10. Severe traumatic brain injury – also see flow chart Appendix 5

Introduction

Severe traumatic brain injury (TBI) is the leading cause of death in children in the UK, accounting for 15% of deaths in 1-15 year olds and 25% of deaths in 5-15 year olds. The most common cause is road traffic accidents followed by falls. Abusive head trauma remains an important cause in infants.

The definition of severe TBI is a post resuscitation Glasgow Coma Sore (GCS) of 8 or less.

The **primary brain injury** may result in a combination of the following features:

- Skull fracture
- Cerebral oedema
- Subarachnoid, subdural, extradural or intracerebral haemorrhage
- Intraventricular haemorrhage +/- hydrocephalus
- Vascular injury and consequent stroke

These mechanisms all contribute to an increase in intracranial pressure (ICP). There is a significant risk of **secondary brain injury** due to raised intracranial pressure and hypoxic ischaemic insult after the primary brain injury has occurred.

Aims

The aims of management are to **prevent secondary brain injury** by the prevention of hypoxia, hypotension, and raised ICP.

In most circumstances, when severe TBI is suspected, a CT scan of the brain and cervical spine should be completed at the local Trauma Unit prior to transfer to the Major Trauma Centre (MTC). Situations may arise when the patient is best served by immediate transfer to the MTC. An example would be the child with multiple injuries who has been brought to the nearest hospital to secure the airway but then requires immediate transfer to the MTC, particularly where transfer times to the MTC are relatively short. For information on referral pathways see here.

If CT imaging identifies a time critical lesion (eg. extradural haematoma with mass effect) requiring urgent neurosurgical intervention then the patient requires rapid transfer to the paediatric neurosurgical centre by the local team. Even if the situation is not immediately time critical, the clinical situation can change quickly in severe TBI and a sense of urgency should be maintained by the treating clinicians in getting the patient safely to definitive care.

Key principles of treatment

1. Avoid hypoxia and hypotension
2. Avoid abnormal pCO_2
3. Maintain normothermia
4. Keep cervical spine immobilised
5. Keep ICP <20 mmHg*
6. Maintain adequate cerebral perfusion pressure (CPP)

*When the child presents they will not have an ICP monitor in place, so it should be assumed that the ICP is 20mmHg and the mean arterial blood pressure (MAP) should be maintained high enough to ensure an adequate CPP.

Priorities

1. Standard c-ABC approach as per APLS / ATLS guidelines
    - **C**ontrol massive haemorrhage
    - **A**irway with cervical spine control
    - **B**reathing with ventilation support
    - **C**irculation with haemorrhage control
    - **D**isability – AVPU, posture and pupils
    - **E**xposure with temperature control

2. CT brain and cervical spine scan – aim within 30 minutes to enable identification of time critical brain injury.

3. Urgent referral to the Major Trauma Centre (MTC) stating severe TBI and whether time critical - *for contact details see flow chart*. Clinical advice can be facilitated by Embrace, but too many phone calls can introduce delays that may impact on outcomes. Children with potential time critical pathology requiring intervention will not be refused by the Major Trauma Centre, regardless of bed capacity.

4. Prepare for time critical transfer by local team. The transferring clinician should be the most senior anaesthetic / critical care clinician available. Aim to depart within 60 minutes of the CT scan if time critical. Every effort must be made not to introduce unnecessary delays in transfer to the MTC.

Airway and C-spine

- All children with a GCS 8 or less should be intubated orally and ventilated for airway protection and control of oxygenation and ventilation. Nasal intubation should be avoided because of the possibility of basal skull fracture.
- Spinal immobilization before, during and after intubation is essential. Intubation of these patients therefore requires a minimum of four appropriately skilled people (manual in-line immobilization, cricoid pressure, assistant to give drugs, and experienced intubator).
- Please refer to the section on Emergency Anaesthesia for choice of induction agent and muscle relaxant.
- Log roll should be used for all turns and moves to protect the cervical, thoracic and lumbar spine.
- In unconscious children, immobilisation should be with a properly fitting collar, blocks and tape. If a properly fitting collar is not available then blocks or rolled blankets should be used to provide an immobilisation device.
- Use a vacuum mattress for transport to CT scan and to the MTC if one is available. A scoop stretcher is a suitable device for transfer, although a vacuum mattress is preferable. Use of hard spinal extrication boards should be avoided.

Ventilation and oxygenation

- Anaesthesia should be maintained either with morphine and midazolam infusions, or Propofol infusion (which is safe to use as short-term anaesthesia in children who are haemodynamically stable). Muscle relaxation should be maintained with either repeated boluses or an infusion of rocuronium or atracurium.
- For general guidance on drug dosages for induction and maintenance of anaesthesia in critically ill children please refer to the Embrace drug chart. https://www.sheffieldchildrens.nhs.uk/embrace/
- All patients must have continuous oxygen saturation and end-tidal carbon dioxide (etCO2) monitoring.
- Patients should be ventilated to an etCO2 level that correlates to a blood carbon dioxide level (PaCO2) of 4.5-5.3 kPa. Blood samples for blood gas analysis may be venous, capillary or arterial.
- Provide oxygen to maintain saturations >95% or an arterial PaO2 >13kPa.
- Ventilate all patients with positive end expiratory pressure (PEEP) of at least 5 cmH2O, and peak inspiratory pressure (PIP) to achieve tidal volume of 6-7 ml/kg.

Circulation

- Every patient should have a minimum of two secure, large bore points of IV access.
- Blood should be taken for cross match, blood sugar, urea and electrolytes, full blood count, and clotting.
- Treat hypotension aggressively - hypotension is the biggest cause of ischaemic secondary brain injury. Maintain mean arterial blood pressure (MAP) to ensure adequate cerebral perfusion pressure.

Age	MAP
<1 year	>60
1-2 years	>65
3-5 years	>70
6-10 years	>75
>10 years	>80

- **Do not delay CT or time critical transfer for insertion of central and arterial access**
- Consider resuscitation with blood products early in haemorrhagic shock (see massive haemorrhage guideline).
- If cardiovascularly unstable despite fluid resuscitation, it is vital to look for sites of significant blood loss – blood on the floor (external haemorrhage), chest injury, abdominal injury, pelvic injury or femoral fracture. In infants with an open fontanelle, intracranial haemorrhage can cause life threatening hypovolaemia. Some children will need to be transferred to the MTC to manage bleeding. In the situation of uncontrolled blood loss, discussion with the regional major trauma centre is advised. Please see Section 3 for contact details.
- Some children with isolated TBI need vasoactive drug support to maintain their target blood pressure in the specified range. If the patient only has peripheral access, then use dopamine to maintain the target blood pressure. If the patient has central access, then use noradrenaline to maintain the target blood pressure.
- All patients should have a urinary catheter placed to prevent urinary retention if osmotic therapy has been given.

Imaging

- CT brain & cervical spine (or trauma CT if indicated) within 30 minutes of presentation.
- All patients must be transferred to CT by an appropriately trained intensivist or anaesthetist with standard AAGBI monitoring as a minimum (ECG, pulse oximetry, non-invasive blood pressure and end tidal carbon dioxide).
- The CT scan must be reported immediately for life threatening features and by a consultant radiologist within one hour. The scans themselves will need to be transferred electronically to the major trauma centre.
- If a time critical neuro-surgical lesion is identified, then the patient requires rapid transfer by the local team to the regional neurosurgical centre. Refer to the flowchart for the referral pathway and contact details for neurosurgery depending upon which hospital you are in.
- The lack of a working CT scanner constitutes a neurosurgical emergency and should mandate immediate transfer by the referring hospital team. Refer to the flowchart for the referral pathway and contact details for neurosurgery depending upon which hospital you are in.

Neuroprotective measures

- Ensure blood sugar is at least 3mmol/l.
- Ensure the patient's head is in the mid-line position to optimise venous drainage.
- Ensure the bed is tilted to 30 degrees head up.
- Ensure adequate analgesia and sedation (often require large amounts of morphine & midazolam). Muscle relaxation must be maintained during transport.
- Maintain good oxygenation (saturations ≥95% or arterial PaO2 >13kPa).
- Maintain PaCO2 at 4.5-5.3 kPa (this can be correlated with a blood gas which can be venous, capillary or arterial).
- Maintain mean arterial blood pressure according to the targets as above.
- Maintain normothermia - core temperature 36 to 37 °C.
- Load with phenytoin 20mg/kg over 20 minutes as per the BNF for children guidance.
- Intravenous maintenance fluids should be given at 2/3 maintenance. If the patient weighs more than 10kg, use 0.9% sodium chloride as maintenance fluid. If the patient weighs less than 10kg, use 0.9% sodium chloride with 5% dextrose.
- Aim to keep serum sodium between 140 – 150 mmol/l and avoid hyponatraemia. Boluses of 3ml/kg of 3% hypertonic sodium chloride are safe and effective in the management of raised intracranial pressure.

Management of Raised Intracranial Pressure

This should be undertaken if the patient shows evidence of raised intracranial pressure - bradycardia, hypertension, poorly reactive or fixed dilated pupil(s). These procedures should not be undertaken solely to treat evidence of cerebral oedema on the CT brain scan.

- Ensure all neuro-protective steps are optimized.
- Place the patient on a manual bagging circuit and initiate manual hyperventilation with 100% oxygen. Reduce the end tidal carbon dioxide level to correlate with a PaCO2 of 4 to 4.5kPa.
- Give Osmotic therapy. A dose of either of the below therapies act to reduce cerebral oedema
    - Mannitol 0.5g/kg (2.5ml/kg of 20% solution preferred) over 20 minutes OR
    - 3% hypertonic sodium chloride 3ml/kg over 15 minutes
- Follow osmotic therapy with volume as required to maintain blood pressure. Repeat osmotic therapy as needed.
- Update the regional neurosurgical centre but be mindful that time is of the essence and every effort must be made not to introduce unnecessary delays. Refer to the flowchart for the referral pathway and contact details for neurosurgery depending upon which hospital you are in.

Appendix 5

Severe Traumatic Brain Injury Pathway (GCS 8 or less)

A

Intubate and ventilate with cervical spine control
- Oral endotracheal tube
- C-spine immobilization

B

Avoid desaturation
- Monitor end tidal CO_2, aim to correlate $PaCO_2$ 4.5-5.3 kPa
- Monitor saturations (aim >95%) and PaO_2 aim >13kPa

C

Avoid Hypotension
- Do not delay CT for arterial/central access
- Consider blood after 20ml/kg fluid boluses
- Target mean arterial blood pressure by age (Box 4)
- Dopamine or noradrenaline if needed to maintain BP

D

In the child with severe multiple trauma, consider immediate transfer to MTC without scan

CT brain and cervical spine within 30 minutes
- Institute neuroprotective measures (Box 2)
- Management of raised ICP (Box 3)
- Urgent neurosurgical referral to Major Trauma Centre
- Prepare for time critical transfer by local team

Time critical injury on CT

1. Signs of critically raised ICP

Unequal or unreactive pupils

Bradycardia or hypertension

Decorticate or decerebrate posturing

GCS <8, responding to pain only or unresponsive

Bulging fontanelle

Seizures

2. Neuroprotective measures

Avoid desaturation

Avoid hypotension (Box 4)

Sedate and muscle relax

30 degrees head up

Head in midline

Normothermia

Normoglycaemia

Keep Na>135 mmol/l

Phenytoin 20mg/kg

Avoid neck lines

3. Management of raised ICP

Ensure fully sedated and muscle relaxed

Hyperventilate to a $PaCO_2$ of 4.0-4.5 kPa

Maintain mean blood pressure to age specific targets (Box 4)

Osmotic therapy - either 3% hypertonic saline 3ml/kg or mannitol 0.5g/kg (will need urine catheter)

Aim temperature 36-37°C

4. Maintain mean arterial blood pressure (MAP)

Ensure adequate cerebral perfusion pressure
CPP = MAP – ICP

Age	MAP
<1 year	>60
1-2 years	>65
3-5 years	>70
6-10 years	>75
>10 years	>80

North Yorkshire & Humberside Major Trauma Network

Call Embrace 0845 147 2472 state MAJOR TRAUMA

Paediatric Neurosurgery Leeds (for patients from York, Scarborough and Hull) on call registrar mobile 07979 928120

Paediatric Neurosurgery Sheffield (for patients from NLAG sites) via switchboard 0114 271 7000 bleep 174

West Yorkshire Major Trauma Network

Call Embrace 0845 147 2472 state MAJOR TRAUMA OR direct call Leeds ED 0113 245 9405

Paediatric Neurosurgery Leeds on call registrar mobile 07979 928120

South Yorkshire Major Trauma Network

Call Embrace 0845 147 2472 state MAJOR TRAUMA

Paediatric Neurosurgery Sheffield via switchboard 0114 271 7000 bleep 174