18th ANNUAL CONFERENCE

RIVER of DREAMS

envisioning best practices in trauma care
Controversy in the Care of Those with Severe TBI: Can’t We All Just Get Along?
Disclosure Statement

- Faculty/Presenters/Authors/Content Reviewers/Planners disclose no conflict of interest relative to this educational activity.
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Learning Objectives

• To identify the various treatment options for traumatic brain injury
Overview:

• Over 1.4 million people in the US sustain traumatic brain injury (TBI) annually
  • Approximately 250,000 hospitalized and 50,000 die
• Severe TBI: defined by a GCS of 8 or less is a major cause of this morbidity and mortality
• Significant functional, social and economic sequelae

Langlois, 2007
Overview:

- 2 mechanisms of brain injury:
  - Primary insult: Due to the trauma, irreversible
    - Prevent the accident
  - Secondary insult:
    - May result from Intracranial causes (mass lesions, focal/diffuse brain swelling, ICH, vasospasm and ischemia. Extracranial causes: hypotension, hypoxia, and coagulopathy
    - Management of patients with severe TBI focuses on the prevention and treatment of secondary brain injury
Treatment strategies:

• CPP and volume targeted management strategies
• Osmotherapy: Mannitol and/or Hypertonic Saline (HTS)
• CSF Drainage
• Barbituates
• Decompressive Craniectomy
• Therapeutic hypothermia
• Prevention of seizures
• Normobraric Hyperoxia
Traumatic Brain Injury Guidelines

• Developed by AANS/Joint Section on Neurotrauma & Critical Care and Brain Trauma Foundation
• Evidenced based guidelines - Meticulous process of scientific evidence rather than expert opinion to guide clinical practice
• 14 practice guideline statements
• Published 1995
Guidelines for Managing Severe TBI

• BTF Guidelines
  • 1995, 2000, 2003
  • 2007 Update

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GUIDELINES FOR THE MANAGEMENT
OF SEVERE TRAUMATIC BRAIN INJURY

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DOI: 10.1089/neu.2007.9995
BTF 2007 Severe TBI Guidelines

- BP & Oxygenation
- Hyperosmolar Tx
- Prophylactic Hypothermia
- DVT Prophylaxis
- Indications for ICP Monitoring
- ICP Monitoring Technology
- ICP Thresholds

- CPP Thresholds
- Brain Oxygen Monitoring & Thresholds
- Anesthetics, Analgesics, & Sedatives
- Nutrition
- Anti-Seizure
- Hyperventilation
- Steroids
I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Blood pressure should be monitored and hypotension (systolic blood pressure < 90 mm Hg) avoided.

C. Level III

Oxygenation should be monitored and hypoxia (PaO₂ < 60 mm Hg or O₂ saturation < 90%) avoided.

II. OVERVIEW

For ethical reasons, a prospective, controlled study concerning the effects of hypotension or hypoxia on outcome from severe traumatic brain injury (TBI) has never been done. Nevertheless, there is a growing body of evidence that secondary insults occur frequently and exert a powerful, adverse influence on outcomes from severe TBI. These effects appear to be more profound than those that result when hypoxic or hypotensive episodes of similar magnitude occur in trauma patients without neurologic involvement. Therefore, it is important to determine if there is evidence for specific threshold values for oxygenation and blood pressure support.
I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Mannitol is effective for control of raised intracranial pressure (ICP) at doses of 0.25 gm/kg to 1 g/kg body weight. Arterial hypotension (systolic blood pressure < 90 mm Hg) should be avoided.

C. Level III

Restrict mannitol use prior to ICP monitoring to patients with signs of transtentorial herniation or progressive neurological deterioration not attributable to extracranial causes.

The use of HS for ICP control was discovered from studies on “small volume resuscitation.”28,43,51,59 Hypertonic saline solutions were tested in poly-traumatized patients with hemorrhagic shock. The subgroup with accompanying TBI showed the greatest benefit in terms of survival and hemodynamic parameters were restored effectively.59 The findings that HS may benefit patients with TBI while preserving or even improving hemodynamic parameters stimulated further research on the effects of HS solutions on increased intracranial pressure in patients with TBI15,18,36,40,41,46,51 subarachnoid hemorrhage,18,55,56 stroke,50 and other pathologies.14
III. Prophylactic Hypothermia

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

There are insufficient data to support a Level II recommendation for this topic.

C. Level III

Pooled data indicate that prophylactic hypothermia is not significantly associated with decreased mortality when compared with normothermic controls. However, preliminary findings suggest that a greater decrease in mortality risk is observed when target temperatures are maintained for more than 48 h.

Prophylactic hypothermia is associated with significantly higher Glasgow Outcome Scale (GOS) scores when compared to scores for normothermic controls.
IV. Infection Prophylaxis

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Periprocedural antibiotics for intubation should be administered to reduce the incidence of pneumonia. However, it does not change length of stay or mortality.

Early tracheostomy should be performed to reduce mechanical ventilation days. However, it does not alter mortality or the rate of nosocomial pneumonia.

C. Level III

Routine ventricular catheter exchange or prophylactic antibiotic use for ventricular catheter placement is not recommended to reduce infection.

V. Deep Vein Thrombosis Prophylaxis

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

There are insufficient data to support Level II recommendation for this topic.

C. Level III

Graduated compression stockings or intermittent pneumatic compression (IPC) stockings are recommended, unless lower extremity injuries prevent their use. Use should be continued until patients are ambulatory.
VI. Indications for Intracranial Pressure Monitoring

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a treatment standard for this topic.

B. Level II

Intracranial pressure (ICP) should be monitored in all salvageable patients with a severe traumatic brain injury (TBI; Glasgow Coma Scale [GCS] score of 3–8 after resuscitation) and an abnormal computed tomography (CT) scan. An abnormal CT scan of the head is one that reveals hematomas, contusions, swelling, herniation, or compressed basal cisterns.

C. Level III

ICP monitoring is indicated in patients with severe TBI with a normal CT scan if two or more of the following features are noted at admission: age over 40 years, unilateral or bilateral motor posturing, or systolic blood pressure (BP) < 90 mm Hg.

VII. Intracranial Pressure Monitoring Technology

In the current state of technology, the ventricular catheter connected to an external strain gauge is the most accurate, low-cost, and reliable method of monitoring intracranial pressure (ICP). It also can be recalibrated in situ. ICP transduction via fiberoptic or micro strain gauge devices placed in ventricular catheters provide similar benefits, but at a higher cost.

VIII. Intracranial Pressure Thresholds

B. Level II

Treatment should be initiated with intracranial pressure (ICP) thresholds above 20 mm Hg.

C. Level III

A combination of ICP values, and clinical and brain CT findings, should be used to determine the need for treatment.
IX. Cerebral Perfusion Thresholds

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Aggressive attempts to maintain cerebral perfusion pressure (CPP) above 70 mm Hg with fluids and pressors should be avoided because of the risk of adult respiratory distress syndrome (ARDS).

C. Level III

CPP of <50 mm Hg should be avoided.

The CPP value to target lies within the range of 50–70 mm Hg. Patients with intact pressure autoregulation tolerate higher CPP values.

Ancillary monitoring of cerebral parameters that include blood flow, oxygenation, or metabolism facilitates CPP management.

X. Brain Oxygen Monitoring and Thresholds

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

There are insufficient data to support a Level II recommendation for this topic.

C. Level III

Jugular venous saturation (<50%) or brain tissue oxygen tension (<15 mm Hg) are treatment thresholds.

Jugular venous saturation or brain tissue oxygen monitoring measure cerebral oxygenation.
XI. Anesthetics, Analgesics, and Sedatives

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Prophylactic administration of barbiturates to induce burst suppression EEG is not recommended.

High-dose barbiturate administration is recommended to control elevated ICP refractory to maximum standard medical and surgical treatment. Hemodynamic stability is essential before and during barbiturate therapy.

Propofol is recommended for the control of ICP, but not for improvement in mortality or 6 month outcome. High-dose propofol can produce significant morbidity.

XII. Nutrition

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Patients should be fed to attain full caloric replacement by day 7 post-injury.
XIII. Antiseizure Prophylaxis

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Prophylactic use of phenytoin or valproate is not recommended for preventing late posttraumatic seizures (PTS).

Anticonvulsants are indicated to decrease the incidence of early PTS (within 7 days of injury). However, early PTS is not associated with worse outcomes.

XIV. Hyperventilation

I. RECOMMENDATIONS

A. Level I

There are insufficient data to support a Level I recommendation for this topic.

B. Level II

Prophylactic hyperventilation (PaCO2 of 25 mm Hg or less) is not recommended.

C. Level III

Hyperventilation is recommended as a temporizing measure for the reduction of elevated intracranial pressure (ICP).

Hyperventilation should be avoided during the first 24 hours after injury when cerebral blood flow (CBF) is often critically reduced.

If hyperventilation is used, jugular venous oxygen saturation (SjO2) or brain tissue oxygen tension (PbrO2) measurements are recommended to monitor oxygen delivery.
XV. Steroids

I. RECOMMENDATIONS

A. Level I

The use of steroids is not recommended for improving outcome or reducing intracranial pressure (ICP). In patients with moderate or severe traumatic brain injury (TBI), high-dose methylprednisolone is associated with increased mortality and is contraindicated.
Audience Poll
Do you believe your institution follows the BTF guidelines closely

- Text ….. For yes
- Text ….. for no
Do you have more difficulty with the Neurosurgeons or Trauma/ Critical Care surgeons being non compliant?

- Text …. For NS
- Text …..For Trauma Surgeons
Survey of TBI Management

  - 16% full compliance in 433 active centers
  - Compliance with ICP monitoring was 33%
  - Protocols improved compliance from 7% to 26%
2015 Treatment Strategies
Treatment strategies:

- CPP and volume targeted management strategies
- Osmotherapy: Mannitol and/or Hypertonic Saline (HTS)
- CSF Drainage
- Barbituates
- Decompressive Craniectomy
- Therapeutic hypothermia
- Prevention of seizures
- Normobaric Hyperoxia
CPP and volume targeted management strategies

- Monro-Kellie doctorine
  - In 1783 Alexander Monro deduced that the cranium was a "rigid box" filled with a "nearly incompressible brain" and that its total volume tends to remain constant. The doctrine states that any increase in the volume of the cranial contents (e.g. brain, blood or cerebrospinal fluid), will elevate intracranial pressure. Further, if one of these three elements increase in volume, it must occur at the expense of volume of the other two elements. In 1824 George Kellie confirmed many of Monro's early observations.
Pathophysiology: Intracranial Pressure

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

80% brain, 10% blood, 10% CSF

Brain moves over CSF shunts to spine SAS
Venous blood to heart
Cerebral Blood Flow

- $\text{CBF} = \frac{\text{CPP}}{\text{CVR}}$
- $\text{CPP} = \text{MAP} - \text{ICP}$
  - Injured Brain optimize CPP
  - Normal CPP does not ensure CBF is adequate to meet the needs of the injured brain
In the presence of intact cerebral auto-regulation CBF remains relatively constant within a wide range of perfusion pressures. This occurs by vasoconstrictive responses to increased CPP and vasodilatory responses to decreased CPP. When CPP is outside the breakpoints of pressure auto-regulation (50 and 150 mmHg), CBF becomes directly dependent on CPP.
• Currently there is controversy concerning the optimal CPP thresholds after TBI
• 2 groups of thought on the best approach for optimizing cerebrovascular dynamics
  • CPP-targeted group
  • Volume-targeted group
CPP - targeted approach

• Based on vasodilatory cascade
  • Decreased CPP stimulates vasodilation, increases CBF and ICP
• Supported by BTF
• Some studies show a benefit while others cannot demonstrate any difference in outcome
Volume-targeted therapy

• Based on Starling forces of capillary flow
  • Aim is to reduce intracranial volume and to improve the microcirculation by preserving colloid osmotic pressure using albumin and pRBC’s, reducing capillary hydrostatic pressure using metoprolol and clonidine, and reducing cerebral blood flow using thiopental

• Several centers in Europe
• Mixed results
Osmotherapy: Mannitol or Hypertonic Saline
Background

• The ICP reducing effects of Mannitol:
  • Osmotic diuretic
  • Reduces blood viscosity by decreasing HCT and by decreasing the volume, rigidity and cohesiveness of red blood cells
    • Reduced Cerebrovascular resistance and Increased CBF, causing auto-regulatory decrease CBF and ICP
  • May cause Hypotension in under resuscitated patients
Background

- Hypertonic Saline (HTS) mechanism similar to Mannitol
- Unlike Mannitol though HTS less likely to cross BBB and therefore less likely to cause rebound cerebral edema.
Mannitol versus HTS

• Vialet, et al, Crit Care Med 2003:
  • Small randomized trial involving 20 pts
  • Isovolume infusions of 7.5% HTS or 20% Mannitol
  • Mannitol group had more episodes of elevated ICP and the daily total time was longer
  • Treatment failure higher in Mannitol Group
  • Outcomes not measured
Mannitol versus HTS

- Class 1 studies are lacking but Class 2 and 3 studies show both may be effective
Case #1

- 26 YO male MCC high rate of speed
- Positive for cocaine and alcohol, father was following in his car and witnessed event
- GCS 3T at scene-intubated by EMS
- GCS 6-7T – trauma bay
Case #1

- CT head:
  - Diffuse b/l SAH
  - DAI
  - small SDH
  - B/L frontoparietal hemorrhage
  - Intraventricular hemorrhage
Case # 1

• Management:
  • Ventriculostomy not inserted
  • Would you start treatment with Hypertonic Saline

• Text >>>>> yes
• Text >>>>> No
Case # 1

• 3% NS started-NA 145
• NA –to mid 155-158 for several days
• 3% NS tapered down –d/c ‘d
Repeat Head CT PTD #1

- Significant worsening of SAH, DAI, fronto-parietal bleeding
- Hypertonic Saline continued
Repeat Head CT PTD#2

- Increased cerebral edema
- Effacement of cistern, beginning herniation
- Na 155 Hypertonic Saline off
- ICP’s 20, CPP’s 60’s
Repeat Head CT PTD#3

• Sinus bradycardia
  30-50/min-atropine
• GCS 4 T
• Family discussion X2
• No DNR
• Following morning
  patient coded
Opportunities

- Early ventriculostomy placement
- HTS versus Mannitol
CSF Drainage
CSF Drainage

- Current BTF guidelines recommend that ICP should be monitored in all comatose patients with GCS $\leq 8$ with either an abnormal CT or 2 or more of the following: $>40$ years old, posturing and SBP $<90$
- Intraventricular catheter connected to an extracranial ventricular drain and a pressure transducer is most accurate
  - With the ability drain CSF why use anything else?
Poll

- In your institution what is the most commonly inserted monitoring device
  - Text…. ICP bolt
  - Text ….Ventriculostomy
  - Text…Neither
Barbiturates
Barbituates

- Known as early as the 1930’s that high does barbituates are effective in reducing ICP
  - Shapiro, Br J Anesaesth, 1985
- Cause a dose dependent reversible depression of neuronal activity with reduction of the cerebral metabolic rate, CBF and ICP
  - Kassel, NE, Neurosurgery 1980
Barbituates

- Complications include:
  - Hypotension from myocardial depression and decreased SVR
  - Increased infections, usually pulmonary
- Schwartz, et al 1984 Can J Neurol Sci:
  - Compared Barb’s with mannitol as initial treatment in 59 pts. Randomized.
  - Mannitol more effective in lowering ICP’s
  - No difference in mortality but patients with DAI had worse outcomes with Barb’s
Barbituates

- Are effective when used to control refractory intracranial hypertension but still few evidence exists of an outcome benefit.
Decompressive Craniectomy
Decompressive Craniectomy

- Numerous publications over the last 20 years with variable results.
- Difficulty with making conclusions:
  - Different operative techniques, b/l, one sided, size of flap, etc.
  - Outcome variables different
  - Variability of injuries
  - Variability of presenting GCS
  - Timing of procedure
Case #2

- 55 year old (+) ETOH abuser fell down 12 steps
  - (+) LOC
  - Reported falling about an hour or so before pre-hospital arrival
  - GCS = 9
  - Collared/boarded and loaded into the ambulance
Arrival at Level I Trauma Center

- 132/70, 102, 18, 84%, T = 95.5, GCS = 10
- Sent to CT Scan within 20 minutes of arrival
- ETOH level = 338
- Pupils unequal
- Agitated
- GCS = 11
- Consulted Neurosurgery
CT Results

- Acute subdural hemorrhage along the right cerebral convexity
- Subdural hemorrhage along the right tentorium.
- Associated mass effect an approximately 4 mm leftward midline shift.
- Patchy parenchymal contusions in the inferior left temporal and frontal lobes.
- Fractures of the right temporal bone involving the squamous and mastoid portions.
What is your immediate next step?

1. Intubate?
2. Go directly to the OR for craniectomy or craniotomy?
3. Start 3% Saline?
4. Give Mannitol?
5. Start Keppra?
6. Observe?
7. All of the above
8. None of the above
Observation with a CT in 4 hours

- 4 hour later CT scan
- Chose to continue to watch
- GCS = 14
- Admitted to the ICU
- Started to become very agitated
Morning CT of the Head

- Slight increase in the bleed along the right convexity and a new subfalcine herniation on the left
Now what do you want to do?

• Intubate?
• Go directly to the OR for craniectomy?
• Start 3% Saline?
• Give Mannitol?
• Start Keppra?
• All of the above
• None of the above
We went to the OR for a Craniotomy
Post-op Course

- POD#1
  - Extubated
  - CIWA score demonstrating potential ETOH withdrawal. Score – 16
    - Valium given along with Haldol for extreme agitation

- POD#2
  - Obtunded
  - 3% Saline started
  - Re-intubated
  - Agitated, CIWA’s in the high teens
• POD #3
  • Ventriculostomy placed: ICP’s = 39 (ordered at 10 and remain open)
  • Propofol gtt. started
  • 3% Maintained
Post Craniectomy

- POD #4
  - Returned to the OR for craniectomy
  - Keppra started
  - Temps = 103’s
  - GCS = 4T
• POD #8
  • Palliative Care consult
• POD #10
  • Patient made comfort care
  • Expired
Let’s Discuss our opportunities and

- Neurosurgeon Colleague Input
- Nursing Input
- Trauma Surgeon Input
Hypothermia for TBI and SCI
Hypothermia for neuroprotection

- National Acute Brain Injury Study: Hypothermia
  - Large muti-center randomized controlled trial
  - 48 hrs of moderate hypothermia (33°C) reached within 8 hrs of injury
  - Terminated after enrollment of 392 of a planned 500 patients
- Results:
  - No difference in outcome at 6 months
Hypothermia for ICP control

- Multiple studies demonstrate that mild hypothermia (34° C) reduces ICP in severe TBI but in contrast many also showed no difference in outcome and increased complication rates.
- Several recent studies have shown that maintaining normothermia may be beneficial.
Case SCI

- 24 yo male jumps from boat into water
- Immediately no sensation from neck down
- Immobilized and transported
Case SCI

• When Paramedics arrived at shoreline, iced bags of NS were placed around the patients neck and he was given 2 L ice cold NS en route to the trauma center. Do you think these measures will help or hurt the patient?

• Text >>>>> Definitely will help patient
• Text ….. May help patient
• Text….. May hurt patient
Case SCI

• Upon arrival to the trauma center the patients undergoes resuscitation, started on Neosyneprhine for spinal shock and undergoes CT of head and C-spine
Operative Treatment

• Reduction and Stabilization while cold

• Rewarming: Automatic
  • 0.5°C per hour
  • 37°C

• Hypothermic Treatment for Acute Spinal Cord Injury

• W. Dalton Dietrich,¹,² Allan D. Levi,¹,² Michael Wang,¹,² and Barth A. Green¹,²
Selection of patients

- Age 16-65 years
- ASIA Injury Score A
- Non penetrating injury
- Lower temperature to 33°C
- Maintained for 48 hours
- Patients taken to the OR for surgical reduction may be included
- Slow re-warming
Selection of Patients - Contraindications

- Age >65 years
- ASIA score B C D
- Hyperthermia on admission (>38.5)
- Severe systemic injury
- Severe bleeding
- Pregnancy
- Coagulopathy
- Thrombocytopenia
- Known cardiac history
- Blood dyscrasia
- Pancreatitis
- Reynauds syndrome
- Spinal cord transaction
- Patients intubated and sedated prior to initial exam by the trauma surgeon and neurosurgeon
Initial Study Showed

- N=14
- 6 improved
- 3 from A to B
- 2 from A to C
- 1 from A to D
- 42.8% improvement
- Control group without hypothermia showed 12.5% improvement
Complications

- Respiratory, predominantly atelectasis
- No problems with Coagulopathy, DVT PE
- Prevents hyperthermic damage to cells!
Prevention of Seizures
Evidence

• Level 1:
  • Phenytoin is effective in decreasing the risk of early PTS prophylaxis
  • Valproate should not be used for prophylaxis
  • Phenytoin, carbamazepine, and valproate are ineffective in decreasing the risk of late PTS
  • Insufficient data to recommend routine PTS prophylaxis in patients with mild or moderate TBI

• Cheatham, 2012
Evidence

• Level 2:
  • Levetiracetam is an effective and safe alternative to phenytoin for early PTS prophylaxis
  • Routine prophylaxis of late PTS is not recommended

• Level 3:
  • Levetiracetam should not replace phenytoin as a first line agent for PTS prophylaxis
    • Higher seizure potential
      • Cheatham, 2012
Normobaric Hyperoxia
Results of Changing Practice: TBI Guidelines/ Oxygen Monitoring

<table>
<thead>
<tr>
<th>Pre PbtO2</th>
<th>Post PbtO2</th>
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<tbody>
<tr>
<td>23 Patients</td>
<td>24 Patients</td>
</tr>
<tr>
<td>GOS 4-5 42%</td>
<td>GOS 4-5 75%</td>
</tr>
<tr>
<td>GOS 1 41%</td>
<td>GOS 1 25%</td>
</tr>
</tbody>
</table>

“Management and therapy aimed at preventing cerebral hypoxia and maintaining brain tissue oxygen is successful in reducing mortality in traumatic brain injury.” Steifel et al (Le Roux), U of Pennsylvania experience (J of Neurosurgery 2005)