

## Guidelines for the Management of Severe Traumatic Brain Injury Patients:

### ICP Monitor Group

1. Required patient monitoring measures
  - a. Place ICP monitor
    - i. If the initial placement of the ICP monitor is delayed due to contraindications (eg coagulopathy), then the contraindication must be corrected as rapidly as possible and catheter implantation be performed as soon as the contraindication is removed.**
    - ii. In the case of an ICP monitor failure due to catheter breakage, unintentional removal of catheter, or any other damage or compromise of catheter every attempt should be made to replace the catheter with a new properly functioning one.**
    - iii. Every attempt should be made to insert a new ICP monitor following a cranial operative procedure.**
2. Additional patient monitoring measures: We strongly suggest using these interventions whenever available and/or possible.
  - a. Place continuous SaO<sub>2</sub> and EtCO<sub>2</sub> monitors
  - b. Insert indwelling urinary catheter to monitor urine output
  - c. Insert arterial catheter for arterial pressure monitoring
  - d. Insert central venous catheter for infusion of solution and central venous pressure monitoring
  - e. Monitor clinical neurological status each hour
    - i. Pupil size and reactivity
    - ii. GCS
  - f. Obtain brain CT
    - i. To evaluate evolution 48 hours after the admission CT
    - ii. To evaluate evolution 5-7 days after the admission CT
    - iii. As needed based on patient clinical condition
3. General management measures
  - a. Place patient on mechanical ventilation, goal SaO<sub>2</sub> > 90% and PaO<sub>2</sub> > 60 mmHg

- b. Use adequate sedation and analgesia
  - i. Acceptable medications include benzodiazepines, opioids, propofol and low dose barbiturates
    - 1. Low dose barbiturate dosing:
      - a. Thiopental (Pentothal) 1-2 mg/kg/hr IV continuous infusion (approx. 1.5-3 gm/day)**
- c. Maintain head of bed at 30°
- d. Maintain head and neck aligned and in neutral position
- e. Actively monitor body temperature and treat hyperthermia
  - i. Hyperthermia defined as central temperature  $\geq 38^{\circ}\text{C}$
  - ii. Non-pharmaceutical cooling measures
    - 1. Cooling blanket, ice packs
  - iii. Pharmaceutical cooling measures
    - 1. Dipirone (Metamizole sodium)
- f. Early enteral nutritional support
  - i. Initiate within 48 hours of injury
  - ii. Give 25 Kcal/kg patient weight per day
- g. Pharmacologic prophylaxis for early post traumatic seizures
  - i. Phenytoin (IV or PO)
    - 1. Loading and maintenance doses as per individual hospital guidelines
    - 2. Continue for 7-28 days
- h. Gastric bleeding prophylaxis
  - i. Ranitidine or Omeprazole (IV or PO)
    - 1. Administer as per individual hospital guidelines
- i. Prevent decubitus lesions and treat as indicated
- j. Deep venous thrombosis prophylaxis
- k. Frequent tracheal suctioning with sterile technique to prevent pulmonary infections

1. Maintain Hb  $\geq$  7 mg/dL, use blood transfusions as needed
4. CT scans
  - a. First CT: upon hospital admission
  - b. Second CT: 48 hours after the first CT
  - c. Third CT: 5-7 days after the first CT
  - d. Additional CT scans as needed based on patient clinical condition
5. Treatment Goals for adequate cerebral perfusion and oxygenation
  - a. ICP  $\leq$  20 mmHg
  - b. Cerebral Perfusion Pressure (CPP) 50-70 mmHg
  - c. **Arterial blood oxygen saturation (SaO<sub>2</sub>) > 90% or PaO<sub>2</sub> > 60 mm Hg**
6. Initial Therapeutic Interventions
  - a. Normal saline solution (0.9% NaCl) to obtain a CVP of 10-12 cmH<sub>2</sub>O
  - b. Vasopressors when necessary to obtain a systolic blood pressure (SBP) > 90 mmHg or mean arterial pressure (MAP) > 70 mmHg **prior to ICP monitoring (use CPP after monitoring begins).**
  - c. Maintain PaCO<sub>2</sub> 35-40 mmHg if CT is normal
    - i. In Cochabamba, correct for altitude and maintain PaCO<sub>2</sub> 32-36 mmHg.
  - d. If a space-occupying lesion exists, surgical evacuation is indicated if possible
7. Specific therapeutic interventions-**ICP Monitor with Elevated ICP Treatment algorithm. Use the following treatment interventions sequentially when ICP is elevated or not responding to basic treatment. Note that clinically significant ICP elevation (not resolving within 5 minutes) requires treatment, which should be reflected by an increase in the Therapeutic Intensity Level (TIL) for that hour. Failure of ICP response after 20 minutes should prompt further treatment.**
  - a. Maintain CPP between 50-70 mmHg
    - i. Every effort should be made to insert an arterial line for continuous MAP monitoring
    - ii. If arterial line cannot be placed then calculate MAP from non-invasive blood pressure monitoring every hour to calculate CPP

- b. Ventricular drainage should be considered if available. If an intraparenchymal catheter is already inserted, consider **placing the ventricular drain separately**. Drainage of intraventricular fluid should be intermittent, with removal of the smallest volume of fluid necessary to control intracranial pressure and used for the shortest period of time possible. **It is suggested that drainage be for two minutes and the ventricular catheter then be clamped and the PIC rechecked. When both an intraparenchymal monitor and a ventricular catheter are present, the intraparenchymal device should be used to measure the pressure. Note that the ventricular catheter should be clamped when measuring the pressure using either monitor to ensure accuracy.**
- c. Neuromuscular blockade should be used, suspend if ICP not responding
- d. Mild hyperventilation to maintain PaCO<sub>2</sub> 30-35 mmHg (PaCO<sub>2</sub> 28-32 mmHg in Cochabamba)
- e. Hyperosmolar/hypertonic therapy
  - i. Mannitol should be used first except in the following situations (HHH):
    - a. Arterial Hypotension
    - b. Hypovolemia
    - c. Hyponatremia
  - 2. Hyperosmolar (Mannitol) therapy guidelines and dosing
    - a. Plasma osmolarity **or tonicity** should be monitored at least every 12-24 hours
      - i. Plasma osmolarity **or tonicity** should be calculated using the following formulae:
        - 1. 
$$\text{Osmolarity} = 2 * (\text{Na}) + (\text{BUN} / 2.8) + (\text{Glucose} / 18)$$
          - a. **Tonicity = 2 \* (Na + K) + (Glucose/18)**
        - ii. Hyperosmolar therapy should be suspended for plasma osmolarity > 320 **or tonicity > 340**
    - b. Mannitol dosing regimen using 20% Mannitol bolus:
      - i. For ICP elevation > 20 mmHg give 0.25-1 gm/kg 20% Mannitol bolus

- ii. Extra doses can be administered for sustained elevation of ICP if plasma osmolarity < 320
- 3. Hypertonic saline therapy guidelines and dosing
  - a. Hypertonic saline should only be used in cases of HHH as described above
  - b. Plasma osmolarity **or tonicity** and serum sodium should be monitored every 12-24 hours
    - i. Plasma osmolarity **or tonicity** should be calculated using the following formulae:
      - 1.  $\text{Osmolarity} = 2 * (\text{Na}) + (\text{BUN} / 2.8) + (\text{Glucose} / 18)$
      - 2.  **$\text{Tonicity} = 2 * (\text{Na} + \text{K}) + (\text{Glucose} / 18)$**
    - ii. **Hypertonic saline therapy should be suspended for plasma osmolarity > 360 or tonicity > 380 or serum sodium > 160**
  - c. Hypertonic saline dosing regimen using 5%NaCl solution bolus:
    - i. 80ml normal saline (0.9%NaCl) + 20ml 20%NaCl = 100ml 5%NaCl solution
    - ii. 100ml IV given over 1 hour, may repeat as needed for sustained elevations in ICP if plasma osmolarity < **360** and serum sodium < **160**
  - f. When increasing the therapeutic intensity level obtain a CT scan if possible
- 8. Neuroworsening requires increased therapeutic intensity level, including decompressive craniectomy when necessary and available. Any one or all of the following therapeutic interventions should be utilized based on patient conditions.
  - a. Neuroworsening defined as:
    - 1. Decrease in the motor GCS  $\geq 2$
    - 2. New loss of pupil reactivity
    - 3. Interval development of pupil asymmetry of  $\geq 2\text{mm}$

4. New focal motor deficit
  5. Herniation syndrome
  - ii. Mannitol dosing regimen using 20% Mannitol bolus:
    1. For ICP elevation  $> 20$  mmHg give 0.25-1 gm/kg 20% Mannitol bolus
    2. Extra doses can be administered for sustained elevation of ICP if plasma osmolarity  $< 320$
  - iii. Increase hyperventilation (HV)
    1. Maintain PaCO<sub>2</sub> of 25-30 mmHg (PaCO<sub>2</sub> 22-28 mmHg in Cochabamba)
    2. Use for shortest time period possible to reverse neurological deterioration
  - b. If no response, stop HV and use barbiturates
    - i. High dose IV barbiturates
      1. **Thiopental (Pentothal) 2.5-4 mg/kg/hr IV continuous infusion for 3 days**
      2. **Hypotension must be avoided**
  - c. Head CT is strongly suggested if possible
9. Second tier therapy to be considered in salvageable patients **under conditions such as:**
- a. To be considered in case of:
    - i. **ICP not responding to first tier therapy**
    - ii. **Persistent neuroworsening not responding to an increased therapeutic intensity level (as indicated above). CT is recommended, if possible.**
    - iii. **Follow-up CT (eg day 5 CT) showing Inadequate response to treatment such as persistent edema**
  - b. **Primary options**
    - i. **Decompressive craniectomy**
    - ii. **High dose IV barbiturates:**

**1. Thiopental (Pentothal) 2.5-4 mg/kg/hr IV continuous infusion (approx. 4-6 gm/day)**

**2. Hypotension must be avoided**

**c. Other options**

**i. Hyperventilation to maintain PaCO<sub>2</sub> 25-30 mmHg (PaCO<sub>2</sub> 22-28 mmHg in Cochabamba), use for shortest time period possible to reverse neurological deterioration**

**ii. Hypothermia**

**iii. Lund therapy**

**10. Management following decompressive craniectomy**

**a. Every attempt should be made to insert a new ICP monitor post-operatively, using techniques such as:**

**1. Ventriculostomy**

**2. Placing another bolt through an Harborview peninsula left along the margins of the craniectomy**

**ii. If placement of the new ICP monitor is problematic, contact Gustavo Petroni, MD (mobile telephone +549-341-514-7543, home telephone +54-341-482-7588, fax +54-341-423-1087, e-mail [gustavopetroni@gmail.com](mailto:gustavopetroni@gmail.com)) or Silvia Lujan, MD, (mobile telephone +549-341-560-9239, home telephone +54-341-440-2056, fax +54-341-423-1087, e-mail [silviablujan@gmail.com](mailto:silviablujan@gmail.com)) **immediately.****

**b. Use adequate sedation and analgesia**

**c. Mild hyperventilation to maintain PaCO<sub>2</sub> 30-35 mmHg (PaCO<sub>2</sub> 28-32 mmHg in Cochabamba)**

**d. If ICP monitor is placed, treat ICP elevations > 20 as indicated above.**

**11. Intracranial pressure definitions**

**a. Treatable intracranial hypertension:**

**i. ICP > 20 mmHg for > 5 minutes**

**b. Treatment failure:**

**i. ICP not reduced to  $\leq$  20 mmHg within 20 minutes after a treatment intervention is initiated, and**

**ii. Persistent elevation in ICP > 20 mmHg requires increase in therapeutic intensity level**

12. Investigation of the patient with intracranial hypertension: After assessment of the following factors and initiation of appropriate interventions as indicated below, if the interventions are ineffective in reducing ICP, increase the therapeutic intensity level.
  - a. Check for factors that could increase ICP
  - b. Pain or agitation: consider increasing sedation/analgesia
  - c. Respiratory agitation, consider the following:
    - i. Stopping the procedure
    - ii. Lidocaine IV or ET (endotracheal tube)
    - iii. Technique modification
  - d. Patient manipulation and rotation, consider the following:
    - i. Stopping the procedure
    - ii. Increasing sedation/analgesia
    - iii. Technique modification
  - e. Endotracheal tube (ET) problems, consider the following:
    - i. Change the ET holder
    - ii. Change the ET tube care techniques
  - f. Elevated intrathoracic pressure or elevated PEEP, consider the following:
    - i. Drain any hemopneumothorax
    - ii. Change ventilator technique
  - g. Raised intra-abdominal pressure: consider decompressive laparotomy
  - h. Evidence of seizures: consider evaluation and treatment
  - i. Check laboratory and vital signs values
    - i. Hyperthermia: consider reducing the temperature to  $< 38^{\circ}\text{C}$
    - ii. Increased PaCO<sub>2</sub>: consider increasing ventilatory rate
    - iii. Hypoxia: consider increasing fraction of inspired oxygen
    - iv. Abnormal CPP:
      1. Consider increasing MAP with fluids or vasopressors

2. Consider reducing ICP with sedation and analgesia, hyperventilation, hyperosmolar/hypertonic therapy, and/or high dose barbiturates

v. Hyponatremia: consider correcting plasma electrolytes

j. If you feel that the intracranial situation may have changed, obtain head CT when possible

13. ICP monitor removal:

a. Consider removal of catheter if ICP  $\leq$  20 mmHg for  $\geq$  24 hours WITHOUT treatment

**b. Confounding factors that may require longer monitoring:**

**i. Hemodynamic instability**

**ii. Need for intraoperative monitoring during extracranial surgery**

**iii. “Clinical judgment”**

14. Contraindicated treatments

**a. Corticosteroids for brain injury treatment**

**b. Prophylactic hyperventilation**

**c. Use of anticonvulsants for prophylaxis of late epilepsy (beyond 28 days)**