# NATIONAL INSTITUTE FOR HEALTH AND CLINICAL EXCELLENCE

## Centre for Clinical Practice

## *Review consultation document*

**Review of Clinical Guideline (CG56) - Triage, assessment, investigation and early management of head injury in infants, children and adults**

**Background information**

Guideline issue date: 2003
First review year and partial update: 2007
7 year review: 2011
National Collaborating Centre: National Clinical Guidelines Centre (formerly the National Collaborating Centre for Acute Care)

## 1. Consideration of the evidence

### Literature search

From initial intelligence gathering and a high-level randomised controlled trial (RCT) search clinical areas were identified to inform the development of clinical questions for focused searches. Through this stage of the process 9 studies were identified relevant to the guideline scope. The identified evidence was related to the following areas within the guideline:

- Clinical prediction rules for selecting patients with head or spinal injuries in adults and children
- Diagnostic circulating biomarkers for predicting different outcomes in patients with mild traumatic head injury to aid early management and referral
- Optimal predictor variables for long term sequealae following mild traumatic brain injury

Three clinical questions were developed based on the clinical areas above, qualitative feedback from other NICE departments and the views expressed by the Guideline Development Group, for more focused literature searches. Four additional clinical areas were also selected for more focused literature searches as a result of this feedback. The additional clinical questions identified related to the following areas of the guideline:

- Investigation in patients with no history of amnesia or loss of consciousness after history of head injury who are on anticoagulant and anti-platelet therapy
- Predictive values of different prediction models in investigation, diagnosis and early management of traumatic brain injury associated with better prognosis
- Diagnostic tools for assessment of sustained injuries to cervical spine
- Outcomes of patients with severe Traumatic brain injury (TBI) who do not need neurosurgical intervention but are still being treated at the neurosurgical centre compared to similar group of patients in non-specialist centres

The results of the focused searches are summarised in the table below. All references identified through the initial intelligence gathering, high-level RCT search and the focused searches can be viewed in Appendix 1

| Clinical area 1: Investigation in patients with no history of amnesia or loss of consciousness after history of head injury who are on anticoagulant and anti-platelet therapy | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **Should patients on either anticoagulant or anti-platelet therapy with no history of amnesia or loss of consciousness after history of a head injury be subjected to a head CT or MRI?** | Through the focused search fifteen studies relevant to the review question were identified.<br><br>• An observational study examining traumatic intracranial haemorrhage (TICH) in elderly patients on anticoagulants and anti-platelets reported a fivefold increase (2.2 % vs 10.3%; P < .01) in TICH, while another study examining CT evidence of TICH in elderly patients with mild and moderate head injury reported no statistically significant difference in the frequency or types of TICH between patients who had received aspirin prophylaxis and those who had not.<br>• A retrospective study examining predictors of mortality in trauma patients with intracranial haemorrhage (ICH) on pre-injury aspirin, warfarin or clopidogrel reported high mortality. Deaths based on initial CT grade were: grade I, 5/70; grade II, 4/17; grade III, 5 of 10; grade IV, 6 of 12 (p = 0.002). Another retrospective case control study examining preinjury aspirin, warfarin or | Potential new evidence that may change current recommendation(s). |

| | | |
|---|---|---|
| | clopidogrel reported traumatic brain injury (TBI) patients on clopidogrel may have increased disability and fatal consequences as compared to other agents.<br>• While three other studies examined preinjury aspirin, warfarin or clopidogrel-first, a retrospective review in older haemorrhagic blunt injury patients reported that preinjury anticoagulation is not associated with increased mortality. The second retrospective study reported that preinjury anticoagulation did not have any significant impact on outcomes. The third retrospective study, examining Intra cranial haemorrhage (ICH) among elderly fallers presenting without focal findings, reported anticoagulation alone did not appear to increase the risk of ICH and found aspirin to be protective.<br>• Another retrospective study examining patients with head injury with normal Glasgow coma scale (GCS) scores, and no focal neurologic deficits on heparin or coumadin reported that they may not necessarily require emergency CT.<br>• Two retrospective studies examined the degree of anticoagulation with warfarin one reporting that the degree of therapeutic anticoagulation with warfarin is associated with adverse outcome with TBI in the elderly (INR value greater than or equal to 2). The other, reported that all patients on warfarin should have their INR performed and CT scan done.<br>• Two retrospective studies examined the role of preinjury warfarin anti- | |

| | | |
|---|---|---|
| | coagulated patients, with one study reporting the adverse effect on mortality of fall from standing with a head injury. It also reported that adverse effect is most prominent in patients admitted awake with significant CT findings. While another study reported that the group on warfarin experienced greater morbidity after trauma and had higher mortality rates than their non-anticoagulated counterparts.<br>• One retrospective study examining the role of aspirin and warfarin cautioned about the early discharge of patients on anticoagulants and the high risk of developing TICH among those on anti-platelets. While another study reported that the patients on anticoagulation treatment suffering from mild TBI could be managed with strict neurologic observation without routinely performing a control CT scan.<br>• Another retrospective study reported that use of preinjury antiplatelet and/or anticoagulation therapy does not significantly increase the risk of mortality in the trauma patient.<br>• In summary, there is conflicting evidence on the association between patients on pre-injury anti-platelet therapy and subsequent traumatic intracranial haemorrhage (TICH), and the utility of CT scan or MRI for early identification of intracranial haemorrhage in this particular subgroup of patients. However, as the | |

| | | |
|---|---|---|
| | harmful outcomes of intracranial haemorrhage are significant (i.e. death), the risk of this subgroup of patients needs to be addressed in the guideline. | |

| Clinical area 2: Clinical prediction rule for selecting the patients with head or spinal injuries in adults and children | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **Which is the best clinical prediction rule for selecting the patients with head or spinal injuries in adults or children who require treatment in neurosurgical care facility?**<br>**(NICE research recommendation)** | Through the focused search eleven studies relevant to the review question was identified.<br>• A well validated large cohort derived clinical prediction rule in a north American population by the Paediatric Emergency Care Applied Research Network (PECARN) among patients younger than 18 years reported clinically important traumatic brain injuries for which CT may be unnecessary. The clinical prediction rule for children under 2 years old reported negative predictive value (NPV) and sensitivity for clinically important TBI of 100.0%. Similarly, it reported a NPV of 99.95% and sensitivity of 96.8% among children older than 2 years.<br>• A systematic review examining rules for head CT among children identified eight different clinical prediction rules but reported considerable variation in population, methodological quality and performance.<br>• One observational study derived rule in minor paediatric head trauma reported, the sensitivity of 95.4%, specificity of 48.9% and NPV of 99.3% for detection of | Potential new evidence that may change current recommendation(s). |

| | | |
|---|---|---|
| | intracranial injury. Another prediction rule proposed from an observational study in children younger than 16 years of age reported a sensitivity of 98% and specificity of 87%. The decision rule needs to be validated.<br>• One observational study leading to validation of clinical scoring system (<2 yrs of age) reported determination of an infant's skull fracture with sensitivity of 90% and specificity of 78% .<br>• A retrospective study of using Children's head injury algorithm for the prediction of important clinical events (CHALICE in children) in Australia reported that the application of CHALICE would double the proportion of CT scans with a comparatively small gain in delayed pick of CT abnormalities.<br>• The Canadian assessment of tomography for childhood injury (CATCH) using data from a multicentre cohort examining minor head injuries in children has stratified into 2 levels of risk (100% for high risk and 98% sensitivity for medium risk), this decision rule has not yet been validated.<br>• A prospective study examining early predictors of unfavourable outcome in adults reported six variables; basal skull fracture, sub-arachnoid haemorrhage (SAH), coagulopathy, subdural haematoma, modified marhall's category and the glasgow coma scale, to be strong predictors of unfavourable outcome with 95% sensitivity and 86% specificity at 6 months. | |

| | | |
|---|---|---|
| | • Another observational study using the CT in head injury patients (CHIP) prediction rule, for use of CT in minor head injury stratified the rule into two components; detailed and simple. The sensitivity of both (detailed and simple rule) for neurosurgical interventions was 100% while specificity of 23 and 30% respectively. It was reported that potential CT reduction by implementing the prediction rule was 23-30%.<br>• An observational study reported that NEXUS-II and Scandinavian decision tool displayed the best specificity and sensitivity to aid in CT scanning decisions in mild closed traumatic injury in adolescent and adults.<br>• A validation study to detect chronic subdural hematoma reported a sensitivity of 88% and specificity of 68%.<br>• In summary, there is potential new evidence on new clinical prediction rules, particularly for children who require treatment in neurosurgical care facility and identify those in whom CT scan may be unnecessary, that may need to be included in the guideline. | |

| Clinical area 3: Predictive values of different prediction models in investigation, diagnosis and early management of traumatic brain injury associated with better prognosis | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **What are the best predictive values of different prediction models in investigation, diagnosis and early management of traumatic brain injury associated with better prognosis?** | Through the focused search ten studies relevant to the review question was identified.<br>• A prognostic model validated and derived from Corticosteroid randomisation after significant head injury (CRASH) trial was developed to reflect on prognostic models for death at 14 days and for death or severe disability six months after traumatic brain injury has been reported. The basic model included four predictors: age, Glasgow coma scale, pupil reactivity, and the presence of major extracranial injury. The CT model also included the presence of petechial haemorrhages, obliteration of the third ventricle or basal cisterns, subarachnoid bleeding, midline shift, and non-evacuated haematoma. In the derivation sample the models showed excellent discrimination (C statistic above 0.80).<br>• Another study reported cross validation of the CRASH prognostic model with another model reported that combined age, motor score, and pupillary reactivity had an area under the receiver operating characteristic curve (AUC) between | Potential new evidence that may change current recommendation(s). |

| | | |
|---|---|---|
| | 0.66 and 0.84 at cross-validation.<br>• One observational study reported validated predictive model based on age, absence of light reflex, presence of extensive subarachnoid haemorrhage, intracranial pressure, and midline shift was shown to have high predictive value (PPV 97.3, NPV-87.1).<br>• Another prognostic model among blunt head injury (GCS<13) proposed that CT scans were always normal in patients < 65 years old who did not have an obvious head wound, a raccoon sign, vomiting, memory deficit, or a decrease in their GCS score. Patients with 1 major criterion or 2 minor criteria reported an abnormal CT scan in 13% of the cases.<br>• Another study validating 3-point simplified motor score demonstrated similar test performance when compared with the 15-point GCS score and its components for the prediction of 4 traumatic brain injury outcomes (emergency intubation, clinically significant brain injury, neurosurgical intervention, and mortality).<br>• One prospective study comparing the GCS, abbreviated injury score(AIS) and Injury severity score (ISS), reported that the combination of GCS and AIS/ISS correlate with outcome better than do any of the three measures alone.<br>• An observational study of severe TBI in children using Glasgow outcome score extended and Disability rating scale (DRS) reported that the DRS offered the | |

| | | |
|---|---|---|
| | best investigative possibilities for long-term level of functioning. While, another prognostic model examining cerebral perfusion pressure (CPP) and intracranial pressure (ICP) reported that initial ICP and CPP measurements were useful as prognostic factors in paediatric patients with severe TBIs.<br>• Another study reported that the temporal and brain stem contusions constitute independent risk factors for poor outcome in survivors of severe TBI.<br>• An observational study comparing Mortality prediction model II (MPM), SAPS (Simplified acute physiology score)and ISS (Injury severity score) reported that MPM performed slightly better than SAPS in terms of overall mortality prediction and discrimination, while SAPS performed well in patients with SAH.<br>• In summary, there is potential new evidence on new prognostic models, particularly the prognostic model derived from the CRASH trial that may need to be included in the guideline. | |

| Clinical area 4: Diagnostic tools for assessment of sustained injuries to cervical spine | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **Which are the best diagnostic tools for assessment of sustained injuries to cervical spine?** | Through the focused search sixteen studies relevant to the review question was identified.<br>• A retrospective study on effectiveness of Swimmer's views (3 film series) reported that Swimmer's view did not satisfactorily provide adequate visualisation of the cervical spine in trauma patients.<br>• Four relevant studies were found analysing X-ray and CT scan in cervical spine imaging. First, a meta analysis comparing these modalities reported CT is superior to plain radiography in the detection of cervical spine injury However, the optimal imaging strategy depends on the patients' relative risk of injury. Second, a retrospective study reported that in imaging of cervical spine, in more than one third of the patients primarily assessed with three-view X-ray series of the C-spine, the results are incomplete or in-evaluable, and hence necessitating CT scanning. Third, a decision analytic model reported that the use of CT is more favourable over the use of radiography alone or radiography with CT by a | Potential new evidence that may change current recommendation(s). |

| | | |
|---|---|---|
| | factor of 13, for low risk 20 year old patients; to a factor of 23, for high risk patients younger than 80 years old. Fourth, a study comparing lateral x-ray and CT reported that lateral cervical spine film has no value as a screening tool in the blunt trauma patient since most are either inaccurate or incomplete.<br>• A retrospective study comparing the CT with x-ray films, reported that the sensitivity for CT was 100%, whereas that of plain films was 61%. 19.1% of patients with cervical spine injuries who had false-negative plain films required operative intervention. Therefore three standard X-ray views of the c-spine provided no clinically significant advantage to multi-detector row CT in diagnosing C- spine injuries.<br>• A retrospective study examining diagnosis of cervical spine injury in children reported that limited computed tomography from occiput to third cervical vertebra may increase diagnostic yield appreciably in young children compared with flexion-extension views.<br>• One meta analysis examining clearance of cervical spine reported that a magnetic resonance image that did not disclose anything abnormal can conclusively exclude cervical spine injury and is established as a gold standard for clearing the cervical spine in a clinically suspicious or un-evaluatable blunt trauma patient. | |

| | | |
|---|---|---|
| | • A retrospective study examining clinical outcomes of Magnetic resonance imaging (MRI) use in blunt trauma reported that an abnormal MRI after normal plain XR and CT cervical spine studies resulted in a change in non-operative management at discharge & early MRI resulted in one patient (out of three) receiving surgery before discharge while another prospective evaluation examining MRI and CT for c-spine reported that MR-CS may be unnecessary in the obtund blunt trauma patients if the CT-CS is negative. While another review reported that in an obtund patient with normal initial CT, if maintaining same status for 72 hours then a MRI should be obtained.<br>• A retrospective study examining c-spine imaging reported that the intubated patients, patients with severe trauma or patients with GCS <13 should have CT as a primary screening examination for suspected C-spine fracture rather than X-ray.<br>• Another review examining imaging of traumatic soft tissue injuries of the cervical spine reported that MRI is the technique of choice.<br>• A retrospective study comparing 4- and 64-slice CT reported that 64-slice CT scan does not miss clinically significant cervical spinal injuries and may allow clearance of the cervical spine in blunt trauma patients without the addition of a MRI. | |

| | | |
|---|---|---|
| | • Another observational study analysing imaging in cranio-vertebral junction injuries reported the dynamic MRI was able to detect cases of cord compression that were not seen in neutral position and was diagnostic in all cases of cranio vertebral junction injuries.<br>• In a study, the appropriateness criteria from American college of radiology (ACR) on suspected spine trauma has reported criteria on which patients need imaging, how much imaging is necessary and what kind of imaging needs to be performed.<br>• In summary, there is potential new evidence on the clinical utility of newer imaging modalities such as CT scan and MRI, and the number of imaging required. The evidence may change current recommendations on the optimal imaging strategy for patients with sustained injuries to cervical spine. | |

| **Clinical area 5: Diagnostic circulating biomarkers for predicting different outcomes in patients with mild traumatic head injury to aid early management and referral** | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **What is the clinical effectiveness of diagnostic circulating biomarker for predicting different outcomes in patients with mild traumatic head injury to aid early management and referral**? | Through the focused search 21 studies relevant to the review question were identified.<br>• One meta- analysis of S100b in adults with minor head injury (MHI) reported that low serum S100b levels accurately predict normal CT findings after MHI in adults. It recommended that S100b should be considered in MHI patients with no focal neurological deficit, an absence of significant extra-cerebral injury, taken within 3 hours of injury, and reported a cut off for omitting CT set at less than 0.10 microgram/L.<br>• Two studies examining S100b in severe TBI were identified, one observational study reporting temporal profile of S100b release from admission to 72 hours post-TBI was recommended for use in identifying patients at risk of developing a worse outcome, while another prospective study reported S-100b to be reflective of injury severity and improving prediction of outcome.<br>• Another case control study examining role of Cerebro-spinal fluid (CSF) values | Potential new evidence that may change current recommendation(s). |

| | | |
|---|---|---|
| | of S100b among severe TBI patients reported that monitoring CSF S100b might help to prospectively identify patients with progressive intracranial haemorrhage.<br>• Two observational studies examined S100b in children with mild TBI. The first reported that elevations of S100b do not necessarily lead to a pathological finding in the CT scan, but values below the cut-off safely rule out the evidence of intracranial lesions. While the second study reported the lack of a definitive role of S100b in paediatric mild TBI.<br>• Two other studies examining S100b in mild TBI reported lack of reliability as a marker in mild TBI due to low sensitivity and negative predictive value seen from samples taken greater than 3 hours after injury.<br>• Two observational studies on S100b, one in children, reported it to be an unreliable prognostic marker while another examining urine S100b levels obtained on admission are to be unreliable indicator for assessing the extent of brain damage.<br>• Another prospective study comparing S100b and neuron specific enolase (NSE) in children with mild TBI reported that both the markers do not adequately discriminate between symptomatic and asymptomatic children with mild TBI.<br>• One observational study using single time point at 24 hours reported S100b to be significantly associated with outcome at 24 hrs after the injury while another | |

| | | |
|---|---|---|
| | prospective study examining association of S100b and Glasgow outcome scale confirmed it as a clinically valuable indicator of severity of injury and proposed it as an effective predictor of risk outcome.<br>• One retrospective study comparing glial fibrillatory acidic protein (GFAP) with S100b and NSE reported Serum GFAP to be of remarkable diagnostic value for TBI with a sensitivity of 88.9% and 100% specificity.<br>• One study reported matrix mettalo-protein (MMP) to be increased in CSF of severe TBI patients while another study examining IL-6 reported that it can be used for the differential diagnosis of elevated ICP in isolated TBI.<br>• One prospective study examining NSE in head injury reported that serum NSE was 87% sensitive and 82.1% specific in predicting poor neurologic outcome in the study patients. The area under the curve was 0.931. The initial serum NSE levels in moderate and severe head trauma patients correlate inversely with GOS 1 month later. Another study comparing NSE, hs-CRP, IL6, L8, TnF alpha found NSE levels to be significant independent predictors of mortality.<br>• One prospective observational study examining the prognostic value of admission serum albumin levels in patients with head injury reported that hypo-albuminemia is an effective indicator of the severity of head injury, and an independent predictor for unfavourable outcome at 3 months. | |

| | | |
|---|---|---|
| | • Another observational study examining Ubiquitin c-terminal hydrolase (UCH-L1) in severe head injury reported significantly higher levels of UCH-L1 in patients with a lower GCS score at 24 hours, post-injury complications subgroup, 6-week mortality subgroup, and in those with a poor 6-month dichotomized Glasgow outcome score.<br>• In summary, there is potential new evidence on the effectiveness of biomarkers, particularly S100b, for predicting outcomes and to aid management in patients with mild traumatic head injury. | |

| Clinical area 6: Optimal predictor variables for long term sequealae following mild traumatic brain injury | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **Which are the optimal predictor variables for long term sequealae following mild traumatic brain injury? (NICE research recommendation)** | Through the focussed search four studies relevant to the review question was identified.<br>• A retrospective case control study examining predictors of minor head injury patients and requiring neurosurgical intervention reported six warning signs to be statistically significant: severe headache, vomiting more than once, drop in GCS, confusion/restlessness, bleeding from ear and skull fracture in the X-ray.<br>• An observational study examining post concussion syndrome in children with mild TBI reported that among school-aged children with mild TBI, 13.7% were symptomatic three months after injury. These findings could not be explained by trauma, family dysfunction, or maternal psychological adjustment.<br>• Another observational study examining predictors of post-concussive syndrome (PCS) in a population of trauma patients with mild TBI reported that anxiety among women and noise sensitivity to be important predictors of PCS. It also reported other physical symptoms, while more prevalent to be | No evidence was identified that would invalidate current guideline recommendations. |

| | | |
|---|---|---|
| | poor predictors of PCS.<br>• Another observational study examining mild TBI and PCS, reported that PCS was not found to be specific to mild TBI. | |

| **Clinical area 7: Outcomes of patients with severe TBI who do not need neurosurgical intervention but are still being treated at the neurosurgical centre compared to similar group of patients in non-specialist centres** | | |
|---|---|---|
| **Clinical question** | **Summary of evidence** | **Relevance to guideline recommendations** |
| **What are the outcomes of patients with severe TBI who do not need neurosurgical intervention but are still being treated at the neurosurgical centre compared to similar group of patients in non-specialist centres?**<br>**(NICE research recommendation)** | Through the focused search no studies relevant to the review question were identified. | No evidence was identified that would invalidate current guideline recommendations. |

## Guideline Development Group and National Collaborating Centre perspective

A questionnaire was distributed to Guideline Development Group (GDG) members and the National Collaborating Centre (NCC) to consult them on the need for an update of the guideline.

Five responses were received with respondents highlighting areas with potential new evidence on prediction models such as, outcome from the CRASH and IMPACT trials, paediatric decision rules, predictive value of circulating biomarkers in TBI and delivery of neurocritical care. Other areas highlighted were on the uptake and cost impact of the the guideline.

Potential new areas to be covered by the guideline were suggested and these include imaging modalities for anticoagulant or anti-platelet users with head injury, CT/MR Angiography to predict the adverse outcomes manifested as neuro-physiological impairment, and blast TBI.

GDG members also highlighted other ongoing important trials, the outcomes of which are not yet available, but in due course may provide better evidence on hypertonic saline, hypothermia and further analysis of CRASH trials.

## Implementation and post publication feedback

In total, 32 enquiries were received from post-publication feedback which included two coroner's reports. Some of the queries received related to the need for imaging in elderly patients on anticoagulants and anti-platelets, clinical prediction rules (height of fall and in the over 65 age group), adult and paediatric proforma charts and urgency of scanning. Other queries received related to pituitary dysfunction after traumatic brain injury, cervical spine mobilisation, suicidal depression rates following TBI and follow up letters after discharge.

Implementation feedback identified the following implementation studies. A national audit found the median time taken for a CT scan for a serious brain injury was around 1.5 hours and reported that 25 per cent of patients with a head injury had to wait in excess of two hours. The guideline recommends time taken to have a CT scan following a suspected serious head injury should be less than one hour after arrival at the emergency department. An audit in Barnet district hospital reported an increase in CT requests and rising cost following the NICE guidance on head injury.

Another study examining isolated head injuries investigated with a CT scan during the period April-June 2008 reported that out of 39 CT scans, 10 were not performed in accordance with the NICE guideline and did not reveal any pathology. However, out of six scans performed for unclear reasons (patient on warfarin), three revealed intracranial pathology.

In a 12 month retrospective audit on intubated patients with cervical spine imaging in patients with multiple injuries, it was reported that no patient was intubated without undergoing CT of the cervical spine.

Hospital Episode Statistics (HES) national data warehouse reported the proportion of CT head examinations has increased slightly since the publication of the guideline. In 2008-09 the proportion of CT investigations for head injury was 97.72% as compared to 97.18% in 2006-07.

Qualitative input from the field team underlined following themes; major barriers to implementation such as finance and other resources in particular with respect to implementation of CT scans, conflicts with local trust's neurosurgical policies, complexity of guidance, variation in anticipated length of stay and CT scanning element not implemented due to PCTs having a local policy.

## Relationship to other NICE guidance

The following NICE guidance is related to CG 56:

| Guidance | Review date |
|---|---|
| Management of transient loss of consciousness in adults. In progress. Publication date: August 2010 | August 2014 |

## Anti-discrimination and equalities considerations

No evidence was identified to indicate that the guideline scope does not comply with anti-discrimination and equalities legislation. The original scope is inclusive of adults and children (including infants) who present with a suspected or confirmed traumatic head injury with or without other major trauma.

**Conclusion**

From the evidence and intelligence identified through the process, it suggests that some areas of the guideline may need updating at this stage, particularly in relation to:

- Investigation in patients with no history of amnesia or loss of consciousness after history of head injury who are on anticoagulant and anti-platelet therapy
- Clinical prediction rules for selecting the patients with head or spinal injuries in adults and children
- Predictive values of different prediction models in investigation, diagnosis and early management of traumatic brain injury associated with better prognosis
- Diagnostic tools for assessment of sustained injuries to cervical spine
- Diagnostic circulating biomarkers for predicting different outcomes in patients with mild traumatic head injury to aid early management and referral.

## 3. Review recommendation

The guideline should be considered for an update at this time.

Centre for Clinical Practice
24 February 2011

## Appendix 1

2007. Clinical criteria predict serious head injury risk in kids. *Journal of Family Practice*, 56, (1) 16-17

Abouzari, M., Rashidi, A., Zandi-Toghani, M., Behzadi, M., & Asadollahi, M. 2009. Chronic subdural hematoma outcome prediction using logistic regression and an artificial neural network. *Neurosurgical Review* , 32, (4) 479-484

Ahmed, N., Bialowas, C., Kuo, Y.H., & Zawodniak, L. 2009. Impact of preinjury anticoagulation in patients with traumatic brain injury. *Southern Medical Journal*, 102, (5) 476-480

Atabaki, S.M., Stiell, I.G., Bazarian, J.J., Sadow, K.E., Vu, T.T., Camarca, M.A., Berns, S., & Chamberlain, J.M. 2008. A clinical decision rule for cranial computed tomography in minor pediatric head trauma. *Archives of Pediatrics and Adolescent Medicine*, 162, (5) 439-445

Barlow, K.M., Crawford, S., Stevenson, A., Sandhu, S.S., Belanger, F., & Dewey, D. 2010. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. *Pediatrics*, 126, (2) e374-e381

Baskin, T. 2007. Cervical spine clearance in the obtunded patient: it takes more than a simple CT. [Review] [6 refs]. *Journal of Trauma-Injury Infection & Critical Care*, 62, (6:Suppl) Suppl

Bin, S.S., Schutzman, S.A., & Greenes, D.S. 2010. Validation of a clinical score to predict skull fracture in head-injured infants. *Pediatric Emergency Care*, 26, (9) 633-639

Brown, C.V.R., Foulkrod, K.H., Reifsnyder, A., Bui, E., Lopez, I., Hummell, M., & Coopwood, B. 2010. Computed tomography versus magnetic resonance imaging for evaluation of the cervical spine: How many slices do you need? *American Surgeon*, 76, (4) 365-368

Cain, G., Shepherdson, J., Elliott, V., Svensson, J., & Brennan, P. 2010. Imaging suspected cervical spine injury: Plain radiography or computed tomography? Systematic review. *Radiography*, 16, (1) 68-77

Castellani, C., Bimbashi, P., Ruttenstock, E., Sacherer, P., Stojakovic, T., & Weinberg, A.M. 2009. Neuroprotein s-100B -- a useful parameter in paediatric patients with mild traumatic brain injury? *Acta Paediatrica*, 98, (10) 1607-1612

Catala-Temprano, A., Claret, T.G., Cambra Lasaosa, F.J., Pons, O.M., Noguera, J.A., & Palomeque, R.A. 2007. Intracranial pressure and cerebral perfusion pressure as risk factors in children with traumatic brain injuries. *Journal of Neurosurgery*, 106, (6 Suppl) 463-466

Catroppa, C., Anderson, V.A., Morse, S.A., Haritou, F., & Rosenfeld, J.V. 2008. Outcome and predictors of functional recovery 5 years following pediatric traumatic brain injury (TBI). *Journal of Pediatric Psychology*, 33, (7) 707-718

Chan, C.H. 2010. Clinical predictors of minor head injury patients presenting with Glasgow coma scale score of 14 or 15 and requiring neurosurgical intervention. *Hong Kong Journal of Emergency Medicine*, 17, (3) 256-261

Cohen, D.B., Rinker, C., & Wilberger, J.E. 2006. Traumatic brain injury in anticoagulated patients. *Journal of Trauma-Injury Infection & Critical Care*, 60, (3) 553-557

Como, J.J., Thompson, M.A., Anderson, J.S., Shah, R.R., Claridge, J.A., Yowler, C.J., & Malangoni, M.A. 2007. Is magnetic resonance imaging essential in clearing the cervical spine in obtunded patients with blunt trauma? *Journal of Trauma-Injury Infection & Critical Care*, 63, (3) 544-549

Crowe, L., Anderson, V., & Babl, F.E. 2010. Application of the CHALICE clinical prediction rule for intracranial injury in children outside the UK: impact on head CT rate. *Archives of Disease in Childhood*, 95, (12) 1017-1022

Daffner, R.H. & Hackney, D.B. 2007. ACR Appropriateness Criteria on suspected spine trauma. *Journal of the American College of Radiology*, 4, (11) 762-775

Delgado Almandoz, J.E., Schaefer, P.W., Kelly, H.R., Lev, M.H., Gonzalez, R.G., & Romero, J.M. 2010. Multidetector CT angiography in the evaluation of acute blunt head and neck trauma: a proposed acute craniocervical trauma scoring system. *Radiology*, 254, (1) 236-244

Dhandapani, S.S., Manju, D., Vivekanandhan, S., Sharma, B.S., & Mahapatra, A.K. 2009. Prognostic value of admission serum albumin levels in patients with head injury. *Pan Arab Journal of Neurosurgery*, 13, (1) 60-65+143

Dischinger, P., Read, K., Kerns, T., Ho, S., Kufera, J., Burch, C., Jawed, N., Burgess, A., & Bents, F. 2003. Causes and outcomes of mild traumatic brain injury: an analysis of CIREN data. *Annual Proceedings/Association for the Advancement of Automotive Medicine*, 47, 577-589

Eilander, H.J., Timmerman, R.B.W., Scheirs, J.G.M., Van Heugten, C.M., De Kort, P.L.M., & Prevo, A.J.H. 2007. Children and young adults in a prolonged unconscious state after severe brain injury: Long-term functional outcome as measured by the DRS and the GOSE after early intensive neurorehabilitation. *Brain Injury*, 21, (1) 53-61

Fabbri, A., Servadei, F., Marchesini, G., Stein, S.C., & Vandelli, A. 2008. Early predictors of unfavourable outcome in subjects with moderate head injury in the emergency department. *Journal of Neurology, Neurosurgery and Psychiatry*, 79, (5) 567-573

Filippidis, A.S., Papadopoulos, D.C., Kapsalaki, E.Z., & Fountas, K.N. 2010. Role of the S100B serum biomarker in the treatment of children suffering from mild traumatic brain injury. *Neurosurgical Focus*, 29, (5) E2

Fischler, L., Lelais, F., Young, J., Buchmann, B., Pargger, H., & Kaufmann, M. 2007. Assessment of three different mortality prediction models in four well-defined critical care patient groups at two points in time: A prospective cohort study. *European Journal of Anaesthesiology*, 24, (8) 676-683

Foreman, B.P., Caesar, R.R., Parks, J., Madden, C., Gentilello, L.M., Shafi, S., Carlile, M.C., Harper, C.R., & Diaz-Arrastia, R.R. 2007. Usefulness of the abbreviated injury score and the injury severity score in comparison to the Glasgow Coma Scale in predicting outcome after traumatic brain injury. *Journal of Trauma - Injury, Infection and Critical Care*, 62, (4) 946-950

Fortuna, G.R., Mueller, E.W., James, L.E., Shutter, L.A., & Butler, K.L. 603. The impact of preinjury antiplatelet and anticoagulant pharmacotherapy on outcomes in elderly patients with hemorrhagic brain injury. *Surgery*, 144, (4) 598-603

Gangavati, A.S., Kiely, D.K., Kulchycki, L.K., Wolfe, R.E., Mottley, J.L., Kelly, S.P., Nathanson, L.A., Abrams, A.P., & Lipsitz, L.A. 2009. Prevalence and characteristics of traumatic intracranial hemorrhage in elderly fallers presenting to the emergency department without focal findings. *Journal of the American Geriatrics Society*, 57, (8) 1470-1474

Garton, H.J.L. & Hammer, M.R. 2008. Detection of pediatric cervical spine injury. *Neurosurgery*, 62, (3) 700-707

Geyer, C., Ulrich, A., fe, G., Stach, B., & Till, H. 2009. Diagnostic value of S100B and neuron-specific enolase in mild pediatric traumatic brain injury. *Journal of Neurosurgery*, Pediatrics.., (4) 339-344

Gittleman, A.M., Ortiz, A.O., Keating, D.P., & Katz, D.S. 2005. Indications for CT in patients receiving anticoagulation after head trauma. *Ajnr: American Journal of Neuroradiology*, 26, (3) 603-606

Grandhi, R., Duane, T.M., Dechert, T., Malhotra, A.K., Aboutanos, M.B., Wolfe, L.G., & Ivatury, R.R. 2008. Anticoagulation and the elderly head trauma patient. *American Surgeon*, 74, (9) 802-805

Grossetete, M., Phelps, J., Arko, L., Yonas, H., & Rosenberg, G.A. 2009. Elevation of matrix metalloproteinases 3 and 9 in cerebrospinal fluid and blood in patients with severe traumatic brain injury. *Neurosurgery*, 65, (4) 702-708

Gupta, V., Khandelwal, N., Mathuria, S.N., Singh, P., Pathak, A., & Suri, S. 2007. Dynamic magnetic resonance imaging evaluation of craniovertebral junction abnormalities. *Journal of Computer Assisted Tomography*, 31, (3) 354-359

Hallen, M., Karlsson, M., Carlhed, R., Hallgren, T., & Bergenheim, M. 2010. S-100B in serum and urine after traumatic head injury in children. *Journal of Trauma-Injury Infection & Critical Care*, 69, (2) 284-289

Hashem, R., Evans, C.C., Farrokhyar, F., & Kahnamoui, K. 2009. Plain radiography does not add any clinically significant advantage to multidetector row computed tomography in diagnosing cervical spine injuries in blunt trauma patients. *Journal of Trauma-Injury Infection & Critical Care*, 66, (2) 423-428

Haukoos, J.S., Gill, M.R., Rabon, R.E., Gravitz, C.S., & Green, S.M. 2007. Validation of the Simplified Motor Score for the prediction of brain injury outcomes after trauma. *Annals of Emergency Medicine*, 50, (1) 18-24

Hergenroeder, G.W., Moore, A.N., McCoy, J.P., Jr., Samsel, L., Ward, N.H., III, Clifton, G.L., & Dash, P.K. 2010. Serum IL-6: a candidate biomarker for intracranial pressure elevation following isolated traumatic brain injury. *Journal of Neuroinflammation*, 7, 19

Honda, M., Tsuruta, R., Kaneko, T., Kasaoka, S., Yagi, T., Todani, M., Fujita, M., Izumi, T., & Maekawa, T. 2010. Serum glial fibrillary acidic protein is a highly specific biomarker for traumatic brain injury in humans compared with S-100B and neuron-specific enolase. *Journal of Trauma-Injury Infection & Critical Care*, 69, (1) 104-109

Howard II, J.L., Cipolle, M.D., Horvat, S.A., Sabella, V.M., Reed III, J.F., Fulda, G., Tinkoff, G., & Pasquale, M.D. 2009. Preinjury warfarin worsens outcome in elderly patients who fall from standing. *Journal of Trauma - Injury, Infection and Critical Care*, 66, (6) 1518-1522

Ivascu, F.A., Howells, G.A., Junn, F.S., Bair, H.A., Bendick, P.J., & Janczyk, R.J. 2008. Predictors of mortality in trauma patients with intracranial hemorrhage on preinjury aspirin or clopidogrel. *Journal of Trauma-Injury Infection & Critical Care*, 65, (4) 785-788

Jones, C. & Jazayeri, F. 2007. Evolving standards of practice for cervical spine imaging in trauma: a retrospective review. *Australasian Radiology*, 51, (5) 420-425

Kaen, A., Jimenez-Roldan, L., Arrese, I., Delgado, M.A., Lopez, P.G., Alday, R., Alen, J.F., Lagares, A., & Lobato, R.D. 2010. The value of sequential computed tomography scanning in anticoagulated patients suffering from minor head injury. *Journal of Trauma-Injury Infection & Critical Care*, 68, (4) 895-898

Kirchhoff, C., Buhmann, S., Braunstein, V., Leidel, B.A., Vogel, T., Kreimeier, U., Mutschler, W., & Biberthaler, P. 2008. Cerebrospinal s100-B: a potential marker for progressive intracranial hemorrhage in patients with severe traumatic brain injury. *European Journal of Medical Research*, 13, (11) 511-516

Korfias, S., Stranjalis, G., Boviatsis, E., Psachoulia, C., Jullien, G., Gregson, B., Mendelow, A.D., & Sakas, D.E. 2007. Serum S-100B protein monitoring in patients with severe traumatic brain injury. *Intensive Care Medicine*, 33, (2) 255-260

Kuppermann, N., Holmes, J.F., Dayan, P.S., Hoyle, J.D., Jr., Atabaki, S.M., Holubkov, R., Nadel, F.M., Monroe, D., Stanley, R.M., Borgialli, D.A., Badawy, M.K., Schunk, J.E., Quayle, K.S., Mahajan, P., Lichenstein, R., Lillis, K.A., Tunik, M.G., Jacobs, E.S., Callahan, J.M., Gorelick, M.H., Glass, T.F., Lee, L.K., Bachman, M.C., Cooper, A., Powell, E.C., Gerardi, M.J., Melville, K.A., Muizelaar, J.P., Wisner, D.H., Zuspan, S.J., Dean, J.M., Wootton-Gorges, S.L., & Pediatric Emergency Care Applied Research Network (PECARN) 2009. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet*, 374, (9696) 1160-1170

Labattaglia, M.P., Cameron, P.A., Santamaria, M., Varma, D., Thomson, K., Bailey, M., & Kossmann, T. 2007. Clinical outcomes of magnetic resonance imaging in blunt cervical trauma. *Emergency Medicine Australasia*, 19, (3) 253-261

ller, K., Townend, W., Biasca, N., Und&#x00E9, n J, Waterloo, K., Romner, B., & Ingebrigtsen, T. 2007. S100B serum level predicts computed tomography findings after minor head injury. *Journal of Trauma-Injury Infection & Critical Care*, 62, (6) 1452-1456

ltke, E., Sadanand, V., Kelly, M.E., Griebel, R.W., & Juurlink, B.H. 2009. Can admission S-100beta predict the extent of brain damage in head trauma patients? *Canadian Journal of Neurological Sciences*, 36, (5) 612-616

Maguire, J.L., Boutis, K., Uleryk, E.M., Laupacis, A., & Parkin, P.C. 2009. Should a head-injured child receive a head CT scan? A systematic review of clinical prediction rules. *Pediatrics*, 124, (1) e145-e154

Major, J. & Reed, M.J. 2009. A retrospective review of patients with head injury with coexistent anticoagulant and antiplatelet use admitted from a UK emergency department. *Emergency Medicine Journal*, 26, (12) 871-876

Meares, S., Shores, E.A., Taylor, A.J., Batchelor, J., Bryant, R.A., Baguley, I.J., Chapman, J., Gurka, J., Dawson, K., Capon, L., & Marosszeky, J.E. 2008. Mild traumatic brain injury does not predict acute postconcussion syndrome. *Journal of Neurology, Neurosurgery & Psychiatry*, 79, (3) 300-306

Meric, E., Gunduz, A., Turedi, S., Cakir, E., & Yandi, M. 2010. The prognostic value of neuron-specific enolase in head trauma patients. *Journal of Emergency Medicine*, 38, (3) 297-301

Morochovic, R., cz, O., Kitka, M., Pingorov&#x00E1, S, Cibur, P., Tomkov&#x00E1, D, Len&#x00E1, rtov&#x00E1, & R 2009. Serum S100B protein in early management of patients after mild traumatic brain injury. *European Journal of Neurology*, 16, (10) 1112-1117

MRC CRASH, T.C., Perel, P., Arango, M., Clayton, T., Edwards, P., Komolafe, E., Poccock, S., Roberts, I., Shakur, H., Steyerberg, E., & Yutthakasemsunt, S. 2008. Predicting outcome after traumatic brain injury: practical prognostic models based on large cohort of international patients. *BMJ*, 336, (7641) 425-429

Muchow, R.D., Resnick, D.K., Abdel, M.P., Munoz, A., & Anderson, P.A. 2008. Magnetic resonance imaging (MRI) in the clearance of the cervical spine in blunt trauma: a meta-analysis. *Journal of Trauma-Injury Infection & Critical Care*, 64, (1) 179-189

Murillo-Cabezas, F., oz, S., Ferrari, M.D., guez, J.F., Amaya-Villar, R., mez, S., Le&#x00F3, n-Carri&#x00F3, & n J 2010. The prognostic value of the temporal course of S100beta protein in post-acute severe brain injury: A prospective and observational study. *Brain Injury*, 24, (4) 609-619

Osmond, M.H., Klassen, T.P., Wells, G.A., Correll, R., Jarvis, A., Joubert, G., Bailey, B., Chauvin-Kimoff, L., Pusic, M., McConnell, D., Nijssen-Jordan, C., Silver, N., Taylor, B., Stiell, I.G., & Pediatric Emergency Research Canada (PERC) Head Injury Study Group 2010. CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury. *CMAJ Canadian Medical Association Journal*, 182, (4) 341-348

Ott, M.M., Eriksson, E., Vanderkolk, W., Christianson, D., Davis, A., & Scholten, D. 2010. Antiplatelet and anticoagulation therapies do not increase mortality in the absence of traumatic brain injury. *Journal of Trauma-Injury Infection & Critical Care*, 68, (3) 560-563

Papa, L., Akinyi, L., Liu, M.C., Pineda, J.A., Tepas, J.J., III, Oli, M.W., Zheng, W., Robinson, G., Robicsek, S.A., Gabrielli, A., Heaton, S.C., Hannay, H.J., Demery, J.A., Brophy, G.M., Layon, J., Robertson, C.S., Hayes, R.L., & Wang, K.K. 2010. Ubiquitin C-terminal hydrolase is a novel biomarker in humans for severe traumatic brain injury. *Critical Care Medicine* , 38, (1) 138-144

Piazza, O., Storti, M.P., Cotena, S., Stoppa, F., Perrotta, D., Esposito, G., Pirozzi, N., & Tufano, R. 2007. S100B is not a reliable prognostic index in paediatric TBI. *Pediatric Neurosurgery*, 43, (4) 258-264

Pieracci, F.M., Eachempati, S.R., Shou, J., Hydo, L.J., & Barie, P.S. 2007. Degree of anticoagulation, but not warfarin use itself, predicts adverse outcomes after traumatic brain injury in elderly trauma patients. *Journal of Trauma-Injury Infection & Critical Care*, 63, (3) 525-530

Rainey, T., Lesko, M., Sacho, R., Lecky, F., & Childs, C. 2009. Predicting outcome after severe traumatic brain injury using the serum S100B biomarker: results using a single (24h) time-point. *Resuscitation*, 80, (3) 341-345

Rethnam, U., Yesupalan, R.S., & Bastawrous, S.S. 2008. The Swimmer's view: does it really show what it is supposed to show? A retrospective study. *BMC Medical Imaging*, 8, 2

Saadat, S., Ghodsi, S.M., Naieni, K.H., Firouznia, K., Hosseini, M., Kadkhodaie, H.R., & Saidi, H. 2009. Prediction of intracranial computed tomography findings in patients with minor head injury by using logistic regression. *Journal of Neurosurgery*, 111, (4) 688-694

Saltzherr, T.P., Fung Kon Jin, P.H., Beenen, L.F., Vandertop, W.P., & Goslings, J.C. 2009. Diagnostic imaging of cervical spine injuries following blunt trauma: a review of the literature and practical guideline. [Review] [79 refs]. *Injury*, 40, (8) 795-800

Saltzherr, T.P., Beenen, L.F., Reitsma, J.B., Luitse, J.S., Vandertop, W.P., & Goslings, J.C. 2010. Frequent computed tomography scanning due to incomplete three-view X-ray imaging of the cervical spine. *Journal of Trauma-Injury Infection & Critical Care*, 68, (5) 1213-1217

Siracuse, J.J., Robich, M.P., Gautam, S., Kasper, E.M., Moorman, D.W., & Hauser, C.J. 729. Antiplatelet agents, warfarin, and epidemic intracranial hemorrhage. *Surgery*, 148, (4) 724-729

Smits, M., Dippel, D.W., Steyerberg, E.W., de Haan, G.G., Dekker, H.M., Vos, P.E., Kool, D.R., Nederkoorn, P.J., Hofman, P.A., Twijnstra, A., Tanghe, H.L., & Hunink, M.G. 2007. Predicting intracranial traumatic findings on computed tomography in patients with minor head injury: the CHIP prediction rule. *Annals of Internal Medicine*, 146, (6) 397-405

Sogut, O., Guloglu, C., Orak, M., Sayhan, M.B., Gokdemir, M.T., Ustundag, M., & Akkus, Z. 2010. Trauma scores and neuron-specific enolase, cytokine and c-reactive protein levels as predictors of mortality in patients with blunt head trauma. *Journal of International Medical Research*, 38, (5) 1708-1720

Spektor, S., Agus, S., Merkin, V., & Constantini, S. 2003. Low-dose aspirin prophylaxis and risk of intracranial hemorrhage in patients older than 60 years of age with mild or moderate head injury: a prospective study. *Journal of Neurosurgery*, 99, (4) 661-665

Stein, S.C., Fabbri, A., Servadei, F., & Glick, H.A. 2009. A critical comparison of clinical decision instruments for computed tomographic scanning in mild closed traumatic brain injury in adolescents and adults. *Annals of Emergency Medicine*, 53, (2) 180-188

Steyerberg, E.W., Mushkudiani, N., Perel, P., Butcher, I., Lu, J., McHugh, G.S., Murray, G.D., Marmarou, A., Roberts, I., Habbema, J.D., & Maas, A.I. 2008. Predicting outcome after traumatic brain injury: development and international validation of prognostic scores based on admission characteristics. *PLoS Medicine / Public Library of Science*, 5, (8) e165

Tasaki, O., Shiozaki, T., Hamasaki, T., Kajino, K., Nakae, H., Tanaka, H., Shimazu, T., & Sugimoto, H. 2009. Prognostic indicators and outcome prediction model for severe traumatic brain injury. *Journal of Trauma - Injury, Infection and Critical Care*, 66, (2) 304-308

Theocharopoulos, N., Chatzakis, G., & Damilakis, J. 2009. Is radiography justified for the evaluation of patients presenting with cervical spine trauma? *Medical Physics*, 36, (10) 4461-4470

Unden, J. & Romner, B. 2010. Can low serum levels of S100B predict normal CT findings after minor head injury in adults?: an evidence-based review and meta-analysis. [Review]. *Journal of Head Trauma Rehabilitation*, 25, (4) 228-240

Wong, D.K., Lurie, F., & Wong, L.L. 2008. The effects of clopidogrel on elderly traumatic brain injured patients. *Journal of Trauma-Injury Infection & Critical Care*, 65, (6) 1303-1308

Zurek, J., Bartlova, L., Marek, L., & Fedora, M. 2010. Serum S100B protein as a molecular marker of severity in traumatic brain injury in children. *Ceska a Slovenska Neurologie a Neurochirurgie*, 73, (1) 37-44

Dischinger, P., Read, K., Kerns, T., Ho, S., Kufera, J., Burch, C., Jawed, N., Burgess, A., & Bents, F. 2003. Causes and outcomes of mild traumatic brain injury: an analysis of CIREN data. *Annual Proceedings/Association for the Advancement of Automotive Medicine*, 47, 577-589

Meares, S., Shores, E.A., Taylor, A.J., Batchelor, J., Bryant, R.A., Baguley, I.J., Chapman, J., Gurka, J., Dawson, K., Capon, L., & Marosszeky, J.E. 2008. Mild traumatic brain injury does not predict acute postconcussion syndrome. *Journal of Neurology, Neurosurgery & Psychiatry*, 79, (3) 300-306

Babikian T, Asarnow R: Neurocognitive outcomes and recovery after pediatric TBI: meta-analytic review of the literature. [Review] [56 refs]. Neuropsychology 2009, 23: 283-296.

Chong CS: Management strategies for post-concussion syndrome after mild head injury: A systematic review. Hong Kong Journal of Occupational Therapy 2008, 18: 59-67.

Elgmark AE, Emanuelson I, Bjorklund R, Stalhammar DA: Mild traumatic brain injuries: the impact of early intervention on late sequelae. A randomized controlled trial. Acta Neurochirurgica 160, 149: 151-159.

Fan JY, Kirkness C, Vicini P, Burr R, Mitchell P: An approach to determining intracranial pressure variability capable of predicting decreased intracranial adaptive capacity in patients with traumatic brain injury. Biological Research for Nursing 2010, 11: 317-324.

Idris Z, Ghani RI, Musa KI, Ibrahim MI, Abdullah M, Nyi NN et al.: Prognostic study of using different monitoring modalities in treating severe traumatic brain injury. Asian Journal of Surgery 2007, 30: 200-208.

Ruttan L, Martin K, Liu A, Colella B, Green RE: Long-term cognitive outcome in moderate to severe traumatic brain injury: a meta-analysis examining timed and untimed tests at 1 and 4.5 or more years after injury. [Review] [83 refs]. Archives of Physical Medicine & Rehabilitation 2008, 89: Suppl-76.

Stiell IG, Clement CM, Grimshaw J, Brison RJ, Rowe BH, Schull MJ et al.: Implementation of the Canadian C-Spine Rule: prospective 12 centre cluster randomised trial. BMJ 2009, 339: b4146.

**References by Implementation team**

Ball C et al; A 12 month clinical audit of cervical spine imaging in multiply injured and intubated patients *The British Journal of Radiology* 2010: 83(987)

Prowse, S; NICE guidelines for the investigation of head injuries-an anticoagulant loophole? *Emergency Medical Journal* 201027:277-278

Shravat, B P 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 Medical Journal* 2006: 23(2): 109-113