European Journal of Neurology 2012, 19: 191–198 doi:10.1111/j.1468-1331.2011.03581.x

EFNS GUIDELINES/CME ARTICLE

Mild traumatic brain injury

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Keywords:
guideline, mild traumatic brain injury

Received 27 September 2011
Accepted 29 September 2011

Traumatic brain injury (TBI) is one among the most frequent neurological disorders. Of all TBIs 90% are considered mild with an annual incidence of 100–300/100 000. Intracranial complications of mild traumatic brain injury (MTBI) are infrequent (10%), requiring neurosurgical intervention in a minority of cases (1%), but potentially life threatening (case fatality rate 0.1%). Hence, a true health management problem exists because of the need to exclude the small chance of a life-threatening complication in a large number of individual patients. The 2002 EFNS guideline used the best evidence approach based on the literature until 2001 to guide initial management with respect to indications for computed tomography (CT), hospital admission, observation and follow-up of MTBI patients. This updated EFNS guideline for initial management in MTBI proposes a more selective strategy for CT when major [dangerous mechanism, Glasgow Coma Scale (GCS) < 15, 2 points deterioration on the GCS, clinical signs of (basal) skull fracture, vomiting, anticoagulation therapy, post-traumatic seizure] or minor (age, loss of consciousness, persistent anterograde amnesia, focal deficit, skull contusion, deterioration on the GCS) risk factors are present based on published decision rules with a high level of evidence. In addition, clinical decision rules for CT now exist for children as well. Since 2001, recommendations, although with a lower level of evidence, have been published for clinical observation in hospitals to prevent and treat other potential threats to the patient including behavioural disturbances (amnesia, confusion and agitation) and infection.

Introduction

Traumatic brain injury (TBI) caused by sudden impact or acceleration deceleration trauma of the head is among the most frequent neurological disorders [1]. The acute phase of mild traumatic brain injury (MTBI) is characterized by a 10% risk for intracranial abnormalities like contusion, subdural or epidural haematoma, brain swelling, subarachnoid haemorrhage, or pneumocephalus; a low risk (1%) of life-threatening intracranial haematoma that needs immediate neurosurgical operation both in adults and in children; and a very low mortality of 0.1% in adults and even lower in children [2,3]. Early management in MTBI deals with the recognition and immediate medical treatment of physiological parameters that may worsen brain pathology. Key to the acute management of MTBI patients is the recognition of clinical signs and symptoms (risk factors) that increase the likelihood of intracranial haematoma that need neurosurgical operation. In 2002, the EFNS guideline on early management in MTBI was published. MTBI was defined as patients with head injury and a Glasgow Coma Scale (GCS) 13–15 (see Table 1 for classification). This guideline was largely based on two formal evidence-based clinical decision rules [4,5]. In the 2002 EFNS guideline, risk factors were defined as those that are associated with intracranial abnormalities including life-threatening haematoma, which resulted in a set of rules for diagnostic imaging, observation and follow-up of patients.

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Edited by N. E. Gilhus, M. P. Barnes and M. Brainin © 2011 Blackwell Publishing Ltd. ISBN: 978-1-405-18533-2

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EUROPEAN JOURNAL OF NEUROLOGY
THE OFFICIAL JOURNAL OF THE EUROPEAN FEDERATION OF NEUROLOGICAL SOCIETIES

Table 1 Classification of traumatic brain injury and indication for immediate head CT

Classification	Characteristics	Indication for immediate head CT[a]
Mild	Hospital admission GCS = 13–15 Loss of consciousness if present 30 min or less	
Category		
1	GCS = 15 No risk factors or only 1 minor risk factor present (CHIP rule) Head injury, no TBI	No
2	GCS = 15 With risk factors: ≥1 major risk factor(s) or ≥2 minor risk factors (CHIP rule)	Yes
3	GCS = 13–14	Yes
Moderate	GCS = 9–12	Yes
Severe	GCS ≤ 8	Yes
Critical	GCS = 3–4, with loss of pupillary reactions and absent or decerebrate motor reactions	Yes

[a]Major and minor risk factors for indication of immediate head CT in MTBI are shown in Table 2.
GCS, Glasgow Coma Scale; TBI, traumatic brain injury; CHIP, CT in head injury patients.

Since the appearance of the EFNS guideline new data have been published. Results of an independent Dutch multicentre study on 3181 patients with MTBI demonstrated that the EFNS guideline has 100% sensitivity for the detection of intracranial abnormalities after MTBI [6]. Despite this convincing result from the patient safety perspective, it was also concluded that the specificity of the EFNS guideline is low and that the number of patients needed to be scanned to detect abnormalities is very high.

These limitations form an important reason to update and refine the EFNS guideline; and there have also been reports that caution against the liberal use of computed tomography (CT) because of an increase in lifetime cancer mortality risks attributable to radiation from CT [7]. Second, healthcare costs form a concern in MTBI. A restrictive use of CT compared to the current guideline has been propagated. Selecting patients with MTBI for CT, i.e. ordering a CT less frequently, may be cost-effective as long as the sensitivity of such procedures for the identification of patients who require neurosurgery remains high.

In this version, based on new publications since 2001, we present updated guidelines for early management in MTBI with respect to the indication for CT and early management (admission, clinical observation and follow-up).

Search strategy

A systematic search of the English literature in the MEDLINE, EMBASE, Cochrane database (2001–2009) using the key words minor head injury, mild head injury, mild traumatic brain injury, traumatic brain injury, guidelines and management. Additional articles were identified from the bibliographies of the articles retrieved, and from textbooks. Articles were included if they contained data on classification system used (i.e. admission GCS 13–15) and outcome data (CT abnormalities, need for neurosurgical intervention, mortality) or management. Articles judged to be of historical value and existing (new) guidelines were also included and reviewed for useful data. Where appropriate, a classification of evidence level was given for interventions, diagnostic tests and grades of recommendation for management according to the neurological management guidelines of the EFNS [8]. Where there was a lack of evidence but consensus was clear we have stated our opinion as Good Practice Points (GPP).

Clinical decision rules for CT

Adults

The 2002 version of the EFNS guideline, which weighed heavily on two prospective Class I/II studies, offered a decision rule for use of CT to demonstrate the need for neurosurgical intervention or clinically important brain injury after MTBI [4,5,9]. It was subsequently demonstrated that the EFNS guideline compared to other existing guidelines has a high sensitivity for the identification of patients with clinical relevant traumatic findings at CT [6,10]. In addition, the EFNS guideline confirmed that in patients with MTBI the use of CT can be safely limited to those who have certain clinical findings. The generalizability and reliability of existing guidelines and prediction rules is in general lower than those described in the original studies as was demonstrated in an independent sample of 1101 patients evaluating 11 existing guidelines [10]. For an overview of the risk factors used in existing guidelines rules and studies from which they were derived, see Table 2. The sensitivity of the original studies forming the basis for the guidelines after external validation amounts to 85–100% for neurosurgical intervention and 85–96% for clinical important findings [10,11].

Conclusion

Various prediction rules that employ different risk factors have high sensitivity and low specificity for clinically relevant intracranial abnormalities and the need for neurosurgical operation (Evidence Level I).

Table 2 Overview of prediction rules/guidelines for the detection of intracranial lesions and need for neurosurgical operation after MTBI in adults

Risk factor	EFNS 2002	NOC	CCHR	CHIP	NICE	NEXUS II
	GCS = 13–15 guideline	LOC GCS = 15 n = 909	LOC or PTA GCS = 13–15 n = 3121	GCS = 13–14 GCS = 15 + risk factor n = 3181	GCS = 13–15 guideline	Blunt head trauma
History						
Age	+	+ (>60 year)	+ (>65 year)	+ (>60 year) or minor (40–60 year)	+ (>65 year, if LOC)	>65
Loss of consciousness	+	Inclusion	Inclusion	Minor	–	
Headache	+	+	–	–		
Vomiting	+	+	+ (>2)	+	+ (>1)	+
Post-traumatic seizure	+	+	Excluded	+	+	
Dizziness						
Pre-traumatic seizure	–	–	–	–	–	
Anticoagulation therapy	+	–	Excluded	+	+ if LOC	+
Examination						
GCS score < 15	+	Excluded	+ (at 2 h post injury)	+	+ (2 h post injury)	+
Suspicion of open or depressed skull fracture	+	+	+	+	+	+
Clinical signs of basal skull fracture	+	+	+	+	+	+
Clinical signs of skull fracture	+	+	+	+	–	
Intoxication	+	+	–	–	–	
Persistent anterograde amnesia	+	+	–	Minor	–	+
Focal neurologic deficit	+	Excluded	Excluded	Minor	+	+
Retrograde amnesia	+	–	+ (>30 min)	–	+ (>30 min)	
Contusion of the skull		+	–	Minor		
Signs of facial fracture	+	+	–	–	–	
Contusion of the face	–	+	–	–	–	
GCS score deterioration	+	–	+	+ (>2 pts) or minor (1 pt)	–	
Prolonged PTA	+	–	+	+ (>4 h) or minor (2 to <4 h)		
Multiple injuries	+	–	–	–	–	
Mechanism						
Dangerous mechanism[a]	–	–	+	+	+ if LOC	
High-energy trauma	+	–	–	–	–	
Unclear trauma mechanism	+	–	–	–	–	

Continued post-traumatic amnesia is defined as a GCS verbal reaction of 4 and hence the GCS is by definition <15. High-energy (vehicle) accident in EFNS defined as initial speed >64 km/h, major auto-deformity, intrusion into passenger compartment >30 cm, extrication time from vehicle >20 min, falls >6 m, roll-over, auto-pedestrian accidents, or motor cycle crash >32 km/h or with separation of rider and bike [26,34].
[a]Dangerous mechanism in CHIP defined as ejected from vehicle, pedestrian or cyclist versus vehicle. Neurosurgery defined in EFNS as: death within 7 days, craniotomy, elevation of skull fracture, intracranial pressure monitoring or intubation for head injury; in NOC as craniotomy, or placing of monitoring bolt; in CCHR as death or craniotomy; in CHIP as craniotomy, elevation of depressed skull fracture, ICP monitoring. In NEXUS-II intracranial injury was defined as mass effect or sulcal effacement, signs of herniation, basal cistern compression or midline shift, substantial epidural or subdural haematomas (>1 cm in width, or causing mass effect), substantial cerebral contusion (>1 cm in diameter, or more than one site), extensive subarachnoid haemorrhage, haemorrhage in the posterior fossa, intraventricular haemorrhage, bilateral haemorrhage of any type, depressed or diastatic skull fracture, pneumocephalus, diffuse cerebral oedema, or diffuse axonal injury.
GCS, Glasgow Coma Scale; LOC, loss of consciousness; EFNS, European Federation of Neurological Societies; NOC, New Orleans Criteria; CCHR, Canadian Closed Head Injury Rule; CHIP, CT in head injury patients; NICE, National Institute of Clinical Excellence.

Recommendation

Protocols for initial management in MTBI should include a decision scheme or prediction rule algorithm for the use of CT after MTBI (Grade A recommendation).

Children

A quarter of all patients presenting to emergency departments are children. Until recently no formal prediction rule existed for the selection of children with head

injury at risk for intracranial abnormalities. So it was questioned if in young patients with MTBI prediction rules originally developed for adults may apply. In a preliminary study, Haydel and Shembekar [12] determined whether or not a clinical decision rule developed for adults could be used in children aged 5 years and older with MTBI and a normal consciousness. In 175 patients aged 5–17 years with minor head injury (defined as normal GCS or modified GCS in infants, plus normal brief neurological examination) and loss of consciousness (LOC), the presence of six clinical variables: headache, vomiting, intoxication, seizure, short-term memory deficits and physical evidence of trauma above the clavicles, was assessed. CT was obtained for all patients. Fourteen (8%) patients had intracranial injury or depressed skull fracture on CT. The presence of any of the six criteria was significantly associated with an abnormal CT scan result ($P < 0.05$) and was 100% [95% confidence interval (CI) 73–100%] sensitive for identifying patients with intracranial injury. Use of this clinical decision rule previously validated in adults could safely reduce CT use by 23% in the paediatric population older than 5 years of age with a normal consciousness at the emergency department (ED) (Evidence Level II).

In 2006 and 2009, two large studies appeared (involving more than 60 000 patients) that demonstrated that in children, as in adults, use of prediction rules in the selection of CT to detect life-threatening haematoma is feasible [3,13].

The CHALICE study, a prospective multicentre diagnostic cohort study, aimed to provide a rule for selection of high-risk children with head injury for CT scanning and included all children presenting to the EDs of 10 hospitals [13]. From 40 clinical variables, defined from the literature, 14 were appointed prior to the study. Presence of one of these variables would require a CT. Of 22 772 patients with any severity of head injury that were evaluated, 96.6% had a GCS of 15 at hospital admission [13]. Clinically significant head injury was defined as death, need for neurosurgical intervention, or abnormality on a CT scan. Recursive partitioning was used to create a highly sensitive rule for the prediction of significant intracranial pathology. Of the study population 56% were younger than 5 years. In 766, a CT scan was carried out, of which 281 (37.7%) showed a traumatic abnormality, 137 had a neurosurgical operation and 15 died. The Chalice rule was 98% (95% CI 96–100) sensitive and 87% (95% CI 86–87) specific for the prediction of clinically significant head injury. With this rule the CT scan rate would be 14%. Although a highly sensitive clinical decision rule was derived for the identification of children who should undergo CT scanning after head injury, the rule has not been externally validated yet. A potential weakness of this study is that only patients who had a skull radiograph or CT, were admitted to hospital, or underwent neurosurgery were followed up. However, to minimize the chance of missing a poor outcome in those not followed up endpoints were verified indirectly via collection of data collected in the participating centres and two tertiary hospitals separately on every child who had a skull radiograph or CT of the brain. In addition, hospitals prospectively collected data on patients who were admitted, underwent neurosurgery, or stayed in the intensive care unit or neurorehabilitation unit from 12 centres. These data were then cross-checked with those in the study database. Finally, to verify unexpected poor outcome in patients at low risk for important injury, the Office of National Statistics provided the investigators with details of children who died, in whom head injury was any part of the cause of death.

The Chalice rule describes criteria for use of CT that may be applicable in all children 0–17 years of age, criteria yielding a high sensitivity of 97.6% (CI: 94–99.4) in those with a GCS of 13–15 (Evidence Level I).

A second study aiming to identify children at low risk of clinically important traumatic brain injuries for whom CT might be unnecessary, enrolled 42 412 patients younger than 18 years with a GCS of 14–15 [3]. CT scans were obtained on 14 969 (35.3%), 376 (0.9%) had clinically significant head injury (death from traumatic brain injury, neurosurgery, intubation >24 h, or hospital admission $\geq$2 nights), and 60 (0.1%) underwent neurosurgery. Prediction rules were derived and validated separately in children younger than 2 years and for children 2–18 years, for death from traumatic brain injury, neurosurgery, intubation $>$ 24 h, or hospital admission $\geq$ 2 nights).

In 2216 children younger than 2 years (normal mental status, no scalp haematoma except frontal, no LOC or LOC for <5 s, non-severe injury mechanism, no palpable skull fracture and acting normally according to the parents) had a negative predictive value of 100% (95% CI 99.7–100) and sensitivity of 100% (86.3–100%). For children aged 2 years and older, in 6411 patients, a normal mental status, no LOC, no vomiting, non-severe injury mechanism, no signs of basilar skull fracture and no severe headache, yielded a negative predictive value of 99.95% (95% CI 99.81–99.99) and sensitivity of 96.8% (95% CI 89.0–99.6). Both rules identified all neurosurgical operations in the validation populations.

Recommendations

- In young patients with MTBI and a normal consciousness, prediction rules originally developed for adults may apply when they are 5 years of age or older (Grade C).

- In patients under 5 years of age, prediction rules for the need of CT to detect intracranial haematoma also apply but with a different set of risk factors, such as those applied in the Chalice study [13] or the North American [3] prospective cohort study (Grade A)
- In young patients under 5 years of age, CT is a gold standard for the detection of life-threatening (and other intracranial) abnormalities after MTBI (Grade B).
- In children under 2 years of age, a CT is not indicated if normal mental status, no scalp haematoma except frontal, no LOC or LOC for < 5 s, non-severe injury mechanism, no palpable skull fracture and acting normally according to the parents (Grade A).
- In children aged 2 years and older, a CT is not indicated if all apply: a normal mental status, no LOC, no vomiting, non-severe injury mechanism, no signs of basilar skull fracture and no severe headache (Grade A).

Initial patient management

According to the Advanced Trauma Life Support (ATLS) and Advanced Pediatric Life Support (APLS) guidelines, any patient with trauma should be evaluated for surgical trauma (Evidence Level III) [14]. Proper triage includes assessing the airways, breathing and circulation, and the cervical spine. A neurological examination is obligatory and should include level of consciousness, presence of anterograde or retrograde amnesia and/or disorientation, higher cognitive functions, presence of focal neurological deficit (asymmetrical motor reactions or reflexes, unilateral paresis or cranial nerve deficit), pupillary responses, blood pressure and pulse rate [15–17]. In addition, the presence of frontal lobe signs, cerebellar symptoms, or sensory deficits should be actively investigated. Accurate assessment of post-traumatic amnesia (PTA) is relevant to guide clinical decision-making. Although, despite the importance of PTA measurement, no gold standard for PTA assessment exists, use of formal PTA method is recommended (GPP). Existing methods to assess PTA include the Galveston Orientation and Amnesia Test [18], the (Modified) Oxford PTA Scale [19], the Westmead PTA Scale [20] and the Nijmegen PTA scale (Jacobs, van Ekert, Vernooy *et al.*, unpublished data).

Recommendation

Following acute TBI all patients should undergo urgent neurological examination, in addition to a surgical examination (preferably according to ATLS or APLS guidelines). Furthermore, accurate history taking (including medication), preferably with information being obtained from a witness of the accident or personnel involved in first-aid procedures outside the hospital, is important to ascertain the circumstances (mechanism of injury) under which the accident took place and to assess the duration of LOC and amnesia (GPP).

Home discharge

In MTBI, CT can also be used to decide if patients should be admitted or transferred to a neurosurgical centre or discharged home [4,9,11,16,21–23]. The majority of MTBI patients show normal CT scan findings [2,24]. It has been shown before that in patients with a GCS = 15 and no skull fracture the absolute risk of a haematoma is 1 in 7866 in adults and 1 in 12 559 in children (Evidence Level II) [25]. It may be assumed that CT, which is much more sensitive in the detection of intracranial haematoma than the skull X-ray, is a better instrument to select patients for home discharge. Indeed, in a review involving two prospective studies and 52 studies containing over 62 000 patients investigating the safety of early CT in MTBI, only three cases were deemed to have experienced an early adverse outcome despite a normal CT, a GCS = 15, and a normal neurological examination on initial presentation. Only eight cases were identified in which the interpretation was not clear [22]. The conclusion was that the evidence available shows that a CT strategy is a safe way to triage patients for admission (Evidence Level II).

In addition, a multicentre, pragmatic, non-inferiority randomized trial involving 2602 patients aged ≥6 with MTBI within the past 24 h, confirmed or suspected LOC or amnesia, or both, normal results on neurological examination and a GCS of 15, and no associated injuries that required admission, demonstrated that use of CT during triage is feasible and clinical outcomes are similar to those in patients admitted for observation (Evidence Level I) [23].

Recommendation

- Patients with MTBI and a normal neurological examination (including a GCS = 15), no risk factors (in particular a normal coagulation status, no drug or alcohol intoxication, no other injuries, no suspected non-accidental injury, no cerebrospinal fluid leak) and a normal CT could be observed at home and the patient is admitted only if some extracerebral cause occured. (Grade A).
- For children under 6 years of age who are discharged home from the ED, head injury warning instructions are recommended because of the likelihood of delayed cerebral swelling (GPP).

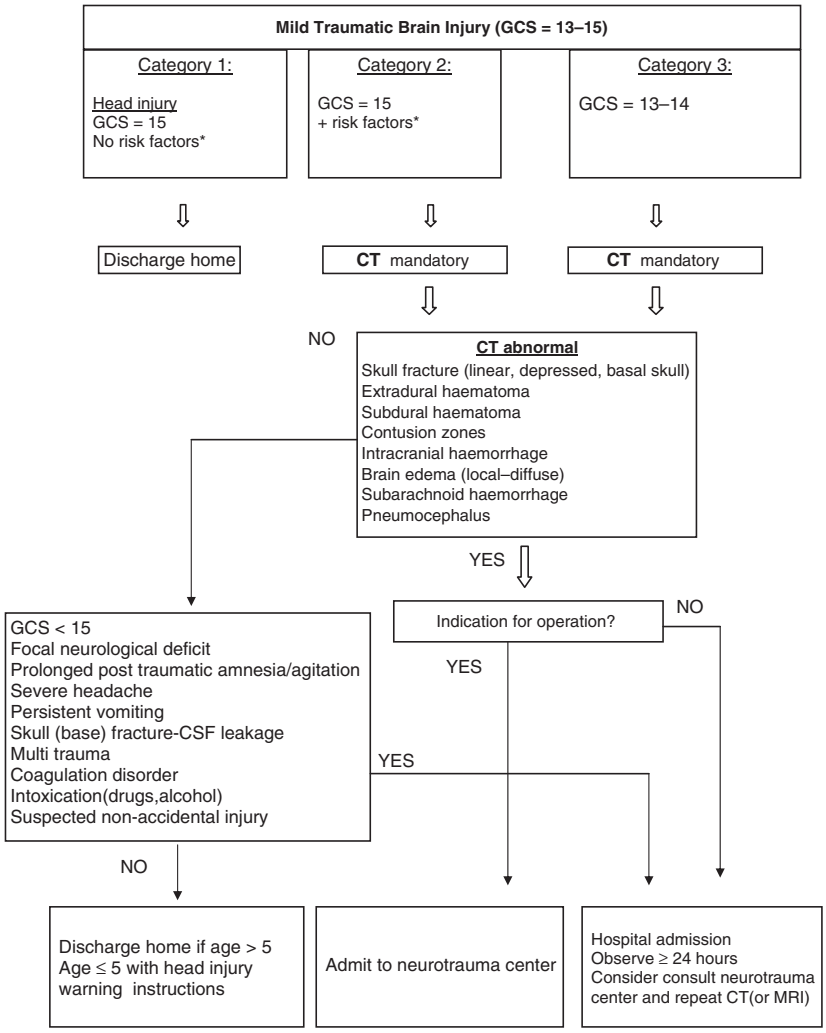

Figure 1 Decision scheme for initial management in Mild traumatic Brain Injury (modified from the Dutch and Scandinavian guidelines) [16,29] GCS, Glasgow Coma Scale; LOC, loss of consciousness; PTA, post-traumatic amnesia; TBI, traumatic brain injury; CT, computed tomography; MRI, magnetic resonance imaging. *Risk factors are shown in Table 2, no risk factor in CHIP rule includes only one minor risk factor.

- Patients with a new and clinically significant traumatic lesion on CT, GCS <15, focal neurological deficit, restlessness or agitation, intoxication with alcohol or drugs, or other extracranial injuries should be admitted to the hospital (Grade C).
- A repeat CT should be considered if the admission CT findings were abnormal or if risk factors are present (Grade C).

Clinical observation

All patients with a GCS <15, including continued PTA, coagulopathy, abnormal neurological examination or intracerebral abnormalities, should preferably be admitted to hospital for observation (Fig. 1). Most guidelines recommend an observation period of minimally 12–24 h [16,26–29]. The main goal of clinical observation is to detect, at an early stage, the development or worsening of extradural or subdural haematoma or diffuse cerebral oedema. A secondary goal is to determine the duration of PTA.

An extradural haematoma usually develops within 6 h, and thus the initial CT may be false-negative when performed very early (within 1 h) [30–32]. Therefore, repeated neurological observation (see above) is obligatory for the timely detection of clinical deterioration and other neurological deficits (such as sensory deficits, frontal lobe signs, cerebellar symptoms, etc).

Although no studies exist as to where patients with MTBI can be best admitted and in as far qualified personnel should carry out observations, the NICE guidelines recommend that in-hospital observation of

patients with a head injury should only be conducted by professionals competent in the assessment of head injury (Evidence Level III) [33].

When patients are observed in the hospital, observations should consist of general and neurological examinations, and include breathing frequency, oxygen saturation, blood pressure, pulse rate, GCS, pupil size and reaction to light, motor reactions and temperature [33].

Recommendation

- A complete neurological examination is mandatory after admission and should include assessment of the GCS, pupillary size and reaction to light, and short-term memory. Repeat neurological examination should be carried out, its frequency being dependent on the clinical condition of the patient; if the GCS is <15 it should be every 30 min. Patients with a GCS of 15 should be examined every 30 min, for 2 h, and if no complications or deterioration occurs, every hour for 4 h, thereafter once every 2 h. The use of a neurological checklist may be helpful to document the neurological condition and its course. If deterioration occurs, possible intracranial causes should be evaluated with (repeated) CT (Grade C).
- In-hospital observation of patients with a head injury should only be conducted by professionals competent in the assessment of head injury (GPP).

Follow-up

It has been shown that regular specialized outpatient follow- up visits are effective in reducing social morbidity and the severity of symptoms after MTBI [34]. In a large randomized controlled trial, patients with a PTA shorter than 7 days who received specialist intervention had significantly less social disability and fewer post-concussion symptoms 6 months after injury than those who did not receive the service (Evidence Level II) [34].

Recommendation

It is recommended that all patients with MTBI who have been admitted to hospital should be seen at least once in the outpatient clinic in the first 2 weeks after discharge (Grade C) [34]. Patients who are discharged immediately should contact their general practitioners, who can decide to refer the patient to the neurologist if complaints persist (Grade C).

Conclusions

This update of the guidelines presented in this article stresses the importance of careful neurological examination, assessment of trauma history and more selective use of CT. The use of a clinical decision rule for CT and hospital admission after MTBI is confirmed. In addition to adults, decision rules now also exist for children, including infants.

Disclosure of conflict of interest

The authors have reported no conflict of interest relevant to this manuscript.

References

1. Hirtz D, Thurman DJ, Gwinn-Hardy K, Mohamed M, Chaudhuri AR, Zalutsky R. How common are the 'common' neurologic disorders? *Neurology* 2007; **68:** 326–337.
2. af Geijerstam JL, Britton M. Mild head injury – mortality and complication rate: meta-analysis of findings in a systematic literature review. *Acta Neurochir* 2003; **145:** 843–850.
3. Kuppermann N, Holmes JF, Dayan PS, *et al*. Identifi cation of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet* 2009; **374:** 1160–1170.
4. Stiell IG, Wells GA, Vandemheen K, *et al*. The Canadian CT Head Rule for patients with minor head injury. *Lancet* 2001; **357:** 1391–1396.
5. Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PM. Indications for computed tomography in patients with minor head injury. *N Engl J Med* 2000; **343:** 100–105.
6. Smits M, Dippel DW, de Haan GG, *et al*. Minor head injury: guidelines for the use of CT. A multicenter validation study. *Radiology* 2007; **245:** 831–838.
7. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from paediatric CT. *AJR Am J Roentgenol* 2001; **176:** 289–296.
8. Brainin M, Barnes M, Baron JC, *et al*. Guidance for the preparation of neurological management guidelines by EFNS scientific task forces – revised recommendations 2004. *Eur J Neurol* 2004; **11:** 577–581.
9. Vos PE, Battistin L, Birbamer G, *et al*. EFNS guideline on mild traumatic brain injury: report of an EFNS task force. *Eur J Neurol* 2002; **9:** 207–219.
10. Ibanez J, Arikan F, Pedraza S, *et al*. Reliability of clinical guidelines in the detection of patients at risk following mild head injury: results of a prospective study. *J Neurosurg* 2004; **100:** 825–834.
11. Smits M, Dippel DW, de Haan GG, *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:** 1519–1525.
12. 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. *Ann Emerg Med* 2003; **42:** 507–514.
13. Dunning J, Daly JP, Lomas JP, Lecky F, Batchelor J, Kway Jones K. 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.

14. American College of Surgeons. Advanced Trauma Life Support for Doctors, 6th edn. Chicago: American College of Surgeons, 1997.
15. Tate RL, Pfaff A, Jurjevic L. Resolution of disorientation and amnesia during post-traumatic amnesia. *J Neurol Neurosurg Psychiatry* 2000; **68:** 178–185.
16. Ingebrigtsen T, Romner B, Kock-Jensen C. Scandinavian guidelines for initial management of minimal, mild, and moderate head injuries. The Scandinavian Neurotrauma Committee. *J Trauma* 2000; **48:** 760–766.
17. Valadka AB, Narayan RK. Emergency room management of the head-injured patient. In: Narayan RK, Wilberger JE, Povlishock JT, eds. *Neurotrauma*. New York: McGraw-Hill, 1996: 119–135.
18. 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.
19. Fortuny LA, Briggs M, Newcombe F, Ratcliff G, Thomas C. Measuring the duration of post traumatic amnesia. *J Neurol Neurosurg Psychiatry* 1980; **43:** 377–379.
20. Shores EA, Marosszeky JE, Sandanam J, Batchelor J. Preliminary validation of a clinical scale for measuring the duration of post-traumatic amnesia. *Med J Aust* 1986; **144:** 569–572.
21. The Brain Trauma Foundation. The American Association of Neurological Surgeons. The Joint Section on Neurotrauma and Critical Care. Initial management. *J Neurotrauma* 2000; **17:** 463–469.
22. af Geijerstam JL, Britton M. Mild head injury: reliability of early computed tomographic findings in triage for admission. *Emerg Med J* 2005; **22:** 103–107.
23. 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:** 465.
24. Servadei F, Teasdale G, Merry G. Defining acute mild head injury in adults: a proposal based on prognostic factors, diagnosis, and management. *J Neurotrauma* 2001; **18:** 657–664.
25. Teasdale GM, Murray G, Anderson E, *et al*. Risks of acute traumatic intracranial haematoma in children and adults: implications for managing head injuries. *BMJ* 1990; **300:** 363–367.
26. Masters SJ, McClean PM, Arcarese JS, *et al*. Skull x-ray examinations after head trauma. Recommendations by a multidisciplinary panel and validation study. *N Engl J Med* 1987; **316:** 84–91.
27. Bartlett J, Kett-White R, Mendelow AD, Miller JD, Pickard J, Teasdale G. Recommendations from the Society of British Neurological Surgeons. *Br J Neurosurg* 1998; **12:** 349–352.
28. American Academy of Pediatrics. The management of minor closed head injury in children. Committee on Quality Improvement, American Academy of Pediatrics. Commission on Clinical Policies and Research, American Academy of Family Physicians. *Pediatrics* 1999; **104:** 1407–1415.
29. Twijnstra A, Brouwer OF, Keyser A, *et al*. Richtlijnen voor de diagnostiek en behandeling van patienten met licht schedel hersenletsel. *Commissie Kwaliteitsbevordering van de Nederlandse Vereniging voor Neurologie* 2001; **1:** 1–26.
30. Smith HK, Miller JD. The danger of an ultra-early computed tomographic scan in a patient with an evolving acute epidural hematoma. *Neurosurgery* 1991; **29:** 258–260.
31. Servadei F, Vergoni G, Staffa G, *et al*. Extradural haematomas: how many deaths can be avoided? Protocol for early detection of haematoma in minor head injuries *Acta Neurochir* 1995; **133:** 50–55.
32. Frowein RA, Schiltz F, Stammler U. Early post-traumatic intracranial hematoma. *Neurosurg Rev* 1989; **12**(Suppl 1)**:** 184–187.
33. National Institute for Clinical Excellence: head Injury: triage, assessment, investigation and early management of head injury in infants, children and adults. Nice Clinical Guideline 2007;No 56. http://www.nice.org.uk/CG056.
34. Wade DT, King NS, Wenden FJ, Crawford S, Caldwell FE. Routine follow up after head injury: a second randomised controlled trial. *J Neurol Neurosurg Psychiatry* 1998; **65:** 177–183.