Best Practices in the Management of Traumatic Brain Injury

Avery B. Nathens, MD, PhD
Director, ACS TQIP
Surgeon-In-Chief, Sunnybrook Health Sciences Center
Professor of Surgery, University of Toronto

Geoffrey Manley, MD, PhD
Chief of Neurosurgery, San Francisco General Hospital
Professor and Vice-Chairman of Neurosurgery, UCSF
Why Best Practices for Traumatic Brain Injury?
TBI in the United States

- At least 2.5 million TBIs occur in the United States each year.*
- 52,000 Deaths
- 275,000 Hospitalizations
- 1,365,000 Emergency Department Visits
- ?? Receiving Other Medical Care or No Care

*CDC, 2014
56 % of mTBI / Concussion cases in a Level I Emergency Department were missed
IMPACT of TBI

~ 80,000 new disabilities from TBI each year

~ 5,300,000 Living with Disability

Cost of TBI
76 Billion !!!!
Large Between-Center Differences in Outcome After Moderate and Severe Traumatic Brain Injury in the International Mission on Prognosis and Clinical Trial Design in Traumatic Brain Injury (IMPACT) Study

**BACKGROUND:** Differences between centers in patient outcome after traumatic brain injury are of importance for multicenter studies and have seldom been studied.

**OBJECTIVE:** To quantify the differences in centers enrolling patients in randomized clinical trials (RCTs) and surveys.

**METHODS:** We analyzed individual patient data from 9578 patients with moderate and severe traumatic brain injury enrolled in 10 RCTs and 3 observational studies. We used random-effects logistic regression models to estimate the between-center differences in unfavorable outcome (dead, vegetative state, or severe disability measured with the Glasgow Outcome Scale) at 6 months adjusted for differences in patient characteristics. We calculated the difference in odds of unfavorable outcome between the centers at the higher end vs those at the lower end of the outcome distribution. We analyzed the total database, Europe and the United States separately, and 4 larger RCTs.

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted for case mix</th>
<th>Adjusted for case mix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IMPACT database</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=9578)</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>IMPACT – US</strong></td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>(n=3325)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Neurosurgery 2011*
Development of TBI Guidelines


- **History – Dr. Jam Ghajar**
  - 1st edition completed in 1995
  - 2nd edition completed in 2007

- A joint initiative of:
  - The Brain Trauma Foundation
  - The Joint Section on Neurotrauma and Critical Care

Data from well-designed, controlled studies of TBI are sparse – only one Class I study

Paucity of high-quality studies limits the strength and scope of their counsel
Based on the best available evidence or, if evidence is lacking, based upon consensus opinion of an expert panel
Development of TBI Best Practices

NIH-funded ProTECT clinical trial protocol based on the Brain Trauma Foundation Guidelines and refined with consensus-based methodology. The ProTECT protocol was successfully implemented in 38 hospitals.
## ProTTECT III: Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Progesterone</th>
<th>Placebo</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
<td>N=442</td>
<td>N=440</td>
<td>N=882</td>
</tr>
<tr>
<td><strong>Mortality</strong></td>
<td>18.8 %</td>
<td>15.7 %</td>
<td>17.2 %</td>
</tr>
<tr>
<td><strong>Favorable</strong></td>
<td>48.2 %</td>
<td>52.7 %</td>
<td>50.5 %</td>
</tr>
<tr>
<td><strong>Not Favorable</strong></td>
<td>45.5 %</td>
<td>41.8 %</td>
<td>43.7 %</td>
</tr>
</tbody>
</table>

Wright et al, NEJM 2014
Best Practices in the Management of TBI

Introduction
Using the Glasgow Coma Scale
Triage and Transport
Goals of Treatment
Intracranial Pressure Monitoring
Management of elevated ICP
Advanced Neuromonitoring
Surgical Management
Nutritional Support
Tracheostomy
Timing of Secondary Procedures
Timing of Pharmacologic VTE Prophylaxis
Management of Pediatric Patients TBI
Management of Elderly Patients TBI
Prognostic Decision-Making
Outcome Assessment and QI in TBI
Glasgow Coma Scale

Standardized Assessment
The Glasgow Coma Scale at 40 years: standing the test of time

Graham Teasdale, Andrew Maas, Fiona Lecky, Geoffrey Manley, Nino Stocchetti, Gordon Murray

<table>
<thead>
<tr>
<th>Indicator of level of consciousness</th>
<th>Term used</th>
<th>1974</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye opening</td>
<td>Spontaneous</td>
<td>To sound</td>
<td>Spontaneous</td>
</tr>
<tr>
<td></td>
<td>To speech</td>
<td>To pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Verbal response</td>
<td>Orientation</td>
<td>Orientated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Confused conversation</td>
<td>Confused</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inappropriate speech</td>
<td>Words</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incomprehensible speech</td>
<td>Sounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Motor response</td>
<td>Obeying commands</td>
<td>Obey commands</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Localising</td>
<td>Localising</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexor</td>
<td>Normal flexion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extensor posturing</td>
<td>Abnormal flexion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>Extension</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
The Glasgow Coma Scale at 40 years: standing the test of time

Graham Teasdale, Andrew Maas, Fiona Lecky, Geoffrey Manley, Nino Stocchetti, Gordon Murray

Specify the score for each of the three components
Glasgow Coma Scale

- Standardized approaches to GCS assessment and reporting are essential

- The GCS should specify the score for each of the three components (eye, verbal, motor) when reporting on individual patients

- The sum of the component scores (GCS 3-15) is relevant for comparisons at the group level for purposes of classification and prognosis
The “Stair Case” Approach
Heterogeneity of TBI

No "One Size Fits All"
**Goals of Treatment for TBI**

<table>
<thead>
<tr>
<th>Goal</th>
<th>Target Range</th>
<th>Target Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Oximetry ≥ 95%</td>
<td>ICP 20 - 25 mmHg</td>
<td>Serum sodium 135-145</td>
</tr>
<tr>
<td>PaO₂ ≥ 100 mmHg</td>
<td>PbtO₂ ≥ 15 mmHg</td>
<td>INR ≤ 1.4</td>
</tr>
<tr>
<td>PaCO₂ 35-45 mmHg</td>
<td>CPP ≥ 60 mmHg</td>
<td>Platelets ≥ 75 x 10³ / mm³</td>
</tr>
<tr>
<td>SBP ≥ 100 mmHg</td>
<td>Temperature 36.0-38°C</td>
<td>Hemoglobin ≥ 7 g/dl</td>
</tr>
<tr>
<td>PH 7.35-7.45</td>
<td>Glucose 80-180 mg/dL</td>
<td></td>
</tr>
</tbody>
</table>

**Goal-Directed Approach**
ICP Monitoring

100-120mL extra – the critical point

Minimal increases in ICP compensated for
ICP Monitoring

• External ventricular drain (EVD) preferred
  • diagnostic (measures ICP)
  • therapeutic (drainage of cerebrospinal fluid (CSF)).

• Parenchymal monitors may be appropriate in some cases (coagulopathy, limited provider experience with EVD placement).
ICP Monitoring

- ICP monitoring is important, but does not replace careful neurological and radiographic examination.

- ICP monitoring is indicated in comatose patients (GCS ≤ 8) and evidence of structural damage on initial CT.

- ICP monitoring should be considered in patients with a GCS > 8 who have structural brain damage with high risk for progression (large/multiple contusions, coagulopathy).
ICP Monitoring

- ICP monitoring is generally not indicated in comatose patients without evidence of structural brain damage or elevated ICP (compressed/absent basal cisterns) on initial CT imaging. Patients may be observed with repeat CT imaging and forego ICP monitoring if there is no progression.

- ICP monitoring should be considered in patients who require urgent surgery for extracranial injuries, who need mechanical ventilation because of extracranial injuries, or who evidence progression of pathology on CT imaging or clinical deterioration.
Management of Increased ICP

Elevated ICP

- edema (cellular, extracellular)
- venous outflow obstruction
- hyperemia
  (autoregulation, vasodilation)
- mass effect (hematoma)
- CSF circulation

This is complicated
Management of Increased ICP

- ICP is a global measure that cannot identify the specific mechanism(s) of pressure elevation. Additional neuromonitoring and assessment of cerebral autoregulation may help to individualize treatment.

- The recommended “3-tiered” approach to ICP management utilizes various treatments to target different mechanisms. Higher tiers reflect more intensive management that is associated with increased complications.
Management of Increased ICP

**Tier I**

- **Head of patient’s bed** to be placed at 30 degrees (reverse Trendelenberg) to improve cerebral venous outflow.

- **Sedation and analgesia** using recommended short-acting agents (propofol, fentanyl, and midazolam) in intubated patients.

- **Ventricular drainage:** CSF can be drained intermittently. Continuous drainage is not recommended unless there is an additional ICP monitor. When the drain is open, it does not accurately reflect the true ICP.

- **Repeat CT imaging and neurological examination** should be considered to rule out the development of a surgical mass lesion and guide treatment.

*If ICP remains 20 – 25 mmHg, proceed to Tier 2.*
Management of Increased ICP

**Tier II**

- **In patients with a parenchymal ICP monitor** an EVD should be considered to allow for intermittent CSF drainage

- **HyperOsmolar Therapy**

  **Mannitol**: intermittent boluses of mannitol (0.25 - 1 gm/kg body weight) should be administered. Attention must be placed upon maintaining a euvolemic state. The serum sodium and osmolality must be assessed frequently (every 6 hr) and additional doses should be held if the serum osmolality exceeds 320 mOsm/L.

  **Hypertonic saline**: boluses of 3% sodium chloride solution (250 cc over ½ hour) or other concentrations (e.g. 23.4% - 30 cc) may be used. Serum sodium and osmolality must be assessed frequently (every 6 hr) and additional doses should be held if the serum sodium exceeds 160 mEq/L.
Management of Increased ICP

**Tier II**

- **Cerebral Autoregulation:** The status of cerebral autoregulation should be assessed. If the patient is not autoregulating, the CPP should be lowered (to no less than 50 mm Hg). Additional neuromonitoring (e.g., PbtO₂, SjvO₂, CBF) may help determine optimal CPP.

- **PaCO₂ goal** 30 - 35 mmHg, as long as brain hypoxia is not encountered. Additional neuromonitoring (e.g., PbtO₂, SjvO₂, CBF) may help determine optimal PaCO₂.

- **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 neuromuscular blocking agent should be employed (Tier 3)

- **Consider repeat CT:** a repeat head CT should be considered to rule out the development of a surgical mass or unexpected intracranial lesion

  *If ICP remains 20 – 25 mmHg, proceed to Tier 3.*
Management of Increased ICP

**Tier III**

- **Decompressive hemi-craniectomy or bilateral craniectomy** should only be performed if treatments in Tiers 1 and 2 are not sufficient or there is toxicity from medical treatment.

- **Neuromuscular paralysis**: if there is a positive response to a bolus dose of pharmacological paralysis, a continuous infusion of a neuromuscular blocking agent can be employed. The infusion should be titrated to maintain at least two twitches (out of a train of four) using a peripheral nerve stimulator. Adequate sedation must be utilized if pharmacologic paralysis is employed.

- **Barbiturate or Propofol (anesthesia dosage) coma**: an induced coma is an option for those patients who have failed to respond to aggressive measures to control malignant intracranial hypertension, however it should only be instituted if a test-dose of barbituates or Propofol results in a decrease in ICP, thereby identifying the patient as a “responder”. Continuous EEG is required to ensure the appropriate dose for burst suppression.
Management of Increased ICP

Tier III

- **Hypothermia**: Hypothermia (<36 °C) is not currently recommended as an early TBI treatment. Hypothermia should be reserved for “rescue” or salvage therapy after reasonable attempts at ICP control from the previous Tier 3 treatments above have failed. The temperature goal should be 33 °C.
Advanced Neuromonitoring

$S_{jv}O_2$

$PbtO_2$

CBF
Advanced Neuromonitoring

- Advanced neuromonitoring and assessment of cerebral autoregulation may be helpful in identifying a more individualized approach to treatment.

- Impaired cerebral oxygenation can occur in the face of normal ICP and CPP.

- Cerebrovascular pressure reactivity index (PRx) and cerebral blood flow (CBF) monitoring can assess autoregulation status, which may help determine patient-specific CPP and ICP goals.
Timing of Pharmacologic Venous Thromboembolism Prophylaxis

- Patients with TBI are at high risk for venous thromboembolism (VTE), with rates as high as 20-30%.

- VTE prophylaxis should be considered within the 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 intracranial bleeding and have a stable repeat head CT scan.

- Placement of a prophylactic inferior vena cava (IVC) filter should be considered in patients at high risk for progression of intracranial hemorrhage who cannot receive pharmacologic prophylaxis, including those with lower extremity long bone fractures or pelvic fractures in addition to TBI.
# Berne-Norwood Criteria

**Phelan, J. Trauma Acute Care Surg, 2012**

<table>
<thead>
<tr>
<th>Low risk</th>
<th>Moderate risk</th>
<th>High risk</th>
</tr>
</thead>
</table>
| - 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 |

**Recommended strategies**

<table>
<thead>
<tr>
<th>Low Risk</th>
<th>Moderate Risk</th>
<th>High Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Prophylaxis if CT stable at 24 hrs</td>
<td>- Prophylaxis if CT stable at 72 hrs</td>
<td>- Consider IVC filter or surveillance</td>
</tr>
</tbody>
</table>
Tracheostomy in TBI

• Strong biases and beliefs about value of early tracheostomy in TBI
  • Reduces time on ventilator?
  • Lower risk of VAP?
  • More comfortable

• Among TQIP centers:
  • 29% of patients with isolated TBI undergo tracheostomy
  • 40% of these tracheostomies are done within 7 days
  • Median time to tracheostomy: 8.6 d

• 24% of patients develop VAP
Early versus Late Tracheostomy in TBI

Early (\(\leq 7\) d) versus Late (>7d)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>47% lower rate (22-48)</td>
</tr>
<tr>
<td>Ventilator days</td>
<td>30% fewer days (24-34)</td>
</tr>
<tr>
<td>ICU LOS</td>
<td>27% shorter (22-31%)</td>
</tr>
<tr>
<td>Hospital LOS</td>
<td>18% shorter (13-23)</td>
</tr>
</tbody>
</table>

Alali, J Trauma Acute Care Surg. 2014
Tracheostomy: Key messages

- If LOC remains persistently depressed, TBI patients should undergo tracheostomy to facilitate liberation from mechanical ventilation.

- Relative contraindications to tracheostomy include high ICP, hemodynamic instability, and severe respiratory failure.

- All TBI patients deemed not likely to improve rapidly should be considered for early tracheostomy within 8 d of injury.
Prognostic Decision Making and Withdrawal of Medical Support
Prognostic Decision Making and Withdrawal of Medical Support

• Severe TBI patients should receive full treatment for at least 72 hours post-injury

• Age alone should not be considered a valid reason for treatment-limiting decisions

• Caution is advised when using prognostic models in individual patients, in particular when considering treatment-limiting decisions

• It is strongly encouraged that each hospital develop a brain death determination policy that is based upon accepted national standards
Outcome Assessment and Quality Improvement in TBI

Predicting Outcome after Traumatic Brain Injury: Development and International Validation of Prognostic Scores Based on Admission Characteristics

Ewout W. Steyerberg¹, Nino Mushkudiani¹, Pablo Perel², Isabella Butcher³, Juan Lu⁴, Gillian S. McHugh³, Gordon D. Murray³, Anthony Marmarou⁴, Ian Roberts², J. Dik F. Habbema¹, Andrew I. R. Maas⁵

Measuring and Benchmarking Clinical Performance
### Outcome Assessment and Quality Improvement in TBI

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Predicted Deaths by IMPACT Model N=239</td>
</tr>
<tr>
<td>91-100%</td>
<td>9</td>
<td>91%</td>
</tr>
<tr>
<td>81-90%</td>
<td>41</td>
<td>85%</td>
</tr>
<tr>
<td>71-80%</td>
<td>44</td>
<td>75%</td>
</tr>
<tr>
<td>61-70%</td>
<td>75</td>
<td>65%</td>
</tr>
<tr>
<td>51-60%</td>
<td>50</td>
<td>56%</td>
</tr>
<tr>
<td>41-50%</td>
<td>52</td>
<td>44%</td>
</tr>
<tr>
<td>31-40%</td>
<td>65</td>
<td>35%</td>
</tr>
<tr>
<td>21-30%</td>
<td>66</td>
<td>25%</td>
</tr>
<tr>
<td>11-20%</td>
<td>144</td>
<td>15%</td>
</tr>
<tr>
<td>0-10%</td>
<td>46</td>
<td>8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>592</td>
<td>40%</td>
</tr>
</tbody>
</table>

33% reduction in mortality from 1987-1996
Outcome Assessment and Quality Improvement in TBI

• Outcome assessment is essential to benchmarking the quality of care in TBI patients

• A standardized and structured outcome assessment using the GOS-E at 6 months is recommended for TBI patients