

HOSPITAL CLINICAL GUIDELINE
Collaborative Practice Council

Title: Severe Traumatic Brain Injury in Children < 30 KG, Management of

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Scope: Physicians, Critical Care Nurses, and Respiratory Therapists

Key Words: @ Neurotrauma, @Pediatric, @ICP, @Severe TBI, @Clinical Guidelines

PART I: GENERAL INFORMATION

Title of Guideline Document: Management of Severe Traumatic Brain Injury in children < 30kg

Clinical Diagnosis or Condition: Traumatic Brain Injury/Increased Intracranial Pressure (ICP)

Target Population: Children <30 kg with a GCS 3 - 8; abnormal CT scan of brain; and/or abnormal clinical exam.

Primary Setting of Care: Pediatric ICU, Emergency Department, Operating Room

Purpose: Identify patients and define treatment options for managing severe traumatic brain injury

Objectives:

- 1 Establish monitoring parameters for treatment
- 2 Enhance cerebral oxygen delivery to brain
- 3 Optimize cerebral perfusion pressure (CPP) to brain
- 4 Control increased ICP

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PART II: CONTENT OF DOCUMENT

Pediatric patients with severe traumatic brain injury sustain the primary insult at the time of the accident. Secondary damage to the brain can occur as a result of increased pressure inside the cranium leading to perfusion deficits, reduced oxygen delivery to tissues, and cellular chemical alterations. These guidelines provide team members with suggested interventions to optimize cerebral perfusion pressure and reduce ICP in order to enhance oxygen delivery to the brain. The patient's PaCO₂ may be managed using the LICOX brain tissue oxygen monitor (PbtO₂) as an indicator of adequate oxygenation and cerebral perfusion. Given the range of normal MAPs in young children and the uncertainty regarding the optimal CPP in young children, the targeted CPP and MAP must vary depending on the PbtO₂, patient's age and individual responses to interventions.

1 Assessment

- 1.1 Clinical assessment of severity of brain injury includes: Glasgow Coma Scale; Level of Consciousness; motor strength; motor tone; cranial nerve exam (pupillary response, extraocular movements, facial symmetry, corneal and gag reflexes); systems assessment; and vital signs. Note any seizure activity.
- 1.2 Diagnostic assessment of brain injury includes:
 - 1.2.1 CT scan of brain
 - 1.2.2 Intracranial pressure (ICP) Monitor
 - 1.2.3 LICOX brain tissue oxygen monitor
 - 1.2.4 EEG or BIS monitor
 - 1.2.5 Transcranial Dopplers
- 1.3 Identification of patients with severe head injury includes: GCS 3 - 8; Abnormal CT scan of brain; and/or abnormal clinical exam.

2 Plan

- 2.1 Secure airway and provide oxygenation, ventilation, & intravenous fluids during trauma resuscitation
 - 2.1.1 Maintain PaO₂ >100 mm Hg or SaO₂>100% and PaCO₂ 35-40 mm Hg
 - 2.1.2 Avoid hypotension: Increase MAP to maintain the optimum CPP for the age of the child. Consider pressor agents
- 2.2 Maintain neck in neutral position with soft cervical collar
- 2.3 Administer sedation/analgesia/short-term muscle relaxant as indicated/ordered
- 2.4 Obtain CT scan of brain as indicated
- 2.5 Consider placement of ICP monitor/ventriculostomy and LICOX brain tissue oxygen monitor

- 2.6 Place arterial line and central intravenous catheters (vascular access and monitoring hemodynamic data)
- 2.7 Consider placement of thermodilution catheter or systemic oximetric venous catheter as indicated

3 **Implementation**

- 3.1 Implement initial resuscitation protocols and ICP/ CPP/ Cerebral Oxygenation management priorities
- 3.2 **PHASE INTERVENTIONS:**
 - 3.2.1 **Emergency Department**
 - 3.2.1.1 Airway: 100% FIO₂ BVM
 - Intubate for GCS 3-8 or unable to protect airway
 - Use Rapid Sequence Intubation Protocol
 - 3.2.1.2 Establish 2 IVs – draw labs (CBC, BMP, & Coags)
 - 3.2.1.3 NG/Foley
 - 3.2.1.4 Mannitol 0.25-1 gram/kg for posturing or unequal pupils
 - 3.2.1.5 **Goals: Keep SaO₂ 100%**
Keep PaCO₂ 35-40 mm Hg
Keep MAP > 80 mm Hg
 - 3.2.2 **Operating Room: Prepare for ICP/LICOX insertion and other neurosurgical procedures as indicated**
 - 3.2.2.1 Place Arterial line/Central lines (CVP small children or PA catheter older children)
 - 3.2.2.2 Administer fluids to keep PCWP >8-12 mm Hg or CVP 4-8 mm Hg
 - 3.2.2.2.1 Albumin/Normal Saline
 - 3.2.2.2.2 Blood products
 - 3.2.2.2.3 Reverse DIC - FFP/Cryo/Platelets for abnormal coags
 - 3.2.2.3 Optimize MAP per age related normals with fluids/vasopressors
 - 3.2.2.3.1 Add Neosynephrine or Dopamine as indicated
 - 3.2.2.4 Titrate PaCO₂ to keep PbtO₂ ≥ 20 mm Hg
 - 3.2.2.5 Drain CSF for ICP > 15 mm Hg
 - 3.2.2.6 Neurosurgical procedures: consider craniectomy for high ICP unresponsive to other measures
 - 3.2.2.7 **Goals: Keep SaO₂ 100%**
Keep PaCO₂ 35-40 mm Hg
Keep MAP > 80 mm Hg or optimal for patient
Keep PbtO₂ ≥ 20 mm Hg
 - 3.2.3 **ICU PHASE I: Initial 24 hours of admission....”Getting into the Zone”**
 - 3.2.3.1 **Rule #1: Do Not Prognosticate!**
 - 3.2.3.2 **Goals: Keep SaO₂ 100%**
Keep MAP optimal for patient
Keep PbtO₂ ≥ 20 mm Hg

Keep ICP < 15 mm Hg

**3.2.3.3 If PbtO2 < 15 mm Hg – place on FIO2 100% (up to 24 hours):
Temporary intervention only until PbtO2 ≥ 20 then titrate FIO2
to 30-50% per pulmonary needs**

3.2.3.3.1 **Priorities:** Maximize these parameters in order to
decrease FIO2

3.2.3.3.2 **GOAL: Keep PbtO2 ≥ 20 mm Hg and ICP < 15 mm
Hg**

3.2.3.3.2.1 Titrate PaCO2 35-45 mm Hg to keep PbtO2 ≥ 20
mm Hg

3.2.3.3.2 Give volume- Maintain PCWP > 8-12mm Hg or CVP 4-8
mm Hg

3.2.3.3.2.1 Use Albumin/NS

3.2.3.3.2.2 Use **Packed RBCs to increase Hematocrit
(goal > 33) if PbtO2 < 20**

3.2.3.4 Determine **optimal CPP for patient.** Target age specific goals.

3.2.3.4.1 Maintain CPP in range to keep PbtO2 ≥ 20 and ICP < 15

Follow these guidelines:

Age	Goal CPP**	Normal BP range	Normal MAP
0 - 1	40-50	75/40 – 105/66	52-80
2 - 4	50-60	87/53 – 105/66	64-80
5-8	50-60	97/57 – 112/71	70-85
8-17	60	112/80 – 128/80	90-96

**Note: The individual patient’s optimal CPP must be determined using the Goal CPP, a PbtO2 > 20mm Hg and an ICP < 15 mm Hg. For example, a 3-year-old with a CPP of 50, PbtO2 25 and ICP of 25 would not be adequate. CPP may need to be increased. Alternatively, a 9 year old with a CPP of 55, PbtO2 25 and ICP of 12 may be ideal and no further increase in CPP needs to take place.

3.2.3.4.1.1 Use fluids until euvolemic

3.2.3.4.1.2 Add vasopressors to increase MAP once volume
loaded

3.2.3.5 Keep ICP < 10 –15 mm Hg for children

3.2.3.6 Keep Temperature (brain temp) 37 degrees C

3.2.3.7 The early use of Propofol is only indicated when primary analgesic
and sedation agents fail to keep ICP < 15. The Pediatric Intensivist,
in consultation with the neurosurgeon, will make the decision to
begin Propofol in patients with refractory ICP. Use BIS monitor to
titrate level of sedation. Monitor triglycerides and pH daily. If
Propofol infusion is required > 48 hours, consider use of
pentobarbital for ICP control.

3.2.3.8 In severe head injured patients, order the following labs to be
completed within 12 hours of admission: TSH, T3, T4, Cortisol
and Lactate levels. Report abnormal levels to physician team.
Repeat TSH, T3, T4 and Cortisol levels at 72 hours after
admission. Repeat Lactate q 6 hours x 48 hours.

3.2.3.9 Closely monitor Intake and Output with the goal to bring fluid

intake/output into balance within 48 –72 hours of admission.
Monitor pH, Base deficit, and Lactate levels q 6 hours x 48 hours.
Use end points of resuscitation to evaluate ongoing treatment: CPP > 60 mm Hg or optimal level, ICP < 20 mm Hg, PbtO₂ > 20 mm Hg, Hematocrit > 30, pH 7.35-7.45, Base deficit 2 to –2, and Lactate Levels < 2.

3.2.4 **ICU PHASE II: Maintaining Therapy.... “Keeping the Brain in the Zone”**

3.2.4.1 **Phase Goals: Maintain PbtO₂ ≥ 20 mm Hg/ ICP < 10-15 mm Hg**

3.2.4.2 **Interventions:**

3.2.4.2.1 Maintain FIO₂ per pulmonary needs

3.2.4.2.2 Titrate PaCO₂ to balance ICP < 15 mm Hg and PbtO₂ > 20 mm Hg

3.2.4.2.3 Drain CSF for ICP > 15 mm Hg

3.2.4.2.4 Determine optimal CPP for patient

3.2.4.2.4.1 Keep PCWP 8-12 mm Hg or CVP 4-8 mm Hg using fluids

3.2.4.2.4.2 Use vasopressors to optimize MAP once euvolemic

3.2.4.2.4.3 Monitor I/O closely with goal of fluid balance (I=O)

3.2.4.2.5 Sedate via continuous Ativan or Versed. Titrate according to BIS

3.2.4.2.6 Deliver pain control with continuous Morphine or fentanyl

3.2.4.2.7 Provide chemical paralysis with paralytic of choice; adjust with neuromuscular blockade monitor

3.2.4.2.8 Minimize stimulation and keep lights low

3.2.4.2.9 Keep temperature 37 degrees Celsius: using cooling measures

3.2.4.2.10 Mannitol 0.25 -.5 g/kg bolus if ICP > 15 mm keep serum osmo < 320; provide fluid replacement to maintain euvolemia. Monitor sodium. If sodium approaches 155, hold mannitol and contact physician.

3.2.4.2.11 Consider pentobarbital drip if unable to control ICP with medical/surgical therapies (Propofol usage see above note 3. 2.3.7 for guidelines on propofol use). Titrate with BIS 10-20 and SR > 60%

3.2.4.3 **If PbtO₂ < 20 mm Hg**

3.2.4.3.1 Administer FIO₂ 100% x 15 minutes

3.2.4.3.2 Drain CSF ICP > 10-15 mm Hg

3.2.4.3.3 Increase PaCO₂ by decreasing rate/altering pressure and balance with ICP: Check ventilator modes and patient responses

- 3.2.4.3.4 Check CVP/PCWP and MAP: Optimize CPP
 - 3.2.4.3.4.1 Give IV NS or 5% albumine to increase CVP or PCWP
 - 3.2.4.3.4.2 Give packed RBCs if Hgb < 11 or Hematocrit < 33
 - 3.2.4.3.4.3 Start Vasopressors: Dopamine, Phenylephrine, Epinephrine, and/or Norepinephrine
 - 3.2.4.3.4.4 Mannitol (if ICP > 15 mm Hg)
- 3.2.4.3.5 Maintain adequate sedation and analgesia
- 3.2.4.3.6 Cooling measures for temperature > 37 degrees C
- 3.2.4.3.7 Consider barbiturate therapy if refractory to all medical/surgical interventions
- 3.2.4.3.8 Note: If shivering or problems with ventilator, consider paralytic
- 3.2.4.4 **If PbtO₂ >20 mm Hg and ICP > 15 mm Hg**
 - 3.2.4.4.1 Drain CSF
 - 3.2.4.4.2 Decrease PaCO₂ to decrease ICP
 - 3.2.4.4.3 Optimize CPP: check CVP/PCWP- if low give fluids then titrate vasopressors to maintain adequate MAP
 - 3.2.4.4.4 Give Mannitol 0.25-1 gm/kg IV
 - 3.2.4.4.5 Consider paralytic for ICP control
 - 3.2.4.4.6 Start/Titrate propofol**/barbiturates for ICP control. The use of Propofol is only indicated when primary analgesic and sedation agents fail to keep ICP < 15. The Pediatric Intensivist, in consultation with the neurosurgeon, will make the decision to begin Propofol in patients with refractory ICP. Monitor triglycerides and pH daily. If Propofol infusion is required > 48 hours, consider use of Pentobarbital for ICP control.
 - 3.2.4.4.7 Consider craniectomy if ICP refractory to interventions

3.2.5 **ICU Phase III: WEANING PHASE**

- 3.2.5.1 Normalize PaCO₂
- 3.2.5.2 Discontinue paralytics
- 3.2.5.3 Normalize CPP/CVP/PCWP
- 3.2.5.4 Discontinue ICP/CSF drain
- 3.2.5.5 Decrease analgesia/sedation – wean and start methadone
- 3.2.6 Review algorithm on “Targeted Therapy for ICP Management”
 - 3.2.6.1 Vasospasm: deliver hypervolemia and induced hypertension
 - 3.2.6.2 Low MAP: volume load with 5% albumin or NS and add pressors prn as indicated to maintain adequate CPP
 - 3.2.6.3 High ICP:
 - 3.2.6.3.1 Edema on CT- Mannitol 0.25-.5 g/kg IV and 5% Albumin to maintain euolemia
 - 3.2.6.3.2 Increased Cerebral blood volume - HOB 30 degrees,
 - 3.2.6.3.3 PaCO₂ Target at 30 mm Hg, Hypertensive CPP therapy or Barbiturates

3.2.6.3.4 Mass effect - Surgery

- 3.2.7 Begin nutrition via appropriate route as soon as possible. If enteral route established, attempt feedings via post-pyloric sphincter.
- 3.2.8 Order appropriate interventions on physician order sheet in medical record
- 3.2.9 Team will implement interventions ordered by physicians

4 **Monitoring: Diagnostics & Patient Responses**

- 4.1 Monitor changes in neurologic status and clinical exam
- 4.2 Reassess patient responses to ordered therapies
- 4.3 Monitor ABGs: SaO₂, PaO₂, PaCO₂, HCO₃, B.E., and pH values; PbtO₂. Monitor TSH, T₃, T₄, Cortisol, and Lactate levels.
- 4.4 Monitor ICP/ MAP and Calculate CPP
- 4.5 Monitor hemodynamic data as indicated: MAP, CVP, PCWP, cardiac output/index, systemic vascular resistance, SVO₂, and systemic oxygen consumption (depends on types of invasive lines)
- 4.6 Monitor serum electrolytes especially sodium, serum osmolarity, potassium, calcium, and magnesium
- 4.7 Monitor CBC and other pertinent laboratory data
- 4.8 Monitor triglycerides and pH daily in patients on Propofol infusions. If the serum Triglyceride level is > 300 mg/dL, notify MD of the level, the patient is at risk for propofol infusion syndrome.
- 4.9 Implement “ICP Weaning Algorithm” as ICP decreases to < 15 mm Hg for 24 hours without aggressive interventions per physician order

5 **Evaluation/Outcomes**

- 5.1 Evaluate patient outcome following therapies using GCS, Rancho Los Amigos Scale, and/or FIM scales
- 5.2 Consult Physiatrist
- 5.3 Obtain consults for Speech Pathology, Occupational Therapy, and Physical Therapy
- 5.4 Obtain rehab consult to evaluate for rehabilitation and discharge needs

6 **Termination of Guidelines**

- 6.1 Patient demonstrating clinical improvement with interventions
- 6.2 Physician order to terminate guidelines at any point during clinical course

Committee Review: Trauma Committee, ICU Committee, Pharmacy and Therapeutics, Neurosurgery Committee, and Children’s Critical Care, Collaborative Practice Council

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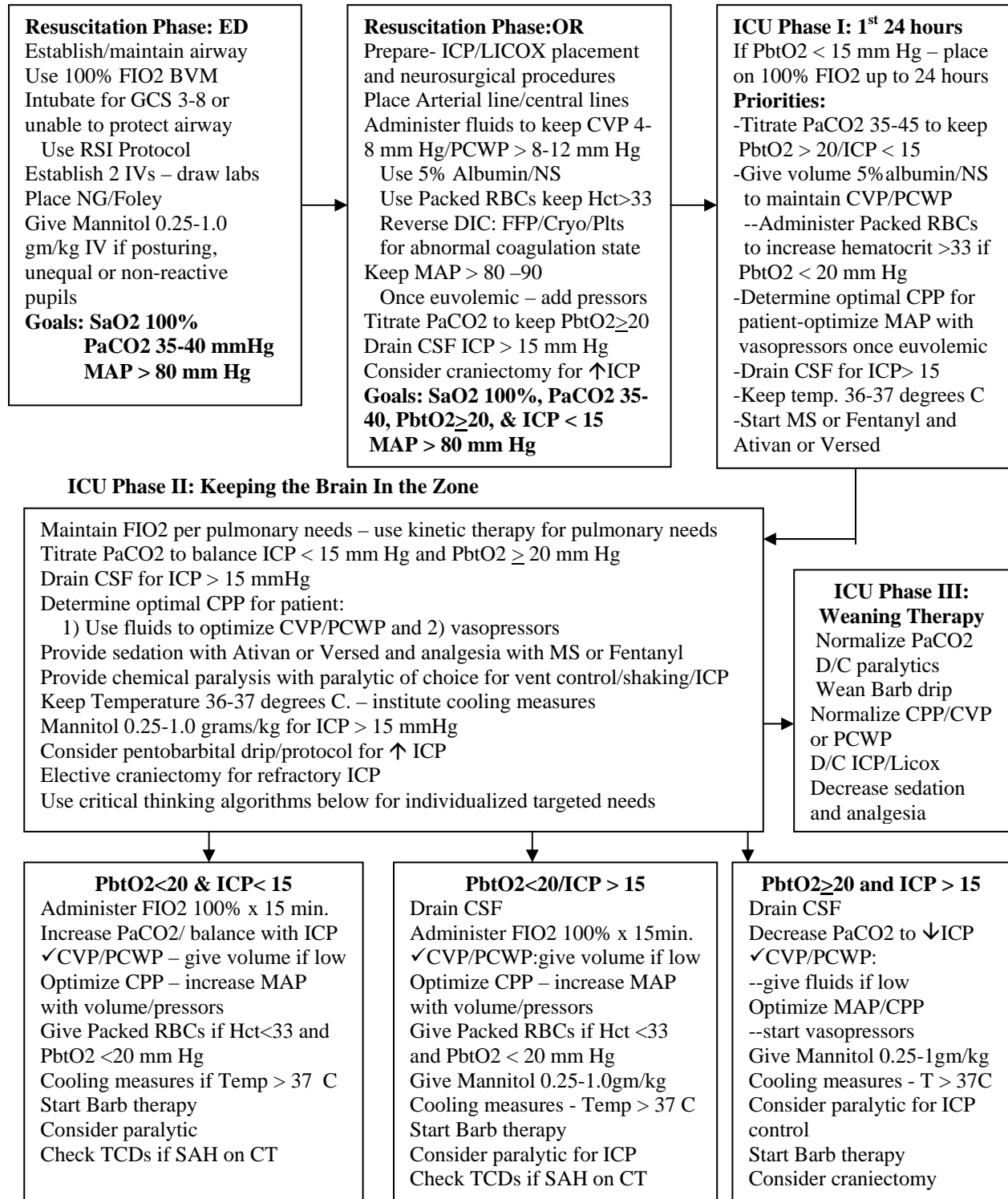
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**Figure 1: Care of the Patient with Severe Head Injury < 30 Kg
Phase Algorithms**



ICP Weaning Algorithm

