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Proposed By: Samuel Picone III, MD, Trauma Medical Director

Approval and Dates:

Dr. Bunch, Section of Neurosurgery: 11/30/2005

Dr. Mollman, Section of Neurosurgery: 11/18/2005

Critical Care Medicine: 11/15/2005

Trauma Service: 12/1/2005

Emergency Medicine: 11/17/2005

Trauma Committee: 12/13/2005

SUBJECT: Clinical Practice Guideline for the Management of Severe Traumatic Brain Injury

PURPOSE:

Standardize the diagnosis and management of severe traumatic brain injury by establishing guidelines for the prevention and management of secondary injury in the severely brain injured patient.

PERFORMED BY:

Medical Staff

DEFINITIONS:

1. Traumatic brain injury (TBI): An injury to the brain resulting in disorders of motor, sensory and/or cognitive function.
2. Severe TBI (mortality > 40%)
 - a. Glasgow Coma Scale (GCS) score <8, and
 - b. Positive CT
3. Secondary brain injury: Secondary injury occurs after the primary event, in response to cerebral ischemia and may be related to the chemical changes that occur after injury, to systemic complications or to direct trauma to brain tissue. Management of patients with severe head injury is directed at minimizing the influences that cause secondary injury. Patients at risk for secondary brain injury:
 - a. Brain injury associated with a GCS score <8.
 - b. Severe diffuse swelling with ventricular effacement or obliteration.
 - c. Hemispheric swelling with effacement of the ventricle or midline shift.
 - d. Intracerebral hematoma with midline shift.
 - e. GCS score 9-12 with abnormal CT if the patient will undergo a prolonged operation for extra cranial injuries
 - f. GCS score 9-12 with 2 or more:
 - i. Age > 40
 - ii. Systolic BP < 90
 - iii. Unilateral or bilateral motor posturing
4. Elevated Intracranial Pressure (ICP): ICP above 20-25 mm Hg
5. Cerebral Perfusion Pressure (CPP): The CPP defined as MAP-ICP, is the physiologic variable that defines the pressure gradient driving cerebral blood flow and metabolic delivery and is, therefore, closely related to ischemia. CPP should be maintained at >60 torr.

6. Barbiturate coma: the use of high dose intravenous pentobarbital in the patient with traumatic brain injury to reduce intracranial pressure and cerebral metabolic rate. Usually used as a late adjunct to the cerebral perfusion management guideline. Approval of neurosurgeon required prior to initiation.

INITIAL MANAGEMENT OF TRAUMATIC BRAIN INJURY:

1. Perform primary survey according to ATLS guidelines:
 - a. Maintain C-spine precautions including rigid collar
 - b. Provide definitive airway for GCS ≤ 8 – remember that hypoxia can be devastating to the injured brain. Consider using lidocaine with intubation (IV and topical).
 - c. Assess for chest injury, ventilate to maintain mild hypocapnia (pCO₂ = 35-40 mmHg). Aggressively maintain PO₂ > 60
 - d. Determine hemodynamic status, resuscitate from shock with normal saline or lactated ringers solution. Maintain normovolemia and normal hemodynamics. Aggressively maintain systolic BP > 90
 - e. Conduct a rapid but thorough neurologic exam, including:
 - i. Level of consciousness.
 - ii. Ability to verbalize.
 - iii. Ability to open eyes.
 - iv. Ability to move all extremities to verbal command or pain.
 - v. Presence of abnormal posturing.
 - vi. Presence of abnormal reflexes.
 - vii. Presence of rectal tone if unable to move lower extremities.
 - viii. Pupillary response.
 - ix. Gag reflex.
 - x. Note presence of bruises, Battle's signs, lacerations, etc.
 - f. Expose patient to look for any non-obvious injury.
2. Resuscitate patient as above until hemodynamic and pulmonary stability is achieved.
3. Calculate and document the Glasgow Coma Scale score
4. Obtain a head CT scan:
 - a. GCS ≤ 14 .
 - b. Any patient with focal neurologic deficit.
 - c. Any patient with witnessed loss of consciousness >5 minutes.CT priorities:
 - i. CT should be abandoned if patient requires emergent operation to stop hemorrhage or immediately repair life-threatening injury. Notify neurosurgery immediately of this situation.
 - ii. CT should be obtained, otherwise, to determine presence of space-occupying clot prior to other surgeries.
5. Obtain immediate neurosurgical consult for the following:
 - a. Epidural hematoma
 - b. Subdural hematoma
 - c. Patients at risk for secondary brain injury (see Definitions)
6. Pain/sedation: Pain should be treated and uncooperative or thrashing patients should be treated with sedation. Paralytics may be utilized in intubated patients if necessary to obtain diagnostic studies. Remember it is imperative to avoid systolic BP <90.
7. Hyperventilation: PaCO₂ ≤ 35 mm Hg may be necessary for brief periods for acute neurological deterioration. Hyperventilation should be used only after all other options have been tried.

8. Seizures: Use of prophylactic anticonvulsants has not been shown to prevent the onset of late post-traumatic seizures (onset after 7 days). Consider anticonvulsants phenytoin or carbamazepine to prevent early post-traumatic seizures in those considered high risk:

- a. GCS score < 10
- b. Penetrating injury.
- c. Skull fracture with depression.
- d. Cortical contusion
- e. Intraparenchymal hematoma.
- f. Subdural
- g. Epidural
- h. Seizure within 24 hours of injury

9. Mannitol: at the discretion of the neurosurgeon, a mannitol bolus can be given for evidence of rising intracranial pressure. This should suggest that an ICP monitor be placed as soon as possible.

10. Operative management: A craniotomy can be performed at the same time as other operative procedures. Consider all possibilities if patient is to be taken to the OR.

ICU MANAGEMENT OF CEREBRAL PERFUSION PRESSURE

All patients with isolated severe TBI should be admitted to the ICU by the neurosurgery service with critical care medicine consultation.

Patients with severe TBI and associated other system injuries should be admitted by the trauma service with neurosurgery and critical care medicine consultation.

If a patient is defined as being at risk for secondary injury (see Definitions) by the neurosurgeons or trauma surgeons then the following protocol should be implemented:

1. Intubate patient; place on volume controlled ventilator.
 - a. Maintain $pO_2 > 80$ torr; maintain O_2 saturation $> 96\%$.
 - b. Maintain pCO_2 35-40 mmHg.
2. Monitor lactate levels every 6 hours and replace volume until normalized if the patient has had an episode of hemorrhagic shock.
3. Insert an intracranial pressure monitor:
 - a. Preferably a ventriculostomy.
 - b. If ventriculostomy cannot be placed, consider intraparenchymal monitor.
 - c. Start cefazolin 1 gm every 8 hours for prophylaxis while catheter is in place.ICP monitors and ventriculostomy placement is the responsibility of the neurosurgeon.
4. Insert arterial line.
5. Insert pulmonary artery catheter, preferably with continuous cardiac output measurement capability. Placement and management of pulmonary artery catheters are the responsibility of the medical intensivist or trauma surgeon.
6. Head of bed at 30° unless otherwise specified.
7. Treat pain and maintain sedation.
8. Treat fevers of > 38.5 .
 - a. Tylenol suppository, 650 mg every 4 hours prn.
 - b. Cooling blanket.
9. Calculate cerebral perfusion pressure (CPP) as mean arterial pressure minus intracranial pressure. Maintain CPP > 60 torr.
10. If CPP < 60 torr, then determine whether this is due to increased ICP or reduced MAP.
 - a. If CPP < 60 torr and ICP > 25 cm H_2O , then consider measures to reduce ICP.
(See Treatment of Elevated ICP, below)
 - b. If CPP < 60 torr, make sure hemodynamics are not compromised.
 - i. Determine Cardiac Index (CI).
 - ii. If CI < 4.0 , then determine PCWP.
 1. Maintain PCWP at > 14 cm H_2O .

2. Use gentle fluid boluses of lactated ringers (500 ml/hr) to increase PCWP to desired level to keep CI >4.0.
- iii. If PCWP >14 cm H₂O and CI <4.0:
 1. Start dopamine 5 mcg/kg/min.
 2. May go up to 10 mcg/kg/min.
- iv. If CI >4.0 and CPP is still <60 torr:
 1. Start neo-syneprine or levophed.
 2. Titrate to keep CPP >60 torr.
11. Maintain normal Magnesium levels
12. Maintain Hct > 30%
13. When the patient is physiologically stable, enteral nutrition may be initiated with the following goals:
 - a. 140 % resting Energy expenditure – non-paralyzed patient
 - b. 100% Resting Energy expenditure – paralyzed
14. Repeat CT scans according to neurosurgery requests. Call neurosurgeon with anatomic changes.
15. If there is any confusion with this protocol, contact neurosurgery or the trauma attending.

TREATMENT FOR ELEVATED ICP (Follow steps 1-8 in sequence if ICP elevation persists)

1. Eliminate factors which can elevate ICP
 - a. Straighten head to promote venous return
 - b. Raise head of bed 60 degrees
 - c. Eliminate hypercarbia
 - d. Rule out anatomic changes with repeat head CT if not recently done. Call neurosurgery for any anatomic changes
2. Treat pain with narcotics MS 2-10 mg IV + benzodiazepines and propofol infusion
3. System neuromuscular paralysis (vecuronium or pancuronium)
4. Drain ventriculostomy
 - a. Drain for 3-5 minutes and record ICP and CPP.
 - b. If ICP remains above limits, may place drain to continuous drainage at the discretion of the neurosurgeon.
5. Mannitol.
 - a. Mannitol 20%, 0.25 gm/kg IV every six hours (may use bolus mannitol 25-50 gm IV Q 4 hours)
 - b. Obtain sodium and serum osmolality every 6 hours.
 - c. Hold if serum osmo > 315mOsm, or sodium > 150
6. Lasix 20-40 mg IV/4 hours
7. Hyperventilation (paCO₂ 28-30 mm Hg) – CAUTION – this for only short duration – usually performed in bursts
8. Barbiturate Coma (See below).

BARBITURATE COMA FOR TRAUMATIC BRAIN INJURY

Approval of neurosurgeon required before initiating barbiturate coma.

Indications: Barbiturate coma is usually reserved for patients with traumatic brain injury with intractably high (>20 mmHg) intracranial pressure in spite of optimal measures to lower ICP including mannitol, sedation, ventriculostomy drainage (if available), and mild hyperventilation. Because of the hemodynamic consequences of barbiturate coma, this therapy is usually follows a trial of aggressive cerebral perfusion pressure optimization.

Goals of therapy:

1. ICP control – try and maintain below 20 mmHg
2. Burst suppression – 4-8 bursts per minute
3. Barbiturate levels are not important but if drawn should be between 3 and 4 mg/dL (levels as high as 9 mg/dL can be seen)

Inclusion criteria (all of the following):

1. Serious traumatic brain injury with global or focal swelling
2. Documented neurologic function
3. Adequate cardiac function (preferably defined by a CI > 4.0 L/min/m²)
4. Adequate pulmonary function (PaO₂/FIO₂ < 200)

Available monitoring lines and equipment

1. Endotracheal intubation (7.0 or greater)
2. Volume controlled ventilator
3. Arterial catheter, continuous monitoring
4. Pulmonary artery catheter
5. Pulse oximeter
6. Bedside EEG monitor – 8 lead or compressed spectral array
7. Adequate IV access
8. DVT prophylaxis

Establish medical stability to compensate for following complications:

1. Cardiovascular instability
 - a. Cardiac depression
 - b. Vasodilatation
2. Loss of secretion clearance
 - a. Loss of cough reflex
 - b. Paralysis of mucociliary elevator
3. Immunologic suppression
4. Skin breakdown

Once patient is stable and fully volume loaded start barbiturates

1. Initiate therapy with a loading dose of 10 mg/kg of pentobarbital sodium over 30 minutes
2. Follow with an infusion of 5 mg/kg/hr for the next 3 hours
3. Then start a continuous drip at 1 (one) mg/kg/hr
4. Monitor for burst suppression – ideally this is 4 to 8 bursts every minute e. Increase dose of pentobarbital sodium up to 3 mg/kg/hr to maintain burst suppression
5. Discontinue barbiturate coma when (no need to taper):
 - a. ICP is under control for 24-48 hours
 - b. All signs of brain activity cease – must confirm brain death with cerebral blood flow study

Expectations and complications

1. Hypotension
 - a. Initially measure PCWP and fluid load if necessary
 - b. Dopamine will overcome myocardial suppression
2. Pneumonia – secretion stasis
 - a. Aggressive pulmonary toilet
 - b. Positioning patient for pulmonary drainage if possible
3. Miosis – common (at higher doses can occasionally see mydriasis)
4. Skin breakdown – consider therapeutic bed
5. Hypothermia – keep temp above 36° C
6. DVT – maintain optimal prophylaxis

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Author: Samuel Picone, MD, Trauma Medical Director
Responsible Department: Trauma Program