

Prehospital management of severe traumatic brain injury

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Traumatic brain injury is a substantial cause of morbidity and mortality in the UK. An estimated 11 000 people per year sustain a severe traumatic brain injury, mostly between ages 15 and 29 years.¹ Patients with severe traumatic brain injury have a high mortality rate (30-50%) and many survivors will have persistent severe neurological disability.² Prompt identification and appropriate early management of traumatic brain injury is essential to optimise outcome, however, few guidelines are available for clinicians on management in the challenging prehospital environment. The 2007 report by the national enquiry into patient outcome and death on the provision of trauma services in the UK³ highlighted concerns about prehospital management of airways and ventilation in 15% of patients with severe head injuries. Doctors from various hospital specialties or general practice may be involved in providing prehospital care, so this review aims to provide a generic overview of available evidence on management of severe traumatic brain injury in adults in this environment.

What is the pathophysiology of severe traumatic brain injury?

Severe traumatic brain injury is defined as a head injury resulting in a Glasgow coma score of less than 9.⁴ Primary brain injuries that can occur at the time of impact include extradural and subdural haematomata, intracerebral contusions, and diffuse axonal injuries. Additional insults such as hypoxaemia, hypotension, or hyperpyrexia result in further cerebral damage and secondary brain injury. Modern management of head injuries focus on the identification and treatment of such potential secondary insults.

What are the priorities in prehospital management of severe traumatic brain injury?

Time from injury to definitive neurosurgical care can affect outcome for patients with severe traumatic brain injury. Patients with mass lesions have a better outcome if they receive neurosurgical treatment within four hours of injury.⁵ Rapid patient transfer to an appropriate secondary care facility is essential, in

addition to the implementation of measures to prevent secondary brain injury. Epidemiological studies show that a third of patients with severe traumatic brain injury already have a documented secondary brain insult on hospital admission.^{w1} Prehospital management of these patients focuses on provision of an adequate airway, effective oxygenation and ventilation, maintenance of an adequate cerebral perfusion pressure and avoidance of further increases in intracranial pressure. Two retrospective reviews found improved outcomes in patients with severe head injuries when these parameters were specifically targeted in the prehospital setting.^{w2 w3} Box 1 lists problems that may be encountered during extrication of the patient from a vehicle (figure).

What are the options for airway management?

Airway compromise is common after severe traumatic brain injury and has an important contribution to the development of secondary brain injury. Basic airway adjuncts are used initially and high flow oxygen is administered. Controlled trials of simulated prehospital scenarios⁶ have shown that laryngeal mask airways have a greater success rate for establishing an airway than endotracheal intubation, particularly with inexperienced clinicians. Laryngeal mask airways are becoming increasingly popular in prehospital care for airway maintenance, particularly in situations where

Sources and selection criteria

We searched Medline 1980-2008, Pubmed and the Cochrane library for clinical trials and reviews. The medical subject headings "head injury", "brain injury", "trauma", "prehospital", and combinations thereof were used. Individual therapeutic options (such as "mannitol") were also searched for. Search results were individually reviewed and manually cross referenced. Reference lists were searched for additional works. Priority was given to review articles, meta analyses, and well designed large trials. The websites www.braintraumafoundation.org, www.trauma.org, and www.east.org were also searched for additional information.



Scene from a road traffic collision demonstrating multiple difficulties encountered during extrication

access to the patient is limited. The devices are easy to insert, usually provide a good seal within the oropharynx, and provide airway protection from upper airway secretions. Regurgitation and aspiration of gastric contents remains a risk, but may be reduced with the use of alternative laryngeal masks such as LMA Pro-Seal.

Endotracheal intubation is inevitably required in almost all patients with severe traumatic brain injury, although evidence for its benefit in the prehospital environment is controversial. Most studies are retrospective and study paramedics performing endotracheal intubation with minimal use of sedative agents and muscle relaxants. Several large retrospective reviews have, however, shown that this approach results in a high risk of complications, such as failed intubation and hypoxaemia.^{7,8} Laryngoscopy without the use of anaesthetic agents is particularly damaging in patients with traumatic brain injury because increases in intracranial pressure are not attenuated; this may explain the association between prehospital endotracheal intubation and increased mortality and poor neurological outcome in patients with severe traumatic brain injury, which was reported in two retrospective analyses of trauma registries.^{9,10}

Data about true rapid sequence induction of anaesthesia performed by physicians are more promising. A recent retrospective analysis of prehospital rapid sequence induction procedures in the UK reported low incidences of complications,¹¹ and similar studies have reported intubation success rates of 94-97%, in addition to low complication rates for prehospital drug assisted intubation.^{w4} These data suggest that prehospital rapid sequence induction is beneficial if done by an appropriately trained physician; this finding is in line with recommendations from the recent trauma report from the national enquiry into patient outcome and death (box 2). With few doctors present at the scene of emergency situations, only a few patients with severe traumatic brain injury are intubated before hospital transfer in the UK, although at least half of all

Box 1 Problems encountered during extrication from a vehicle

- Multiple hazards in and around the vehicle
- Difficulty with patient assessment due to noise level
- Physical entrapment of patient
- Limited access for interventions
- Poor communication between various agencies involved
- Time pressure

these patients need intubation within 30 minutes of arrival at the hospital.³ A few patients, for example, those with severe facial trauma, may however require a primary surgical airway.

Which anaesthetic agents should be used to facilitate intubation?

Administering anaesthetic and neuromuscular blocking drugs to facilitate intubation leads to improved outcomes in patients with head injuries.¹² Ideal agents should have minimal effects on heart rate and blood pressure and reduce intracranial pressure while maintaining cerebral perfusion. Etomidate results in a low incidence of hypotension when used to facilitate intubation in patients with head injury and is perhaps the most widely used drug despite concerns about inhibition of steroid synthesis after a single dose.^{13 w5} Ketamine has usually been avoided in patients with head injuries, but a review of randomised clinical trials concluded that with controlled normocapnic ventilation, ketamine has minimal or favourable effects on intracranial pressure in sedated patients with head injury.¹⁴ Ketamine has also been associated with maintenance of better cerebral perfusion pressure compared with other sedative agents.^{w6} After intubation, adequate sedation and neuromuscular blockade must be provided for all patients during transfer to avoid rises in intracranial pressure associated with coughing.

Box 2 Indications for prehospital rapid sequence induction of anaesthesia (Great North Air Ambulance standard operating protocol)

- Airway problems that cannot reliably be managed by simple manoeuvres, such as severe facial injury
- Respiratory insufficiency (SpO₂ <92%) despite 15 l/min oxygen or impending respiratory collapse due to exhaustion or pathology
- Glasgow coma scale <9 or rapidly falling
- Patients at risk of respiratory deterioration when access is difficult during transfer to definitive care (for example, those with facial burns)
- Patients needing sedation before transfer to hospital because they present a danger to themselves or attending staff, or for humanitarian reasons (for example, to provide complete analgesia)

Box 3 Guidelines for monitoring patients with severe traumatic brain injury in the prehospital environment⁴

Patients with suspected severe traumatic brain injury should be monitored in the prehospital setting for hypoxaemia (arterial desaturation <90%) or hypotension (systolic blood pressure <90 mm Hg)

Blood oxygen saturation should be monitored continuously in the field with a pulse oximeter

Systolic blood pressure and diastolic blood pressure should be measured with the most accurate method available

Oxygenation and blood pressure should be measured as often as possible and should be monitored continuously if possible

End-tidal carbon dioxide monitoring is essential for the transfer of ventilated patients¹⁸

How should patients with severe traumatic brain injury be ventilated?

Hypoxaemia is common after severe traumatic brain injury and prospective studies show an association with increased mortality rate and poorer neurological outcome.^{w7} Hypoxaemia is usually multifactorial in patients with such injury and the presence of serious chest injuries—for example, haemopneumothorax or pulmonary contusions—needs to be considered. Hypercapnia is a common consequence of respiratory depression leading to cerebral vasodilatation, increased cerebral blood flow, and a rise in intracranial pressure. One argument in favour of performing rapid sequence induction before transfer to hospital is that this approach allows carbon dioxide levels to be controlled. Hyperventilation leads to cerebral vasoconstriction and ischaemia and should be avoided in patients with head injuries. A large retrospective review reported that 18% of head injured patients were hypocapnic after prehospital intubation with a worse outcome in the group that had a PaCO₂ of less than 4 kPa on admission to the emergency department.¹⁵ A well conducted prospective randomised study showed that monitoring end-tidal carbon dioxide reduced the incidence of hyperventilation by more than 50%.¹⁶ End tidal monitoring of carbon dioxide is now considered a routine standard of monitoring for all mechanically ventilated patients during transfer.¹⁷ Box 3 describes additional monitoring standards.

How should circulatory complications be managed?

Patients with severe traumatic brain injury who are hypotensive have a doubled risk of mortality compared with normotensive patients.³ Hypotension results in reduced cerebral perfusion and neuronal ischaemia and is often multifactorial in origin in trauma patients. It is best to assume that hypotension is due to hypovolaemia until proven otherwise. Cerebral perfusion pressure (CPP) is calculated by subtracting intracranial pressure from the mean arterial

pressure. Maintaining a CPP of 60-70 mm Hg is an essential foundation of hospital management of severe traumatic brain injury. However, measuring an accurate mean arterial pressure is difficult in the prehospital environment so most guidelines use the systolic value as a target during the resuscitation phase.

The Brain Trauma Foundation recommends a minimum systolic pressure of 90 mm Hg in adults with severe head injuries.⁴ This target is based on prospectively collected large datasets showing that a systolic blood pressure of less than 90 mm Hg is an independent risk factor for mortality after severe traumatic brain injury.¹⁹ No studies have been done to assess the effects of aiming for values higher than 90 mm Hg, although this approach is probably desirable in patients with isolated severe traumatic brain injury. In patients with multiple injuries and hypovolaemia a conflict exists between “permissive hypotension” resuscitative strategies to minimise blood loss and the need to maintain an adequate cerebral perfusion pressure to prevent secondary brain injury. The ideal resuscitation fluid is unknown for patients with severe traumatic brain injury. A well conducted large multicentre randomised controlled trial found a relative risk of death of 1.8 in patients with such injuries in intensive care who were resuscitated with albumin compared with 0.9% saline.²⁰ This finding has led guidelines to recommend use of small boluses of isotonic crystalloid to correct hypotension in patients with severe traumatic brain injury.¹⁸ Hypertonic crystalloid solutions may have a future clinical role in this subgroup. A meta-analysis of randomised, double-blinded controlled trials,²¹ found improved survival rates in patients with head injury who were resuscitated with hypertonic saline and dextran solutions compared with those who received standard care. Currently the use of hypertonic solutions is not widespread in prehospital care in the UK.

Box 4 Recommendations for management of head injury³

Prehospital assessment of neurological status should be done in all cases where head injury is apparent or suspected, using the Glasgow coma scale. Pupil size and reactivity should also be recorded

A pre-alert should be made for all trauma patients with a Glasgow coma scale less than or equal to 8, to ensure appropriately experienced professionals are available and to prepare for imaging

Patients with severe head injury need early definitive airway control and rapid delivery to a centre with onsite neurosurgical service. This requires regional planning of trauma services, including prehospital physician involvement

Patients with severe head injury should have a CT scan as soon as possible after admission and within an hour of arrival at hospital

All patients with severe head injury should be transferred to a neurosurgical or critical care centre irrespective of need for surgical intervention

What treatments can be used to reduce intracranial pressure?

Intracranial pressure is often raised in patients with severe traumatic brain injury and specific treatment should be given to lower it if clinical signs are present (for example, pupillary dilatation) and if transfer time allows. Hypoxaemia, hypotension, hypercapnia, and inadequate sedation (in an intubated patient) should all be addressed before specific treatment. Little data is available about strategies to reduce intracranial pressure in the prehospital environment. A recent Cochrane review reported a relative risk of death of 0.8 when mannitol was used to reduce intracranial pressure compared with standard care in hospital, but it concluded that there was insufficient data to support prehospital administration of the drug.²² Hypertonic saline can be used as an alternative to mannitol; studies directly comparing the drugs' capacity to lower intracranial pressure have yielded conflicting results. A large randomised prehospital trial of hypertonic saline in traumatic brain injury is about to begin recruiting.

What is the role of corticosteroids in patients with severe traumatic brain injury?

Owing to the findings of a large randomised controlled trial published in 2004, which showed a significant increase in the risk of death in patients randomised to receive corticosteroids, routine use of corticosteroids is no longer recommended for patients with head injury.²³

How should patients with severe traumatic brain injury be immobilised?

The presence of a head injury is the strongest independent risk factor for injury of the cervical spine. In patients with severe traumatic brain injury, an assumption of spinal injury should be made and full spinal immobilisation should be implemented as early as practically possible in the field. Early assessment of the cervical spine should be done after transfer to hospital to avoid the risk of intracranial hypertension associated with hard cervical collars.⁸ In sedated and paralysed patients the use of sandbags and tape may achieve better immobilisation than rigid cervical collar.

Is hypothermia beneficial?

There is little doubt that hyperpyrexia is detrimental to outcome after severe traumatic brain injury, but the role of induced hypothermia in severe head injury is

Additional educational resources

- Trauma.org (www.trauma.org)—education and resources for all involved in care of trauma patients
- Eastern Association for the Surgery of Trauma (www.east.org)
- Brain Trauma Foundation (www.braintrauma.org)—evidence based guidelines on management of traumatic brain injury
- Association of Anaesthetists of Great Britain and Ireland. Transfer of patients with brain injury. www.aagbi.org

unclear. Early randomised controlled trials showed benefits in outcome for hypothermia as a treatment for refractory intracranial hypertension in patients with severe traumatic brain injury, but subsequent meta analyses have not confirmed this benefit.²⁴ One randomised trial⁹ showed improved neurological outcome at six months in younger patients (younger than age 45 years) who arrived at hospital with a low body temperature, which was then maintained, suggesting that patients with severe traumatic brain injury who are cold should not be actively rewarmed. This observation must be considered in relation to the fact that hypothermia is a key factor in the development of traumatic coagulopathy in patients with multiple injuries.

Should patients with traumatic brain injury be transferred directly to a neurosurgical centre?

A recent retrospective analysis showed a reduction in mortality in patients with head injuries managed in neurosurgical centres and concluded that all patients with severe traumatic brain injury should be managed in such centres (box 4).²⁵ Although this review was large, it only included data from about two thirds of institutions in the UK and may have been subjected to a triage bias because patients with very severe injuries are not usually accepted for treatment in neurosurgical centres. Currently, in the UK, neurointensive care beds are insufficient to manage all patients with severe traumatic brain injury and so a substantial proportion will still be treated in non-specialist centres. The presence of other injuries to the patient, mode of transport and proximity to institutions should all be considered when deciding which secondary care facility is appropriate.

Conclusion

Severe traumatic brain injury is common and often results in a poor neurological outcome. Outcomes can be improved if patients receive definitive treatment for their head injury as soon as possible after injury, preferably in a neurosurgical centre. Hypoxaemia and hypotension are common in these patients and together result in a mortality rate of more than 75%.³

Tips for non-specialists

- Airway obstruction is common in these patients but can usually be managed initially with simple manoeuvres and adjuncts
- Focus on the basics, ensuring adequate oxygenation and ventilation
- Do not delay patient extrication by performing unnecessary interventions
- Transfer rapidly to secondary care

SUMMARY POINTS

Management of severe traumatic brain injury is focused on rapid transfer to secondary care while preventing secondary brain injury

Airway compromise and inadequate ventilation are common and should be addressed immediately

Prehospital endotracheal intubation should be undertaken with the assistance of anaesthetic drugs by appropriately trained physicians

Hypotension is an independent risk factor for mortality; small boluses of isotonic crystalloid fluids should be given if it occurs

Patients may be best managed in a neurosurgical centre where they should receive definitive neurosurgical treatment within 4 hours of injury

There is no role for the routine use of corticosteroids in patients with head injury

Careful identification and treatment of these factors can reduce the development of secondary brain injury.

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