilitation* 2001, **23**(14):635-8.
 35. Levitt MA, Sutton M, Goldman J, Mikhail M, Christopher T. Cognitive dysfunction in patients suffering minor head trauma. *American Journal of Emergency Medicine* 1994, **12**(2):172-5.
 36. Powell TJ, Collin C, Sutton K. A follow-up study of patients hospitalized after minor head injury. *Disability and Rehabilitation* 1996, **18**(5):231-7.
 37. Kaufman HH. Civilian gunshot wounds to the head. *Neurosurgery* 1993, **32**(6):962-4.

38. Kelly DF, Becker DP. Advances in management of neurosurgical trauma: USA and Canada. *World Journal of Surgery* 2001, **25**(9):1179-85.
39. National Center for Injury Prevention and Control. (1999) Traumatic brain injury in the United States : a report to Congress. Atlanta, GA: National Center for Injury Prevention and Control.
40. NIH Consensus Development Panel on rehabilitation of persons with traumatic brain injury. *JAMA* 1999, **282**(10):974-83.
41. Lecky FE, Woodford M, Bouamra O, Yates DW. Lack of change in trauma care in England and Wales since 1994. *Emerg Med J* 2002, **19**(6):520-3.
42. Crimmins DW, Palmer JD. Snapshot view of emergency neurosurgical head injury care in Great Britain and Ireland. *Journal of Neurology, Neurosurgery and Psychiatry* 2000, **68**(1):8-13.
43. Ashkan K, Edwards RJ, Bell BA. Crisis in resources: a neurosurgical prospective. *British Journal of Neurosurgery* 2001, **15**(4):342-6.
44. National Institute for Health and Clinical Excellence. (2007) The guidelines manual. London: National Institute for Health and Clinical Excellence.
45. National Institute for Health and Clinical Excellence. (2006) The guidelines manual. London: National Institute for Health and Clinical Excellence.
46. Servadei F, Teasdale G, Merry G. Defining acute mild head injury in adults: a proposal based on prognostic factors, diagnosis, and management. *Journal of Neurotrauma* 2001, **18**(7):657-64.
47. Teasdale G, Murray G, Parker L, Jennett B. Adding up the Glasgow Coma Score. *Acta Neurochirurgica Supplementum* 1979, **28**(1):13-6.
48. Hylek EM, Singer DE. Risk factors for intracranial hemorrhage in outpatients taking warfarin. *Annals of Internal Medicine* 1994, **120**(11):897-902.
49. Saab M, Gray A, Hodgkinson D, Irfan M. Warfarin and the apparent minor head injury. *Journal of Accident and Emergency Medicine* 1996, **13**(3):208-9.
50. Munro PT, Smith RD, Parke TR. Effect of patients' age on management of acute intracranial haematoma: prospective national study. *BMJ* 2002, **325**(7371):1001.
51. Arienta C, Caroli M, Balbi S. Management of head-injured patients in the emergency department: a practical protocol. *Surgical Neurology* 1997, **48**(3):213-9.
52. Stiell IG, Wells GA, Vandemheen KL, Clement CM, Lesiuk H, De Maio VJ et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA* 2001, **286**(15):1841-8.
53. Dunning J. A multicentre study to develop a set of clinical decision rules for the management of head injury in children. Incorporating the CHALICE study: children's head injury algorithm to predict important clinical events. 2006. University of Manchester.
54. Cook LS, Levitt MA, Simon B, Williams VL. Identification of ethanol-intoxicated patients with minor head trauma requiring computed tomography scans. *Academic Emergency Medicine* 1994, **1**(3):227-34.
55. Miller EC, Holmes JF, Derlet RW. Utilizing clinical factors to reduce head CT scan ordering for minor head trauma patients. *Journal of Emergency Medicine* 1997, **15**(4):453-7.
56. Jeret JS, Mandell M, Anziska B, Lipitz M, Vilceus AP, Ware JA et al. Clinical predictors of abnormality disclosed by computed tomography after mild head trauma. *Neurosurgery* 1993, **32**(1):9-15.
57. Brown FD, Brown J, Beattie TF. Why do children vomit after minor head injury? *Journal of Accident and*

- Emergency Medicine* 2000, **17**(4):268-71.
58. Pointer JE, Levitt MA, Young JC, Promes SB, Messana BJ, Ader ME. Can paramedics using guidelines accurately triage patients? *Annals of Emergency Medicine* 2001, **38**(3):268-77.
 59. Warren A. Paediatric coma scoring researched and benchmarked. *Paediatr Nurs* 2000, **12**(3):14-8.
 60. Tatman A, Warren A, Williams A, Powell JE, Whitehouse W. Development of a modified paediatric coma scale in intensive care clinical practice. *Arch Dis Child* 1997, **77**(6):519-21.
 61. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. *Lancet* 1974, **2**(7872):81-4.
 62. James HETDA. The Glasgow Coma Scale. In: James HE et al, ed. *Brain Injuries in Infants and Children*, 2007. Orlando, Florida: Grune and Statton.
 63. Ng SM, Toh EM, Sherrington CA. Clinical predictors of abnormal computed tomography scans in paediatric head injury. *Journal of Paediatrics and Child Health* 2002, **38**(4):388-92.
 64. Brain Trauma Foundation, American Association of Neurological Surgeons. Guidelines for the management of severe traumatic brain injury. In: *Management and prognosis of severe traumatic brain injury*, Pt 1, 2000. New York: Brain Trauma Foundation.
 65. Garner AA, Schoettker P. Efficacy of pre-hospital interventions for the management of severe blunt head injury. *Injury* 2002, **33**(4):329-37.
 66. Hannan EL, Farrell LS, Cooper A, Henry M, Simon B, Simon R. Physiologic trauma triage criteria in adult trauma patients: are they effective in saving lives by transporting patients to trauma centers? *Journal of the American College of Surgeons* 2005, **200**(4):584-92.
 67. DiRusso SM, Sullivan T, Risucci D, Nealon P, Slim M. Intubation of pediatric trauma patients in the field: predictor of negative outcome despite risk stratification. *Journal of Trauma* 2005, **59**(1):84-90.
 68. Stevenson MD, Oakley PA, Beard SM, Brennan A, Cook AL. Triage patients with serious head injury: results of a simulation evaluating strategies to bypass hospitals without neurosurgical facilities. *Injury* 2001, **32**(4):267-74.
 69. Sethi D, Kwan I, Kelly AM, Roberts I, Bunn F, (on behalf of the WHO Pre-Hospital Trauma Care Steering Committee). Advanced trauma life support training for ambulance crews (Cochrane Review). *The Cochrane Library*, Issue 4 2002.
 70. Wilson S, Cooke M, Morrell R, Bridge P, Allan T, Emergency Medicine Research Group (EMeRG). A systematic review of the evidence supporting the use of priority dispatch of emergency ambulances. *Prehospital Emergency Care* 2002, **6**(1):42-9.
 71. O'Cathain A, Turner J, Nicholl JP. The acceptability of an emergency medical dispatch system to people who call 999 to request an ambulance. *Emergency Medicine Journal: EMJ* 2002, **19**(2):160-3.
 72. Bricolo AP, Pasut LM. Extradural hematoma: toward zero mortality. A prospective study. *Neurosurgery* 1984, **14**(1):8-12.
 73. Duus BR, Lind B, Christensen H, Nielsen OA. The role of neuroimaging in the initial management of patients with minor head injury. *Annals of Emergency Medicine* 1994, **23**(6):1279-83.
 74. Stein SC, Ross SE. Mild head injury: a plea for routine early CT scanning. *Journal of Trauma* 1992, **33**(1):11-3.
 75. Halley MK, Silva PD, Foley J, Rodarte A. Loss of consciousness: when to perform computed tomography? *Pediatric Critical Care Medicine* 2004, **5**(3):230-3.
 76. Stein SC, Burnett MG, Glick HA. Indications for CT scanning in mild traumatic brain injury: A cost-

- effectiveness study. *Journal of Trauma* 2006, **61**(3):558-66.
77. Kelly AB, Zimmerman RD, Snow RB, Gandy SE, Heier LA, Deck MD. Head trauma: comparison of MR and CT--experience in 100 patients. *AJNR American Journal of Neuroradiology* 1988, **9**(4):699-708.
 78. af Geijerstam JL, Oredsson S, Britton M. Medical outcome after immediate computed tomography or admission for observation in patients with mild head injury: randomised controlled trial. *BMJ* 2006, **333**(7566):465.
 79. Norlund A, Marke LA, af Geijerstam JL, Oredsson S, Britton M. Immediate computed tomography or admission for observation after mild head injury: cost comparison in randomised controlled trial. *BMJ* 2006, **333**(7566):469.
 80. Stiell IG, Wells GA. Methodologic standards for the development of clinical decision rules in emergency medicine. *Annals of Emergency Medicine* 1999, **33**(4):437-47.
 81. Stiell IG, Clement CM, Rowe BH, Schull MJ, Brison R, Cass D *et al.* Comparison of the Canadian CT Head Rule and the New Orleans Criteria in patients with minor head injury.[see comment]. *JAMA* 2005, **294**(12):1511-8.
 82. Holmes JF, Baier ME, Derlet RW. Failure of the Miller criteria to predict significant intracranial injury in patients with a Glasgow Coma Scale score of 14 after minor head trauma. *Academic Emergency Medicine* 1997, **4**(8):788-92.
 83. Mower WR, Hoffman JR, Herbert M, Wolfson AB, Pollack CV, Jr., Zucker MI. Developing a decision instrument to guide computed tomographic imaging of blunt head injury patients. *Journal of Trauma* 2005, **59**(4):954-9.
 84. Smits M, Dippel DW, de Haan GG, Dekker HM, Vos PE, Kool DR *et al.* External validation of the Canadian CT Head Rule and the New Orleans Criteria for CT scanning in patients with minor head injury. *JAMA* 2005, **294**(12):1519-25.
 85. Oman JA, Cooper RJ, Holmes JF, Viccellio P, Nyce A, Ross SE *et al.* Performance of a decision rule to predict need for computed tomography among children with blunt head trauma. *Pediatrics* 2006, **117**(2):e238-e246.
 86. Haydel MJ, Shembekar AD. Prediction of intracranial injury in children aged five years and older with loss of consciousness after minor head injury due to nontrivial mechanisms. *Annals of Emergency Medicine* 2003, **42**(4):507-14.
 87. Palchak MJ, Holmes JF, Vance CW, Gelber RE, Schauer BA, Harrison MJ *et al.* A decision rule for identifying children at low risk for brain injuries after blunt head trauma. *Ann Emerg Med* 2003, **42**(4):492-506.
 88. Shravat BP, Huseyin TS, Hynes KA. NICE guideline for the management of head injury: an audit demonstrating its impact on a district general hospital, with a cost analysis for England and Wales. *Emergency Medicine Journal: EMJ* 2006, **23**(2):109-13.
 89. Mower WR, Hoffman JR, Herbert M, Wolfson AB, Pollack CV, Jr., Zucker MI. Developing a clinical decision instrument to rule out intracranial injuries in patients with minor head trauma: methodology of the NEXUS II investigation. *Annals of Emergency Medicine* 2002, **40**(5):505-14.
 90. Greenes DS, Schutzman SA. Clinical significance of scalp abnormalities in asymptomatic head-injured infants. *Pediatric Emergency Care* 2001, **17**(2):88-92.
 91. Greenes DS, Schutzman SA. Clinical indicators of intracranial injury in head-injured infants. *Pediatrics* 1999, **104**(4 Pt 1):861-7.
 92. Wang MY, Griffith P, Sterling J, McComb JG, Levy ML. A prospective population-based study of pediatric trauma patients with mild alterations in consciousness (Glasgow Coma Scale score of 13-14). *Neurosurgery* 2000, **46**(5):1093-9.
 93. Viccellio P, Simon H, Pressman BD, Shah MN, Mower WR, Hoffman JR. A prospective multicenter study of

- cervical spine injury in children. *Pediatrics* 2001, **108**(2):E20.
94. Ajani AE, Cooper DJ, Scheinkestel CD, Laidlaw J, Tuxen DV. Optimal assessment of cervical spine trauma in critically ill patients: a prospective evaluation. *Anaesthesia and Intensive Care* 1998, **26**(5):487-91.
 95. Berne JD, Velmahos GC, El Tawil Q, Demetriades D, Asensio JA, Murray JA *et al.* Value of complete cervical helical computed tomographic scanning in identifying cervical spine injury in the unevaluable blunt trauma patient with multiple injuries: a prospective study. *Journal of Trauma* 1999, **47**(5):896-902.
 96. McDonald TW, Franzen MD. A validity study of the WAIT in closed head injury. *Brain Injury* 1999, **13**(5):331-46.
 97. Hadley M. Radiographic assessment of the cervical spine in symptomatic trauma patients. *Neurosurgery* 2002, **50**(Suppl):S36-S43.
 98. Streitwieser DR, Knopp R, Wales LR, Williams JL, Tonnemacher K. Accuracy of standard radiographic views in detecting cervical spine fractures. *Annals of Emergency Medicine* 1983, **12**(9):538-42.
 99. Blackmore CC, Deyo RA. Specificity of cervical spine radiography: Importance of clinical scenario. *Emergency Radiology* 1997, **4**(5):283-6.
 100. Freemyer B, Knopp R, Piche J, Wales L, Williams J. Comparison of five-view and three-view cervical spine series in the evaluation of patients with cervical trauma. *Annals of Emergency Medicine* 1989, **18**(8):818-21.
 101. Cohn SM, Lyle WG, Linden CH, Lancey RA. Exclusion of cervical spine injury: a prospective study. *Journal of Trauma* 1991, **31**(4):570-4.
 102. Lewis LM, Docherty M, Ruoff BE, Fortney JP, Keltner RA, Jr., Britton P. Flexion-extension views in the evaluation of cervical-spine injuries. *Annals of Emergency Medicine* 1991, **20**(2):117-21.
 103. Juhl JH, Miller SM, Roberts GW. Roentgenographic variations in the normal cervical spine. *Radiology* 1962, **78**:591-7.
 104. Benzel EC, Hart BL, Ball PA, Baldwin NG, Orrison WW, Espinosa MC. Magnetic resonance imaging for the evaluation of patients with occult cervical spine injury. *Journal of Neurosurgery* 1996, **85**(5):824-9.
 105. Klein GR, Vaccaro AR, Albert TJ, Schweitzer M, Deely D, Karasick D *et al.* Efficacy of magnetic resonance imaging in the evaluation of posterior cervical spine fractures. *Spine* 1999, **24**(8):771-4.
 106. Emery SE, Pathria MN, Wilber RG, Masaryk T, Bohlman HH. Magnetic resonance imaging of posttraumatic spinal ligament injury. *Journal of Spinal Disorders* 1989, **2**(4):229-33.
 107. Willis BK, Greiner F, Orrison WW, Benzel EC. The incidence of vertebral artery injury after midcervical spine fracture or subluxation. *Neurosurgery* 1994, **34**(3):435-41.
 108. Holmes JF, Akkinepalli R. Computed tomography versus plain radiography to screen for cervical spine injury: a meta-analysis. *Journal of Trauma* 2005, **58**(5):902-5.
 109. Nygren de Boussard C, Lundin A, Karlstedt D, Edman G, Bartfai A, Borg J. S100 and cognitive impairment after mild traumatic brain injury. *Journal of Rehabilitation Medicine* 2005, **37**(1):53-7.
 110. Brohi K, Healy M, Fotheringham T, Chan O, Aylwin C, Whitley S *et al.* Helical computed tomographic scanning for the evaluation of the cervical spine in the unconscious, intubated trauma patient. *Journal of Trauma* 2005, **58**(5):897-901.
 111. Bach CM, Steingruber IE, Peer S, Peer-Ku[spacing diaeresis]hberger, Jaschke W, Ogon M. Radiographic evaluation of cervical spine trauma. Plain radiography and conventional tomography versus computed tomography. *Archives of Orthopaedic and Trauma Surgery* 2001, **121**(7):385-7.

112. Diaz JJ, Jr., Gillman C, Morris JA, Jr., May AK, Carrillo YM, Guy J. Are five-view plain films of the cervical spine unreliable? A prospective evaluation in blunt trauma patients with altered mental status. *Journal of Trauma* 2003, **55**(4):658-63.
113. Griffen MM, Frykberg ER, Kerwin AJ, Schinco MA, Tepas JJ, Rowe K *et al.* Radiographic clearance of blunt cervical spine injury: plain radiograph or computed tomography scan? *Journal of Trauma* 2003, **55**(2):222-6.
114. Nunez DB, Jr., Zuluaga A, Fuentes-Bernardo DA, Rivas LA, Becerra JL. Cervical spine trauma: how much more do we learn by routinely using helical CT? *Radiographics* 1996, **16**(6):1307-18.
115. Schenarts PJ, Diaz J, Kaiser C, Carrillo Y, Eddy V, Morris JA, Jr. Prospective comparison of admission computed tomographic scan and plain films of the upper cervical spine in trauma patients with altered mental status. *Journal of Trauma* 2001, **51**(4):663-8.
116. Widder S, Doig C, Burrowes P, Larsen G, Hurlbert RJ, Kortbeek JB. Prospective evaluation of computed tomographic scanning for the spinal clearance of obtunded trauma patients: preliminary results. *Journal of Trauma* 2004, **56**(6):1179-84.
117. Adelgais KM, Grossman DC, Langer SG, Mann FA. Use of helical computed tomography for imaging the pediatric cervical spine. *Academic Emergency Medicine* 2004, **11**(3):228-36.
118. Antevil JL, Sise MJ, Sack DI, Kidder B, Hopper A, Brown CV. Spiral computed tomography for the initial evaluation of spine trauma: A new standard of care? *Journal of Trauma* 2006, **61**(2):382-7.
119. McCulloch PT, France J, Jones DL, Krantz W, Nguyen TP, Chambers C *et al.* Helical computed tomography alone compared with plain radiographs with adjunct computed tomography to evaluate the cervical spine after high-energy trauma. *Journal of Bone and Joint Surgery American Volume* 2005, **87**(11):2388-94.
120. Grogan EL, Morris JA, Jr., Dittus RS, Moore DE, Poulouse BK, Diaz JJ *et al.* Cervical spine evaluation in urban trauma centers: lowering institutional costs and complications through helical CT scan. *Journal of the American College of Surgeons* 2005, **200**(2):160-5.
121. Blackmore CC, Ramsey SD, Mann FA, Deyo RA. Cervical spine screening with CT in trauma patients: a cost-effectiveness analysis (Structured abstract). *Radiology* 1999, **212**(1):117-25.
122. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker ML. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *New England Journal of Medicine* 2000, **343**(2):94-9.
123. Stiell IG, Clement CM, McKnight RD, Brison R, Schull MJ, Rowe BH *et al.* The Canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. *New England Journal of Medicine* 2003, **349**(26):2510-8.
124. Bandiera G, Stiell IG, Wells GA, Clement C, De M, V, Vandemheen KL *et al.* The Canadian C-spine rule performs better than unstructured physician judgment. *Annals of Emergency Medicine* 2003, **42**(3):395-402.
125. Dietrich AM, Bowman MJ, Ginn-Pease ME, Kosnik E, King DR. Pediatric head injuries: can clinical factors reliably predict an abnormality on computed tomography? *Annals of Emergency Medicine* 1993, **22**(10):1535-40.
126. Hahn YS, McLone DG. Risk factors in the outcome of children with minor head injury. *Pediatric Neurosurgery* 1993, **19**(3):135-42.
127. Wells RG, Vetter C, Laud P.G. Intracranial hemorrhage in children younger than 3 years: prediction of intent. *Archives of Pediatrics and Adolescent Medicine* 2002, **156**(3):252-7.
128. Gentleman D, Jennett B. Audit of transfer of unconscious head-injured

- patients to a neurosurgical unit. *Lancet* 1990, **335**(8685):330-4.
129. Neuroanaesthesia Society of Great Britain and Ireland, Association of Anaesthetists of Great Britain and Ireland. (1996) Recommendations for the transfer of patients with acute head injuries to neurosurgical units. London: Association of Anaesthetists of Great Britain and Ireland.
 130. Coles JP, Minhas PS, Fryer TD, Smielewski P, Aigbirihio F, Donovan T *et al.* Effect of hyperventilation on cerebral blood flow in traumatic head injury: clinical relevance and monitoring correlates. *Crit Care Med* 2002, **30**(9):1950-9.
 131. Diring MN, Yundt K, Videen TO, Adams RE, Zazulia AR, Deibert E *et al.* No reduction in cerebral metabolism as a result of early moderate hyperventilation following severe traumatic brain injury. *J Neurosurg* 2000, **92**(1):7-13.
 132. Diring MN, Videen TO, Yundt K, Zazulia AR, Aiyagari V, Dacey RG, Jr. *et al.* Regional cerebrovascular and metabolic effects of hyperventilation after severe traumatic brain injury. *J Neurosurg* 2002, **96**(1):103-8.
 133. Neuroanaesthesia Society of Great Britain and Ireland, Association of Anaesthetists of Great Britain and Ireland. (2006) Recommendations for the safe transfer of patients with brain injury. London: Association of Anaesthetists of Great Britain and Ireland.
 134. Patel HC, Bouamra O, Woodford M, King AT, Yates DW, Lecky FE. Trends in head injury outcome from 1989 to 2003 and the effect of neurosurgical care: an observational study. *Lancet* 2005, **366**(9496):1538-44.
 135. Poon WS, Li AK. Comparison of management outcome of primary and secondary referred patients with traumatic extradural haematoma in a neurosurgical unit. *Injury* 1991, **22**(4):323-5.
 136. Härtl R, Gerber LM, Iacono L, Ni Q, Lyons K, Ghajar J. Direct transport within an organized state trauma system reduces mortality in patients with severe traumatic brain injury. *Journal of Trauma* 2006, **60**(6):1250-6.
 137. Department of Health. (2001) High-Dependency Care for Children - Report of an Expert Advisory Group For the Department of Health. London: Department of Health.
 138. Department of Health. (2000) Domestic Violence: A resource Manual for Health Care Professionals. London: Department of Health.
 139. Bazarian JJ, Atabaki S. Predicting postconcussion syndrome after minor traumatic brain injury. *Academic Emergency Medicine* 2001, **8**(8):788-95.
 140. Mittenberg W, Wittner MS, Miller LJ. Postconcussion syndrome occurs in children. *Neuropsychology* 1997, **11**(3):447-52.
 141. Rimel RW, Giordani B, Barth JT, Boll TJ, Jane JA. Disability caused by minor head injury. *Neurosurgery* 1981, **9**(3):221-8.
 142. Berg J. Economic evidence in trauma: A review. *European Journal of Health Economics* 2004, **5**(SUPPL. 1):S84-S91.
 143. Worthington AD, Matthews S, Melia Y, Oddy M. Cost-benefits associated with social outcome from neurobehavioural rehabilitation. *Brain Injury* 2006, **20**(9):947-57.
 144. Hashimoto K, Nakamura T, Wada I, Yoshida K, Satoh S, Abo M *et al.* How great is willingness to pay for recovery from sequelae after severe traumatic brain injury in Japan? *Journal of Rehabilitation Medicine* 2006, **38**(2):141-3.
 145. Aronow H. Rehabilitation effectiveness with severe brain injury: translating research into policy. *Journal of Head Trauma Rehabilitation* 1987, **2**:24-36.
 146. Cope N, Hall K. Head injury rehabilitation: benefits of early intervention. *Archives of Physical*

- Medicine and Rehabilitation* 1982, **63**:433-7.
147. Wood RL, McCrea JD, Wood LM, Merrimen RN. Clinical and cost effectiveness of post-acute neurobehavioural rehabilitation. *Brain Injury* 1999, **13**(2):69-88.
 148. Ponsford J, Harrington H, Olver J, Roper M. Evaluation of a community-based model of rehabilitation following traumatic brain injury (Provisional record). *Neuropsychological Rehabilitation* 2006, **16**(3):315-28.
 149. Ashley MJ, Schultz JD, Bryan VL, Krych DK, Hayes DR. Justification of post-traumatic brain injury rehabilitation using net present value techniques: a case study. *Journal of Rehabilitation Outcomes Measurement* 1997, **1**(5):33-41.
 150. Salazar AM, Warden DL, Schwab K, Spector J, Braverman S, Walter J *et al.* Cognitive rehabilitation for traumatic brain injury: A randomized trial. Defense and Veterans Head Injury Program (DVHIP) Study Group. *JAMA* 2000, **283**(23):3075-81.
 151. Turner-Stokes L, Wade D. Rehabilitation following acquired brain injury: Concise guidance. *Clinical Medicine* 2004, **4**(1):61-5.
 152. Wehman P, Targett P, West M, Kregel J. Productive work and employment for persons with traumatic brain injury: What have we learned after 20 years? *Journal of Head Trauma Rehabilitation* 2005, **20**(2):115-27.
 153. Turner-Stokes L. The evidence for the cost-effectiveness of rehabilitation following acquired brain injury. *Clinical Medicine* 2004, **4**(1):10-2.
 154. Brain Trauma Foundation, American Association of Neurological Surgeons. Early Indicators of prognosis in severe traumatic brain injury. In: *Management and prognosis of severe traumatic brain injury*, Pt 2, 2000. New York: Brain Trauma Foundation.
 155. Royal College of Physicians, British Society of Rehabilitation Medicine. (2003) Rehabilitation following acquired brain injury: national clinical guidelines. London: Royal College of Physicians.
 156. Voss M, Knottenbelt JD, Peden MM. Patients who reattend after head injury: a high risk group. *BMJ* 1995, **311**(7017):1395-8.
 157. Hadden DS, Dearden CH, Rocke LG. Short stay observation patients: general wards are inappropriate. *Journal of Accident and Emergency Medicine* 1996, **13**(3):163-5.
 158. Knuckey NW, Gelbard S, Epstein MH. The management of "asymptomatic" epidural hematomas. A prospective study. *Journal of Neurosurgery* 1989, **70**(3):392-6.
 159. Shrimpton PC, Edyvean S. CT scanner dosimetry. *British Journal of Radiology* 1998, **71**(841):1-3.
 160. Hart D, Wall BF. UK population dose from medical X-ray examinations. *Eur J Radiol* 2004, **50**(3):285-91.
 161. Shrimpton PC, Jones DG, Hillier MC, Wall BF, Le Heron JC, Faulkner K. (1991) Survey of CT practice in the UK: Part 2: dosimetric aspects. Chilton: National Radiological Protection Board.
 162. Shrimpton PC. (2005) Computer Tomography (CT) Examinations in the UK - 2003 Review. Chilton: National Radiological Protection Board.
 163. Chan CY, Wong YC, Chau LF, Yu SK, Lau PC. Radiation dose reduction in paediatric cranial CT. *Pediatric Radiology* 1999, **29**(10):770-5.
 164. Golding SJ, Shrimpton PC. Commentary. Radiation dose in CT: are we meeting the challenge? *British Journal of Radiology* 2002, **75**(889):1-4.
 165. International Commission on Radiological Protection. Managing patient dose in computed tomography. *Annals of the ICRP* 2000, **30**(4):7-45.
 166. Hart D, Wall BF. (2002) Radiation exposure of the UK population from

- medical and dental x-ray examinations. Didcot: National Radiological Protection Board.
167. Khursheed A, Hillier MC, Shrimpton PC, Wall BF. Influence of patient age on normalized effective doses calculated for CT examinations. *Br J Radiol* 2002, **75**(898):819-30.
 168. Wall BF, Kendall GM, Edwards AA, Bouffler S, Muirhead CR, Meara JR. What are the risks from medical X-rays and other low dose radiation? *Br J Radiol* 2006, **79**(940):285-94.
 169. International Commission on Radiological Protection. (1991) Recommendations of the International Commission on Radiological Protection.
 170. National Radiological Protection Board. (1993) Guidance on the 1990 Recommendations of ICRP. Chilton: National Radiological Protection Board.
 171. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimates of the cancer risks from pediatric CT radiation are not merely theoretical: comment on "point/counterpoint: in x-ray computed tomography, technique factors should be selected appropriate to patient size. against the proposition". *Medical Physics* 2001, **28**(11):2387-8.
 172. Committee on Clinical Practice Guidelines IoM. (1992) Guidelines for clinical practice. from development to use. Washington DC: National Academy Press.
 173. Drummond MF, O'Brien B, Stoddart GL, Torrance GW. Methods for the economic evaluation of health care programmes. Oxford: Oxford Medical Publications, 1997.
 174. National Institute for Clinical Excellence. (2001) Guidance for manufacturers and sponsors. London: National Institute for Clinical Excellence.
 175. Weinstein MC, Siegel JE, Gold MR, Kamlet MS, Russell LB. Recommendations of the Panel on Cost-effectiveness in Health and Medicine. *JAMA* 1996, **276**(15):1253-8.
 176. Nee PA, Hadfield JM, Yates DW. Biomechanical factors in patient selection for radiography after head injury. *Injury* 1993, **24**(7):471-5.
 177. Department of Health. (2006) NHS Reference Costs 2005-2006. London: Department of Health.
 178. Mendelow AD, Campbell DA, Jeffrey RR, Miller JD, Hessel C, Bryden J *et al.* Admission after mild head injury: benefits and costs. *BMJ* 1982, **285**(6354):1530-2.
 179. Royal College of Radiologists Working Party on the Effective Use of Diagnostic Technology. Costs and benefits of skull radiography for head injury. A national study by the Royal College of Radiologists. *Lancet* 1981, **2**(8250):791-5.
 180. Royal College of Radiologists Working Party on the Effective Use of Diagnostic Technology. Patient selection for skull radiography in uncomplicated head injury. *Lancet* 1983, **1**(8316):115-8.
 181. Ingebrigtsen T, Romner B. Routine early CT-scan is cost saving after minor head injury. *Acta Neurologica Scandinavica* 1996, **93**(2-3):207-10.
 182. Shackford SR, Wald SL, Ross SE, Cogbill TH, Hoyt DB, Morris JA *et al.* The clinical utility of computed tomographic scanning and neurologic examination in the management of patients with minor head injuries. *Journal of Trauma* 1992, **33**(3):385-94.
 183. Stein SC, O'Malley KF, Ross SE. Is routine computed tomography scanning too expensive for mild head injury? *Annals of Emergency Medicine* 1991, **20**(12):1286-9.
 184. Riche H, Jourdan C, Chiara Y, Guichard P, Grau A, Deschamps J *et al.* Has the development of x-ray computed tomography modified morbidity and mortality of extradural

- hematoma? 559 cases (1972-1986). *Agressologie* 1988, **29**(4):255-60.
185. Mendelow AD, Karim MZ, Paul KS, Fuller GA, Gillingham FJ. Extradural haematoma: effect of delayed treatment. *BMJ* 1979, **1**(6173):1240-2.
 186. Seelig JM, Becker DP, Miller JD, Greenberg RP, Ward JD, Choi SC. Traumatic acute subdural hematoma: major mortality reduction in comatose patients treated within four hours. *New England Journal of Medicine* 1981, **304**(25):1511-8.
 187. Bramley R, Whitehouse RW, Taylor PM. The Canadian CT Head Rule for patients with minor head injury: consequences for radiology departments in the U.K. *Clinical Radiology* 2002, **57**(2):151-2.
 188. de Geijerstam JL, Britton M, Marke LA. Mild head injury: observation or computed tomography? Economic aspects by literature review and decision analysis. *Emergency Medicine Journal: EMJ* 2004, **21**(1):54-8.
 189. Fiser SM, Johnson SB, Fortune JB. Resource utilization in traumatic brain injury: the role of magnetic resonance imaging. *American Surgeon* 1998, **64**(11):1088-93.
 190. Kaneriyappa PP, Schweitzer ME, Spettell C, Cohen MJ, Karasick D. The cost-effectiveness of oblique radiography in the exclusion of C7-T1 injury in trauma patients. *AJR American Journal of Roentgenology* 1998, **171**(4):959-62.
 191. Tan E, Schweitzer ME, Vaccaro L, Spetell AC. Is computed tomography of nonvisualized C7-T1 cost-effective? *Journal of Spinal Disorders* 1999, **12**(6):472-6.
 192. Banit DM, Grau G, Fisher JR. Evaluation of the acute cervical spine: a management algorithm. *Journal of Trauma* 2000, **49**(3):450-6.
 193. Frank JB, Lim CK, Flynn JM, Dormans JP. The efficacy of magnetic resonance imaging in pediatric cervical spine clearance. *Spine* 2002, **27**(11):1176-9.
 194. Board of the Faculty of Clinical Radiology TRCoR. (2002) Clinical radiology: a workforce in crisis. London: Royal College of Radiologists.
 195. Bylund PO, Bjornstig U. Sick leave and disability pension among passenger car occupants injured in urban traffic. *Spine* 1998, **23**(9):1023-8.
 196. London Severe Injury Working Group. Modernising trauma services in London: report and recommendations. [unpublished data] 2001.
 197. Patel HC, Menon DK, Tebbs S, Hawker R, Hutchinson PJ, Kirkpatrick PJ. Specialist neurocritical care and outcome from head injury. *Intensive Care Med* 2002, **28**(5):547-53.
 198. Shavelle RM, Strauss DJ, Day SM, Ojdana KA. Life expectancy. In: Zasler ND, Katz DI, Zafonte RD, eds. *Brain injury medicine: principles and practice*, 17, 2007. pp 247-61. New York, New York: Demos Medical Publishing.
 199. Strauss DJ, Shavelle RM, Ashwal S. Life expectancy and median survival time in the permanent vegetative state. *Pediatric Neurology* 1999, **21**(3):626-31.
 200. Shavelle RM, Strauss D, Whyte J, Day SM, Yu YL. Long-term causes of death after traumatic brain injury. *American Journal of Physical Medicine and Rehabilitation* 2001, **80**(7):510-6.
 201. Kind P, Dolan P, Gudex C, Williams A. Variations in population health status: results from a United Kingdom national questionnaire survey. *BMJ* 1998, **316**(7133):736-41.
 202. Aoki N, Kitahara T, Fukui T, Beck JR, Soma K, Yamamoto W *et al.* Management of unruptured intracranial aneurysm in Japan: a Markovian decision analysis with utility measurements based on the Glasgow Outcome Scale. *Medical Decision Making* 1998, **18**(4):357-64.
 203. Tsao JY, Hwang JS, Chiu WT, Hung CC, Wang JD. Estimation of expected utility gained from the helmet law in Taiwan by quality-adjusted survival

- time. *Accident Analysis and Prevention* 1999, **31**(3):253-63.
204. Curtis L, Netten A. (2006) Unit Costs of Health and Social Care 2006. Canterbury: Personal Social Services Research Unit (PSSRU).
 205. Nyein K, Turner-Stokes L, Robinson I. The Northwick Park Care Needs Assessment (NPCNA): a measure of community care needs: sensitivity to change during rehabilitation. *Clinical Rehabilitation* 1999, **13**(6):482-91.
 206. Davis DP, Vadeboncoeur TF, Ochs M, Poste JC, Vilke GM, Hoyt DB. The association between field Glasgow Coma Scale score and outcome in patients undergoing paramedic rapid sequence intubation. *Journal of Emergency Medicine* 2005, **29**(4):391-7.
 207. Hodgkinson DW, Berry E, Yates DW. Mild head injury--a positive approach to management. *European Journal of Emergency Medicine* 1994, **1**(1):9-12.
 208. Brookes M, MacMillan R, Cully S, Anderson E, Murray S, Mendelow AD *et al.* Head injuries in accident and emergency departments. How different are children from adults? *Journal of Epidemiology and Community Health* 1990, **44**(2):147-51.
 209. Royal College of Surgeons of England, British Orthopaedic Association. (2000) Better care for the severely injured. London: Royal College of Surgeons of England.
 210. Borczuk P. Predictors of intracranial injury in patients with mild head trauma. *Annals of Emergency Medicine* 1995, **25**(6):731-6.
 211. Ciccicarese E, Milletti S, Venturoli L. Minor head injury in adults. Results of the application of a guideline. *Radiologia Medica* 1998, **96**(5):480-4.
 212. Cigada M, Figini S, Guatteri L, Zaniboni M, Gavazzi A, Iapichino G. Minor head injury: Effects of diagnostic and therapeutic guidelines. *Chirurgia* 1999, **12**(6):405-7.
 213. Culotta VP, Sementilli ME, Gerold K, Watts CC. Clinicopathological heterogeneity in the classification of mild head injury. *Neurosurgery* 1996, **38**(2):245-50.
 214. Cummins BH. The management of head injuries. *Current Orthopaedics* 1992, **6**(4):240-4.
 215. Dunham CM, Coates S, Cooper C. Compelling evidence for discretionary brain computed tomographic imaging in those patients with mild cognitive impairment after blunt trauma. *Journal of Trauma* 1996, **41**(4):679-86.
 216. Duus BR, Boesen T, Kruse KV, Nielsen KB. Prognostic signs in the evaluation of patients with minor head injury. *British Journal of Surgery* 1993, **80**(8):988-91.
 217. Finizio FS, Galassi E. Extradural hematomas in childhood and adolescence. *Riv Neuroradiol* 1992, **5**(SUPPL. 1):45-50.
 218. Frush DP, O'Hara SM, Kliever MA. Pediatric imaging perspective: Acute head trauma - Is skull radiography useful? *Journal of Pediatrics* 1998, **132**(3 pt 1):553-4.
 219. Gutman MB, Moulton RJ, Sullivan I, Hotz G, Tucker WS, Muller PJ. Risk factors predicting operable intracranial hematomas in head injury. *Journal of Neurosurgery* 1992, **77**(1):9-14.
 220. Harad FT, Kerstein MD. Inadequacy of bedside clinical indicators in identifying significant intracranial injury in trauma patients. *Journal of Trauma* 1992, **32**(3):359-61.
 221. Herbert ME. Issues in minor head injury: To CT or not to CT, that is the question. *Emergency Radiology* 2000, **7**(1):7-13.
 222. Hsiang JN, Yeung T, Yu AL, Poon WS. High-risk mild head injury. *Journal of Neurosurgery* 1997, **87**(2):234-8.
 223. Hung CC, Chiu WT, Lee LS, Lin LS, Shih CJ. Risk factors predicting surgically significant intracranial hematomas in patients with head injuries. *Journal of the Formosan Medical Association* 1996, **95**(4):294-7.

224. Ingebrigtsen T, Trumphy JH, Anke IM. Minor head injuries. May early CT-scanning replace in-hospital observation? *Tidsskr Nor Laegeforen* 1995, **115**(13):1601-3.
225. Kelly AM, Kerr D. Are too many head CT scans ordered in emergency departments? *Emergency Medicine* 2000, **12**(1):50-4.
226. Livingston DH, Loder PA, Koziol J, Hunt CD. The use of CT scanning to triage patients requiring admission following minimal head injury. *Journal of Trauma* 1991, **31**(4):483-7.
227. Lucchi S, Giua G, Bettinelli A, Farabola M, Sina C, Mangiagalli E et al. The role of computerized tomography in the management of mild head injury patients. *Riv Neuroradiol* 1995, **8**(3):415-28.
228. Mikhail MG, Levitt MA, Christopher TA, Sutton MC. Intracranial injury following minor head trauma. *American Journal of Emergency Medicine* 1992, **10**(1):24-6.
229. Miller EC, Derlet RW, Kinser D. Minor head trauma: Is computed tomography always necessary? *Annals of Emergency Medicine* 1996, **27**(3):290-4.
230. Mohanty SK, Thompson W, Rakower S. Are CT scans for head injury patients always necessary? *Journal of Trauma* 1991, **31**(6):801-4.
231. Moran SG, McCarthy MC, Uddin DE, Poelstra RJ. Predictors of positive CT scans in the trauma patient with minor head injury. *American Surgeon* 1994, **60**(7):533-5.
232. Murshid WR. Role of skull radiography in the initial evaluation of minor head injury: a retrospective study. *Acta Neurochirurgica* 1994, **129**(1-2):11-4.
233. Murshid WR. Management of minor head injuries: admission criteria, radiological evaluation and treatment of complications. *Acta Neurochirurgica* 1998, **140**(1):56-64.
234. Nagy KK, Joseph KT, Krosner SM, Roberts RR, Leslie CL, Dufty K et al. The utility of head computed tomography after minimal head injury. *Journal of Trauma* 1999, **46**(2):268-70.
235. Nelson JB, Bresticker MA, Nahrwold DL. Computed tomography in the initial evaluation of patients with blunt trauma. *Journal of Trauma* 1992, **33**(5):722-7.
236. Otte A, Jeungling FD, Nitzsche EU. Rethinking mild head injury. *Journal of Vascular Investigation* 1998, **4**(1):45-6.
237. Packard RC. Mild head injury. *Headache Q* 1993, **4**(1):42-52.
238. Pasman P, Twijnstra A, Wilmink J, Leffers P. The value of skull radiography in patients with head trauma. *Journal Belge de Radiologie* 1995, **78**(3):169-71.
239. Pasman P, Twijnstra A, Wilmink J, Leffers P. Is skull radiography indicated in patients with head injuries? *Nederlands Tijdschrift Voor Geneeskunde* 1992, **136**(48):2370-3.
240. Porchet F. Acute management of mild traumatic brain injury. *Schweizer Archiv fur Neurologie und Psychiatrie* 1998, **149**(2):68-72.
241. Reinus WR, Zwemer FLJ, Wippold FJ, Erickson KK. Emergency imaging of patients with resolved neurologic deficits: value of immediate cranial CT. *AJR American Journal of Roentgenology* 1994, **163**(3):667-70.
242. Rosenorn J, Duus B, Nielsen K, Kruse K, Boesen T. Is a skull X-ray necessary after milder head trauma? *British Journal of Neurosurgery* 1991, **5**(2):135-9.
243. Savastio G, Golfieri R, Pastore-Trossello M, Venturoli L. Cranial trauma: the predictability of the presentation symptoms as a screening for radiologic study. *Radiologia Medica* 1991, **82**(6):769-75.
244. Schynoll W, Overton D, Krome R, Wesolowski D, Wang AM, Wilson A et al. A prospective study to identify high-yield criteria associated with acute intracranial computed tomography findings in head-injured patients. *American Journal of*

- Emergency Medicine* 1993, **11**(4):321-6.
245. Servadei F, Vergoni G, Nasi MT, Staffa G, Donati R, Arista A. Management of low-risk head injuries in an entire area: results of an 18-month survey. *Surgical Neurology* 1993, **39**(4):269-75.
246. Servadei F, Ciucci G, Laroni L, Cuscini M, Piola C, Arista A. Diagnosis and management of minor head injury: a regional multicenter approach in Italy. *Journal of Trauma* 1995, **39**(4):696-701.
247. Servadei F, Vergoni G, Staffa G, Zappi D, Nasi MT, Donati R *et al.* Extradural haematomas: how many deaths can be avoided? Protocol for early detection of haematoma in minor head injuries. *Acta Neurochirurgica* 1995, **133**(1-2):50-5.
248. Servadei F, Faccani G, Roccella P, Seracchioli A, Godano U, Ghadirpour R *et al.* Asymptomatic extradural haematomas. Results of a multicenter study of 158 cases in minor head injury. *Acta Neurochirurgica* 1989, **96**(1-2):39-45.
249. Shaabat AO. Do we need to admit children with minor head injury? *Current Pediatric Research* 2001, **5**(1-2):27-9.
250. Sharma M, Sharma AK. Mode, presentation, CT findings and outcome of pediatric head injury. *Indian Pediatrics* 1994, **31**(6):733-9.
251. Stein SC, Spettell C, Young G, Ross SE. Limitations of neurological assessment in mild head injury. *Brain Injury* 1993, **7**(5):425-30.
252. Stein SC, Doolin EJ. Management of minor closed head injury in children and adolescents. *Pediatric Surgery International* 1995, **10**(7):465-71.
253. Stein SC. Management of minor closed head injury. *Neurosurgery Quarterly* 1996, **6**(2):108-15.
254. Sturloni N, Laudizi L, Venuta A, Venturelli C, Bettelli F, Franceschini L. Head injuries in the pediatric emergency department: a 5-year experience at the Pediatric Clinic of Modena. *Pediatrica Medica e Chirurgica* 1997, **19**(1):43-8.
255. Taheri PA, Karamanoukian H, Gibbons K, Waldman N, Doerr RJ, Hoover EL. Can patients with minor head injuries be safely discharged home? *Archives of Surgery* 1993, **128**(3):289-92.
256. Tsai MC, Yang LH, Wu MH. Value of emergency room computed tomographic brain scan in mild head injury patients. *Journal Surgical Association Republic of China* 1994, **27**(2):2278-82.
257. Uchino Y, Okimura Y, Tanaka M, Saeki N, Yamaura A. Computed tomography and magnetic resonance imaging of mild head injury--is it appropriate to classify patients with Glasgow Coma Scale score of 13 to 15 as "mild injury"? *Acta Neurochirurgica* 2001, **143**(10):1031-7.
258. Vilke GM, Chan TC, Guss DA. Use of a complete neurological examination to screen for significant intracranial abnormalities in minor head injury. *American Journal of Emergency Medicine* 2000, **18**(2):159-63.
259. Viola L, Zotta D, Martino V, Barbato R, Schisano G. Minor head injuries: one year experience according to the new Italian guideline. *Acta Neurochirurgica* 2000, **142**(11):1281-5.
260. Tomei G, Brambilla GL, Delfini R, Servadei F, Ambrosio A, Acampora S *et al.* Guidelines for minor head injured patients' management in adult age. *Journal of Neurosurgical Sciences* 1996, **40**(1):11-5.
261. Adams J, Frumiento C, Shatney-Leach L, Vane DW. Mandatory admission after isolated mild closed head injury in children: is it necessary? *Journal of Pediatric Surgery* 2001, **36**(1):119-21.
262. Benito-Fernandez J, Mintegui-Raso S, Sanchez-Echaniz J, Martinez-Gonzalez MJ, Fernandez-Cuesta MA. Head injuries in children: can clinical features identify patients with high or low risk for intracranial injury? *Anales Espanoles de Pediatría* 1998, **48**(2):122-6.

263. Chan KH, Yue CP, Mann KS. The risk of intracranial complications in pediatric head injury. Results of multivariate analysis. *Childs Nervous System* 1990, **6**(1):27-9.
264. Chan KH, Mann KS, Yue CP, Fan YW, Cheung M. The significance of skull fracture in acute traumatic intracranial hematomas in adolescents: a prospective study. *Journal of Neurosurgery* 1990, **72**(2):189-94.
265. Davis RL, Mullen N, Makela M, Taylor JA, Cohen W, Rivara FP. Cranial computed tomography scans in children after minimal head injury with loss of consciousness. *Annals of Emergency Medicine* 1994, **24**(4):640-5.
266. Davis RL, Hughes M, Gubler KD, Waller PL, Rivara FP. The use of cranial CT scans in the triage of pediatric patients with mild head injury. *Pediatrics* 1995, **95**(3):345-9.
267. Gruskin KD, Schutzman SA. Head trauma in children younger than 2 years: are there predictors for complications? *Archives of Pediatrics and Adolescent Medicine* 1999, **153**(1):15-20.
268. Keskil IS, Baykaner MK, Ceviker N, Kaymaz M. Assessment of mortality associated with mild head injury in the pediatric age group. *Childs Nervous System* 1995, **11**(8):467-73.
269. Levi L, Guilburd JN, Linn S, Feinsod M. The association between skull fracture, intracranial pathology and outcome in pediatric head injury. *British Journal of Neurosurgery* 1991, **5**(6):617-25.
270. Loroni L, Ciucci G, Piccinini G, Cuscini M, Scorza P, Piola C et al. Approach to head trauma in childhood in a district general hospital. *European Journal of Emergency Medicine* 1996, **3**(3):141-8.
271. Mander M, Wencil T, Bazowski P, Krauze J. How should we manage children after mild head injury? *Childs Nervous System* 2000, **16**(3):156-60.
272. Murgio A, Patrick PD, Andrade FA, Boetto S, Leung KM, Munoz Sanchez MA. International study of emergency department care for pediatric traumatic brain injury and the role of CT scanning. *Childs Nervous System* 2001, **17**(4-5):257-62.
273. Quayle KS, Jaffe DM, Kuppermann N, Kaufman BA, Lee BC, Park TS et al. Diagnostic testing for acute head injury in children: when are head computed tomography and skull radiographs indicated? *Pediatrics* 1997, **99**(5):E11.
274. Roddy SP, Cohn SM, Moller BA, Duncan CC, Gosche JR, Seashore JH et al. Minimal head trauma in children revisited: Is routine hospitalization required? *Pediatrics* 1998, **101**(4 Pt 1):575-7.
275. Schunk JE, Rodgerson JD, Woodward GA. The utility of head computed tomographic scanning in pediatric patients with normal neurologic examination in the emergency department. *Pediatric Emergency Care* 1996, **12**(3):160-5.
276. Shane SA, Fuchs SM. Skull fractures in infants and predictors of associated intracranial injury. *Pediatric Emergency Care* 1997, **13**(3):198-203.
277. Simon B, Letourneau P, Vitorino E, McCall J. Pediatric minor head trauma: indications for computed tomographic scanning revisited. *Journal of Trauma* 2001, **51**(2):231-7.
278. Toupin JM, Lechevallier J, Chaput E, Dacher JN, Le Dosseur P, Proust B et al. Selective indications of skull radiography after head injury in children. *Revue de Chirurgie Orthopedique et Reparatrice de l'Appareil Moteur* 1996, **82**(3):201-7.
279. Nguyen GK, Clark R. Adequacy of plain radiography in the diagnosis of cervical spine injuries. *Emergency Radiology* 2005, **11**(3):158-61.
280. Bachulis BL, Long WB, Hynes GD, Johnson MC. Clinical indications for cervical spine radiographs in the traumatized patient. *American Journal of Surgery* 1987, **153**(5):473-8.
281. Baker C, Kadish H, Schunk JE. Evaluation of pediatric cervical spine injuries. *American Journal of Emergency Medicine* 1999, **17**(3):230-4.

282. Barba CA, Taggart J, Morgan AS, Guerra J, Bernstein B, Lorenzo M *et al.* A new cervical spine clearance protocol using computed tomography. *Journal of Trauma* 2001, **51**(4):652-6.
283. Bayless P, Ray VG. Incidence of cervical spine injuries in association with blunt head trauma. *American Journal of Emergency Medicine* 1989, **7**(2):139-42.
284. Borock EC, Gabram SG, Jacobs LM, Murphy MA. A prospective analysis of a two-year experience using computed tomography as an adjunct for cervical spine clearance. *Journal of Trauma* 1991, **31**(7):1001-5.
285. Brillhart J. Which patients with blunt trauma do not require cervical spine x-rays? *Journal of Family Practice* 2000, **49**(10):884-5.
286. Crim JR, Moore K, Brodke D. Clearance of the cervical spine in multitrauma patients: the role of advanced imaging. *Seminars in Ultrasound, CT and MR* 2001, **22**(4):283-305.
287. Davis JW, Phreaner DL, Hoyt DB, Mackerse RC. The etiology of missed cervical spine injuries. *Journal of Trauma* 1993, **34**(3):342-6.
288. Edwards MJ, Frankema SP, Kruit MC, Bode PJ, Breslau PJ, van Vugt AB. Routine cervical spine radiography for trauma victims: Does everybody need it? *Journal of Trauma* 2001, **50**(3):529-34.
289. Ersoy G, Karcioglu O, Enginbas Y, Eray O, Ayrik C. Are cervical spine X-rays mandatory in all blunt trauma patients? *European Journal of Emergency Medicine* 1995, **2**(4):191-5.
290. Fischer RP. Cervical radiographic evaluation of alert patients following blunt trauma. *Annals of Emergency Medicine* 1984, **13**(10):905-7.
291. Ghen MJ, Corso NA. Protocol for diagnosis of the traumatized cervical spine. *J Neurol Orthop Med Surg* 1992, **13**(1):65-7.
292. Gonzalez RP, Fried PO, Bukhalo M, Holevar MR, Falimirski ME. Role of clinical examination in screening for blunt cervical spine injury. *Journal of the American College of Surgeons* 1999, **189**(2):152-7.
293. Hanson JA, Blackmore CC, Mann FA, Wilson AJ. Cervical spine injury: a clinical decision rule to identify high-risk patients for helical CT screening. *AJR American Journal of Roentgenology* 2000, **174**(3):713-7.
294. Harris JH, Jr. What is the minimum number of plain radiographs necessary to evaluate the cervical spine in patients who have had trauma? *AJR American Journal of Roentgenology* 1994, **163**(1):217-8.
295. Harris MB, Kronlage SC, Carboni PA, Robert KQ, Menmuir B, Ricciardi JE *et al.* Evaluation of the cervical spine in the polytrauma patient. *Spine* 2000, **25**(22):2884-91.
296. Hoffman JR, Mower WR, Wolfson AB. Absence of 5 clinical criteria ruled out cervical spine injury in blunt trauma in the emergency department. *Evidence-Based Medicine* 2001, **6**(2):63.
297. Hoffman JR, Mower W. When to image cervical spine injuries. *Western Journal of Medicine* 1991, **155**(3):290.
298. Hoffman JR, Wolfson AB, Todd K, Mower WR. Selective cervical spine radiography in blunt trauma: methodology of the National Emergency X-Radiography Utilization Study (NEXUS). *Annals of Emergency Medicine* 1998, **32**(4):461-9.
299. Holliman CJ, Mayer JS, Cook RT, Jr., Smith JS, Jr. Is the anteroposterior cervical spine radiograph necessary in initial trauma screening? *American Journal of Emergency Medicine* 1991, **9**(5):421-5.
300. Jacobs LM, Schwartz R. Prospective analysis of acute cervical spine injury: a methodology to predict injury. *Annals of Emergency Medicine* 1986, **15**(1):44-9.
301. Jen LH, Sharma V, Shah K, Gor D. The role of spiral CT vs plain films in acute cervical spine trauma: A comparative study. *Emergency Radiology* 2001, **8**(6):311-4.

302. Keenan HT, Hollingshead MC, Chung CJ, Ziglar MK. Using CT of the cervical spine for early evaluation of pediatric patients with head trauma. *AJR American Journal of Roentgenology* 2001, **177**(6):1405-9.
303. Kreipke DL, Gillespie KR, McCarthy MC, Mail JT, Lappas JC, Broadie TA. Reliability of indications for cervical spine films in trauma patients. *Journal of Trauma* 1989, **29**(10):1438-9.
304. Kriss VM, Kriss TC. Imaging of the cervical spine in infants. *Pediatric Emergency Care* 1997, **13**(1):44-9.
305. Link TM, Schuierer G, Hufendiek A, Peters PE. Fractures of the cervical spine. Diagnosis in multiple trauma patients. *Radiologe* 1994, **34**(12):721-7.
306. Link TM, Schuierer G, Hufendiek A, Horch C, Peters PE. Substantial head trauma: value of routine CT examination of the cervicocranium. *Radiology* 1995, **196**(3):741-5.
307. Maurice S, Brown S, Robertson C, Beggs I. The effect of introducing guidelines for cervical spine radiographs in the accident and emergency department. *Journal of Accident and Emergency Medicine* 1996, **13**(1):38-40.
308. McNamara RM, Heine E, Esposito B. Cervical spine injury and radiography in alert, high-risk patients. *Journal of Emergency Medicine* 1990, **8**(2):177-82.
309. McNamara RM, O'Brien MC, Davidheiser S. Post-traumatic neck pain: a prospective and follow-up study. *Annals of Emergency Medicine* 1988, **17**(9):906-11.
310. Mower WR, Hoffman JR, Pollack CV, Jr., Zucker MI, Browne BJ, Wolfson AB. Use of plain radiography to screen for cervical spine injuries. *Annals of Emergency Medicine* 2001, **38**(1):1-7.
311. Neifeld GL, Keene JG, Hevesy G, Leikin J, Proust A, Thisted RA. Cervical injury in head trauma. *Journal of Emergency Medicine* 1988, **6**(3):203-7.
312. Panacek EA, Mower WR, Holmes JF, Hoffman JR. Test performance of the individual NEXUS low-risk clinical screening criteria for cervical spine injury. *Annals of Emergency Medicine* 2001, **38**(1):22-5.
313. Pollack CV, Jr., Hendey GW, Martin DR, Hoffman JR, Mower WR. Use of flexion-extension radiographs of the cervical spine in blunt trauma. *Annals of Emergency Medicine* 2001, **38**(1):8-11.
314. Ptak T, Kihiczak D, Lawrason JN, Rhea JT, Sacknoff R, Godfrey RR *et al.* Screening for cervical spine trauma with helical CT: Experience with 676 cases. *Emergency Radiology* 2001, **8**(6):315-9.
315. Roberge RJ, Wears RC, Kelly M, Evans TC, Kenny MA, Daffner RD *et al.* Selective application of cervical spine radiography in alert victims of blunt trauma: a prospective study. *Journal of Trauma* 1988, **28**(6):784-8.
316. Roberge RJ, Wears RC. Evaluation of neck discomfort, neck tenderness, and neurologic deficits as indicators for radiography in blunt trauma victims. *Journal of Emergency Medicine* 1992, **10**(5):539-44.
317. Rosenberg NM, Schweich PJ, Joffee M, Vinci RJ. Cervical spine injuries: to x-ray or not to x-ray? *Pediatric Emergency Care* 1994, **10**(1):48-50.
318. Ross SE, O'Malley KF, DeLong WG, Born CT, Schwab CW. Clinical predictors of unstable cervical spinal injury in multiply injured patients. *Injury* 1992, **23**(5):317-9.
319. Roth BJ, Martin RR, Foley K, Barcia PJ, Kennedy P. Roentgenographic evaluation of the cervical spine. A selective approach. *Archives of Surgery* 1994, **129**(6):643-5.
320. Saddison D, Vanek VW, Racanelli JL. Clinical indications for cervical spine radiographs in alert trauma patients. *American Surgeon* 1991, **57**(6):366-9.
321. Scharkowski P, Friedrich JM, Arand M, Mutschler W. Cervical spine injuries in head traumas: X-ray diagnosis on the day of the accident. *Rofo* 1991, **154**(6):605-9.

322. Schroder RJ, Vogl T, Hidajat N, Schedel H, Sudkamp N, Haas N *et al.* Comparison of the diagnostic value of CT and MRI in injuries of the cervical vertebrae. *Aktuelle Radiologie* 1995, **5**(4):197-202.
323. Williams J, Jehle D, Cottingham E, Shuffelbarger C. Head, facial, and clavicular trauma as a predictor of cervical-spine injury. *Annals of Emergency Medicine* 1992, **21**(6):719-22.
324. Woodring JH, Lee C. Limitations of cervical radiography in the evaluation of acute cervical trauma. *Journal of Trauma* 1993, **34**(1):32-9.
325. Zabel DD, Tinkoff G, Wittenborn W, Ballard K, Fulda G. Adequacy and efficacy of lateral cervical spine radiography in alert, high-risk blunt trauma patient. *Journal of Trauma* 1997, **43**(6):952-6.
326. Anglen J, Metzler M, Bunn P, Griffiths H. Flexion and extension views are not cost-effective in a cervical spine clearance protocol for obtunded trauma patients. *Journal of Trauma* 2002, **52**(1):54-9.
327. Brady WJ, Moghtader J, Cutcher D, Exline C, Young J. ED use of flexion-extension cervical spine radiography in the evaluation of blunt trauma. *American Journal of Emergency Medicine* 1999, **17**(6):504-8.
328. Clancy MJ. Clearing the cervical spine of adult victims of trauma. *Journal of Accident and Emergency Medicine* 1999, **16**(3):208-14.
329. Mirvis SE, Shanmuganathan K. Trauma radiology: Part V. Imaging of acute cervical spine trauma. *Journal of Intensive Care Medicine* 1995, **10**(1):15-33.
330. Palmer SH, Maheson M. A radiological review of cervical spine injuries from an accident and emergency department: has the ATLS made a difference? *Journal of Accident and Emergency Medicine* 1995, **12**(3):189-90.
331. Ralston ME, Chung K, Barnes PD, Emans JB, Schutzman SA. Role of flexion-extension radiographs in blunt pediatric cervical spine injury. *Academic Emergency Medicine* 2001, **8**(3):237-45.
332. Tehranzadeh J, Bonk RT, Ansari A, Mesgarzadeh M. Efficacy of limited CT for nonvisualized lower cervical spine in patients with blunt trauma. *Skeletal Radiology* 1994, **23**(5):349-52.
333. West OC, Anbari MM, Pilgram TK, Wilson AJ. Acute cervical spine trauma: diagnostic performance of single-view versus three-view radiographic screening. *Radiology* 1997, **204**(3):819-23.
334. Woods WA, Brady WJ, Pollock G, Kini N, Young JS, Swischuk LE. Flexion-extension cervical spine radiography in pediatric blunt trauma. *Emergency Radiology* 1998, **5**(6):381-4.
335. Albrecht RM, Kingsley D, Schermer CR, Demarest GB, Benzel EC, Hart BL. Evaluation of cervical spine in intensive care patients following blunt trauma. *World Journal of Surgery* 2001, **25**(8):1089-96.
336. Brooks RA, Willett KM. Evaluation of the Oxford protocol for total spinal clearance in the unconscious trauma patient. *Journal of Trauma* 2001, **50**(5):862-7.
337. D'Alise MD, Benzel EC, Hart BL. Magnetic resonance imaging evaluation of the cervical spine in the comatose or obtunded trauma patient. *Journal of Neurosurgery* 1999, **91**(1 Suppl):54-9.
338. Davis JW, Parks SN, Detlefs CL, Williams GG, Williams JL, Smith RW. Clearing the cervical spine in obtunded patients: the use of dynamic fluoroscopy. *Journal of Trauma* 1995, **39**(3):435-8.
339. Davis JW, Kaups KL, Cunningham MA, Parks SN, Nowak TP, Bilello JF *et al.* Routine evaluation of the cervical spine in head-injured patients with dynamic fluoroscopy: a reappraisal. *Journal of Trauma* 2001, **50**(6):1044-7.
340. Gerrelts BD, Petersen EU, Mabry J, Petersen SR. Delayed diagnosis of

- cervical spine injuries. *Journal of Trauma* 1991, **31**(12):1622-6.
341. Hindman BW, Watkins GE, Song AK. Evaluation of the cervical spine in the obtunded patient. *Emergency Radiology* 1998, **5**(6):391-3.
 342. Holly LT, Kelly DF, Counelis GJ, Blinman T, McArthur DL, Cryer HG. Cervical spine trauma associated with moderate and severe head injury: incidence, risk factors, and injury characteristics. *Journal of Neurosurgery* 2002, **96**(3 Suppl):285-91.
 343. Jelly LM, Evans DR, Easty MJ, Coats TJ, Chan O. Radiography versus spiral CT in the evaluation of cervicothoracic junction injuries in polytrauma patients who have undergone intubation. *Radiographics* 2000, **20 Spec No**:S251-S259.
 344. Katzberg RW, Benedetti PF, Drake CM, Ivanovic M, Levine RA, Beatty CS *et al.* Acute cervical spine injuries: prospective MR imaging assessment at a level 1 trauma center. *Radiology* 1999, **213**(1):203-12.
 345. Kirshenbaum KJ, Nadimpalli SR, Fantus R, Cavallino RP. Unsuspected upper cervical spine fractures associated with significant head trauma: role of CT. *Journal of Emergency Medicine* 1990, **8**(2):183-98.
 346. Malomo AO, Shokunbi MT, Adeyoye A. Evaluation of the use of plain cervical spine radiography in patients with head injury. *East African Medical Journal* 1995, **72**(3):186-8.
 347. Sees DW, Rodriguez Cruz LR, Flaherty SF, Ciceri DP. The use of bedside fluoroscopy to evaluate the cervical spine in obtunded trauma patients. *Journal of Trauma* 1998, **45**(4):768-71.
 348. Dietrich AM, Ginn-Pease ME, Bartkowski HM, King DR. Pediatric cervical spine fractures: predominantly subtle presentation. *Journal of Pediatric Surgery* 1991, **26**(8):995-9.
 349. Dwek JR, Chung CB. Radiography of cervical spine injury in children: are flexion-extension radiographs useful for acute trauma? *AJR American Journal of Roentgenology* 2000, **174**(6):1617-9.
 350. Laham JL, Cotcamp DH, Gibbons PA, Kahana MD, Crone KR. Isolated head injuries versus multiple trauma in pediatric patients: do the same indications for cervical spine evaluation apply? *Pediatric Neurosurgery* 1994, **21**(4):221-6.
 351. Schwartz GR, Wright SW, Fein JA, Sugarman J, Pasternack J, Salhanick S. Pediatric cervical spine injury sustained in falls from low heights. *Annals of Emergency Medicine* 1997, **30**(3):249-52.
 352. Asikainen I, Kaste M, Sarna S. Predicting late outcome for patients with traumatic brain injury referred to a rehabilitation programme: a study of 508 Finnish patients 5 years or more after injury. *Brain Injury* 1998, **12**(2):95-107.
 353. Barth JT, Macciocchi SN, Giordani B, Rimel R, Jane JA, Boll TJ. Neuropsychological sequelae of minor head injury. *Neurosurgery* 1983, **13**(5):529-33.
 354. Bazarian JJ, Wong T, Harris M, Leahey N, Mookerjee S, Dombovy M. Epidemiology and predictors of post-concussive syndrome after minor head injury in an emergency population. *Brain Injury* 1999, **13**(3):173-89.
 355. Bazarian J, Hartman M, Delahunta E. Minor head injury: predicting follow-up after discharge from the Emergency Department. *Brain Injury* 2000, **14**(3):285-94.
 356. Blakely TA, Jr., Harrington DE. Mild head injury is not always mild; implications for damage litigation. *Medicine, Science and the Law* 1993, **33**(3):231-42.
 357. Blostein PA, Jones SJ, Buechler CM, Vandongen S. Cognitive screening in mild traumatic brain injuries: analysis of the neurobehavioral cognitive status examination when utilized during initial trauma hospitalization. *Journal of Neurotrauma* 1997, **14**(3):171-7.
 358. Cattalani R, Gugliotta M, Maravita A, Mazzocchi A. Post-concussive

- syndrome: paraclinical signs, subjective symptoms, cognitive functions and MMPI profiles. *Brain Injury* 1996, **10**(3):187-95.
359. Deb S, Lyons I, Koutzoukis C. Neuropsychiatric sequelae one year after a minor head injury. *Journal of Neurology, Neurosurgery and Psychiatry* 1998, **65**(6):899-902.
360. Koelfen W, Freund M, Dinter D, Schmidt B, Koenig S, Schultze C. Long-term follow up of children with head injuries-classified as "good recovery" using the Glasgow Outcome Scale: neurological, neuropsychological and magnetic resonance imaging results. *European Journal of Pediatrics* 1997, **156**(3):230-5.
361. Masson F, Vecsey J, Salmi LR, Dartigues JF, Erny P, Maurette P. Disability and handicap 5 years after a head injury: a population-based study. *Journal of Clinical Epidemiology* 1997, **50**(5):595-601.
362. McGregor K, Pentland B. Head injury rehabilitation in the U.K.: an economic perspective. *Social Science and Medicine* 1997, **45**(2):295-303.
363. Millis SR. Assessment of motivation and memory with the Recognition Memory Test after financially compensable mild head injury. *Journal of Clinical Psychology* 1994, **50**(4):601-5.
364. Ogasawara K, Numagami Y, Kitahara M. How mild is mild head injury? A neuropsychiatric study. *Brain and Cognition* 2000, **44**(1):83-6.
365. Paret G, Barzilai A, Lahat E, Feldman Z, Ohad G, Vardi A *et al.* Children's adaptive behavioural competence after head injury. *Neuropsychological Rehabilitation* 1993, **3**(4):321-40.
366. Rao N, Rosenthal M, Cronin-Stubbs D, Lambert R, Barnes P, Swanson B. Return to work after rehabilitation following traumatic brain injury. *Brain Injury* 1990, **4**(1):49-56.
367. Ruff RM, Crouch JA, Troster AI, Marshall LF, Buchsbaum MS, Lottenberg S *et al.* Selected cases of poor outcome following a minor brain trauma: comparing neuropsychological and positron emission tomography assessment. *Brain Injury* 1994, **8**(4):297-308.

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) Practices of Sports Medicine Professionals

Tracey Covassin, PhD, ATC*; Robert J. Elbin III, MA*;
Jennifer L. Stiller-Ostrowski, PhD, ATC*; Anthony P. Kontos, PhD†

*Michigan State University, East Lansing, MI; †Humboldt State University, Arcata, CA

Context: Computerized neurocognitive testing is becoming popular among clinicians evaluating sport-related concussions across all levels of sport. Baseline neurocognitive testing has been recommended to provide more accurate representation of the preconcussion cognitive status of individual athletes. However, little is known about the use of baseline neurocognitive testing in concussion assessment and management.

Objective: To examine implementation and practice trends of sports medicine professionals using baseline neurocognitive testing at the high school and collegiate levels.

Design: Quantitative survey research.

Setting: Online survey.

Patients or Other Participants: Certified athletic trainers (ATs) from approximately 1209 US institutions listed on the ImPACT Web site were recruited. A total of 399 ATs completed the survey, for a response return rate of 32.7%.

Main Outcome Measure(s): Survey questions addressed educational level, years of certification, employment setting, percentage of athletes baseline tested, and accuracy of baseline tests. Other items addressed postconcussive neurocognitive testing protocols and scenarios for return-to-play decisions based on neurocognitive testing.

Results: Nearly all ATs (94.7%) administered baseline computerized neurocognitive testing to their athletes. However, only 51.9% examined these baseline tests for validity. The majority of ATs indicated that they administer baseline neurocognitive tests most frequently to football players (88.4%), followed by women's soccer players (78.8%) and men's soccer players (71.2%). Nearly all respondents (95.5%) stated that they would not return a symptomatic athlete to play if the athlete's neurocognitive scores were back to baseline. However, when asked if they would return an athlete who is symptom free but who scores below his or her baseline, 86.5% responded *no*, 9.8% responded *yes*, and 3.8% indicated that it *depended on the importance of the competition*.

Conclusions: The use of baseline testing, baseline testing readministration, and postconcussion protocols among ATs is increasing. However, the ATs in this study reported that they relied more on symptoms than on neurocognitive test scores when making return-to-play decisions.

Key Words: concussions, baseline testing, computerized neurocognitive testing

Key Points

- Most athletic trainers administered baseline computerized neurocognitive testing to their athletes, but only half examined these tests for validity.
- Although virtually no athletic trainers would return a symptomatic athlete to play despite baseline neurocognitive test scores, some would return a symptom-free athlete despite below-baseline neurocognitive test scores.

The assessment and management of sport-related concussions should be a multifaceted approach that consists of a clinical examination, completion of a self-reported symptom checklist, postural assessment, and neurocognitive testing.¹ Computerized neurocognitive testing has been deemed^{2–5} a more objective measure for determining the subtle cognitive changes associated with concussion. Recently, numerous concussion consensus statements and position papers^{1,6–9} have supported and emphasized the use of baseline preinjury and serial postinjury follow-up neurocognitive testing protocols.

Because of the difficulty in detecting the signs and symptoms that often accompany concussion, baseline neurocognitive testing has resulted in increased detection of postconcussion neurocognitive impairments.^{2,5,10,11} Moreover, baseline neurocognitive testing provides the

most accurate representation of an athlete's preinjury cognitive status. The need for individual baseline examinations arises from individual differences in cognitive performance in the areas of attention, memory, concentration, information processing, and reaction time. Without this information, it is difficult to ascertain if a concussed athlete's postconcussion neurocognitive scores are the result of concussion or individual variability. In addition, baseline neurocognitive tests may be used as a tool to determine concussion resolution for return-to-play decisions.⁷ Although normative data may be valuable in clinical cases when baseline scores are not available for each athlete, collecting preconcussion and postconcussion neurocognitive data allows sports medicine professionals to track the cognitive recovery of each concussed athlete, rather than using a universal or "one-size-fits-all" ap-

proach to managing concussion.^{2,12,13} However, no authors have investigated the compliance or practice trends of sports medicine professionals using baseline neurocognitive testing at the high school and collegiate levels.

When baseline data are not available, neurocognitive scores can be compared with normative data. Normative data currently exist for sex, age, and educational level.¹⁴ However, other factors, such as history of concussion, race, and acculturation, are usually not included in these data. Therefore, it is important that clinicians conduct baseline tests for postconcussion comparisons.

Computerized neurocognitive testing provides accurate reaction time calculation, randomization of test trials, and automation of data collection and analysis. Given the large number of athletes participating within collegiate and high school athletic programs, computer-based neurocognitive screening measures may be beneficial. Despite the increased use of neurocognitive test batteries, little is known about the integration of baseline neurocognitive testing into concussion assessment and management. Therefore, the purpose of our study was to examine the practice trends of certified athletic trainers (ATs) using baseline neurocognitive testing at the high school and collegiate levels.

METHODS

Approval for the study was granted by the university's institutional review board. Approximately 1209 American institutions (404 high schools, 805 universities and colleges) listed on the ImPACT Web site (<http://www.impacttest.com>) were contacted via e-mail regarding participation. The ImPACT neurocognitive test battery is a computer-based program for assessing neurocognitive function and concussion symptoms and is the most widely used computerized testing program in the sports setting. This neurocognitive test battery consists of 3 categories: demographics, concussion symptoms, and neurocognitive tests. Specifically, the software program consists of 6 modules that evaluate attentional processes, verbal recognition memory, visual working memory, visual processing speed, reaction time, numerical sequencing ability, and learning.¹⁵

A 20-item survey was developed for the purpose of evaluating high school and collegiate institutions' neurocognitive testing practices and protocols. An expert panel of ATs and neuropsychologists reviewed the survey for content and face validity. The survey was then sent to the head AT at each institution. In the event that the head AT was not responsible for conducting ImPACT testing, he or she was asked to forward the e-mail to the individual who conducted ImPACT testing at that institution. A follow-up e-mail was sent to the head AT 3 weeks after the initial e-mail. By completing and returning the online survey, participants provided implied consent. The e-mail explained the study and gave an online link to the survey, which was hosted by SurveyMonkey.com (Menlo Park, CA). The survey took approximately 5 to 10 minutes to complete. All responses were returned to the survey Web site as anonymous data. Participants could withdraw at any time without penalty and were allowed to skip any questions they did not wish to answer.

Demographic information (eg, education level, years of experience as an AT, employment setting) was collected from all respondents. Participants were then asked (1) to specify

Table 1. Participants' Highest Level of Education (N = 399)^a

| Degree | n (%) |
|--------|------------|
| MS | 155 (38.8) |
| BS | 75 (18.8) |
| MEd | 41 (10.3) |
| MD | 28 (7.0) |
| PhD | 21 (5.2) |
| BA | 21 (5.2) |
| Other | 8 (2.0) |
| DO | 2 (0.5) |

^a Not all respondents provided this information.

the number of years they had been using ImPACT and their protocols and practices when using this tool, (2) if they were taking the time to administer baseline testing and to ensure the validity of baseline tests, (3) if normative data were used in the absence of a valid baseline, (4) to identify the sports in which athletes underwent baseline ImPACT testing, and (5) when they first readministered ImPACT after a concussion. Other items addressed subsequent retest protocols and methods used to make return-to-play decisions.

Respondents were also given 2 scenarios of reported symptoms and ImPACT scores and were asked about making return-to-play decisions. First, if an athlete was still reporting symptoms but ImPACT scores were back to baseline, participants were asked if they would allow the athlete to return to competition. Second, if an athlete was no longer reporting symptoms but had below-baseline scores on ImPACT, participants were asked if they would allow the athlete to return to competition. Finally, participants were asked if they had attended an ImPACT workshop and who was responsible for interpreting postconcussion ImPACT scores. Survey data were analyzed using descriptive statistics. All statistics were calculated using SPSS (version 15.0; SPSS Inc, Chicago, IL).

RESULTS

Of the 1209 institutions ATs contacted via e-mail, a total of 399 ATs (272 men, 127 women) completed the survey, for a response rate of 32.7%. Respondents reported an average of 13.5 (\pm 8.3) years of experience as an AT. More than one-third of participants had earned an MS degree (155/399 [38.8%]), followed by a BS degree (75/399 [18.8%]) and an MEd degree (41/399 [10.3%]) (Table 1). Over half of the ATs graduated from an accredited athletic training education program (209/399 [52.4%]). The most common employment setting was the high school (167/399 [41.9%]), followed by the university (162/399 [40.6%]) and the clinic (28/399 [7.0%]) (Table 2).

Respondents reported using ImPACT for 3.27 \pm 2.25 years. Almost all participants reported administering baseline testing to their athletes (378/399 [94.7%]); however, only half examined whether or not the baseline tests were accurate (207/378 [54.8%]). A third of respondents who administered baseline tests (123/378 [32.5%]) readministered them every 2 years, with the majority of these retests taking place at the high school level (Table 3). When baseline data were not available, 81% of respondents compared the test scores with normative data. Most respondents administered baseline ImPACT tests to football players (334/378 [88.4%]), followed by women's soccer players (298/378 [78.8%]), men's soccer players (269/378

Table 2. Participants' Current Employment Setting (N = 399)

| Employment | n (%) |
|--------------------|------------|
| High school | 167 (41.9) |
| University | 162 (40.6) |
| Clinic | 28 (7.0) |
| High school/clinic | 17 (4.3) |
| Hospital | 11 (2.8) |
| Other | 11 (2.8) |
| Industrial | 2 (0.5) |
| Junior college | 1 (0.3) |

[71.2%]), men's basketball players (259/378 [68.5%]), and women's basketball players (251/378 [66.4%]) (Table 4).

Various methods were used by ATs to assess concussions. All participants completed a clinical examination (100%); this step was followed by a computerized neuropsychological test (349/399 [87.5%]) and a physician recommendation (342/399 [85.7%]) (Table 5). More than half of the respondents (215/399 [53.9%]) administered the first postconcussion test 1 to 2 days after the injury (Table 6). In addition, one-third of respondents (120/399 [30.1%]) reported administering the second postconcussion test after the athlete was symptom free (Table 7).

When presented with a scenario on return-to-play decisions, 95.5% (381/399) of ATs would not return an athlete to competition despite a return to baseline performance on ImPACT if the athlete was still experiencing concussion symptoms. When asked if they would return an athlete who is symptom free but who scores below ImPACT baseline scores, 86.5% (345/399) responded *no*, 9.8% (39/399) responded *yes*, and 3.8% (15/399) indicated that it *depended on the importance of the competition*. Additional results indicated that both ATs and a physician interpreted the ImPACT results 27.8% (111/399) of the time, followed by interpretation by an AT alone (72/399 [18.1%]), a physician alone (43/399 [10.8%]), and then a neuropsychologist alone (27/399 [6.8%]) (Table 8). Finally, fewer than half of the participants had attended an ImPACT training workshop (168/399 [42.1%]), with only 26.4% (19/72) of ATs who examined ImPACT data reporting attendance at an ImPACT workshop.

DISCUSSION

We investigated the computerized neurocognitive testing practices of ATs. Overall, the majority of ATs administered baseline neurocognitive testing to their athletes; however, only half reported verifying the validity of these

Table 3. Do Participants Readminister Baseline ImPACT Tests Every 2 Years? (N = 395)^a

| Employment | Yes | No | Other |
|--------------------|-----|-----|-------|
| University | 19 | 126 | 14 |
| High school | 76 | 44 | 46 |
| Clinic | 8 | 13 | 7 |
| High school/clinic | 11 | 2 | 4 |
| Hospital | 6 | 2 | 3 |
| Other | 2 | 5 | 4 |
| Industrial | 1 | 0 | 1 |
| Junior college | 0 | 1 | 0 |

^a Not all respondents provided this information.

Table 4. Sports Baseline Tested by Certified Athletic Trainers (N = 378)^a

| Sport | n (%) |
|--------------------|------------|
| Football | 334 (88.4) |
| Women's soccer | 298 (78.8) |
| Men's soccer | 269 (71.2) |
| Men's basketball | 259 (68.5) |
| Women's basketball | 251 (66.4) |
| Baseball | 161 (42.6) |
| Softball | 160 (42.3) |

^a Not all respondents provided this information.

results. Our findings have significant implications, because if baseline scores are invalid as a result of poor motivational efforts or misinterpretation of instructions, sports medicine professionals cannot accurately interpret neurocognitive status after a concussion. Comparing postconcussion neurocognitive test scores with invalid baseline scores could predispose an athlete to being prematurely cleared for returning to competition, which could in turn potentially place the athlete at risk for catastrophic consequences.¹⁶

Ensuring the validity of baseline neurocognitive testing is recommended in user and clinical interpretation manuals.¹⁷ Specifically, the ImPACT clinical interpretation manual¹⁷ provides suggestions for ensuring validity on baseline test administrations, yet our results indicate that these instructions are often ignored. A baseline test is invalid if the impulse control composite score is greater than 30 (indicating that the test participant was not paying attention, did not understand the directions, or purposefully "sabotaged" performance to ensure a low baseline score), the processing speed composite score is less than 25, reaction time scores are greater than 0.80 (in an athlete with no history of concussion or learning disabilities), the verbal memory composite score is below 70, and the visual memory composite score is below 60.¹⁷ Any athlete who scores below these cutoff values should be retested at a later date.

Nearly all of the ATs surveyed indicated that they conduct baseline testing; however, just over two-thirds of ATs conducted baseline tests with men's and women's soccer and basketball players. Concussions have been reported^{18–21} to constitute 2% to 11% of all soccer injuries. Research by Barnes et al¹⁸ indicated that male and female

Table 5. Methods Respondents Used to Assess Concussion^a (N = 399)

| Method | n (%) |
|---|-------------|
| Clinical examination | 399 (100.0) |
| Neuropsychological testing (computer) | 349 (87.5) |
| Physician recommendations | 342 (85.7) |
| Symptom checklist | 308 (77.2) |
| Return-to-play guidelines | 263 (65.9) |
| Computed tomography or magnetic resonance imaging | 111 (27.8) |
| Standard Assessment of Concussion | 106 (26.6) |
| Concussion graded scale | 91 (22.8) |
| Neuropsychological testing (paper/pencil) | 28 (7.0) |
| Balance Error Scoring System | 71 (17.8) |

^a Respondents were asked to check all that apply.

Table 6. Time of First Postconcussion ImPACT Test Administered by Athletic Trainers (N = 399)^a

| First ImPACT Test | n (%) |
|-------------------|------------|
| 1 to 2 d | 215 (53.9) |
| Symptom free | 64 (16.0) |
| Less than 24 h | 60 (15.0) |
| 3 to 5 d | 38 (9.5) |
| Other | 10 (2.5) |
| 1 wk | 3 (0.8) |

^a Not all respondents provided this information.

soccer players are at a 50% and 22% risk, respectively, of sustaining a concussion within a 10-year period. Additionally, Boden et al¹⁹ indicated that 17 (59%) collegiate men and 12 (41%) collegiate women were diagnosed with concussions over 2 soccer seasons. Although concussion rates for basketball players are slightly lower than those for football and ice hockey players, concussions in basketball players still accounted for 4.7% and 3.2% of all injuries for collegiate females and males, respectively.²² In addition, high school basketball concussions accounted for 6.2% of all injuries in females and 5.7% of all injuries in males.²¹ Thus, concussions in basketball and soccer players are relatively comparable with those in football (6.0%) and hockey (7.9) players.²² Although normative data are available for computerized neurocognitive test batteries, baseline measures still provide the most reliable and accurate comparisons for postconcussion measures. Therefore, ATs should administer baseline neurocognitive tests to all collision-sport and contact-sport athletes to ensure accurate management of sport-related concussions.

Our results revealed inconsistent use of postconcussion protocols. Only half of the respondents administered the first postconcussion test within 1 to 2 days postinjury. A total of 15% administered the first posttest either when the athlete was symptom free or within the first 24 hours. Researchers¹ have suggested 2 common retest protocols. A fixed time protocol (eg, 2 days postconcussion and 1 week postconcussion) can be implemented until the athlete is back to baseline. This type of protocol is effective in tracking improvement (ie, recovery of cognitive function) and is very popular in research studies.^{23,24} Another recommendation for administering postconcussion neurocognitive testing is to test only when athletes are asymptomatic.¹ This method eliminates practice effects and decreases cost and time due to multiple test administrations.

Current consensus statements and position papers^{1,6,7,9} recommend that athletes should not return to play until they are asymptomatic and neurocognitive scores are back to baseline. It appears that these guidelines and recommendations are being followed, as we found that 86% of

Table 8. Individuals Responsible for Interpreting Results of Postconcussion ImPACT Test Scores^a (N = 399)

| Who Interprets Results | n (%) |
|--------------------------------|------------|
| AT/physician | 111 (27.8) |
| AT | 72 (18.1) |
| Physician | 43 (10.8) |
| Neuropsychologist | 27 (6.8) |
| Physician/AT/neuropsychologist | 20 (5.0) |
| AT/neuropsychologist | 17 (4.3) |
| AT/physician/CIC | 17 (4.3) |
| AT/physician/neurologist | 11 (2.8) |
| CIC | 10 (2.5) |
| AT/neurologist | 9 (2.3) |
| AT/CIC | 9 (2.3) |
| Other combinations | 53 (13.2) |

Abbreviations: AT, certified athletic trainer; CIC, certified ImPACT consultant.

^a Participants were asked to check all that apply.

ATs would not return even an asymptomatic athlete to competition if he or she was still clinically impaired on ImPACT, whereas 95% would not return an athlete to competition if he or she was still symptomatic but ImPACT scores had returned to baseline values. Returning an athlete to play too soon has been shown¹⁶ to increase the risk of cumulative neurocognitive impairments and potential catastrophic injury associated with second-impact syndrome. Continued education and awareness of potential problems associated with premature return to play are essential for the health and welfare of athletes.

The qualifications required for the interpretation of computerized neurocognitive tests have received little attention in the literature. The current computerized neurocognitive testing batteries available have been made “user friendly” with respect to interpreting postconcussion scores. However, many of these tests have been based on paper-and-pencil versions that require training and years of experience. We found that the majority of ATs are interpreting ImPACT results without attending a neuropsychological testing workshop. This workshop is not a requirement, as interpretation guidelines and recommendations are documented in the ImPACT user manual. Yet, considering the high rate of ATs who did not double check for baseline validity in the current study (which is also recommended in the user manual), it is possible that postinjury ImPACT data are being interpreted incorrectly.

We focused on only 1 subset (ie, ImPACT users) of neurocognitive testing in concussion management. As Ferrara et al²⁵ and Notebaert and Guskiewicz²⁶ reported, relatively few ATs (15% and 18%, respectively) used neurocognitive testing to manage concussion. Notebaert and Guskiewicz²⁶ also suggested that these low numbers may be the result of limited accessibility to computerized equipment and neuropsychologists for consultation, inadequate resources and funding, lack of experience and knowledge of neuropsychological testing, and positional time constraints. More specifically, Notebaert and Guskiewicz²⁶ reported that ATs with more experience in the field used neurocognitive testing more often than did those with less experience, and ATs working at colleges and universities used it more often than did those working at high schools. Although we did not examine overall neurocognitive testing usage patterns among ATs, issues of time,

Table 7. Time of Second Follow-Up Postconcussion ImPACT Test (N = 399)

| Second ImPACT Test | n (%) |
|--------------------|------------|
| Symptom free | 120 (30.1) |
| 3 to 5 d | 112 (28.1) |
| 1 to 2 d | 68 (17.0) |
| 1 wk | 64 (16.0) |
| Other | 35 (8.8) |

access, knowledge, and experience might play roles in the implementation of baseline neurocognitive testing. Hence, future researchers should explore the barriers to neurocognitive testing and strategies for mitigating them among ATs. For example, investigators might compare computerized neurocognitive testing implementation practices of ATs who complete a training workshop with those who receive no training.

This study is not without certain limitations inherent to survey research. Our response rate of 33% was low. Such a low rate might have provided an inaccurate representation, as several schools could receive medical coverage from 1 nonrespondent (eg, a sports medicine clinic responsible for 10 high schools). Nonetheless, the response rate for our study was similar to that of previously published concussion management surveys of ATs (34% in Notebaert and Guskiewicz²⁶). In addition, not all institutions included in the study offered all the listed sports. Consequently, the proportions of specific sports that were baseline tested may not accurately reflect actual ImPACT use. Another limitation to this study was the use of only those institutions listed on the ImPACT Web site. We contacted the developers of HeadMinder (New York, NY), Automated Neuropsychological Assessment Metrics (Defense and Veterans Brain Injury Center, Washington, DC), and CogState Sport (Melbourne, Australia) and invited them to participate in our study, but they were unable to provide access to a list of institutions currently using their computerized neurocognitive software. Given the similarities of these computerized neuropsychological testing programs, we anticipate that our findings have implications for users of all 4 testing programs. Developers of all computerized neuropsychological testing programs are urged to emphasize to users the importance of validating baseline tests before making return-to-play decisions based on comparisons with postconcussion scores.

A variable that may have influenced the reported use of baseline testing was the employment setting of the health professional. A total of 7% of respondents were employed in a clinical setting and, therefore, they may not have had the opportunity to baseline test athletes or to administer a retest protocol. These professionals (eg, ATs who were also clinical neuropsychologists or neurologists) are often involved only in postconcussion management through referrals from colleges and high schools and typically are not present during preseason baseline ImPACT testing.

CONCLUSIONS

As neurocognitive testing increases in popularity in the sports medicine field, it is important for practitioners to take the time to use this tool properly. In addition, practitioners could benefit from reviewing pertinent material (eg, user manuals and relevant publications) on neurocognitive testing administration and interpretation. This information will not only help them interpret and understand the scores but will also place them in a position to educate and help the concussed athlete understand the meaning of the scores. Such knowledge could also enhance communication and adherence to further clinical recommendations made by medical professionals. Future researchers should focus on expanding and improving educational efforts for practitioners using neurocognitive

testing as well as other tools (eg, symptom checklists and postural assessments) in the management of sport-related concussion.

REFERENCES

1. Guskiewicz KM, Bruce SL, Cantu R, et al. National Athletic Trainers' Association position statement: management of sports-related concussion. *J Athl Train.* 2004;39(3):280–297.
2. Barth JT, Alves W, Ryan T, et al. Mild head injury in sports: neuropsychological sequelae and recovery of function. In: Levin H, Eisenberg H, Benton A, eds. *Mild Head Injury*. New York, NY: Oxford University Press; 1989:257–275.
3. Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA.* 1999;282(10):964–970.
4. Erlanger D, Kutner KC, Barth JT, Barnes R. Neuropsychology of sports-related head injury: dementia pugilistica to post concussion syndrome. *Clin Neuropsychol.* 1999;13(2):193–209.
5. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train.* 2001;36(3):263–273.
6. Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 1st International Symposium on Concussion in Sport, Vienna 2001. *Clin J Sport Med.* 2002;12(1):6–11.
7. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med.* 2005;39(4):196–204.
8. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006;21(5):375–378.
9. Concussion (mild traumatic brain injury) and the team physician: a consensus statement. *Med Sci Sports Exerc.* 2006;38(2):395–399.
10. Erlanger D, Saliba E, Barth JT, Almquist J, Webright W, Freeman J. Monitoring resolution of postconcussion symptoms in athletes: preliminary results of a Web-based neuropsychological test protocol. *J Athl Train.* 2001;36(3):280–287.
11. Van Kampen DA, Lovell MR, Pardini JE, Collins MW, Fu FH. The “value added” of neurocognitive testing after sports-related concussion. *Am J Sports Med.* 2006;34(10):1630–1635.
12. Lovell MR, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil.* 1998;13(2):9–26.
13. Hinton-Bayre AD, Geffen GM, Geffen LB, et al. Concussion in contact sports: reliability change indices of impairment and recovery. *J Clin Exp Neuropsychol.* 1999;21(1):70–86.
14. *Immediate Post-Concussion Assessment Cognitive Testing* [computer program]. Version 6.0. Pittsburgh, PA: NeuroHealth Systems; 2006.
15. Iverson GL, Lovell MR, Collins MW. Interpreting change on ImPACT following sport concussion. *Clin Neuropsychol.* 2003;17(4):460–467.
16. Cantu RC, Voy R. Second impact syndrome: a risk in any contact sport. *Physician Sportsmed.* 1995;23(6):27–34.
17. Lovell MR. Clinical Interpretation Manual. ImPACT Web site. <http://www.impacttest.com/interpretation.php>. Accessed June 6, 2008.
18. Barnes BC, Cooper L, Kirkendall DT, McDermott TP, Jordan BD, Garrett WE Jr. Concussion history in elite male and female soccer players. *Am J Sports Med.* 1998;26(3):433–438.
19. Boden BP, Kirkendall DT, Garrett WE Jr. Concussion incidence in elite college soccer players. *Am J Sports Med.* 1998;26(2):238–241.
20. Covassin T, Swanik CB, Sachs ML. Epidemiology considerations of concussions in NCAA athletes. *Appl Neuropsychol.* 2003;10(1):12–22.
21. Powell JW, Barber-Foss KD. Traumatic brain injury in high school athletes. *JAMA.* 1999;282(10):958–963.
22. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train.* 2007;42(2):311–319.

23. Lovell MR, Collins MW, Iverson GL, Johnston KM, Bradley JP. Grade 1 or “ding” concussions in high school athletes. *Am J Sports Med.* 2004;32(1):47–54.
24. Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *J Pediatr.* 2003;142(5):546–553.
25. Ferrara MS, McCrea M, Peterson CL, Guskiewicz KM. A survey of practice patterns in concussion assessment and management. *J Athl Train.* 2001;36(2):145–149.
26. Notebaert AJ, Guskiewicz KM. Current trends in athletic training practice for concussion assessment and management. *J Athl Train.* 2005;40(4):320–325.

Tracey Covassin, PhD, ATC; Robert J. Elbin III, MA; and Jennifer L. Stiller-Ostrowski, PhD, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Anthony P. Kontos, PhD, contributed to analysis and interpretation of the data and critical revision and final approval of the article.

Address correspondence to Tracey Covassin, PhD, ATC, 105 IM Sports Circle, Michigan State University, East Lansing, MI 48823. Address e-mail to covassin@msu.edu.