Minor traumatic brain injuries – what is new?

Minor traumatic brain injuries have been the topic of an extensive body of literature in recent years.

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Research has concentrated on indications for neuroimaging, management guidelines for sports-related concussion and sequelae of minor traumatic brain injuries (mTBIs). Despite the emergence of several guidelines there is little agreement on several important issues, including the definition of mTBIs and concussion. There is even less consensus on the management of mTBIs in children.

It was thought that guidelines formulated for adults could be extended to children, but evidence is emerging that children may react differently when sustaining a TBI.[1] Children are more prone to sustaining a TBI. The disastrous, but fortunately rare, complication of diffuse cerebral swelling that may occur after mTBI is described only in children. Children recover at a slower pace than adults after an mTBI. If they are under the age of 2 the usual signs and symptoms of TBI are more difficult to assess, and in one series half of the infants who sustained an intracerebral injury were asymptomatic.[2]

Children recover at a slower pace than adults after an mTBI.

Definitions

Most authorities define an mTBI in terms of the level of consciousness at the time of presentation after satisfactory resuscitation. TBIs that occur in patients with a Glasgow Coma Scale (GCS) of 13 or more are mTBIs. The most commonly used definition of a concussion is that of the American Academy of Neurology: 'A trauma-induced alteration in mental status that may or may not involve loss of consciousness (LOC).'[3] Although mTBIs and concussion are often used interchangeably, the term concussion should be reserved for a patient with a 'rapid onset of short-lived impairment of neurological function that resolves spontaneously'.[4]

The 2nd International Conference on Concussion in Sport (ICCS) distinguished between simple concussion, where the symptoms resolve over 7 - 10 days, and complex concussion.[3] This distinction was however abandoned by the recently held 3rd ICCS as being too simplistic.[4] The conference panel stressed that 80 - 90% of concussions in adults resolve within 7 - 10 days, although recovery times in children 'may be longer'.

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Identifying the child at risk

Intracerebral injuries are uncommon in children with mTBI. Significant injuries occur in 1 - 3% of children hospitalised for mTBI,[5] and neurosurgery is required in less than 0.5%.[6] Prompt

recognition of such children is important as early operation, where indicated, improves prognosis. Although some researchers have advocated a policy of computered tomography (CT) scanning in all children with TBIs,[7] except in those with very minor TBIs, this is undesirable, because:

- CT scanning in this age group often requires procedural sedation. This in itself is associated with adverse effect rates of 0 - 31%[8] when performed by non-anaesthetists outside of theatre. Although the majority of these are minor and reversible, fatalities and permanent neurological injury have been reported.[9]
- Concerns have been raised about the oncogenic effect of CT scanning. The lifelong risk of fatal cancer rises exponentially with decreasing age at CT scan, and for a 1-year-old has been calculated as 0.07% for a CT scan of the head.[10] This would imply that, with a policy of performing CT scans on all children with mTBI who require admission, for every 7 significant intracerebral injuries diagnosed 1 fatal cancer would be induced.

It has been estimated that more than half of all concussions are sports related.

The question therefore arises whether children at low risk of intracerebral injury cannot be recognised on a basis of clinical signs and symptoms. Teasdale *et al.*,[11] in a study from the pre-CT scan era, concluded that the main risk factors for intracerebral pathology were an altered level of consciousness and a skull fracture, with a risk of 1 in 12 in the presence of both factors, and of 1 in 13 000 in their absence. The last decade has seen the development of a large number of decision rules for head-injured adults[12-14] and children.[5,15-19] The decision rules differ in the importance they assign to various signs and symptoms, and in whether a positive rule will directly indicate CT scanning or whether a skull radiograph should be done first. A comparison of the decision rules for children highlights a number of unresolved issues:

- What is the significance of LOC? Should every patient with LOC be scanned (PECARN (Pediatric Emergency Care Applied Research Network))? If not, what is a significant period for LOC (5 minutes, CHALICE (Children's Head Injury Algorithm)), or is a history of LOC insignificant (CATCH rule (Clinical Decision Rule for the Use of Computed Tomography of the Head))? Dunning *et al.*,[20] in a meta-analysis of variables that predict significant intracerebral injury in mTBI, found that a history of LOC was associated with a relative risk ratio of 2.23. In a study of 22 772 children with head injuries they found that LOC of more than 5 minutes had a positive predictive value of 0.45.[5] However, inclusion of LOC in the decision rule (CHALICE, PECARN) does not increase the sensitivity of the rule over those decision rules that omit LOC (CATCH, NEXUS II study (National Emergency X-Radiography Utilization II Study)).
- Is there still a role for skull radiographs in children with mTBI? The presence of a skull fracture is associated with a relative risk ratio for intracerebral injury of 6.13.[20] This raises the question whether one should actively search for a skull fracture. The American Academy of Pediatrics, in their 1999 statement on mTBI, argued that skull radiographs should only be employed where CT scanning is unavailable. With the concerns raised about the cancer risk of CT scanning, others, however, have argued for using skull radiographs in otherwise asymptomatic children with a scalp haematoma after mTBI as a way of reducing CT scanning, particularly in those under 2 years of age.[20,21]
- Is vomiting after a head injury an indication for head imaging? Although all decision rules consider (repeated) vomiting an indication for neuroimaging, there seems to be scanty evidence for this. Dunning *et al.*,[20] in their meta-analysis and own research,[5] found no relationship between vomiting and intracranial injuries. There seems to be little evidence to retain vomiting as an indication for CT scanning. Furthermore, injured children have a higher tendency to vomit than older patients.
- In which children are scalp haematomas a reason for head imaging? Greenes and Schutzman,[2] in a prospective study of children up to 2 years with mTBI, observed that 14 of 30 (48%) children with intracerebral injury had no signs or symptoms of such injury. Thirteen of these children, however, had a significant scalp haematoma with an underlying skull fracture. In a follow-up study[21] they identified parietal and temporal haematoma as high, occipital haematoma as moderate, and frontal haematoma as no risk.

In Durban we use the following indications for CT scanning: GCS ≤14 with either a skull fracture or focal neurological signs; a fixed dilated pupil; a scalp haematoma in children under 2 years old; and any decrease in GCS. GCS ≤14, skull fractures or neurological symptoms, coagulopathy and suspicion of non-accidental injury are indications for admission.

Eighty to ninety per cent of patients suffering a minor head injury will recover within 7 - 10 days.

Concussion in sport

Much of the recent discussion around mTBI has centred around sport-related concussion. The ICCS in 2001, 2004[3] and 2008[4] is the leading authority in the field. It has been estimated that more than half of all concussions are sports related.[6] Most of the research deals with return-to-play guidelines for professional athletes and the role of neuropsychological testing in such decisions. Only in its 2009 statement did the ICCS identify children as a separate group, and advised that all athletes, whether professional or not, should be treated similarly.

Return-to-play guidelines (whether they concern a professional athlete returning to match fitness, or a schoolchild returning to full school participation) are important, as returning too early may have the following untoward and occasionally disastrous consequences:

- Full and speedy recovery of a concussed child may be delayed, as they need physical and cognitive rest.
- Cognitive sequelae of concussion, such as difficulty in concentrating and slow reaction times, expose concussed children to a higher risk of further injury.
- Repeated injuries may have a cumulative effect.
- Concern has been raised in the literature that a second head impact while a child is recovering from concussion may cause massive brain oedema with a high fatality rate, the so-called 'second impact syndrome'. Although this disease entity is controversial,[22] children who are recovering from a concussion are more vulnerable to sustaining a second TBI. Any TBI in a child, however minor, can cause diffuse brain oedema.

Diagnosis of concussion

The first requirement for management of concussion is making the diagnosis. A period of LOC is not necessary for the diagnosis, and concussion, post-concussional syndromes and intracranial injuries have all been described in patients who have never experienced LOC. The symptoms of concussion are described in the following three groups:[1]

- Cognitive problems: Impairment of short memory, amnesia, confusion, LOC. Short, intermediate and long-term memory are tested using standardised questions, such as the modified Maddox questions, i.e.: At what venue are we? Which half is it? Who scored last? What team did we play last? Did we win the last game?
- Physical symptoms: Headache, nausea and vomiting, dizziness, visual disturbances (seeing stars, double vision), ringing in the ears and feeling stunned.
- Physical signs: Decreased level of consciousness, poor co-ordination or balance, seizures, slowness in answering questions or obeying commands, poor concentration, inappropriate emotions, vomiting, slurred speech, and inappropriate or decreased play.

Decisions as to whether a player has concussion and must be taken off the field often have to be made on the sideline in less than ideal circumstances. Therefore the ICCS has developed a diagnostic tool, i.e. the Sports Concussion Assessment Tool (SCAT).[23]

Early management of concussion

Eighty to ninety per cent of patients suffering a minor head injury will recover within 7 - 10 days. Children may take somewhat longer, but the majority should have recovered within 3 weeks.[6] The mainstay of the management of minor brain injury is education, cognitive rest and allowing time for the brain to recover.[23]

- Any activity will exacerbate symptoms and prolong recovery. Physical activity should therefore be restricted to walking about the house. Cognitive rest should be strict and such activities as reading, watching television, playing video games and communicating via sms should be avoided. This should be continued until the child is symptom free.
- Education, in the form of explanation and reassurance to the child and its caregivers, in combination with providing symptom-related-information, has been shown to help families cope better with sequelae of the head injury and to speed up recovery.[24,25]
- Pharmacological treatment of concussion-related symptoms such as headaches should be avoided. Comper *et al.*,[26] in a review of pharmacological studies of mTBI, concluded that they have 'failed to produce solid evidence that any specific drug treatment is effective for one or more symptoms of mTBI'. Although there have been early reports of the effectiveness of sertraline in the management of concussion-related depression, and of dihydro-ergotamine for the management of concussion-related headaches, it requires confirmation in large randomised controlled trials.
- Graduated return to activity. There has been a move from standard return-to-play protocols to an individualised approach. The graduated return-to-play protocol advocated by the ICCS involves 6 steps: no activity, light aerobic activity, sport-specific exercise, non-contact training drills, full-contact practice and return to play.[4] Adult athletes progress to the second stage when they are completely symptom free. If they remain symptom free, they move to the next stage after 24 hours, and so on. In this manner they return to full play after about 1 week. If, however, symptoms recur during one of the stages, the athlete drops back to the previous stage, and progression is attempted again after another 24 hours. Children and adolescents are expected to progress more slowlt than adults, and it is recommended to increase the length of asymptomatic rest and of graded exertion. Children should never be allowed back on the playing field on the day they had a concussion.

Management of the concussed child

The 3rd ICCS abandoned the differentiation between simple and complex concussions. Instead, it introduced the concept of 'Modifying factors in concussion management'.[4] Such factors include duration of symptoms over 10 days, initial LOC of more than 1 minute, seizures, repeated concussions, children and adolescents, pre-morbid conditions (migraine, attention deficit hyperactivity disorder (ADHD), sleep disorders), anticoagulation use, dangerous style of play, and high-risk sport. In such patients additional investigations such as neuropsychological testing and balance assessment may be considered. It is also advisable that these patients be referred to a sports physician or neurologist for management. Children are thus automatically classified as having modifying factors.

Balance testing has been recommended as a sensitive indicator of recovery.[23] Although this can be accomplished using sophisticated equipment such as the Neurocom Smart Balance Master, Gordon[6] simply recommends asking the child to pirouette 3 times while walking forward and then to carry on walking forward. Each 360° turn should be accomplished in 3 steps.

The mainstay of the management of minor brain injury is education, cognitive rest and allowing time for the brain to recover.

The role of neuropsychological testing, although well established in adult athletes, is still somewhat controversial in children and adolescents.[22,27] Between the ages of 9 and 15 children's cognitive abilities improve rapidly, making baseline testing essential every 6 - 12 months. Comparison of the performance of South African children with internationally established norms-for-age requires validation before they can be relied on in clinical practice. Although neuropsychological and balance testing is desirable in children, particularly as cognitive recovery may lag behind resolution of physical symptoms, it is advisable that neuropsychological testing in children and adolescents be performed by a psychologist or sports physician experienced in the technique and its interpretation. We recommend that it be used wherever possible. In children in whom neuropsychological testing is not feasible, a more conservative return-to-play approach should be followed.[4]

References

1. McCrory P, Collie A, Anderson V, Davis G. Can we manage sports-related concussion in children the same as in adults? *Br J Sports Med* 2004; 38: 516-518.
2. Greenes D, Schutzman S. Clinical indicators of intracranial injury in head-injured infants. *Pediatrics* 1999; 104: 861-867.
3. McCrory P, Johnston K, Meeuwisse W, *et al.* Summary and Agreement of the 2nd International Conference on Concussion in

Sport, Prague 2004. *Br J Sports Med* 2005; 39: 196-202.

4. McCrory P, Johnston K, Meeuwisse W, *et al.* Consensus Statement on Concussion in Sport – 3rd International Conference on Concussion in Sport, Zurich, November 2008. *J Sci Med Sport* 2009; 12: 340-351.
5. Dunning J, Daly JP, Lomas JP, *et al.* Derivation of the children's head injury algorithm for the prediction of important clinical events decision rule for head injury in children. *Arch Dis Child* 2006; 91: 885-891.
6. Gordon K. Pediatric minor traumatic brain injury. *Semin Neurol* 2006; 13: 243-255.
7. Halley MK, Silva PD, Foley J, Rodarte A. Loss of consciousness: when to perform computed tomography? *Pediatr Crit Care Med* 2004; 5: 230-233.
8. Twite MD, Friesen RH. Pediatric sedation outside the operating room: the year in review. *Curr Opin Anaesth* 2005; 18: 442-446.
9. Coté CJ, Notterman DA, Karl HW, Weinberg JA, McCloskey C. Adverse sedation events in pediatrics: a critical incident analysis of contributing factors. *Pediatrics* 2000; 105: 805-814.
10. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimated risk of radiation-induced fatal cancer from pediatric CT. *Am J Radiol* 2001; 176: 289-296.
11. Teasdale GM, Murray G. Anderson E, *et al.* Risks of acute traumatic intracranial hematoma in children and adults: implications for managing head injuries. *Br Med J* 1990; 300: 363-367.
12. Haydel MJ, Preston CA, Mills TJ, *et al.* Indications for computed tomography in patients with minor head injury. *N Engl J Med* 2000; 343: 100-105.
13. Stiell IG, Wels GA, Vanderheen K, *et al.* The Canadian CT head rule for patients with minor head injury. *Lancet* 2001; 357: 1391-1396.
14. Smits M, Dippel DWJ, Steyerberg EW, *et al.* Predicting intracranial traumatic findings on computed tomography in patients with minor head injury: the CHIP prediction rule. *Ann Intern Med* 2007; 146: 397-405.
15. Atabaki SM, Stiell IG, Bazarian JJ, *et al.* A clinical decision rule for cranial computed tomography in minor pediatric head trauma. *Arch Pediatr Adolesc Med* 2008; 162: 439-445.
16. Beaudin M, Saint-Vil D, Quimet A, *et al.* Clinical algorithm and resource use in the management of children with minor head trauma. *J Pediatr Surg* 2007; 42: 849-852.
17. Kuppermann N, Holmes JF, Dayan PS, *et al.* Identification of children at very low risk of clinically important brain injuries after head trauma: a prospective cohort study. *Lancet* 2009; 374: 2260-2269.
18. Oman JA, Cooper RJ, Holmes JF, *et al.* Performance of a decision rule to predict need for computed tomography among children with blunt head trauma. *Pediatrics* 2006; 117: e238-e246.
19. Osmond MH, Klassen TP, Stiell IG, Correll R. The CATCH rule: a clinical decision rule for the use of computed tomography of the head in children with minor head injury. *Acad Emerg Med* 2006; 13: S11.
20. Dunning J, Bachelor J, Stradford-Smith P, *et al.* A meta-analysis of variables that predict significant intracranial injury in minor head trauma. *Arch Dis Child* 2004; 89: 653-659.
21. Greenes D, Schutzman S. Clinical significance of scalp abnormalities in asymptomatic head-injured patients. *Pediatr Emerg Care* 2001; 17: 88-92.
22. McCrory P. Does second impact syndrome exist? *Clin Sports Med* 2001; 11: 144-149.
23. Hunt T, Asplund C. Concussion assessment and management. *Clinics in Sports Management* 2010; 29: 5-17.
24. Falk A-C, von Wendt L, Klang B. Informational needs in families after their child's mild head injury. *Patient Education and Counseling* 2007; 70: 251-255.
25. Ponsford J. Rehabilitation interventions after mild head injury. *Curr Opin Neurol* 2008; 18: 692-697.
26. Comper P, Bisschop SM, Carnide N, Tricco SA. A systematic review of treatments for mild traumatic brain injury. *Brain Injury* 2005; 19: 863-880.
27. Purcell L. What are the most appropriate return-to-play guidelines for concussed child athletes? *Br J Sports Med* 2009; 43: i51-i55.

In a nutshell

- Children are more prone to developing TBIs than adults, and recover more slowly.
- Even minor concussion without LOC may be followed by a period of physical and cognitive dysfunction, which may last up to 3 weeks.
- Children with a GCS ≤14 and a skull fracture or focal neurological signs, with a fixed dilated pupil, children under 2 years of age with a scalp haematoma, and any child with a decrease in GCS should immediately have a CT scan.
- Any child with a GCS ≤14, a skull fracture, focal neurological signs, coagulopathy or suspicion of child abuse should be admitted.
- The cornerstones of management of mTBI are physical and cognitive rest, education and allowing time for the brain to recover.
- The use of medications should be avoided in concussed children.
- Return to play or return to school of a concussed child should be graded.
- Neuropsychological and balance testing should be considered in any child recovering from a concussion.