Purpose Statement: To provide a guideline for medical management of pediatric patients with severe TBI (GCS < 8 without sedating medications and with evidence of TBI on CT).

1. Airway:
   a. Intubate all unconscious patients with RSI (GCS < 9) to secure airway.
   b. Maintain cervical spine immobilization in all unconscious or symptomatic (neck pain or tenderness) patients.

2. Breathing: Oxygenation and ventilation.
   a. Administer high flow oxygen to all patients with suspected head injury.
   b. Monitor oxygen saturation.
      i. Avoid hypoxia (SaO2 ≤ 90% or PaO2 ≤ 60 mmHg.)
   c. Ventilation.
      i. Avoid hyperventilation unless signs of herniation are present
      ii. Maintain PaCO2 35-40 mmHg.
      iii. Monitor ETCO2 (check ABG if acute change >20%)

3. Circulation:
   a. Resuscitate to goal mean arterial pressure (MAP) to maintain a presumptive cerebral perfusion pressure (CPP). Consider inotropic use if blood pressure is refractory to fluid resuscitation. If after 2-3 boluses blood pressure remains marginal start norepinephrine to maintain CPP
      - Infants/Toddlers >40 mmHg.
      - Children >50 mmHg.
      - Adults >60 mmHg

   b. Fluids and blood products as needed to correct coagulopathy and base deficit. *Avoid crystalloids and albumin for boluses*. No dextrose in maintenance fluids

   Indications for Pediatric MTP include, but are not limited to:
   - Massive bleeding/ trauma patient
• Massive blood loss with profound hemorrhagic hypovolemic shock
• >50% of total blood volume loss in 3 hours with continuous bleeding

4. **Seizure prophylaxis:**
   • Initiated at the recommendation of Neurosurgery team on a case-by-case basis.
   • *Alternative antiepileptic agents may be considered for use, however the Brain Trauma Foundation (BTF) states, “There is insufficient evidence to recommend levetiracetam over phenytoin regarding efficacy in preventing early post traumatic seizures and toxicity.”* 
   • All patient with intracranial blood should receive either Levetiracetam (20-40mg/kg) IV once for loading dose then scheduled maintenance per weight based dosing or fosphenytoin (20mg/kg) IV once for loading dose then scheduled weight bases maintenance.

5. **Temperature:**
   • Aggressively treat hyperthermia >100.4 with antipyretics, Extended/active cooling may promote shivering and require a neuromuscular blockade. Avoid hypothermia unless ICP is refractory after optimizing other therapies

6. **Positioning**
   • HOB 30°, reverse Trendelenburg for those in Cspine precautions
   • Ensure no venous obstruction to neck i.e. ill-fitting collar, head tilted to side, tracheostomy ties too tight

7. If patient requiring intensive management of ICP:
   • Obtain q6 BMP and serum osmolality, urine osmolality; consider adding ABG, CBC, and/or TEG if clinically indicated
   • Consider a CVL to monitor CVP, avoid placing Internal Jugular lines when possible
   • Place an arterial line for blood pressure measurement and frequent labs

**Goals of Care:**

<table>
<thead>
<tr>
<th>Neuro</th>
<th>ICP</th>
<th>&lt;20 mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPP</td>
<td>Infant/toddler &gt;40mmHg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children &gt;50 mmHg,</td>
<td></td>
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<tr>
<td></td>
<td>Adults &gt;60 mmHg</td>
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<tr>
<td>Seizure Prophylaxis</td>
<td>Levetiracetam/fosphenytoin</td>
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<td></td>
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<tr>
<td>Head of bed</td>
<td>&gt;30 degrees</td>
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<tr>
<td>CV</td>
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</tr>
<tr>
<td>MAP</td>
<td>Minimum required to maintain CPP</td>
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</tr>
<tr>
<td>CVP</td>
<td>&gt;5mmHg</td>
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<tr>
<td>Pulm</td>
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</tr>
<tr>
<td>SpO\textsubscript{2}</td>
<td>&gt;93%</td>
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<tr>
<td>PaO\textsubscript{2}</td>
<td>&gt;60mmHg</td>
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</tr>
<tr>
<td>PaCO\textsubscript{2}</td>
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<tr>
<td>Heme</td>
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<td></td>
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<tr>
<td>Hgb</td>
<td>≥7 g/dL</td>
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<tr>
<td>TEG r-value</td>
<td>&lt;8min</td>
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<tr>
<td>Rapid TEG ACT</td>
<td>&lt;128 sec</td>
<td></td>
</tr>
<tr>
<td>TEG/rapid TEG k-time</td>
<td>&lt;2.5min</td>
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<tr>
<td>TEG/rapid TEC alpha angle</td>
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</tr>
<tr>
<td>TEG/rapid TEG lysis</td>
<td>&lt;3%</td>
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<td>DVT prophylaxis ≥14years</td>
<td>TED/SCD: LMWH 24h after stable head CT and NSY clearance</td>
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<tr>
<td>Endo</td>
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<tr>
<td>Glucose</td>
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<tr>
<td>Renal</td>
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<td>Serum osmolality</td>
<td>280-320</td>
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</tr>
<tr>
<td>Serum Na</td>
<td>145-165</td>
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</tr>
<tr>
<td>GI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress ulcer ppx</td>
<td>Famotidine/ranitidine/Protonix</td>
<td></td>
</tr>
<tr>
<td>Nutrition</td>
<td>Early enteral feeding</td>
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<table>
<thead>
<tr>
<th>ACT</th>
<th>Normal</th>
<th>Abnormal</th>
<th>Primary Treatment</th>
<th>Secondary Treatment</th>
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<tbody>
<tr>
<td></td>
<td>86-118</td>
<td>118-150</td>
<td>FFP (10ml/kg)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>150-170</td>
<td></td>
<td>FFP (15ml/kg)</td>
<td>rFVIIa (30 μg/kg)</td>
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</table>
Intracranial pressure (ICP) and cerebral perfusion pressure (CPP) monitoring.

1. Indications for ICP/CPP monitoring:

   General indications:
   
   a. Severe head injury (GCS 3-8) + abnormal CT scan.
   
   b. Severe head injury + normal CT scan and at least 2 of the following 3:
      
      i. Unilateral or bilateral posturing.
      
      ii. SBP<90 mmHg.
      
      c. Inability to monitor neuro exam: prolonged sedation or anesthesia.

2. Technique:

   a. ICP: Parenchymal ICP monitoring catheter or ventricular
      
      Catheter.

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Treatment</th>
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<tbody>
<tr>
<td>a-angle</td>
<td>64-80</td>
<td>&lt;60</td>
</tr>
<tr>
<td>MA</td>
<td>52-71</td>
<td>46-52</td>
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<tr>
<td></td>
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<td>40-46</td>
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<tr>
<td></td>
<td></td>
<td>&lt;40</td>
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<tr>
<td>LY&lt;sub&gt;30&lt;/sub&gt;</td>
<td>0-7%</td>
<td>&gt;7%</td>
</tr>
</tbody>
</table>

- **>170**: FFP (20ml/kg) + rFVIIa (60 μg/kg)
- **<60**: Cryoprecipitate (10 ml/kg)
- **FP (10-15 ml/kg)**, rFVIIa (30 μg/kg)
- **DDAVP (0.3 units/kg)** or Apheresis platelets (10 ml/kg)
- **Apheresis platelets (10 ml/kg)**
- **Cryoprecipitate (10 ml/kg)**
- **Consider Amicar 200 mg/kg or Tranexamic Acid 10 mg/kg IV**
  
  *TXA only if in first 2-3 hours post injury*

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b. CPP: Arterial line needed for continuous monitoring

i. CPP = mean arterial pressure (MAP) – ICP

3. Ensure that coagulation parameters are normalized in a timely fashion prior to ICP monitor placement

INR ≤1.4 PLT count ≥ 100,000, Correct TEG to normal

Contraindications and Exclusions:

a. Severe coagulopathy
b. Unsalvageable

ICP/CPP treatment

Treatment is for ICP elevated >20mmHg for > 5 min. in which the patient is not agitated or under sedated. Should not be initiated without monitor placement or plans for placement, as there will not be a way to monitor efficacy

Parameters:

a. Normal ICP:

Term Infants 5-6 mmHg
Young Children 3-7 mmHg
Adults/Older Children 10-15mmHg,

b. Goal CPP

Infants/Toddlers >40 mmHg.
Children >50 mmHg,
Adults >60 mmHg

First Tier Therapies

- HOB ≥30°
- Maintain normothermia (36.5-38C/100.4 F)
- CSF drainage via ventriculostomy, ensure patency and function
  - EVD drainage point is set at the prescribed level (as per Neurosurgeon documentation in postoperative orders)
- EVD transducer is leveled to the patient’s external auditory meatus (Tragus) and re-leveled with repositioning
- ICP waveform is pulsatile on monitor
- Observe and record volume level of CSF in burette hourly
- Report any signs of changes in patient’s neurological condition to medical staff.
- Only Neurosurgery team may access EVD circuit i.e. flushing or obtaining specimen

- Head/neck neutral position, no external compression

### Sedation and Analgesia:

- Ensure adequate pain control with continuous infusion of Fentanyl (1mcg/kg/hr) and Midazolam (0.1mg/kg/hr) continuous drip for sedation. Provide bolus doses as needed prior to noxious stimuli (suctioning and repositioning).
- If three or more prn doses are required in a 1 hour period and all care is optimized increase the basal rate on the gtts or consider alternative prn.

### Hypertonic Saline Treatment:

Initiate HTS if ICP remains elevated after sedation/pain control optimized

- 3% or 7.3% hypertonic saline may be used as either bolus or continuous infusion, which are titrated to maintain an optimal serum sodium level and lower ICP.

- 7.3% HTS 2ml/kg bolus as need to increase serum Na to 150s

- 3% HTS 1-2ml/kg gtt for maintenance, *may utilize 7.3% (1ml/kg/h) for maintenance if fluid restricting or difficulty achieving goal NA*

Hold HTS for NA >165 or serum >300

All patients receiving HTS for treatment of intracranial hypertension must have the following:

  a) Central venous pressure monitoring
b) Intracranial pressure monitoring
c) Serum Na Q6H or more frequent if needed

**Mannitol:**

- Initial evaluation: Use mannitol without ICP monitoring *only if* signs of Herniation or progressive neurologic deterioration, not attributable to Extracranial causes, are present.

- For treatment of intracranial hypertension:
  i. Effective doses range from 0.25-1 gram/kg, given by intermittent bolus Infusion Q 4-6 hrs.
  ii. Maintain euvoemia. Foley mandatory. CVP monitor recommended.
  iii. Monitor serum osmolality. Do not exceed 320 mOsm/kg.

**Second Tier Therapies**

- Paralysis: Give one Rocuronium dose (1mg/kg) then observe response, if ICP improves begin drip. *Prior to Rocuronium drip initiation, obtain a baseline train of four (TOF). Monitor TOF q6h and prn*
- Continuous or spot check EEG monitoring recommended

If ICP refractory to initial treatment notify Neurosurgery. Consider repeat CT (portable)

- Barbiturates- Barbiturate coma with continuous EEG monitoring
  a. High dose barbiturates may be considered for hemodynamically stable, Salvageable, severe head injury patients with intracranial hypertension
  b. Refractory to maximal medical and surgical therapy. Load: 10-mg/kg pentobarbital IV over 30 minutes, then 5-mg/kg q1h x 3 doses Maintenance: 1 –mg/kg/hr, *PICU attending must discuss with neurosurgery and trauma attending before instituting barbiturate therapy*

- Decompressive hemicraniectomy at the judgment of the attending neurosurgeon
- *Steroids should not be used in patients with severe head injury.*
Recognize and treat brain herniation syndromes.

1. Signs:
   a. Pupils: Anisocoria (asymmetric, irregular, or sluggish reaction, progressing to fixed, dilated, and nonreactive.
   c. Progressive neurologic deterioration, not attributable to extracranial Causes.

2. Emergency treatment of herniation:
   a. Hyperventilation.
   b. Mannitol, if not hypotensive.

3. In the absence of a herniation syndrome, do not initiate treatment for Intracranial hypertension, until CT scan is done or ICP monitor inserted.

References


15 Guidelines for the Management of Severe Traumatic Brain injury 4th edition. Brain Trauma Foundation,