

Traumatic Brain Injury (TBI) Pathway Pre-hospital, and Transport Phase, and Emergency Department

PURPOSE:

To provide a treatment algorithm for the management of infants, children, and adolescents with severe traumatic brain injury.

Inclusion Criteria:

Any patient with the mechanism and a Glasgow Coma Scale (GCS) ≤ 13 or a known head injury from a CT scan

Exclusion Criteria:

Glasgow Coma Scale (GCS) 14-15



**Steroids
contraindicated
in patients with TBI**

Baseline Management for ALL patients with TBI

- Keep head midline and head of bed (HOB) elevated 30 degrees
- Place patient in reverse Trendelenburg position if the thoracic/lumbar spine is not cleared to achieve elevation of the head to 30 degrees
- Change C-collar to Aspen collar and ensure that it is not compressing the anterior portion of the neck
- Maintain normothermia ($< 38^{\circ}\text{C}$)
- Administer Levetiracetam (Keppra) if any single criterion is met (see yellow box)
- Intravenous fluids with normal saline (NS). No hypotonic fluids.
- Check accucheck before departure and upon arrival in children less than 1 year of age
- Ensure appropriate intravascular volume status
- Maintain systolic blood pressure (SBP) and mean arterial pressure (MAP), if available, based on age
- Consider 3% hypertonic saline IV 5-10 mL/kg/dose over 5-10 minutes if GCS ≤ 8 , or if GCS is rapidly declining and a concern for an increased ICP.
- Intubate patient of GCS ≤ 8 or if the GCS is rapidly declining
- Provide analgesia and sedation
- Maintain ETco₂ at 35 mm Hg

Criteria for initiating Levetiracetam (Keppra) (Dose 20 mg/kg loading dose (max 1 gram))

- Patient less than 2 years of age with GCS ≤ 8
- Suspected non-accidental trauma
- Patient ≥ 2 years of age with GCS ≤ 8 and abnormal head CT scan
- Depressed skull fracture (GCS < 13)
- Subdural hemorrhage or epidural hemorrhage (GCS < 13)
- Status post craniotomy
- Patient presenting with prolonged seizure activity

Age	Systolic Blood Pressure (SBP) & Mean Arterial Pressure (MAP) Goals		
	SBP (mm Hg)	MAP (mm Hg)	GCS ≤ 8 MAP (mm Hg)
< 1 year	70	45	55
1-9 years	70 + (age in years x 2)	(age x 1.5) +45	(age x 1.5) +55
10-15 years	90	(age x 1.5) +45	(age x 1.5) +55
> 15 years	110	(age x 1.5) +45	75

Traumatic Brain Injury (TBI) Pathway ACH Mechanically Ventilated Patients

PURPOSE:

To preserve injured, but salvageable brain tissue by controlling intracranial pressure (ICP) and optimizing cerebral perfusion pressure (CPP).

Inclusion Criteria:

Traumatic brain injury with GCS ≤ 8 , or intubated with a presumed head injury.

Exclusion Criteria:

Non-severe TBI with GCS > 8 and / or not intubated.

GCS ≤ 8 ?

NO

Continue with Baseline Management of a TBI

YES

Baseline Care [All TBI at risk for increased ICP]

- Keep head midline. Keep head of bed (HOB) elevated to 30 degrees
- Change C-collar to Aspen collar (if not done already) and ensure that it is not compressing the anterior portion of neck
- Optimize analgesia and sedation
- Maintain normal body temperature (35.5°-37°C) with cooling blanket (e.g. Arctic Sun device). May use intermittent paralytic agent to control shivering. Place pt. on continuous EEG if placed on a continuous paralytic agent
- Administer Levetiracetam (Keppra) if criteria met and patient did NOT receive a dose at an outside hospital (see criteria from pre-hospital/transport/ED page)
- Place on continuous EEG if any of the following criteria met:
 - Patient on Keppra
 - Paralytic administered
 - Presentation suspicious for non-accidental trauma
 - Intracranial monitoring in place.
- Maintain PaCO₂ between 35-40 mm Hg
- Ensure appropriate intravascular status [consider central venous pressure (CVP) monitoring]
- Maintain hemoglobin (Hgb) > 7 g/dL (minimum): higher levels may be optimal based on advanced monitoring
- Treat coagulopathy
- Place an intracranial pressure monitor [or external ventricular drain (EVD)] and monitor if GCS < 8 with an abnormal head CAT Scan (CT) and/or posturing on examination. No wake-up tests while ICP monitor in place. EVD is left open for drainage at all times; level determined by Neurosurgery team. Once an EVD or ICP monitor is placed, patient proceeds to Tier 1 therapy.
- Begin nutrition as early as possible and treat hypoglycemia. Consider D5 or normal saline in younger patients to avoid hypoglycemia
- Avoid prolonged hyperglycemia (serum glucose > 180 mg/dL)

Levetiracetam (Keppra)

- Schedule Levetiracetam (Keppra) based off time of initial dose administration
- Q12 hours dosed at 20 mg/kg/dose (maximum 1 gram)
- Continue for 7 days if no evidence of seizures
- If patient has a seizure after initial Keppra load, discontinue prophylaxis dose and start treatment dose as per Neurosurgery recommendations

Place on continuous EEG if any of the following criteria met:

- Patient on Levetiracetam (Keppra)
- Paralytic administered
- Presentation suspicious for non-accidental trauma
- ICP monitor placed

Traumatic Brain Injury (TBI) Pathway ACH Mechanically Ventilated Patients (cont'd)

PURPOSE:

To preserve injured, but salvageable brain tissue by controlling ICP and optimizing CPP and P_{bO_2}

Inclusion Criteria:

Patients admitted to PICU with severe accidental or non-accidental TBI including Glasgow Coma Scale (GCS) ≤ 8

Exclusion Criteria:

Non-severe TBI with GCS > 8

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Notify LIP if serum sodium is <145 OR > 150 mmol/L

Tier 1 Therapy Severe TBI post-resuscitation GCS ≤ 8

Intracranial Pressure (ICP) Pathway

ICP greater than goal for 5 minutes

- Keep head midline and HOB elevated to 30 degrees
- Verify Aspen collar is not compressing the anterior portion of neck
- Optimize analgesia and sedation
- Maintain normal body temperature (35.5°C - 37°C) with cooling blanket (e.g. Arctic Sun device). May use intermittent or continuous paralytic agent to control shivering
- Maintain PaCO_2 between 35-40 mm Hg
- CSF drainage if ventriculostomy present
- Administer 3% hypertonic saline IV 5-10 mL/kg/dose over 5-10 minutes
- Goal Sodium (Na): 145-150 mmol/L
- Neuromuscular blockade
- If LICOX monitor in place, refer to LICOX pathway for further management options
- Proceed to Tier 2 therapy if goal ICP not achieved.
- Notify Neurosurgery

Cerebral Perfusion (CPP) Pathway

- Maintain goal CPP, if necessary start pressor support
- Confirm appropriate intravascular volume status (central venous pressure or CVP)
- Administer 3% hypertonic saline IV 5-10 mL/kg/dose over 5-10 minutes
- Goal sodium (Na): 145-150 mmol/L
- Consider surgery for mass lesions
- If LICOX monitor in place, refer to LICOX pathway for further management options
- Proceed to Tier 2 therapy of goal CPP not achieved
- Notify Neurosurgery

Brain Tissue Partial Pressure of Oxygen (P_{bO_2}) Pathway

If LICOX monitor in place, refer to LICOX pathway for further management options

Traumatic Brain Injury (TBI) Pathway ACH Mechanically Ventilated Patients (cont'd)

PURPOSE:

To preserve injured, but salvageable brain tissue by controlling ICP and optimizing CPP and PbrO₂

Inclusion Criteria:

Patients admitted to PICU with severe accidental or non-accidental TBI including Glasgow Coma Scale (GCS) ≤ 8

Exclusion Criteria:

Non-severe TBI with GCS > 8

Tier 2 Therapy

Notify Neurosurgery Team of failure of Tier 1 therapy

ICP greater than goal for 5 minutes

- Verify all Tier 1 therapies are being implemented
- Goal sodium (Na): 155-160 mmol/L
- Administer 3% hypertonic saline IV 5-10 ml/kg/dose over 5-10 minutes
- Maintain PaCO₂ at 32-35 mm Hg
- Consider a head CT scan if the vital signs are stable or if there is an acute clinical deterioration
- If above ICP, CPP, and PbrO₂ goals not met with Tier 2 therapy after 10 minutes, notify Neurosurgery

Tier 3 Therapy

Verify that Neurosurgery Team has been notified

- Consider decompressive craniectomy. Discuss post-operative management including ICP and CPP goals with the neurosurgery team. Each case may have characteristics that require a different management strategy than outlined in the TBI Management Algorithm
- Consider "rescue" or "therapeutic" hypothermia with a target temperature of 32° - 34°C. If patient receives hypothermia, they will be slowly rewarmed by 0.5°C every 12 hours
- Consider a Pentobarbital (bolus and/or continuous infusion) to induce a "barbiturate" coma. If patient is already in burst suppression, then there is no reason to start a pentobarbital infusion.
- Place on continuous EEG monitor if not already done
- Pentobarbital loading dose 2-5 mg/kg IV over 1-2 hours
- Pentobarbital maintenance infusion 1 mg/kg/hour up to 2-3 mg/kg/hour until burst suppression is achieved
- Notify LIP if no burst suppression observed on continuous EEG or if burst suppression lasts longer than 5 minutes
- Stop enteral feeds
- Consider early institution of a bowel regimen in order to minimize constipation

Other Interventions

- Enteral feeds to start no later than post trauma day #3. Transpyloric feeds are preferred if patient is intubated
- Venous Thromboembolism (VTE) prophylaxis as per hospital policy
 - Compression stocking/pneumatic compression devices in all Tanner > 1
 - Pharmacologic prophylaxis when cleared by neurosurgery (typically 48 hours after injury/intervention)

Traumatic Brain Injury (TBI) Pathway

LICOX Algorithm

PURPOSE:

To preserve injured, but salvageable brain tissue by controlling intracranial pressure (ICP) and optimizing cerebral perfusion pressure (CPP).

Inclusion Criteria:

Patients admitted to PICU with severe accidental or non-accidental TBI including Glasgow Coma Scale (GCS) ≤ 8

Exclusion Criteria:

Non-severe TBI with GCS > 8

GCS ≤ 8 ?

YES

NO

Off TBI Pathway

Baseline Care for ALL patients with TBI

- Follow TBI Management algorithm
- Place an intracranial pressure (ICP) monitor [or external ventricular drain (EVD)] and LICOX/ICP monitor if GCS < 8 with an abnormal head CT scan and/or posturing on examination.
- No wake-up tests while ICP monitor/LICOX in place.
- EVD is left open for drainage at all times (level determined by Neurosurgery)

Tier 1 Therapy- Severe TBI post-resuscitation GCS ≤ 8

Goal brain tissue partial pressure of oxygen (PbrO₂) via LICOX monitoring ≥ 20 mm Hg

High ICP for 5 minutes

- Follow TBI Management algorithm

Low PbrO₂ (via LICOX)

- Consider chest x-ray
- Increase FiO₂ up to 60%
- Increase positive end-expiratory pressure (PEEP) to optimize oxygenation if tolerated
- Adjust PaCO₂ if possible
- Consider judicious fluid boluses in order to maintain a cerebral perfusion pressure (CPP) based on age. Ensure appropriate intravascular status [consider central venous pressure (CVP) monitoring]
- Consider vasopressor infusion if goal intravascular volume status has been achieved
- Optimize hemoglobin level to goal of ≥ 10 gm/dL
- Consider surgery for mass lesions

ICP, CPP, and PbrO₂ goals met?

YES

Consider de-escalation

NO

Notify Neurosurgery Attending and proceed to Tier 2

Tier 2 Therapy

High ICP for 5 minutes

- Follow TBI Management algorithm

Low PbrO₂ (via LICOX)

- Maintain goal CPP for age. Consider vasopressor support in order to increase mean arterial pressure (MAP) if intravascular volume status goal achieved
- Increase the FiO₂, but keep the PaO₂ ≤ 250 mm Hg. Do not maintain a FiO₂ $> 60\%$ for prolonged periods of time in order to avoid oxygen toxicity
- Increase the PEEP to optimize oxygenation if tolerated
- Optimize hemoglobin level to goal of ≥ 10 gm/dL
- Decrease ICP to 10 mm Hg in order to improve CPP

ICP, CPP, and PbrO₂ goals met?

YES

Consider de-escalation

NO

Notify Neurosurgery Attending and proceed to Tier 3

Tier 3 Therapy

- Consider decompressive craniectomy
- Follow TBI Management algorithm

Systolic Blood Pressure (SBP), Cerebral Perfusion Pressure (CPP) & Intracranial Pressure (ICP) Goals

Age	SBP (mm Hg)	CPP (mm Hg)	ICP (mm Hg)
< 1 year	70	>40	<15
1-9 years	$70 + (\text{age in years} \times 2)$	>50	<20
10-15 years	90	>60	<20
>15 years	110	>60	<20

Traumatic Brain Injury (TBI) Herniation Pathway

Signs and Symptoms of Herniation:

- Pupillary dilation
- Hypertension/bradycardia
- Extensor posturing

Emergent Treatment:

- Hyperventilation – titrate to reverse pupillary dilation
- $\text{FiO}_2 = 100\%$
- **Administer:**
 - 3% hypertonic saline 5-10 ml/kg/dose over 5-10 minutes
 - OR**
 - Mannitol 0.5 g/kg/dose over 20 minutes
- Open External Ventricular Device (EVD) to continuous drainage
- Emergent head CT

Metrics

1. Systolic blood pressure and mean arterial pressure targets (avoiding hypotension)
2. Cerebral perfusion pressures (CPP)
3. Temperature goals (avoid fever)
4. Serum glucose levels
5. PaCO₂ (avoid hypocarbia)

Contributing Members

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References

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<https://doi.org/10.1007/s00134-019-05805-9>