

## UNIVERSITY HOSPITAL GUIDELINES FOR THE MANAGEMENT OF SEVERE TRAUMATIC BRAIN INJURY: ADULTS GENERAL INFORMATION

- Document Title:** Management of Severe Traumatic Brain Injury (TBI)
- Purpose:** Define treatment options for managing severe traumatic brain injury
- Objectives:**
1. Establish monitoring parameters for treatment
  2. Control increased intracranial pressure (ICP)
  3. Optimize cerebral perfusion pressure (CPP) to brain
  4. Enhance cerebral oxygen delivery to brain
  5. Guidelines for decompression
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### CONTENT OF DOCUMENT

Patients with severe traumatic brain injury sustain the primary insult at the time of the accident. Secondary damage to the brain occurs as a result of increased pressure inside the cranium leading to perfusion deficits, reduced oxygen delivery to tissues, and cellular chemical alterations. These guidelines are based on and reflect the recommendations of the AANS / BTF documents “Guidelines for the Management of Severe Traumatic Brain Injury”<sup>1,2</sup> and the ACS TQIP “Best Practices in the Management of Traumatic Brain Injury.”<sup>3</sup> This document was developed to provide team members with information on:

- a) identifying patients at risk for secondary injury
- b) suggesting interventions to reduce intracranial pressure (ICP), maintain adequate cerebral perfusion pressure (CPP), and enhance brain tissue oxygen values (PbtO<sub>2</sub>)
- c) providing general information regarding indications for surgical intervention after TBI
- d) guiding decision making regarding discontinuation of neuromonitoring.

### I. Assessment

- A. Clinical assessment includes: Glasgow Coma Scale (Table 1); level of consciousness; cranial nerve exam (pupillary response, extraocular movements, facial symmetry, corneal and gag reflexes); motor strength; motor tone; sensory assessment; and vital signs. Note any seizure activity.
- B. Standard diagnostic assessment of brain injury may include:
  1. Brain imaging: CT, MRI
  2. Cerebral vascular imaging: CTA, MRA, MRV, angio
  3. Cerebral perfusion imaging
  4. Intracranial pressure (ICP) monitor
  5. Cerebral brain tissue oxygen monitor (PbtO<sub>2</sub>)
  6. EEG, ECoG with depth electrodes
  7. Cerebral blood flow (CBF) monitor (Hemedex)
  8. Transcranial dopplers
  9. Somatosensory evoked potentials (SSEP)
- C. Definition of severe head injury includes: Post resuscitation GCS of 3 – 8 with or without an abnormality noted on a head CT scan.
- D. Resuscitation is an urgent process that may require hours of intensive medical and surgical interventions. This process should be performed simultaneously with neurosurgical / neurological stabilization. Non-emergent invasive procedures may be delayed until all resuscitation and life-saving procedures are completed, especially in those patients with normal or nearly normal head CT.

	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>Eye Opening</b>	None	To Pressure	To Sound	Spontaneous		
<b>Verbal Response</b>	None	Sounds	Words	Confused	Oriented	
<b>Motor Response</b>	None	Extension	Abnormal Flexion	Normal Flexion	Localizing	Obeys Commands

## **II. Initial Management**

**Implement resuscitation protocols to minimize secondary injury. Appropriate interventions include:**

### **A. Emergency Department**

1. **Airway Management:**
  - a. Supplemental O<sub>2</sub> to maintain SaO<sub>2</sub> > 95%.
  - b. Intubate for GCS 3 – 8 or an inability to protect airway. A rapid sequence intubation is recommended. Intubation based solely on imaging findings is not recommended although air transfer or diagnostic testing of patient may dictate intubation for patient safety issues in cases of agitation or combativeness.
  - c. Titrate ventilator to maintain PaO<sub>2</sub> ≥100 mm Hg, and PaCO<sub>2</sub> = 35 – 45 mm Hg. May hyperventilate to PaCO<sub>2</sub> of 25-35 mm Hg for a brief period of time (up to 30 minutes) if there are concerns of herniation (otherwise, prophylactic hyperventilation is not indicated).
2. **Circulation**
  - a. Establish minimum of 2 large bore IVs
  - b. Place NG/Foley if indicated.
  - c. Draw initial assessment labs (CBC, renal profile, & Coags).
  - d. Place central intravenous catheter and arterial line if able during initial care.
3. **Diagnosis:** Arrange for urgent diagnostic imaging (CT head / spine).
4. **Hemodynamic management:**
  - a. Fluid resuscitation with Normal Saline (NS) or 3% Hypertonic Saline (HTS)
  - b. Avoid hypotension (ie, goal SBP > 100 mm Hg; Goal MAP ≥ 70 mm Hg).
5. **Sedatives and analgesics** as indicated for diagnostic procedures. Preferred agents based on desired goal:
  - a. For **Sedation:** use propofol
  - b. For **Analgesia:** use fentanyl
  - c. Avoid paralytics until after initial assessment by the trauma/neurosurgery team. If paralytics are necessary for patient safety, short acting agents (eg, cisatracurium, vecuronium) should be used and treatment time should be clearly documented.
6. Medical Management options for signs of intracranial hypertension or herniation (ie, posturing or unequal / non-reactive pupils).
  - a. Maintain neck in neutral position with cervical collar.
  - b. HOB 30 degrees in reverse trendelenberg position.
  - c. 3% (250-500ml) or 23% (30ml over 10 minutes) HTS bolus
  - d. Hyperventilation (up to 30 minutes)
  - e. Mannitol 0.25 – 1 gram/kg bolus (round to the nearest 25 gm dose) given over 15 minutes as the final measure once patient is euvolemic
  - f. All patients that meet inclusion criterion should undergo advanced neuromonitoring (as in Appendix TBI-A).
    - 1) GCS ≤ 8, with an abnormal admission head CT
    - 2) GCS ≤ 8 with normal head CT if ≥ 2 complicating variables:
      - a) Age > 40
      - b) Unilateral or bilateral posturing
      - c) Systolic BP < 90
7. Surgical intervention should be considered following protocol in Section III
8. Seizure prophylaxis: Those with significant intracranial pathology should receive a loading dose of anti-epileptic medication –levetiracetam 20mg/kg IV or fosphenytoin 20mg/kg
9. **General ED Guidelines: Do not try to predict outcome early. Notify neurosurgery team early.**

**General goals: SaO<sub>2</sub> >95%; PaCO<sub>2</sub> 35 – 45 mm Hg; SBP >100 mm Hg**

**B. Intensive Care Unit Management:**

Management strategies focus on preventing secondary injury and optimizing survival. The neurointensivists and neurosurgery team should be the ultimate providers for the management and optimization of physiological parameters for patients with severe TBI. Coordination between neurointensivists, neurosurgeons, trauma surgeons, and consulting services is necessary for patients with significant polytrauma. Patients with severe TBI should be admitted to the NSICU unit whenever possible.

1. Review all initial care needs from section II. A.
  - a. Insert ventriculostomy / and/or advanced neuromonitoring as indicated per Appendix TBI-A
  - b. Place Arterial line/Central lines if not done.
  - c. Initiate analgesia/sedation, monitor for effects on MAP.
2. Respiratory management
  - a. Initial goal is normocapnia (PaCO<sub>2</sub> = 40 +/- 5 mm Hg)
  - b. Maintain PaO<sub>2</sub> ≥100, SaO<sub>2</sub> >95% and utilize lung protective strategies as necessary.
3. Sedatives and analgesics may be indicated, monitor for their effects on ICP / CPP. Short acting agents should be used whenever possible. Preferred agents based on desired goal are:
  - a. Sedation: propofol. Midazolam or dexmedetomidine are alternative agents.
  - b. Analgesia: fentanyl. Morphine is an alternative agent.
4. Hemodynamic management:
  - a. Monitor MAP and CPP hourly.
  - b. Maintain CPP ≥ 60 mm Hg with fluids and / or vasopressors.
    - 1) Advanced neuromonitoring data should be used to guide determination of desired CPP range.
    - 2) Vasopressors options: norepinephrine (preferred agent), phenylephrine, vasopressin, dopamine. Cardiac responses may impact on choice of vasopressors.
    - 3) Note: The use of vasopressors in patients with TBI has been associated with an increased risk of pulmonary complications and adult respiratory distress syndrome.
  - c. Administer fluids to maintain euolemia. Avoid hypervolemia after initial resuscitation. If CVP is being monitored, keep it at 8 – 12 mm Hg. If questions arise regarding fluid status, daily weights should be utilized.
    - 1) In general, the fluid balance goal should be a range of 500 – 1000 ml positive every 24 hours. This goal may vary based on other clinical issues (ie, sepsis, systemic inflammatory responses).
    - 2) Fluid choice: Normal Saline with or without 20 meq KCl
    - 3) Blood products as indicated. For goal Hgb ≥7, plts ≥ 75, INR ≤ 1.5
    - 4) Absolute avoidance of dextrose solutions (ie: D5W).
5. Neurological examinations:
  - a. Pupils and GCS will be checked hourly with vitals.
  - b. While neuromonitoring devices are in place (ie, ICP monitor, Raumedic, etc), examination will be done OFF sedation no more than 4 times and no less than once a day. All other exams will be done on sedation.
  - c. Once neuromonitoring devices are removed, exams will be performed hourly unless otherwise specified.
6. Ventriculostomy / ICP management:
  - a. See Appendix TBI-A for indications regarding placement of neuromonitoring devices
  - b. General treatment goals include ICP <20 mmHg, CPP >60 mmHg with individualized goals determined by patient cerebral autoregulation status.
  - c. See Appendix TBI-B regarding management algorithm for ICP
7. PbtO<sub>2</sub> management
  - a. Brain tissue oxygen should be measured in conjunction with ICP and utilized to guide patient management when able
  - b. Refer to Appendix TBI-C for PbtO<sub>2</sub> management algorithms.
8. Advanced Neuromonitoring

- a. Consider placement of advanced neuromonitoring devices at the discretion of the attending neurosurgical attending and NSICU team
  - b. Refer to Appendix TBI-A for guidelines regarding indications for placement and management of patients with advanced neuromonitoring devices
9. Seizure prophylaxis:
- a. If not already loaded in the Emergency Department, load with levetiracetam at 20 mg/kg IV loading dose or Fosphenytoin at 20 mg/kg loading dose. May load with phenytoin if central access available.
  - b. Maintenance dosing: Levetiracetam at 500 – 1000 mg or Phenytoin at 5 mg/kg/d divided every 8 – 12 hours, every 12 hours for 7 days.
  - c. Other antiepileptics may be indicated based on clinical situation.
10. General Care Issues:
- a. Glucose: Initiate treatment for hyperglycemia. Goal glucose = 80 – 180 mg/dL.
  - b. Sodium: Maintain in normal range (135 – 145 mEq/L) initially. Hypertonic saline may be used for correction of hyponatremia
  - c. Magnesium: Maintain  $\geq$  1.8 mg/dL.
  - d. Hematologic: Reverse coagulopathy (FFP/Cryoprecipitate/Platelets/vitamin K). Although the optimal INR is normal (ie:  $\leq$  1.2), active correction may stop once the INR is  $\leq$  1.5. For clinical signs of continued bleeding, utilize TEG and platelet function assays to guide treatment of coagulopathy
  - e. Temperature: Goal is normothermia. Every effort should be made to maintain a temperature between 98 – 99° F. Culture per NSICU protocol for fever  $\geq$  101.5 F ( $\geq$ 38.5C)
  - f. Nutrition: address within first 24 – 48 hours after admission.
  - g. Mechanical DVT prophylaxis on admission. Chemical DVT prophylaxis 24hrs after stable head CT with agreement of neurosurgery service.
11. **General Guidelines: Do not try to predict outcome early. Coordination of patient management with input from neurocritical care and neurosurgery teams is necessary.**

### **III. Surgical guidelines for management of: A) intracranial mass lesion or B) elevated ICP refractory to medical management.**

- A. Guidelines for Emergency Surgery following TBI. This section is a summary statement of the surgical guidelines published in Neurosurgery, 2006, and the updates contained in the 4<sup>th</sup> edition of the Brain Trauma Foundation Guidelines for the Management of Severe Traumatic Brain Injury.<sup>2,4-6</sup> All decision regarding emergent surgical intervention should be discussed with the attending neurosurgeon on call. In general, early surgical interventions for emergent situations may improve clinical outcomes.
- 1. CT findings play a significant role in determination of surgical eligibility.
    - a. Epidural hematoma warrants aggressive intervention in almost every clinical situation (including but not limited to elderly, coagulopathies, and multiple co-morbidities).
    - b. Focal temporal tip epidural hematomas with cisternal compression should be considered for aggressive evacuation in all patients with a GCS less than 15.
  - 2. Triggers for emergent decompression of subdurals, intracerebral hematomas and cerebral contusions
    - a. GCS  $\leq$  8 with focal mass lesion and associated mid-line shift of 5 mm or greater
    - b. GCS  $>$  8 with mass lesion and associated mid-line shift of 5 mm or greater with worsening neurological exam during resuscitation
    - c. Age  $>$  65 is generally associated with poor outcomes.<sup>7</sup> Therefore, age may be a consideration in medical decision making, but should not be used as an absolute exclusion for any life-saving interventions. Each case should be assessed individually.
    - d. Coagulation correction to INR  $\leq$ 1.5 with FFP, cryoprecipitate, vitamin K, Factor VII. Active reversal of coagulopathy can be occurring en route to OR.
    - e. Exclusion criteria for surgical decompression
      - 1) Biventricular penetrating brain injury.
      - 2) Two fixed dilated pupils for a period greater than 1 hour not due to suspected optic nerve or ocular injury and not responsive to medical interventions for elevated ICP, such as HTS bolus.

- 3) GCS of  $\leq 4$  with the absence of most brain stem reflexes (i.e. the patient who appears to be progressing to brain death).
  - 4) GCS  $\leq 4$  with hemodynamic instability without improvement after 24 hours of adequate emergent resuscitation efforts.
  - 5) GCS  $\leq 8$  with a life expectancy  $< 6$  months secondary to other comorbidities.
  - 6) Known irreversible coagulopathy or systemic bleeding disorder.
3. Craniectomy should be considered in lieu of craniotomy when there is evidence or high suspicion of cerebral edema.
  4. Calculation of traumatic ICH volume is done by measuring the width (A), length (B) and depth (C) at the largest point. All measurements are in centimeters. Depth is calculated by counting the number of cuts on the head CT on which the hematoma is seen, and then converting this value to centimeters based on thickness of head CT cuts. The formula for volume is:  $(A \times B \times C)/2$ . Each lesion is calculated independently, and then added together for the total volume of mass lesions.<sup>8,9</sup>

**B. Guidelines for Delayed Decompressive Hemicraniectomy for ICP control**

1. Eligibility criteria for delayed decompression
  - a. Worsening neurologic examination with increased ICP with or without progression of CT changes.
  - b. Progression of ICP to abnormal range i.e. sustained ICP greater than 25 mmHg on consecutive examinations in spite of additional medical management.
  - c. The goal is for optimization of medical management maneuvers (per Section II B) early in the course of patient care. Early delayed decompression ( $< 48$  hours) may be beneficial if medical management has failed. Patients should be identified early in their admission based on severity of head CT findings (i.e. bifrontal contusions, multiple areas of injury) or early elevations in ICP as potential candidates for delayed decompression. Quality of life issues should be discussed with family as salvage decompressive craniectomy is life-saving but does not improve disability rates.<sup>10</sup>
  - d. Recent clinical trials evaluating the efficacy of salvage decompressive hemicraniectomy for TBI have not included patients age  $> 65$ .<sup>10</sup> Age should be a consideration in medical decision making, but should not be used as an absolute exclusion for life-saving interventions. Quality of life issues must be considered in the elderly who show progressive deterioration in the face of aggressive medical therapies. Each case should be assessed individually and discussed with the critical care team.
  - e. Goals for surgical decompression
    - 1) Generous decompression for focal unilateral lesion, with a craniectomy measuring 15 cm to provide adequate hemisphere decompression.
    - 2) Bifrontal craniectomy has not shown benefit for diffuse edema,<sup>11</sup> however may be utilized for those patients with bifrontal contusions or associated pathology.

**V. Discontinuation of intracranial monitoring. Normal ICP is defined as  $< 20$  mm Hg. Transient elevations in ICP related to time off sedation or agitation are not included in below decisions.**

- A. Improvement of neurologic exam
  1. GCS  $> 8$  on all exams for at least 24 hours
    - a. The extubated awake patient does not require the 24 hour time period
  2. GCS = 8 when following commands consistently
    - a. This criteria can be used when effects of injury prevents eye opening
- B. No evidence of elevated intracranial pressure
  1. Stability of imaging and 3 days without requiring intervention (i.e. no 3%)
  2. Stability of imaging and 24 hours of being intervention free when patient is 5 days post injury
- C. Invasive monitoring should not be removed if any surgical intervention is planned in the next 24 hours and ICP required treatment at any point during the monitoring.

## References:

- 1 Brain Trauma Foundation. Guidelines for the management of severe traumatic brain injury, 3rd Edition. *Journal of neurotrauma* **24** (2007).
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- 5 Bullock, M. R. *et al.* Surgical Management of Acute Subdural Hematomas. *Neurosurgery* **58**, S2-16-S12-24, doi:10.1227/01.neu.0000210364.29290.c9 (2006).
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- 8 Appendix I: Post-traumatic Mass Volume Measurement in Traumatic Brain Injury Patients. *Neurosurgery* **58** (2006).
- 9 Appendix II: Evaluation of Relevant Computed Tomographic Scan Findings. *Neurosurgery* **58** (2006).
- 10 Hutchinson, P. J. *et al.* Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension. *The New England journal of medicine*, doi:10.1056/NEJMoa1605215 (2016).
- 11 Cooper, D. J. *et al.* Decompressive Craniectomy in Diffuse Traumatic Brain Injury. *The New England journal of medicine* **364**, 1493-1502 (2011).