Management of severe traumatic brain injury (TBI)

Introduction

The aim of neurocritical care is to prevent secondary brain injury following a significant primary brain insult. The principles of management are (1) to maintain normal parameters (homeostasis) and (2) to reduce cerebral metabolic demand.

Invasive monitoring (mean arterial pressure (MAP), central venous pressure (CVP), and intracranial pressure (ICP)) is used to achieve this aim. Any child with a significant brain injury where the plan is not to wake and extubate should have ICP monitoring commenced.

Excellent neurocritical care requires prompt and effective **communication** and **collaboration** between the neurosurgeons, paediatric intensivists and nursing teams.

Key targets

- Maintain ICP below 20mm Hg
- Maintain cerebral perfusion pressure (CPP) at the appropriate level for age.
- Treat systemic hypotension promptly & aggressively
- Ensure normocapnia, and avoid hypoxia
- Maintain normothermia and normoglycaemia

Neurocritical care

Nursing management

1. Carry out hourly critical care and neuro observations (more frequently if clinically indicated).
2. Raise head end of the bed to 30^0 (use a protractor to measure 30^0 – it is steeper than you think).
3. Keep the head in midline position
4. Remove cervical collars (which can obstruct venous return from the head) only when patient is adequately sedated. Keep head supported in midline using sandbags. Cervical spine protection **must** be in place when the patient is waking.
5. Ensure good analgesia and sedation
6. Place gastric tube (orogastric if nasal trauma or any concern about basal skull injury)
7. Place a urinary catheter.
8. Place CVP monitoring.

Medical Management

Ventilation

1. Maintain normocapnia ($PaCO_2$ 4.5-5.0 kPa).
   (Hypocapnia causes reduced cerebral blood flow; hypercapnia can worsen cerebral oedema.)
2. Prevent hypoxia. Aim to maintain PaO_2 >13 KPa.
3. Use PEEP of 5 or above, in order to decrease the risk of atelectasis and ventilation associated pneumonia (a more significant problem in these children than a small reduction in jugular flow).
4. Use adequate sedation and if required, muscle relaxants to maintain control of ventilation.
   NB Use of muscle relaxants will remove visual cues of seizure activity.
5. Give fentanyl boluses prior to interventions such as suction, physio to minimise response to stimulus.

Cerebral perfusion pressure (CPP) and Intracranial pressure (ICP)

Poor outcomes in paediatric TBI have been associated with low cerebral perfusion pressure and raised intracranial pressure. **Aim to keep CPP at age-appropriate level and ICP < 20 mmHg** (see below).

CPP = MAP – ICP

Maintain cerebral perfusion pressure (CPP) at age appropriate level by maintaining mean arterial pressure (MAP).

Age-appropriate CPP	
2 – 6 yrs	>= 50 mmHg
7-10 yrs	>= 55 mmHg
11-15 yrs	>= 60 mmHg

- Ensure adequate fluid resuscitation.
- Obtain central venous access (usually femoral) early.
- Measure CVP (allows analysis of trends).
- Consider noradrenaline to maintain MAP and hence CPP.

NB: if persistently low MAP consider **occult trauma**, particularly intra-abdominal. TBI does not usually cause hypotension.

Maintain intracranial pressure (ICP) below 20 mmHg

- ICP can be raised for many reasons, e.g. due to hypercarbia, hypoxia, hyperthermia, inadequate sedation, procedures such as suctioning, seizures, new intracranial changes. Ensure that a technical problem with ICP monitoring has been ruled out.
- Treat raised ICP that remains >20 mmHg for 5 minutes (see box)
- Contact neurosurgeons if ICP not responding to medical management; consider repeat neuroimaging **early**

Treatment of raised ICP

- Ensure that the child is adequately sedated and minimise discomfort (stomach empty? bladder empty?)
- Any evidence of seizure activity (may require 2 lead cEEG)?
- Check arterial blood gas: if PaCO2 raised, suction if necessary and adjust ventilation
- Drain CSF via external ventricular drain (EVD) if present. **Do not** adjust height of EVD without discussion with senior colleague
- Osmotic therapy
  - **Hypertonic saline** - 3% saline given as 2-4ml/kg over 20 min (maintain serum osmolality of <360mOsm/L, achieve [Na] >140 mmol/l)
  - **Mannitol** - 0.5g/kg IV given over 20min, repeated every 6 hours if needed (avoid if serum osmolality > 320mOsm/L)
- If no response to above measures:
  - Discuss with PICU consultant
  - Discuss with neurosurgeon
- Consider second tier treatments
  - Hyperventilation
  - Use of barbiturates (thiopental IV bolus & infusion)
  - Neurosurgical measures- decompression craniotomy

Sedation and analgesia

These children have had a significant injury and require effective analgesia. Sedation is also required to assist with ventilation and reduce cerebral metabolic demand. Continuous IV infusions are used to maintain this (morphine and midazolam in normal doses). In addition, boluses of analgesia (particularly fentanyl) are given **before** painful procedures or nursing interventions are undertaken, to minimise ICP spikes.

Children should not routinely be muscle relaxed. Muscle relaxation may be necessary where ICP management is difficult or to prevent shivering when a cooling blanket is used.

Temperature control

Children should be kept normothermic (36 – 37°C). Hyperthermia is associated with poor outcome in TBI.

There is no role for therapeutic hypothermia in paediatric TBI. Evidence to date suggests worse outcomes with therapeutic hypothermia (see Hutchison et al) and the most recent trial was stopped for lack of efficacy.

Fluids, electrolytes, nutrition

- IV maintenance fluid: 70% of total daily requirement as 0.9% NaCl (infants may require 0.9% NaCl / 5% dextrose)
- Maintain strict I/O chart. Watch for evidence of DI or SIADH.
- Monitor serum electrolytes & osmolarity every 6 hours initially. Watch for electrolyte disturbances, particularly hypo- or hypernatraemia (consider SIADH, CSW, DI)
- Maintain serum osmolarity >280 mOsm/Kg, and sodium >140 mmol/L
- Give ranitidine for gastric protection
- Start enteral feeds early

Use of antiepileptic drugs

There is limited evidence to support the use of prophylactic anti-seizure medication (phenytoin) in patients with severe TBI, for early onset seizures. Consider phenytoin if CT brain shows abnormalities associated with increased epileptogenic activity, e.g. haemorrhage.

Investigations

Bloods

On admission: arterial blood gas, FBC, urea & electrolytes, serum osmolarity, coagulation screen, group & save. Note that severe TBI gives rise to coagulation abnormalities.
First 24 hrs: 6 hourly arterial blood gas, urea & electrolytes, serum osmolarity; 12 hourly FBC and coagulation screen; urinary electrolytes / osmolarity if indicated
Daily when stable: FBC, urea & electrolytes; other investigations as indicated

CXR

CXR should be carried out on or before admission, as part of trauma evaluation and to confirm ET tube and gastric tube positions. Daily routine CXR is not required, but children with TBI have increased risk of developing ventilator associated pneumonia (VAP) so unexplained pyrexia would warrant investigation.

Repeat neuroimaging

Repeat imaging should be considered if there are signs of persistent raised ICP, in order to obtain additional information prior to considering neurosurgical intervention. **Imaging should complement a thorough clinical examination**, and not be a substitute**.** Re-imaging should be considered early.

Cervical spine protection

It is essential to consider cervical spine injury in all patients with severe TBI. Cervical collars may be removed during initial critical care management but cervical spine protection **must** be in place when the patient is waking. Appropriately sized Aspen collars should be placed immediately on arrival to the unit, because of pressure sores associated with the emergency C-spine collars.

Clinical clearance of cervical spine can occur only when a child is awake, answering questions with no distracting injury. In any other situation, cervical spine clearance will require imaging (usually MRI) and cervical spine protection must remain in place until this is carried out. The risk of SCIWORA (spinal cord injury without radiological abnormality) may vary with the age of the child and mechanism of injury, but injury has been described even in adolescents.

(See guideline for cervical spine clearance)

S George
G Williamson
Updated 06/03/14
Review 06/04/15

Key References:

Chambers IR et al. Critical thresholds of intracranial pressure and cerebral perfusion pressure related to age in paediatric head injury. J Neurol Neurosurg Psychiatry 2006;77:234–240

Guerguerian A-M, Lo TYM, Hutchison JS. Clinical management and functional neuromonitoring in traumatic brain injury in children. Current Opinion in Paediatrics 2009, 21: 737- 744.

Guideline for management of severe traumatic brain injury. The Hospital for Sick Kids, Toronto (2008)

Guideline for management of severe traumatic brain injury- Great Ormond Street Hospital guidelines (2006)

Hutchison JS et al. Hypothermia therapy after traumatic brain injury in children. N Engl J Med. 2008 Jun 5;358(23):2447-56.

Hutchison JS, Frndova H, Lo TM, Guerguerian AM. Impact of hypotension and low cerebral perfusion pressure on outcomes in children treated with hypothermia therapy following severe traumatic brain injury: A post hoc analysis of the hypothermia paediatric head injury trial. Developmental Neuroscience 2010; 32: 406-412.

Kochanek PM et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children and adoloscents- Second edition. Paediatric critical care medicine 2012: 13(1): supplement.

Triglydas T et al. Spinal cord injuries without radiological abnormality at two pediatric trauma centres in Ontario. Pediatr Neurosurg 2010;46:283–289

Further reading:

NICE guidelines 2007

Agbeko et al PCCM 2012 HOB elevation (and associated editorial by Tasker)

Chesnut et al NEJM 2012 (and associated letters and editorial) use of ICP

Marko Critical Care 2012 (and associated manuscripts) use of NaCl 3%

Desjardins et al Critical Care 2012 meta analysis for Haemoglobin targets