Traumatic Brain Injury Protocol

Section 1. Pre-PICU Management

Sources:
Guidelines for Pre-Hospital Management of Traumatic Brain Injury 2000: BrainTrauma Foundation New York.
Recommendations for the Transfer of Patients with Acute Head Injuries to Neurosurgical Units 1996, Neuroanaesthesia Society GBI

1.1 Immediate care
Stabilisation of airway, breathing and circulation (ABC) is the priority for all patients before attention to other injuries.

Patients with a GCS ≤ 8 there should be early involvement of an anaesthetist or intensivist to provide appropriate airway management
- Depressed conscious level should be ascribed to intoxication only after a significant brain injury has been excluded.
- In principle patients with head injury should not receive systemic analgesia until fully assessed so that an accurate measure of consciousness and other neurological signs can be made.

Intubation and ventilation should be used immediately in the following circumstances.
- Coma – not obeying commands, not speaking, not eye opening (GCS ≤ 8).
- Loss of protective laryngeal reflexes.
- Ventilatory insufficiency as judged by blood gases:
  - hypoxaemia (PaO2 < 9 kPa on air or < 13k Pa on O2)
  - hypercarbia (PaCO2 > 6 kPa).
- Spontaneous hyperventilation (causing PaCO2 < 3.5 kPa).
- Respiratory arrhythmia.

An intubated patient should be ventilated with muscle relaxation and appropriate sedation and analgesia. Aim for PaO2 greater than 13 kPa, and PaCO2 4.5 to 5.3 kPa although in situations of acute cerebral herniation / complications of high ICP it might be appropriate to hyperventilate more aggressive in the short term.
1.2 CT Scanning
CT should be requested immediately in:

1. all patients with any of the following risk factors,
   • GCS less than 13 at any point since the injury.
   • GCS equal to 13 or 14 at 2 hours after the injury.
   • Suspected open or depressed skull fracture.
   • Any sign of basal skull fracture (haemotympanum, ‘panda’ eyes, CSF otorrhoea, Battle’s sign).
   • Post-traumatic seizure.
   • Focal neurological deficit.
   • More than one episode of vomiting (clinical judgement should be used regarding the cause of vomiting in those aged 12 years or younger, and whether imaging is necessary).
   • Amnesia for greater than 30 minutes of events before impact. The assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in any child aged under 5 years.

2. CT should also be requested immediately in the following situations provided they have experienced some loss of consciousness or amnesia since the injury:
   • Dangerous mechanism of injury (pedestrian vs. motor vehicle, an occupant ejected from a motor vehicle or a fall from a height of greater than 1m or five stairs). A lower threshold for height of falls should be used when dealing with infants and young children (< 5 years).
   • Coagulopathy.

1.3 Cervical Spine
Patients who have sustained a head injury and present with any of the following risk factors should have full cervical spine immobilisation attempted unless other factors prevent this:
   • GCS less than 15 at any time since the injury
   • neck pain or tenderness
   • focal neurological deficit
   • paraesthesia in the extremities
   • any other clinical suspicion of cervical spine injury.

Cervical spine imaging of infants and children: Children aged 10 years or more can be treated as adults for the purposes of cervical spine imaging.
In children under 10 years, CT of the cervical spine should only be used in exceptional circumstances (for example, cases where there is a strong suspicion of injury despite normal or inadequate plain films. Children <10 years should receive AP and lateral views without an AP peg view.

Clinical Clearance of Cervical Spine. The absence of all five of the following clinical criteria provides very strong evidence of against cervical spine injury and allows immobilisation to be removed. http://www.pediatrics.org/cgi/content/full/108/2/e20 & NEJM 2000;343:94-9,
• No mid-line cervical tenderness
• No focal neurological deficit
• Normal alertness
• No Intoxication
• No distracting Injury

In practice these criteria will rarely (if ever) be met in child being referred to PICU and clearance will therefore be delayed until these criteria can be met on waking.
We include the presence of a normal (and adequate) lateral cervical spine x ray as an additional essential criterion for C-spine clearance

Section 2. Referral /Transfer

2.1 Referral
A Child with an acute severe head injury requiring PICU / neurosurgery should be referred via STRS.

The PICU team can accept a case but all cases must be discussed with the neurosurgical team registrar.

St. Georges Hospital is a receiving centre for head injury patients in North Thames. If no bed is available, the child should be referred to the King’s College Hospital or Great Ormond Street Hospital via the CATS team.

Criteria for referral to ICU/Neurosurgery include:

- persisting coma (GCS less than or equal to 8) after initial resuscitation
- unexplained confusion which persists for more than 4 hours
- deterioration in GCS score after admission (greater attention should be paid to motor response deterioration)
- progressive focal neurological signs
- a seizure without full recovery
- definite or suspected penetrating injury
- a cerebrospinal fluid leak.

2.2 Transfer
HYPOTENSION AND HYPOXAEAMIA ARE STRONGLY ASSOCIATED WITH POOR OUTCOME FROM HEAD INJURY AND MUST BE AGGRESSIVELY TREATED

Thorough resuscitation and stabilisation of the patient should be completed before transfer. A patient persistently hypotensive despite resuscitation should not be transported until all possible causes of the hypotension have been identified and the patient stabilised.

Intubation and ventilation should be also used before the start of the journey in addition to the urgent indications above in the following circumstances.
- Significantly deteriorating conscious level, even if not coma.
• Bilateral fractured mandible.
• Copious bleeding into mouth (for example, from skull base fracture).
• Seizures.

Transfer of a child or infant to a specialist neurosurgical unit should be undertaken by staff experienced in the transfer of critically ill children.

**Section 3. PICU Management**


3.1 Planning / ICP Monitoring

Immediately after admission the PICU the strategy for an individual child will be planned between the Neurosurgical and Intensive Care Teams based on the history examination and CT findings.

**THERE ARE ONLY 3 OPTIONS:**

1. Wake and assess clinically
2. Full neuro-intensive care (including ICP monitoring)
3. Urgent craniotomy.

This is a crucial stage in the child’s care and the proposed strategy must be discussed with both the consultant neurosurgeon and intensivist on call. Specifically no child should be woken from sedation at this stage without discussion with both the consultant neurosurgeon and intensivist on call.

There are few data to assist with the decision as to wake or institute full neurointensive care: The following recommendations (Pediatr Crit Care Med 2003 Vol. 4, No. 3 S19) are largely derived from adult guidelines:

**ICP monitoring is appropriate for patients with severe head injury (GCS 3-8 after resuscitation).**

**ICP monitoring is MANDATORY in patients with severe head injury (GCS 3-8) AND an abnormal CT scan.**

(abnormal CT = haematomas, contusions, cerebral oedema and/or compressed basal cisterns)

The presence of an open fontanelle and/or sutures in an infant with severe TBI does not preclude the development of intra-cranial hypertension or negate the utility of the ICP monitoring.

**Any infant or child admitted to PICU with a significant head injury who is expected to be sedated and ventilated for >6hr should have intra-cranial pressure monitoring.** This includes cases with relatively mild head trauma that require ventilation for other injuries e.g. liver laceration or lung contusion.

Pressure monitoring should generally come out after 7 days.
3.2 Neuro-intensive Care

3.2.1 Position/Environment:

Head must be maintained midline and the head of the bed raised at approximately 30°. Femoral central venous lines are preferred to subclavian and internal jugular CVLs (though this is less important in older children). Cervical Spine precautions must be adjusted so as not to contribute to compression of neck veins. Unnecessary noise (radio etc.) around the bedscape should be avoided if possible.

3.2.2 Fluids:

There are two main aims of fluid therapy in acute severe head injury.

1. **Avoid hypovolaemia** (maintain cerebral perfusion)
2. **Avoid excess free water / hypo-osmolarity** (minimise cerebral oedema)

These is achieved by giving standard 0.9% saline maintenance at 80% of ‘full maintenance’ in view of the reduced insensible losses associated with humidified ventilator gases and reduced activity. There is no evidence to support restricting fluids further than this and indeed excessive fluid restriction is associated with poor outcome (Clifton GL, Miller ER, Choi SC, Levin HS. Fluid thresholds and outcome from severe brain injury. Crit Care Med 2002;30(4):739-45).

CVP should be routinely monitored and colloid or crystalloid bolus fluids administered as required to avoid hypovolaemia. **Use i.v. colloid gelofusin, boluses of 5-10ml/kg.**

**Maintaince fluid should be given as Normal (0.9%) Saline.** In children less than 2 years of age the risk of hypoglycaemia is higher and 5% Dextrose + 0.9%Saline should be prepared from the addition of hypertonic saline to a bag of 5% dextrose (15mls of 30% saline (4.5g NaCl) in 500 ml 5 dextrose ~ 5% Dextrose + 0.9%Saline).


Keep serum Osmolality between 310-320 mOsm

If a rapid drop in [Na⁺]serum occurs-

1. **Make a diagnosis**
   - most likely SIADH (wet patient & [Na⁺]urine >20mmol/l)
   - Sodium loss > net water loss (variable fluid status [Na⁺]urine <20mmol/l)
   - Possible CSW - rare. (dry patient & [Na⁺]urine >20mmol/l)

2. **Consider giving hypertonic saline to correct [Na⁺]serum**
   - 5ml/kg 3% Saline iv cautiously, into a central vein

**Keep blood glucose 4-8mmol/l** - Do not use insulin infusions
A urinary catheter is essential. Maintain urine output > 1ml/kg/hr

**3.2.3 Nutrition**  Pediatr Crit Care Med 2003 Vol. 4, No. 3 S68

Early enteral feeding is important either NG or NJ. Remember to use Oro-gastric tube if known or potential base of skull fracture.

Calorie targets should be 140% of calculated REE in sedated patients and 100% of REE in sedated and paralysed patients. If this cannot be achieved enterally, consideration should be given to TPN after 72 hours.

There is a high risk of constipation (opiates, inactivity etc). Prophylactic lactulose should be given to all children receiving neuro-intensive care as soon as gastric aspirates allow.

**3.2.4 Ventilation:**

There are two main aims of ventilation in acute severe head injury.
1. Optimise PaO₂ (aim for 12-13kPa) Avoid hypovolaemia (maintain cerebral perfusion)
2. Maintain **normocapnia** (Keep PaCO₂ between 4.5-5.3kPa)

Settings:
Use PEEP at 5cmH₂O (atelectasis is a greater risk than a small increase in venous pressure)

Chest Physiotherapy is essential to maintain these crucial gas exchange goals – give fentanyl premed 5microg/Kg

Use end-tidal capnography in all cases - be proactive in keeping PaCO₂ between 4.5-5.3kPa.
Later; after 6-8 hours, pH is probably more important than PaCO₂ in determining cerebral blood flow,

Optimal mode for the paralysed patient is **IMV** with a fixed tidal / minute volume. For the non-paralysed patient SIMV + autoflow is preferred.

**3.2.5 Sedation / Analgesia/ Paralysis / Anticonvulsants / Antibiotics**

Ensure adequate sedation. Especially for procedures, physiotherapy and movement of the patient.

It is not necessary to keep the child paralysed throughout BUT the child must be adequately sedated so he/she does not cough against the ET tube thereby increasing his ICP.
Paralyse until CT head is obtained and the extent of the injury determined, during ICP device insertion and all patients with sustained intracranial hypertension for >24hr following injury.

a) Sedation
   i) Midazolam infusion at 60-240 µg/kg/h.
ii) Boluses of 0.1-0.2mg/kg

b) Analgesia
i) Morphine infusion at 10-40 µg/kg/hr
ii) Boluses of Fentanyl 5-10 µg/kg; Alfentanil 1-5µg/kg; Remifentanyl 0.05µg/kg

0.05µg/kg

c) Paralyse
i) iv infusion of Vecuronium 1-10µg/kg/hr.
ii) All patients on vecuronium infusions should have train-of-four assessed daily to minimise the risk of prolonged block. This is preferable to ‘vecuronium holidays’ in patients with severe intra-cranial hypertension.

Procedures
You must ensure there is adequate sedation to avoid spikes in ICP.

Use boluses of:
- Midazolam 0.1-0.2mg/kg
- Fentanyl 5-10 µg/kg; or Alfentanil 1-5µg/kg;

Anticipate the possibility of a fall in blood pressure with bolus sedation - prompt treatment may be required.

As a principle, trial effect of bolus sedation in preference to increasing infusion rates to limit risk of accumulation.

Prophylactic anticonvulsants appear to reduce the risk of early (first 7 days) post-traumatic seizures. Cases at high risk for early PTS (significant contusions, haematomas, severe cerebral oedema) should receive phenytoin anti-seizure prophylaxis for the first 7 days. Pediatr Crit Care Med 2003 Vol. 4, No. 3 (S72.)

Antibiotics prophylaxis is recommended with
(i) **Penetrating** head injuries Lancet 2000; 355: 1813–17
(ii) Evidence of CSF leakage

- For children:
  - metronidazole O, IV, or PR, 7.5 mg/kg
  - and
  - iv co-amoxiclav 20 mg/kg q6 h, or iv cefuroxime 20 mg/kg q6 h

3.2. Intracranial Pressure/Cerebral perfusion pressure (CPP)

Brief ‘spikes’ in ICP that return to a low baseline are rarely significant.

High ICP (threshold difficult but definitely >25) should be managed as follows:

Always consider a surgically treatable problem (obstructive hydrocephalus, re-bleed) especially in a sudden ICP rise that is resistant to simple therapies:

1) **Review all the basics:**
   A. Ensure adequate sedation
   B. Review ventilation / blood gases (?PaCO₂ retention)
   C. Fluid balance (? positive/ hyponatraemia)
   D. Correct any cause of relative neck vein obstruction.
E. Is the urinary catheter working?
F. Avoid hyperthermia. Cool to normothermia. Not below 36°C

2) Emergency Management:
G. Brief periods of hand bagging (<2 mins) if ICP > 40cmH2O
H. Consider osmolar therapy
   Mannitol 0.25-0.5 g/kg/dose iv (1.25 -2.5ml/kg of 20% Mannitol)
   over 20 min
   Hypertonic saline (especially if [Na+]serum, <145) 5mls/Kg 3% saline
   over 10 minutes
I. Thiopentone Bolus 1-5mg/kg iv Risk of Hypotension
   Infusion 1-5mg/kg/hr.
   Serum level 150-200μmol/l (x0.24 =μg/ml)

Repeat CT scan

4) Cerebral Perfusion Strategy.

Raised ICP may not respond well to the measures above.
The secondary goal of maintaining CPP should also be considered.
Increase MAP by;
   i) Noradrenaline 0.05-0.5 μg/kg/min.
   ii) Dopamine 5-15μg/kg/min if cardiac output might be low
       or borderline (e.g. sepsis, multi-trauma associated MODS, cardiac
       contusion, or receiving thiopentone infusion).

Targets: Pediatr Crit Care Med 2003 Vol. 4, No. 3 S31
These are not well established but a level of <40mmHg should be avoided at
any age.
Guidance ‘40-65mmHg probably represents the age-related continuum for the
optimum treatment threshold.
A minimum target of 70mmHg is an option (C) for adults.
In practice we recommend the following minimum CPP values.

CPP = MAP - ICP.

Adequate CPP varies with age;
1m - 1y > 40mmHg
1y - 4y > 50mmHg
5y - 8y > 60mmHg
8y and over > 70mmHg

Note that adequate MAP varies with age;
1m - 1y 45 - 70mmHg
1y - 4y 50 - 100mmHg
5y - 12y 60 - 90mmHg
12y and over 65 - 95mmHg

4) Resistant Intracranial Hypertension
Several unproven therapies exist and may be considered in cases in which CPP cannot be maintained.
None should be attempted without the agreement of both the PICU and Neurosurgical consultants on-call.
Examples include:

- EVD placement and CSF Drainage
- Decompressive Craniectomy / Lobe resection
- Therapeutic hyperosmolar therapy.

3.3 Cervical Spine Care / Clearance

a) **Cervical spine immobilisation must be applied to all head injuries while they are receiving neurointensive care.** (unless they have previously fulfilled the criteria in section 1.3 for clinical clearance and have normal and adequate plain films

b) **Cervical Spine clearance.**
The cervical spine can only be cleared by a combination of normal plain radiology (or CT of cervical spine in older children) and a normal clinical examination demonstrating no midline tenderness, and no focal neurology when the child is conscious and not distracted by other painful injuries (as in 1.3).

However in a child who remains comatose after extubation these criteria cannot be met. Therefore further imaging / investigation will need to be planned in discussion between neurosurgery, neuroradiology and Intensive care. 2 questions must be addressed:
1. evidence of cord injury? (very unlikely in the presence of normal plain films +/- CT) and
2. Stability of the cervical spine (flexion and extension views may be required).

Authors:
Mark Peters Daniel Lutman and Dominic Thompson (Great Ormond Street Hospital),

Edited for SGH by
Martin Gray

Date:
October 2006

Review date:
October 2008