

SEVERE TRAUMATIC BRAIN INJURY - PICU - CHW

PRACTICE GUIDELINE[®]

DOCUMENT SUMMARY/KEY POINTS

- This practice guideline describes the management of infants and children with severe traumatic brain injury in PICU
- All management is in conjunction with the neurosurgical team
- Management focuses on therapeutic targets:
 - prevent and/or treat raised intracranial pressure (ICP)
 - optimise cerebral perfusion pressure (CPP)
 - maintain mean arterial blood pressure (MAP) appropriate for age
- Evidence & consensus-based algorithms for ICP/CPP management and cerebral herniation emergency management
- Principles for secondary injury prevention – avoid hyperthermia, seizures, hypoxaemia, hypotension, hypercarbia, acidosis
- Cervical spine precautions until cleared
- Detect associated injuries – ensure trauma surveys are completed
- Prevent complications such as contractures and pressure areas
- Escalate to Fellow/Staff Specialist on call for PICU and neurosurgery:
 - a decrease in GCS
 - unequal/unreactive pupils
 - asymmetric tone
 - seizures
 - ICP/CPP out of target range for the patient despite therapies

This document reflects what is currently regarded as safe practice. However, as in any clinical situation, there may be factors which cannot be covered by a single set of guidelines. This document does not replace the need for the application of clinical judgement to each individual presentation.

Approved by:	SCHN Policy, Procedure and Guideline Committee	
Date Effective:	1 st April 2021	Review Period: 3 years
Team Leader:	Staff Specialist	Area/Dept: PICU

CHANGE SUMMARY

- Due for mandatory review: changes made throughout – recommend reading the entire document.

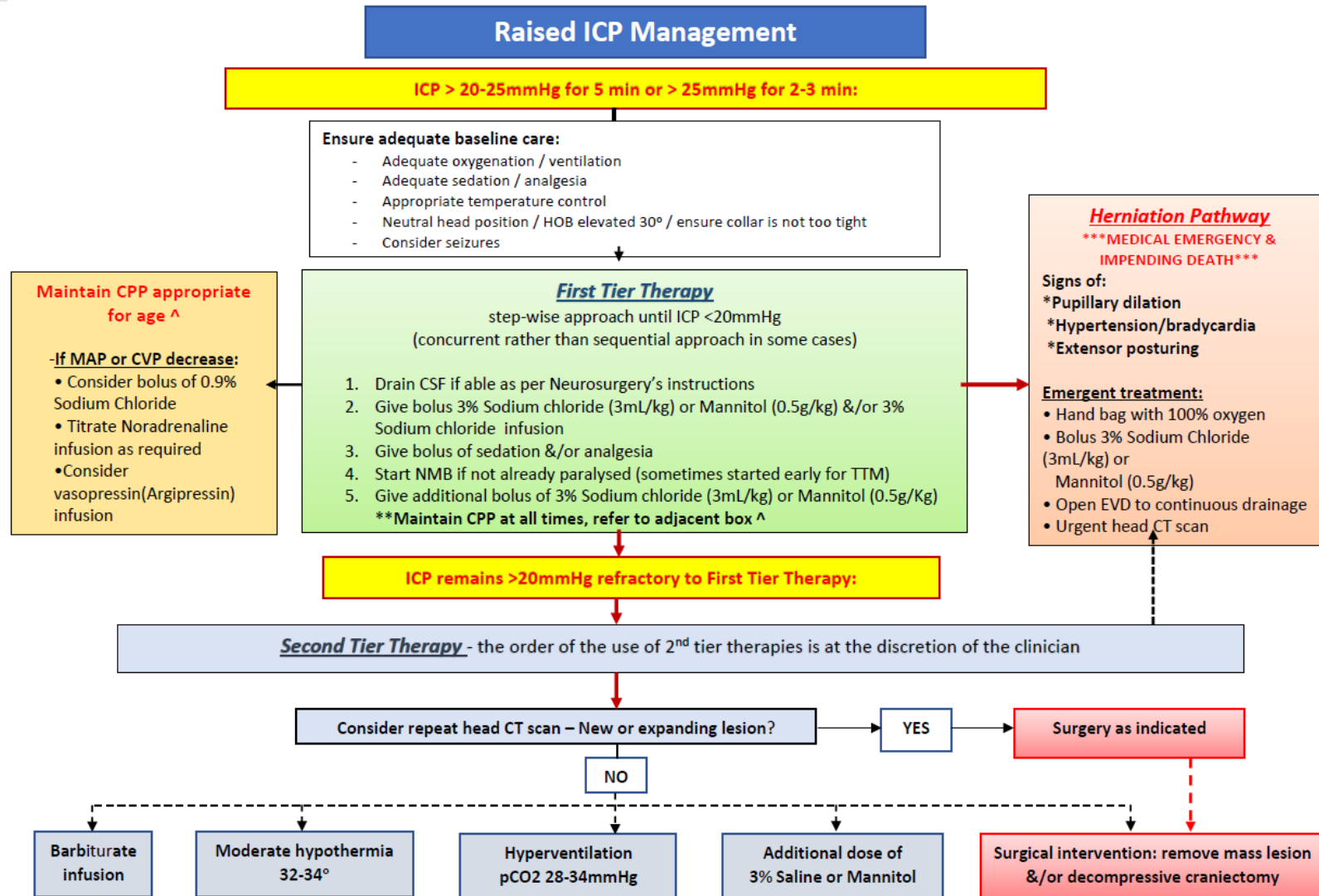
READ ACKNOWLEDGEMENT

- Clinical Staff in PICU
- Neurosurgical team

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Algorithm – Raised ICP Management



Management Goals

CONTROL RAISED ICP	<ul style="list-style-type: none"> • Reduce volume of cranial vault contents • Minimise noxious triggers • Maintain adequate analgesia & sedation
ADEQUATE CPP	Maintain adequate cerebral perfusion with well-oxygenated blood
PREVENT SECONDARY INJURY	<p>Prevention, early recognition and management of events known to contribute to secondary brain injury:</p> <ul style="list-style-type: none"> • Hypotension • Hypoxaemia • Hypercarbia • Acidosis • Hyperthermia • Seizures
NEUROSURGICAL INTERVENTION	Recognition of events that may require neurosurgical intervention
PREVENT OTHER COMPLICATIONS	<p>Prevention of other complications:</p> <ul style="list-style-type: none"> • musculoskeletal contractures • Pressure areas

Retrieval of Patients with Severe Traumatic Brain Injury

A neurosurgeon should be involved in all retrieval phone calls

Admission to PICU

**Rarely a child with severe TBI arrives directly to PICU from another hospital.
If this occurs a "Trauma Attend – Code Brain" page should be placed by calling 2222
Call the Neurosurgeon separately via switchboard**

- In addition to standard PICU bed set up:
 - Cooling blanket on bed or Arctic Sun pads ready to be applied
 - EVD & ICP transducer unopened on standby ready for priming
 - Noradrenaline infusion on standby
 - 3% Hypertonic Saline (3% Sodium chloride) with primed giving set
 - In-line suction
- Facilitate imaging - consider meeting the retrieval team at the CT scanner
- Review the child's immunisation status - consider Tetanus toxoid / immunoglobulin if there are abrasions or open lacerations
- If the patient is stable assess for other injuries (secondary survey):
 - Cervical and thoracic spine
 - Chest
 - Abdomen and pelvis - urine and stool for occult blood, serum amylase
 - Extremities

Neurological Assessment and Special Observations

- Perform nursing clinical assessment hourly (or more frequently if patient unstable)
 - Glasgow Coma Scale (GCS)
 - Pupils - size, shape and reactivity
 - Describe and document movements as follows:
 - body parts affected limbs or trunk
 - quality of movement jerky, floppy
 - symmetry or focal in nature
 - duration
 - change in vital signs

Tachycardia, hypertension and pupillary signs in patients receiving neuromuscular blockers **may indicate seizure activity**

Senior medical staff need to be advised of seizure events

- Monitor for signs of autonomic dysfunction (See [Autonomic Dysfunction Syndrome](#))
- Assess and record any CSF leak from ears, nose or elsewhere
- Organise nursing care to minimise noxious stimulation
- Measure and record CSF loss from external ventricular drainage device **hourly**
- Measure and record head circumference for neonates, infants, or any child with large or multiple skull fractures **daily**
 - a rapidly increasing head circumference may indicate hydrocephalus
- Each shift, a medical officer should perform and record in the notes a complete neurological assessment including cough and gag reflex
 - care needs to be taken not to injure the cornea

Neuromuscular blockers mask signs of neurological deterioration (with the exception of pupillary light response)

Notify PICU Staff Specialist and Neurosurgeon if:

- Clinical signs consistent with herniation
 - pupillary dilatation, hypertension, bradycardia, extensor posturing
 - **activate herniation pathway emergent treatment**

Signs of raised ICP & impending herniation
<ul style="list-style-type: none"> • Decrease in GCS • Extensor posturing or hemiparesis • Hypertension, bradycardia and irregular respirations • Pupillary signs – sluggish reaction or dilatation
Herniation pathway Emergent treatment
<ul style="list-style-type: none"> • Manually hyperventilate with 100% oxygen • Bolus 3% Sodium Chloride or Mannitol • Open EVD to continuous drainage • In parallel to delivering the above organise URGENT head CT scan

- GCS decreases by more than 2 points in the overall score
- Pupillary changes - inequality or decreased reaction to light
- Hemiparesis
- Clinical signs suggestive of seizure activity
- Recurrent ICP spikes > 20 mmHg (with or without stimuli maintained for more than 5 minutes)
- ICP plateau waves > 25 mmHg
- Raised ICP or low CPP
 - **targets to be determined each shift by the PICU senior medical and neurosurgical team with a plan for intervention thresholds**

Principles of Management

Airway	<ul style="list-style-type: none"> • Intubation should be performed in any patient with a GCS of less than 8 • Patients with suspected base of skull fracture should not have nasal endotracheal tubes or nasogastric tubes inserted
Breathing	<p>Mechanical ventilation to achieve the following</p> <ul style="list-style-type: none"> ○ pCO₂ 35-40 ○ pO₂ 90-100 ○ saturations 95-98% ○ PEEP 3-5 cmH₂O and increase as clinically indicated <p>Decision to target pCO₂ 28-34 needs to be made by PICU senior medical staff</p> <p>Consider pre-procedure sedation to minimise risk of ICP elevation</p>
Cardiovascular	<ul style="list-style-type: none"> • Avoid hypotension to ensure adequate brain perfusion <ul style="list-style-type: none"> • use of a vasopressor, Noradrenaline, to maintain MAP & CPP in the absence of hypovolaemia see Target CPP by age
Analgesia and sedation	<ul style="list-style-type: none"> • Adequate sedation and analgesia should be prescribed and assessed regularly • Raise in ICP with stimulus that is sustained requires pre-procedure sedation & analgesia • Brief ICP spikes that recover quickly to baseline do not need treatment <p>Analgesia and Sedation PICU - CHW</p>
Seizures	<ul style="list-style-type: none"> • Prophylactic Phenytoin or Levetiracetam • Continuous EEG monitoring in severe TBI patients <ul style="list-style-type: none"> ○ receiving neuromuscular blockade ○ diffuse axonal injury ○ intracranial haemorrhage ○ depressed skull fracture
Fluid balance and renal function	<ul style="list-style-type: none"> • Restrict IV fluids to 66% maintenance • Maintain euvoemia with 0.9% Sodium Chloride <ul style="list-style-type: none"> ○ Appropriate intravascular volume CVP 4-10 ○ If UO <0.5mL/kg/hr inform PICU medical team ○ UA and specific gravity once every 12 hours • 12 hourly formal bloods for electrolytes

	<p>If SIADH, DI or cerebral salt wasting is suspected send:</p> <ul style="list-style-type: none"> • Paired serum and urine electrolytes (Na, K, Cl, creatinine) and osmolality <ul style="list-style-type: none"> ○ SIADH: ↑ urine output, ↑ urine sodium and osmolality, ↔ or ↑ circulating blood volume and ↓ serum sodium ○ DI: ↓ urine osmolality, ↓ blood volume depleted, ↑ serum sodium ○ Cerebral salt wasting ↓ serum sodium, polyuria with ↑ urinary sodium concentration (>80 mmol/L) and hypovolaemia <p>Water and Electrolyte management in PICU Acute Central Diabetes Insipidus - Management in PICU - CHW</p>
Gastrointestinal	<ul style="list-style-type: none"> • Enteral nutrition improves outcomes if started within 72hr of injury • Manage hyperglycaemia and AVOID hypoglycaemia • Average resting energy expenditure is significantly increased <ul style="list-style-type: none"> ○ Not receiving neuromuscular blockers → 140-150% ○ Receiving neuromuscular blockers → 100-120% • NBM until cleared of abdominal injuries by surgical team • Transpyloric feeding is recommended to optimises nutritional intake in the setting of gastric feed intolerance <ul style="list-style-type: none"> ○ Start stress ulcer prophylaxis (Omeprazole) on admission and cease once enteral nutrition established • Consider the use of aperients if constipated
Haematology	<ul style="list-style-type: none"> • Manage haemoglobin (Hb >7.0g/L) • Correct coagulopathy (INR <1.6; Platelets >100)
Thermoregulation	<ul style="list-style-type: none"> • Aim temperature less than 37.5 degrees Celsius • AVOID hyperthermia → as increases cerebral metabolic requirements, and potentially cerebral blood flow and ICP • consider hypothermia as second tier therapy for refractory raised ICP
Positioning & Pressure Area Care	<ul style="list-style-type: none"> • Elevate head of the bed 30° degrees • Neutral head alignment to optimise cerebral venous drainage <ul style="list-style-type: none"> ○ C-spine precautions, place entire bed on angle • Physiotherapy referral within 24 hours of admission for contracture prevention assessment • Observe occiput, heels and other bony prominences and use pressure-relieving device to reduce risk of pressure injury <p>Pressure Injury Prevention and Management policy</p>

Spinal cord	<ul style="list-style-type: none"> • Treat as suspected cervical-spine fracture until proven otherwise • Prolonged usage of spinal collars can result in pressure ulceration and should be avoided if possible <ul style="list-style-type: none"> ○ the collar should be taken off briefly every day to allow pressure area inspection <p><u>Cervical spine (suspected) injury (paediatric): patient management</u></p>
General	<ul style="list-style-type: none"> • Repeat secondary survey looking for other injuries at 24 hours and again prior to PICU discharge • Rehabilitation Consultation should occur as soon as it seems likely that the patient will survive <ul style="list-style-type: none"> ○ contact the Rehabilitation Registrar via switchboard <p><u>Surgical antibiotic prophylaxis</u></p>

Autonomic Dysfunction Syndrome

- Characterised by autonomic nervous system dysfunction
 - also called Dysautonomia, Thalamic storm, or brainstem seizures
- Clinical signs are usually those of excessive sympathetic activity:
 - Hypertension
 - Tachycardia or bradycardia
 - Diaphoresis (sweating)
 - Piloerection
 - Flushing
 - Fever
 - Abnormal posturing
- Seizures and drug withdrawal (opiates +/- benzodiazepines) are differential diagnoses
- Precipitating factors can include:
 - full bowel/bladder
 - handling/procedures
- Treatment includes:
 - Avoidance of precipitating factors
 - Consider pharmacological intervention - clonidine, sedation (diazepam), beta-blockers, and bromocriptine
- Discuss with the Rehabilitation Service

Management of Raised ICP or Inadequate CPP

Factors that may precipitate raised ICP:

- Hypercapnia/hypoxia
- Pain/cough/agitation
- Procedures
- Collar & position - collar tightness / neck flexion / rotation may obstruct venous return
- Progression of intracranial lesion -enlargement of haemorrhage/ worsening oedema
- Systemic hypotension

Check patient

Neurologic signs	<ul style="list-style-type: none"> • pupillary signs - sluggish reaction or dilation - unilateral/bilateral • extensor posturing or hemiparesis • decrease in GCS • Vital sign change – hypertension, bradycardia, irregular respirations
EVD insertion site	Check for leakage or dislodgement
MAP	Hypotension Hypovolaemia
Ventilation	SaO ₂ ET CO ₂
Patient position	Head and neck – any flexion or rotation, collar position
Sedation & analgesia	Dosing and delivery check
Neuromuscular blockade	Effective blockade, analgesia & sedation
TTM	Hypo/hyperthermia – is patient shivering (consider neuromuscular blockade if not already on)

Check machinery

Ventilator	Working correctly? Check wave forms, mode and settings
Transducers	Level Calibrated
EVD	Appropriate level Drainage open/closed
TTM	Check device and temperature setting

First Tier Management - Recurrent raised ICP

Drain CSF	Open drainage of EVD if in place
3% Sodium Chloride	Give as a rapid bolus Caution in renal dysfunction (creatinine double baseline-review delta creatinine), coagulopathy, or platelets <100
Mannitol	if 3% Sodium Chloride is contraindicated
Bolus analgesia & sedation	Caution with hypotension
Neuromuscular blockade	Vecuronium infusion Consider EEG monitoring
Further dose 3% Sodium Chloride/Mannitol	Monitor osmolarity

Second Tier Management - Refractory Intracranial Hypertension

Repeat CT Scan	?new or expanding lesion
Hyperventilation	PaCO ₂ 28-34mmHg PaO ₂ 90-100mmHg
Hyperosmolar therapies	3% Sodium Chloride for dose review Med4Kids , or Mannitol for dose review Med4Kids (* Don't exceed plasma osmolarity 360mOml/L)
Barbiturate infusion	Thiopentone (negative inotrope, will require concomitant vasoconstrictor) for dose review Med4Kids Continuous EEG recommended Monitor intravascular status, infective markers, bowel motility as high risk for ileus development
Moderate hypothermia	32-34 degrees Celsius Neuromuscular blockade required for shivering
Decompressive craniectomy	Neurosurgical team - guarded prognosis for outcome

Weaning from ICP controlling therapies

Consider when ICP stability maintained for 24-48 hours

Ventilation	Normalise PaCO ₂
TTM	Increase temperature NOT FASTER than 0.5°C every 4 hours If ICP increases re-cool to preceding temperature
Neuromuscular blockade	Cease chemical paralysis only after PaCO ₂ normalised (ensure no rebound raised ICP)
Wean sedation	Monitor withdrawal scores May need slow wean, please refer to hospital analgesia and sedation protocol Analgesia and Sedation PICU - CHW
EVD/ICP monitor removal	Neurosurgical decision
Extubation	PICU Fellow/Staff Specialist decision

References

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3. Kochanek, P. M., Tasker, R. C., Carney, N., Totten, A. M., Adelson, P. D., Selden, N. R., ... Wainwright, M. S. (2019). Guidelines for the Management of Pediatric Severe Traumatic Brain Injury, Third Edition. Pediatric Critical Care Medicine, 20, S1–S82. doi:10.1097/pcc.0000000000001735

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Appendix 1 – Intracranial Pressure (ICP)

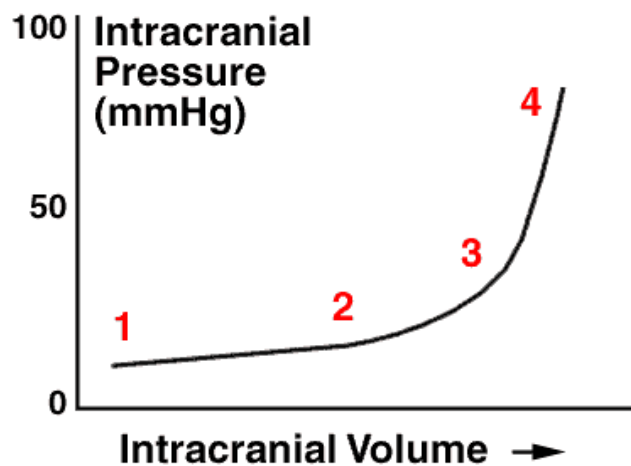
- Intracranial pressure is the pressure exerted by the contents of the cranial vault (brain, CSF, and intravascular blood)
- A change in the volume of the contents of any or all of the compartments may increase ICP
- In TBI, a mass lesion may add a fourth compartment
- ICP is usually measured in mmHg, however, when using a manometer pressure will be measured in cm H₂O (Note that 1 mmHg ≈ 1.36 cm H₂O)

The relationship between ICP and Volume:

As volume rises, initially little change in ICP occurs: 1-2 (compensation phase)

The compensatory process is eventually exhausted (3-4) when venous sinuses are flattened and there is little or no CSF

ICP will then rise rapidly and herniation becomes a possibility



- ICP varies with age - Normal values during childhood:

Age	ICP mmHg
Neonate	<2
1 to 12 months	5
1 to 7 years	6-13
older children	up to 15

- The threshold for treatment of raised ICP will be determined for individual patients but is usually between 15-25 mmHg
- Plateau (or A waves) are waves of increased ICP - pressure rises steeply, if untreated is sustained for 5 to 20 minutes before spontaneous resolution - prognostically unfavourable
- B waves are sharply peaked waves that occur every one to 2 minutes and are less ominous than plateau waves but suggest reduced intracranial compliance

Appendix 2 - Cerebral Perfusion Pressure (CPP)

- Blood vessels in the brain usually auto regulate to maintain stable Cerebral Blood Flow (CBF) over a wide range of perfusion pressures

$$\text{CPP (mmHg)} = \text{MAP} - \text{ICP}$$

- CPP is a surrogate measure for CBF
- An "adequate" CPP in the presence of elevated ICP may result in the incorrect assumption that CBF is also adequate
- No reliable evidence is available to support a target CPP (maintenance of CPP \geq 70 mmHg in adults may be associated with a reduction in mortality and improved outcome)
- RCT data shows ICP > 20 mmHg is a better predictor of poor outcome with no difference in long term outcome with either approach, provided hypotension is avoided
- Aim to minimise ICP while maintaining adequate CPP
- Suggested target CPP values (values are based on "normal" MAP & ICP values for children)

Age	Desirable minimum CPP
Infants <1 month	>40 mmHg
Children 2-12 months	>45 mmHg
Children 1-6 years	>50 mmHg
Children 7-10 years	>55 mmHg
Children >10 years	>60 mmHg