WVU Medicine Children's
CRITICAL CARE & TRAUMA CENTER

Practice Management Guideline
Pediatric Severe Traumatic Brain Injury

Management of Severe Traumatic Brain Injury (TBI) Patients

Initial Management of Severe TBI Patients

1. Severe TBI - Glasgow Coma Score (GCS) </=8
2. ED and ICU resuscitation to maintain mean arterial blood pressure and avoid hypoxia.
3. Imaging to assess injury
4. Operative intervention for hematoma - early removal of hematoma, loosely replacing bone flap as possible to leave out as craniectomy (storage of bone flap in freezer with goal to replace via cranioplasty within 2-3 months)
5. Operative intervention for brain swelling
    a. If unilateral, unilateral hemicraniectomy ensuring large bone flap with or without duraplasty
    b. If bilateral and/or diffuse swelling, bifrontal/bitemporal craniectomy
    c. Neurosurgery attending on-call is in charge of this aspect of management and placement of cerebral monitors/catheters
6. Place eternal ventricular drain (EVD) preferably with clear, antibiotic impregnated catheter if available, intraparen-chymal (IP) intracranial pressure monitor (ICP), and brain oxygenation/brain temperature LICOX catheters
    a. Standard placement is ICP monitoring (EVD/IP) on the right side and LICOX on the left; Neurosurgery decision re: side both sets of caterers should be placed in all cases for monitoring
    b. For children ≤2yo tunnel LICOX catheters (**ensure catheters are well secured with clear dressing!**)
    c. >2yo - place bolt; (try to ensure wire secured so bolt and catheter not dislodged)
7. Neurosurgery, in collaboration with assigned critical care medicine and neurocritical care team, will develop all medical management decisions
8. Recommended Optimal Parameters for Brain Physiology:
    - ICP <18mmHg for children <6y
    - ICP <20mmHg for children ≥6y
    - CPP≥50 and <70mmHg for children <6y
    - CPP≥50 and <70mmHg for children ≥6y
    - PbtO2>25 torr, optimally 30-40 torr
        ◊ This may require high PaO2 to achieve either titrate FiO2 or PEEP as needed - please refer to the LICOX catheter and PbO2 Management document
9. CSF drainage is continuous 3 cm above midbrain
10. Maintain normal PCO2 38-40mmHg (uncorrected for temp) as long as ICP is not elevated
11. Maintain temp 36-37.5°C; continuous monitoring of temp is required
12. Fentanyl (start at 1 mcg/kg/hr) titrate as needed
13. No benzodiazepines (such as midazolam of lorazepam) should be administered
14. Check electrolytes and serum osmolality minimum of Q6 hours for at least the first 72 hours
    a. Urine electrolytes and serum osmolality minimum of Q12-24 hours for at least the first 72 hours
    b. Increase frequency for suspicion of:
        i. Diabetes insipidus (DI) - urine output >3-5mL/kg/hr
        ii. Syndrome of Inappropriate Antidiuretic Hormone (SIADH) - urine output <0.2mL/kg/hr
15. Continuous cVEEG monitoring until improved GCS
16. Repeat imaging only as indicated for change in clinical status; no standard frequency or sequence for repeat imaging

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Optimal Management of ICP (treatments should be used in sequence)

First Tier Treatment for Elevated ICP (above age parameter for >5 minutes)

1. Continuous CSF drainage (3cm above midbrain)
2. Patients should be sedated (fentanyl) then paralyzed (vecuronium 0.1 mg/kg/hr, titrate as needed)
3. If ICP is elevated for >5 minutes, give additional narcotics, paralytics to ensure adequate levels
    - May use twitch monitor to check paralysis
4. Mannitol 0.25-0.5gm/kg bolus every 1-6 hrs is used to treat increases in ICP initially; however, dosage should stop is serum osmolality reached >320mmol/L, or if ICP does not respond
5. Hypertonic therapy (3% saline - 1-2mL/kg/bolus or slow infusion, 0.1-1 mL/kg/hr); ultimate goal will involve achieving serum sodium 155-160 if necessary/serum osm ≤350mmol/L; titrate to effect: reduced ICP, improved PbtO2
6. Mild hyperventilation, check blood gas, and adjust ventilator to PaCO2 ~ 35mmHg - titrate based on additional perfusion measures (NIRS, PbtO2, transcranial doppler)

Second tier Treatment for Continued Increased ICP (above parameter for >5minutes)

1. Moderate hyperventilation for a PaCO2 of 30-35mmHg; continue to evaluate PbtO2 to ensure against ischemia
    - A PaCO1 ≤29mmHg may be used for blown pupils or signs of herniation until other definitive treatments can be instituted
2. For ICP > age limit > 20 minutes, >30mmHg >10 minutes, or >40mmHg at all, pentobarbital is administered in a loading dose of 5mg/kg; if ICP does not respond after 15-30 minutes, repeat 5mg/kg; if 2-3 boluses are unsuccessful, start drip at 1mg/kg/hr; may be escalated to coma with EEG indicative of 90% burst suppression; avoid hypotension; patient who are euvolemic will tolerate barbiturate therapy with considerably fewer complications that patient who are dehydrated
3. Induce mild hypothermia by lowering systemic temperature to 35°C
4. If pentobarbital fails to control intracranial hypertension, this signifies failure of "medical management" and a decompressive craniectomy should be considered
5. Decompressive craniectomy and duraplasty for refractory hypertension
    - Bifrontal for diffuse process
    - Unilateral for unilateral pathology - contusion, hematoma, stroke

If ICP is elevated with poor control despite maximal measures, optimize cerebral perfusion pressure (CPP) appropriate for age and PbtO2. Vasoactive agents may be necessary to maintain an adequate CPP and PbtO2. Epinepherine and norepinephrine are the agents of choice. Titrate as necessary to keep CPP within age limits for the child. Avoid systemic hypertension.

Further Nuances and Points of Management

1. NO dextrose in the IV for 48 hours unless:
    - Children <2 years - serum glucose <80mg/dl
    - Children >/=2 years - serum glucose 70mg/dl
    - Start insulin drip for serum glucose >160mg/dl; titrate to maintain glucose 100-160mg/dl
2. Hypovolemia is avoided by replacement of urine volume; central venous pressure, daily weight, and I&O, urine specific gravity, urine dipstick, urine lytes, and osmolality to monitor adequate hydration. All patients should have central line placed, subclavian if possible, and CVP kept 6-10mmHg.
3. An antiepileptic drug (AED) is administered with an initial loading dose on administration Levetiracetam (Keppra) 20mg/kg IV x1 followed by Levetiracetam (Keppra) 20mg/kg/day IV divided Q12 hours
    - The use of Phenobarbital should be avoided except in infants and even then preferably to use Keppra. Children without large lesions may have the AED discontinued after 14 days if no seizure activity is noted. Children with large intraparenchymal (>2cm) continuous lesions should be left on AED as indicated for up to 3 months. Weaning from the AED will depend on the EEG following acute period.
4. Nutrition is begun parentally 48-72 hours after trauma. No intralipids are to be given if patient is on pentobarbital. Enteral feeding may be started as long as the child is not on pentobarbital and it is not anticipated that the child will need pentobarbital.
5. Neurodiagnostics should include:
    - Transcranial dopplers - see vasospasm protocol
    - Imaging only if clinically indicated (i.e.) change in ICP, brain oxygenation, decision for decompression
    - CSF surveillance for infection should be drawn every other day
    - Serum cortisol should be drawn on post trauma days 1 and 3

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First Tier Therapy

TBI (GCS <8)

Cranial CT

Surgery as indicated

Insert ICP Monitor

The timing of instituting first tier therapies depends on many factors such as the level of ICP and the tempo of disease progression; interventions may need to be bypassed, repeated, or initiated concurrently
*ICP 20-25 for >5 min; more rapidly for ICP>25
**Mannitol could be substituted
#Monitor EEG

CPP Pathway

Maintain CPP
Appropriate for age
Minimum 40 mmHg

Baseline Care

Maintain appropriate analgesia/sedation
Continue mechanical ventilation, maintain adequate arterial oxygenation, $PaCO_2$ ~35mmHg
Maintain normothermia
Ensure appropriate intravascular volume status (CVP)
Maintain Hgb>7 g/dL (minimum); higher levers may be optimal based on advanced monitoring
Elevate HOB 30°
Phenytoin or Levetiracetam/Consider continuous EEG monitoring throughout the management course
Begin nutrition as early as feasible and treat hypoglycemia

Herniation Pathway

Signs and symptoms of herniation:
- Pupillary dilation
- Hypertension/ bradycardia
- Extensor posturing

Emergent Treatment
- Hyperventilation titrate to reverse pupillary dilation
- FiO_2 = 1.0
- Bolus mannitol or hypertonic saline
- Emergent CT

Surgery if indicated

ICP Pathway

YES ↑ICP*
YES CSF drainage if ventriculostomy present
YES ↑ICP*
YES Bolus and/or infusion of hypertonic saline**
YES ↑ICP*
YES Additional analgesia/sedation
YES ↑ICP*
YES Neuromuscular blockade #
YES ↑ICP*
YES Additional hypertonic saline/hyperosmolar therapy
YES ↑ICP*

NO

Carefully withdraw ICP, CPP and/or PbO_2 directed therapy

Neurological examination may help guide withdrawal of therapy and/or extent of monitoring

PbO_2 Pathway

If PbO_2 monitoring used maintain minimum of >10mmHg

↓PbO_2
Raise FiO_2
↓PbO_2
Vasopressor infusion
Adjust $PaCO_2$
Optimize Hgb
↓PbO_2

↓CPP

Confirm appropriate intravascular volume status (CVP)
Vasopressor infusion
Bolus of hypertonic saline

When ICP-directed is deemed to be refractory to first tier therapies depends on many factors such as level of ICP, ant tempo of disease progression and others.

Second Tier Therapy

Revised 1/2024

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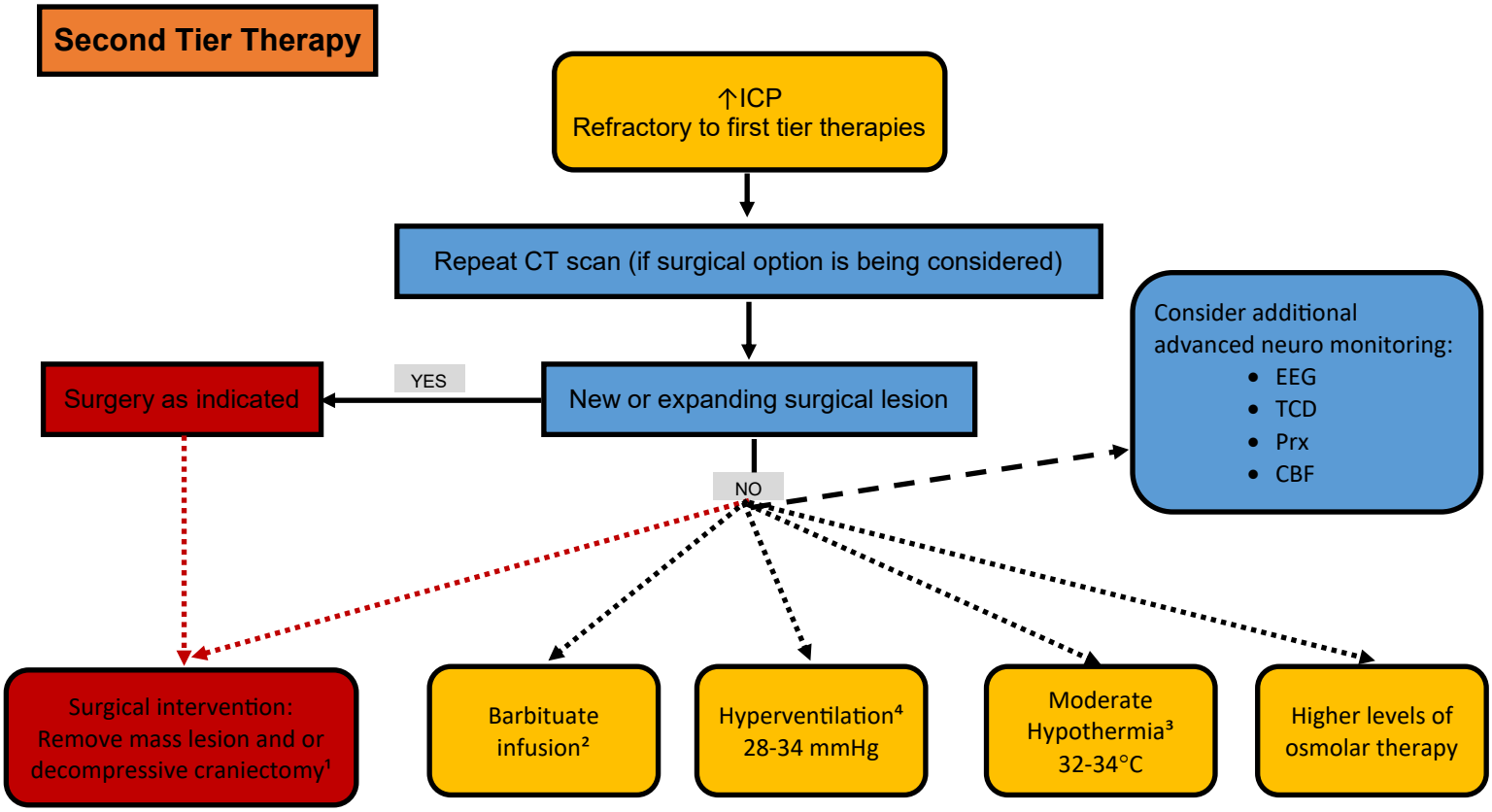

[1]Salvagable patient and evidence of expanding mass lesion or swelling on CT
[2]Active EEG and no medical contraindications
[3]No contraindications
[4]Strongly consider advanced neuroimaging for ischemia