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Managing Severe TBI in the ICU Setting using a Three Tier Approach

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Disclosures

- Bard
  - Honorarium
- Medical Advisory Board/Stock Options
  - Neuroptics
  - Cerebrotech
- Neurocritical Care Society
  - Board of Directors
  - Vice President

Objectives

- 1) Assess the effects of injury to the brain in the neurologic injured patient and implement a tiered approach to manage severe TBI
- 2) Evaluate TBI patients using multimodality monitoring
- 3) Apply interventions to manage brain injury & integrate the complex multi-system issues and manage these patients using an actual case study.

Case DF: Pre-Hospital

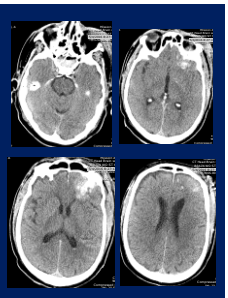
- 75 year old male riding bike with helmet on down hill went over the handlebars
  - VS: BP 166/62 HR 44 R 18 O2 sat 82% on O2
  - Awake at seen: GCS 3-5-1 – deteriorating…
  - Laceration over left eye / blood coming from ears

Trauma Room 1143- Tier 1 Red

- BP 80/40 HR 50s RR 18
- Intubated emergently in trauma room
- Neuro
  - GCS 1-1-1
  - Right eye 3 mm Left eye 4 mm
- Crepitus over left chest with suspicion of tension pneumothorax right
  - Needle thorocostomies
  - Bilateral chest tubes
  - O2 saturation improves to 100% BP 120/60
- Heart rate drops to 30s…Patient arrests (Vfib) 10 minutes after arrival
  - CPR x 6 minutes
  - Defibrillation
  - Epinephrine
  - Thoracotomy performed - Opened chest
  - Blood products given
  - To OR

IntraOp

- Left sided Thoracotomy – cross clamped aorta
  - Obvious cardiac contusion
  - Multiple lung contusions
- Abdomen opened
  - Grade 1 splenic injury
  - Mesenteric hematoma
- Flail chest noted with bilateral hemothoraces
- Massive Transfusion
  - 6 Packed RBCs, 4 FFP, and Super pack Platelets
- Abdomen left open with wound vac placed
- To CT…



Admit SICU 300pm

- Decision to induce hypothermia at 36 degrees C x 24 hours due to V Fib arrest
  - Concerns about bleeding
  - Neurosurgeon decides to hold ICP placement this evening
  - Pads placed strategically with open belly
  - Pacing wires present
  - Bilateral chest tubes to suction
- VS stable
  - MAP 80-90 HR 56 Ventilated at 10 breaths/minute
- Neuro
  - GCS 1-1-1
  - Pupillometer
    - Right pupil: NPI 1 CV 0.52 mm/sec
    - Left pupil: NPI 0.5 CV 0.09 mm/sec

Severe TBI

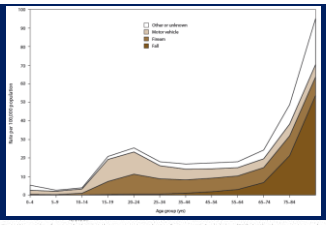
- Sum score 3 to 8 &/or motor score ≤ 5
- Brain injury association
  - Prolonged unconscious state or coma lasting days, weeks or months
- Primary Injury
  - Occurs at the time of the event
  - Includes EDH, SDH, SAH, Contusions, DAI etc

Secondary Brain Injury

- Secondary Head Injury
  - Extracranial causes
    - Hypotension
    - Hypocapnia and Hypercapnia
    - Hypoxia
    - Anemia
    - Hyperglycemia & Hypoglycemia
    - Hyperthermia

TBI Classification by Age Group - Mechanism

FIGURE 5. Average annual rates for traumatic brain injury deaths, by age group and external mechanism of injury — United States, 1997–2007

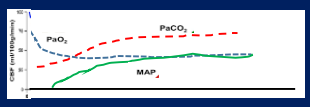


http://www.cdc.gov/mmwr/preview/mmwrhtml/figures/s6005a1f5.gif

A bit of Physiology

3 Factors

- CBF
  - Phases of CBF after TBI
    - Early: Low CBF and
    - Days 2-6: Higher CBF –
    - Days 7 -14: Low CBF – fall in cytotoxic edema
- Pressure
  - Early to mid week: cytotoxic edema forms during this phase as well as vascular engorgement
- Oxygen
  - PaO2 is low – vasodilation
  - PaCO2 is low – vasoconstriction
  - PaCO2 is high - vasodilation

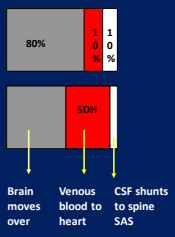


Cerebral Blood Flow Autoregulation

- Vasomotor control
  - Intact: Increase in CPP causes vasoconstriction and decrease in ICP
  - Vasomotor reactivity failure: Increase in CPP causes vasodilation and inc ICP
- Flow metabolism
  - ↑ metabolism ↑ CBF
- Metabolic substances
  - PaO2
  - PaCO2
  - pH i.e., acidosis = vasodilatation

Pressure: Intracranial Pressure

- Theories on Brain Compartment
  - 80% brain
  - 10% blood
  - 10% CSF
- If one increases the other two decrease
- Compensatory mechanisms



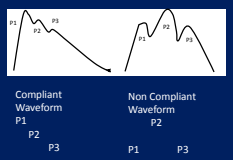
Intracranial Pressure

Normal range
0-15 mm Hg
Abnormal ranges **> 20 mm Hg**

Cerebral Perfusion Pressure

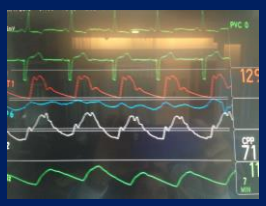
MAP – ICP = CPP
Optimal CPP in TBI
60-80 mm Hg

Intracranial Pressure: It is more than a number…it is all about compliance!



Compliant Waveform
P1
P2
P3

Non Compliant Waveform
P2
P1 P3



Brain Tissue Oxygen (PbtO2)

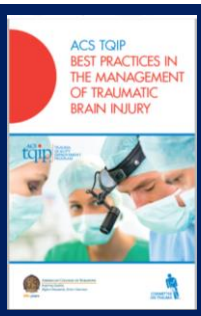
- Normal: 20-40 mm Hg
- Risk of death increases
  - < 15 mm Hg for 30 minutes
  - < 10 mm Hg for 10 minutes
- PbtO2 < 5 mm Hg
  - high mortality
- PbtO2 ≤ 2mm Hg - neuronal death

Influence of Airway/Ventilation Issues Day 8: Lungs Worsening ICP is no longer an issue

CO2	FIO2 %	MAP	ICP	CPP	PbtO2	Interventions
42	80	71	**14**	56	**15.6**	Increase Dopamine
42	80	76	**12**	64	**18**	Chest x-ray reviewed; Order to prone patient
43	80	90	**17**	63	**24.5**	4 Hours go by…sudden change in PbtO2
54	80	101	**18**	83	**12.4**	Lung sounds ↓; Supine; chest xray- Pneumo
	100					Chest tube placed
42	80	94	**10**	84	**34**	FIO2 weaned

Managing Severe TBI

- 2015 ACS TQIP Guidelines



https://www.facs.org/~/media/files/quality%20programs/trauma/tqip/traumatic%20brain%20injury%20guidelines.ashx

ACS TQIP Guidelines Severe TBI

- Recommendations
  - Use GCS to assess Neuro status
  - Triage & Transport
    - Patients with GCS < 13 and/or combination of GCS ≤ 15 and moderate to severe extra-cranial anatomic injuries and AIS ≥ 3 should be transported to highest level trauma center to allow for expedient neurosurgical assessment and intervention
  - ICP Monitoring
    - Important but does not replace neuro exam
    - Indicated in patients with
      - GCS ≤8 (not indicated if no structural injury seen on CT Scan)
      - Considered in GCS > 8 with structural brain damage with hig risk for progression (large contusions/coagulopathy)
      - Indicated in patients requiring urgent surgery for extracranial injuries requiring mechanical ventilation & evidence of CT progression of injury
      - Preferred method for ICP monitoring is EVD

ACS TQIP Guidelines Severe TBI

- Recommendations: ICP Management
  - Global measure
  - Additional neuromonitoring (PbtO2, SjO2, Autoregulation, and CBF) and assessment of cerebral autoregulation may help to individualize treatment
  - 3 Tiered approach to ICP Management
  - Failure to control ICP/CPP within one tier should prompt rapid progression to the next tier's treatment options
  - Repeat CT imaging and neurological exam should be considered to rule out the development of surgical lesion and guide management

ACS TQIP Guidelines Severe TBI

- Recommendations: Advanced Neuro Monitoring
  - Cerebral Autoregulation may be helpful in identify a more individualized approach to treatment
  - Impaired cerebral oxygenation can occur in the face of normal ICP and CPP
  - Cerebrovascular pressure reactivity PRx and CBF monitoring can assess autoregulation status which may be helpful in determining patient specific CPP and ICP goals

ACS TQIP Guidelines Severe TBI

- Recommendations: Surgical Management
  - Large traumatic hematoma should be evacuated before neuro deterioration develops irrespective of GCS
  - Formal craniotomy is necessary to perform adequate resection
  - TBI patients in coma should be taken to the OR immediately if large hematoma is identified as cause of coma
  - Decompressive craniectomy is effective in controlling ICP but uncertainty exists in its potential to improve outcome

Three-Tiered Management of ICP
Tier 1

- Head of Bed elevated 30 degree (reverse Trendelenburg) to improve cerebral venous outflow
- Sedation and analgesia using recommended short acting agents
  - Propofol, Fentanyl, and Midazolam) in intubated patients
- Ventriculostomy drainage performed intermittently.
  - Continuous drainage is not recommended unless additional ICP monitor is placed, as when the drain is open, it does not accurately reflect the true ICP
- Repeat CT imaging and neurologic examination should be considered to rule out the development of a surgical mass lesion and guide treatment
- IF ICP remains > 20-25 mm Hg, proceed to Tier 2

Tier 2

- In patients with a parenchymal ICP monitor, an EVD should be considered to allow for intermittent CSF drainage
- Hyperosmolar therapy should be given intermittently as needed for ICP elevation and not on a routine schedule
  - Mannitol should be administered in intermittent boluses (0.25-1 gm/kg body weight)
    - Caution with hypovolemic patient when osmotic diuresis is instituted with mannitol
    - Serum sodium and osmolality – assess every 6 hours
    - Additional doses should be held if serum osmolality exceeds 320 mOsm/l
    - Mannitol should be held if evidence of hypovolemia

Tier 2

- Hyperosmolar therapy should be given intermittently as needed for ICP elevation and not on a routine schedule
  - Hypertonic saline may be administered in intermittent boluses of 3% sodium chloride solution (250 ml over ½ hour) or other concentrations (e.g., 30 cc of 23.4%)
  - Serum sodium and osmolality must be assessed every 6 hours and a
  - Additional doses should be held if serum sodium exceeds 160 mEq/L
- Cerebral autoregulation should be assessed
  - If patient is not autoregulating, CPP should be lowered to reduce ICP
  - Additional neuromonitoring (e.g., PbtO2, SjvO2, CBF) may help determine optimal CPP

Tier 2 Continued

- PaCO2 goal of 30-35 mm Hg should be maintained, as long as brain hypoxia is not evident.
  - Additional neuromonitoring (e.g. PbtO2, SjbvO2, CBG) may help determine optimal PaCO2
- Repeat CT imaging and neurologic examination should be considered to rule out development of a surgical mass lesion and guide treatment
- Neuromuscular paralysis achieved with a bolus test dose of a neuromuscular blocking agent should be considered if the above measures fail to adequately lower ICP and restore CPP
- If there is a positive response, continuous infusion of a NMB should be employed (Tier 3)
- If ICP remains > 20-25 mm Hg, proceed to Tier 3

Tier 3

- Decompressive hemi-craniectomy or bilateral craniectomy should only be performed if treatments in Tiers 1 and 2 are not sufficient or are limited by development of side effects of medical treatment
- NMB paralysis via continuous infusion can be employed if positive response to test dose is achieved
- Baribiturate or Propofol coma may be induced
- Hypothermia (< 36 degrees C) is not currently recommended as an initial TBI treatment.
  - Hypothermia should be reserved for rescue or salvage therapy after reasonable attempts at ICP controls via previous Tier 3 treatments have failed.

ACS TQIP Guidelines Severe TBI

- Nutrition
  - Nutrition should begin early as soon as patient is hemodynamically stable, within 24-48 hours
  - Enteral nutrition is recommended over parenteral nutrition
  - Post pyloric feeding methods are preferred
- Tracheostomy
  - If LOC remains depressed, TBI patients should undergo tracheostomy to facilitate liberation from MV, decreasing risk of pneumonia & ventilator induced lung injury
  - Relative contraindications: High ICP, Hemodynamic instability, & severe respiratory failure
  - All TBI patients deemed not likely to improve rapidly should be considered within 8 days of injury

ACS TQIP Guidelines Severe TBI

- Venous Thromboembolism prophylaxis
  - High rates of DVT (20-30%)
  - VTE prophylaxis should be considered iwthing first 72 hours following TBI in most patients
    - Earlier initiation of pharmacologic prophylaxis (<72 hours) appears to be safe in patients at low risk for progression of IC bleeding and have stable CT scan
    - Prophylactic inferior vena cava filter should be considered in patients at high risk for progression of IC hemorrhage and cannot receive pharmacologic prophylaxis

ACS TQIP Guidelines Severe TBI

Table 3. Modified Berne-Norwood Criteria

Low risk	Moderate risk	High risk
No moderate or high risk criteria	Subdural or epidural hematoma > 8 mm Contusion or intraventricular hemorrhage > 2 cm Multiple contusions per lobe Subarachnoid hemorrhage with abnormal CT angiogram Evidence of progression at 24 hrs	ICP monitor placement Craniotomy Evidence of progression at 72 hrs
Initiate pharmacologic prophylaxis if CT stable at 24 hrs	Initiate pharmacologic prophylaxis if CT stable at 72 hrs	Consider placement of an IVC filter*

*Consider alternate strategies as described in text

Source: ACS TQIP Guidelines Page 18

2015 ACS TQIP Guidelines

Goals for Treatment

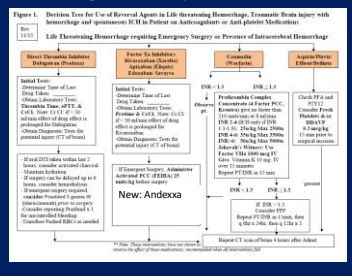
Pulse Oximetry > 95%	ICP 20-25 mm Hg	Serum sodium 135-145
PaO2 > 100 mm Hg	PtbiO2 > 15 mm Hg	INR < 1.4
PaCO2 35-45 mm Hg	CPP > 60 mm Hg	Platelets > 75,000
SBP > 100 mm Hg	Temperature 36-38 C	Hemoglobin > 7g/dL
pH 7.35-7.45	Glucose 80-180 meq/L	

TQIP Guidelines Focus Severe TBI

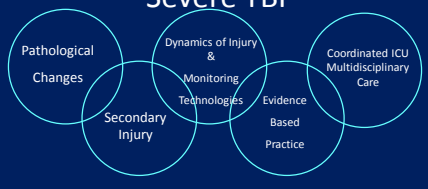
- Section on Elderly Patients with TBI
  - Often present with GCS 13-15 and appear mild in nature due to brain atrophy
  - Neuro evaluation more complicated due to dementia, cognitive decline, and hearing/visual deficits
    - Determine baseline from family
  - Anti-coagulants/Anti-platelet medications exacerbate sequalae of TBI
    - Reversal is important to remember
  - Older age carries higher mortality and worse functional outcome

Management of TBI Presence of Anticoagulants/Antiplatelets

- If patient on Anti-coagulation/anti-platelet medications and have a CT evidence of bleeding
  - Note the type of medication
  - Stop drug
  - Reversal strategies



Critical Care Management of Severe TBI



Severe TBI Patient: GCS 3-8 CT+ Injury

Arrival: Emergency Department Trauma Bay

Assess A-B-C: Oxygenation and Ventilation

Airway: Secured with RSI

Breathing: Connect to Ventilator

Avoid hyperventilation

Use Capnography to monitor ET CO2 (35)

RSI:
Lidocaine 1mg/kg IVP
Etomidate 0.3 mg/kg IVP
Paralytic of Choice
Follow-up: Versed/Fentanyl prn

Severe TBI Patient: GCS 3-8 CT+ Injury

Arrival: Emergency Department Trauma Bay

Assess A-B-C: Oxygenation and Ventilation

Assess Circulation: Assess Pulse, ECG and BP

IV fluids to maintain adequate MAP

Place Foley & OG
Maintain MAP > 80 mm Hg with IV NS:
Assess need for Blood Products and/or Vasopressors
Assess need for Central Line/Arterial Line

Severe TBI Patient: GCS 3-8 CT+ Injury

Arrival: Emergency Department Trauma Bay

Assess Neuro: GCS/Pupils

If S/S Increased ICP
Non-reactive single pupil(s) &/or Posturing

Administer 3% Saline 200 ml (Preferred) or
Mannitol 1gm/kg IV (if no signs hypotension or bleeding)

Severe Brain Injury Algorithm

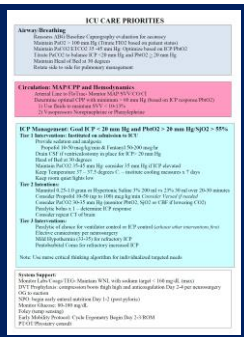
Secondary Survey
Other Interventions as needed

Is patient on any anti-coagulants or anti-platelet medications?

→ Anticoagulation/Anti-platelet Reversal

PCC agents
Platelets/FFP
DDAVP

Radiology:
CT Scan Non-Contrast/C-Spine
Positive for Bleeding?
PACU:
Hold/Lines Placed if time
Place Central Line/Art line with Flotrac
OR:
Monitors (ICP/PbtO2)/Craniotomy
ED Trauma or SICU RN assist in OR



Severe TBI Patient: GCS 3-8 CT+ Injury

ICU Care: Primary Interventions

Airway/Breathing

Reassess ABG/Baseline Capnography evaluation for accuracy
Maintain PaO2 > 100 mm Hg (Titrate FIO2 based on patient status)
Maintain PaCO2/ETCO2 35 -45 mm Hg: Optimize based on ICP and PbtO2
Titrate PaCO2 to balance ICP <20 mm Hg and PbtO2 ≥ 20 mm Hg
Maintain Head of Bed at 30 degrees
Rotate side to side for pulmonary management

Severe TBI Patient: GCS 3-8 CT+ Injury

ICU Care: Primary Interventions

Circulation

Arterial line to Hemodynamic Monitor

√MAP/SVV/CO/CI

Maintain CPP >60 mm Hg as initial target
1) Use fluids to maintain SVV < 10-13%
2) Vasopressors Norepinephrine or Phenylephrine

Severe TBI Patient: GCS 3-8 CT+ Injury

ICU Care: Tier Approach

ICP Management: Goal ICP < 20 mm Hg and PbtO2 > 20 mm Hg

Tier 1 Interventions: Instituted on admission to ICU

Provide sedation and analgesia
Propofol 10-50 mcg/kg/min & Fentanyl 50-200 mcg/hr
Drain CSF if ventriculostomy in place for ICP> 20 mm Hg
Head of Bed at 30 degrees
Maintain PaCO2 35-45 mm Hg: consider 35 mm Hg if ICP elevated
Keep Temperature 37 – 37.5 degrees C.
Institute cooling measures x 7 days
Keep room quiet/lights low

Severe TBI Patient: GCS 3-8 CT+ Injury

ICU Care: Tier Approach

ICP Management: Goal ICP < 20 mm Hg and PbtO2 > 20 mm Hg

Tier 2 Intentions:

Mannitol 0.25-1.0 gram or Hypertonic Saline 3% 200 ml vs 23% 30 ml over 20-30 minutes
Consider Propofol 10-50 (up to 100) mcg/kg/min *Consider Versed if needed*
Consider PaCO2 30-35 mm Hg (monitor PbtO2, SjO2 or CBF if lowering CO2)
Paralytic bolus x 1 – determine ICP response
Consider repeat CT of brain

Tier 3 Interventions:

Paralytic of choice for ventilator control or ICP control (*exhaust other interventions first)*
Elective craniectomy per neurosurgery
Mild Hypothermia (33-35) for refractory ICP
Pentobarbital Coma for refractory increased ICP

Note: Use nurse critical thinking algorithm for individualized targeted needs

ICU Care: Tier Approach

System Support:

Monitor Labs/Coags/TEG- Maintain WNL with sodium target < 160 mg/dL (max)
DVT Prophylaxis: compression boots thigh high and anticoagulation Day 2-4 per MD
OG to suction
NPO: begin early enteral nutrition Day 1-2 (post pyloric)
Monitor Glucose: 80-180 mg/dL
Foley (temp sensing)
Early Mobility Protocol:
Cycle Ergometry Begin Day 2-3/ROM
PT/OT/Physiatry consult

Critical Thinking Algorithms
Severe Brain Injury Population

PbtO2 >20 - 40 mm Hg ICP > 20 mm Hg	PbtO2 < 20 mm Hg ICP > 20 mm Hg	PbtO2 < 20 mm Hg ICP < 20 mm Hg
√ Drain CSF if ventriculostomy	√ Drain CSF if ventriculostomy	√ Titrate PaCO2 to 40 mm Hg as long as ICP < 20 mm Hg
√ Ensure Normothermia: If T ↑, implement cooling measures	√ Ensure Normothermia: If Temperature ↑, implement cooling measures.	√ Reassess possible shivering and administer ant-shivering interventions
√ Optimize CPP 60-80: Determine optimal CPP ≈Assess SVV: Give NS if SVV > 10% ≈Increase MAP with Vasopressor (Norepinephrine/Phenylephrine)	√ Reassess possible shivering with Temp ↑ ≈ Assess BSAS and/or EMG ≈Administer ant-shivering interventions	√ Hemodynamic Profile: Optimize CPP 60-80: Determine optimal CPP ≈Assess SVV/PVV: Administer fluids if fluid responsive ≈Increase MAP with vasopressor Assess ECG rhythm, CO, CI, & SVR Assess for pulmonary edema or fluid overload ≈ √ I/O for fluid balance ≈ √ Chest X-ray ≈ Call MD & consider Lasix
√ Sedation/Analgesia: Titrate	√ Optimize CPP 60-80: Determine optimal CPP for Patient ≈Assess SVV: Give Saline if SVV >10% ≈Increase MAP with vasopressor (Norepinephrine/Phenylephrine)	
√ Lower PaCO2 to 30-35 mm Hg until ICP < 20; stop if PbtO2@ 20	√ Sedation/Analgesia: Titrate if needed	√ Respiratory Status and Ventilator Settings ≈Assess ABGs: If PaO2 low, optimize oxygenation ≈Assess ABGs: If PaCO2 low, allow to increase ≈Assess breath sounds: r/o pneumothorax, pulmonary edema, or increase in secretions- suctioning ≈Ventilator mode: optimize
√ Administer Hypertonic Saline or Mannitol	√ Administer Hypertonic Saline or Mannitol	
√ Discuss treatment options with Neurosurgery ≈Decompressive craniotomy	√ Titrate PaCO2 to 35 mm Hg (no lower)	
	√ CT scan of Brain	
		√ Assess for Traumatic Vasospasm: TCDs stat

CONCLUSION
PROTOCOLIZE AND INDIVIDUALIZE

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