Acute Traumatic Brain Injury – Multimodal Monitoring

S. Danielle Brown, RN, MS
Director, Research Coordination and Education
Barrow Neurological Institute at Phoenix Children’s Hospital
Nothing you do for children is ever wasted. They seem not to notice us, hovering, averting our eyes, and they seldom offer thanks, but what we do for them is never wasted.

-Garrison Keillor
Traumatic Brain Injury

Impact (Primary Injury)

Brain Swelling

Death
Traumatic Brain Injury

Impact (Primary Injury)

- Seizure
- Hypotension
- Hyperthermia
- Hypoxia

Brain Swelling

Death
Traumatic Brain Injury

Impact (Primary Injury)

- Medications
- Oxygenation

Brain Swelling

- DC Surgery
- Biochemistry

Death
INDICATIONS FOR INTRACRANIAL PRESSURE MONITORING IN PEDIATRIC PATIENTS WITH SEVERE TRAUMATIC BRAIN INJURY

Recommendations
Level III
Use of intracranial pressure (ICP Monitoring) may be considered in infants and children with severe traumatic brain injury.

Weak recommendation
Kochanek et al., 2012
Cerebral Oxymetry
Most clinical protocols and algorithms focus on maintaining homeostasis and *reacting* to intracranial hypertension, secondary injury and detrimental response of the TBI.

Other than ICP, CPP, little is known or directed at understanding this pathophysiologic response in common practice.
Outline

• Introduction
• “The Problem”
• Cerebral Oximetry Technologies
• Implementation of a New Technology
• Widespread Application?
TBI 101: Primary Injury vs. “Second” Insult vs. Secondary Injury

Definitions:

- **Primary Injury** - injury that occurs at the time of the impact/trauma
- **Second Insult** - an additional insult following the primary injury (e.g.) hypotension, hypoxia
- **Secondary Injury** - pathophysiologic response following the primary injury (e.g.) excitotoxicity, inflammation, dysautoregulation, leading to further injury/damage
What do we know about the Management of Traumatic Brain Injury?

Supportive care based on Adult and Pediatric Guidelines - Avoidance of second insults

Some treatments for intracranial hypertension - Response to secondary injury

Surgical intervention in select cases - Avoidance of second insults and response to secondary injury
Secondary Injury

• Following acute 1\textsuperscript{o} TBI, the extent of the 2\textsuperscript{o} injury response is worsened by the 2\textsuperscript{nd} insults that follow (i.e. hypoxia, hypotension, hyperthermia, etc.)

• Improved outcome by providing a milieu for optimal recovery by minimizing 2\textsuperscript{nd} insults

• \textit{To achieve this, the insults have to be detectable.}
<table>
<thead>
<tr>
<th>CCU</th>
<th>NICU</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP, DBP, MAP, CVP, PA, PWP, CO, SVR</td>
<td>MAP, ICP</td>
</tr>
<tr>
<td>Sat, O₂, CO₂, pH</td>
<td></td>
</tr>
<tr>
<td>Hg, CK-MB, troponin</td>
<td></td>
</tr>
<tr>
<td>EKG, ECHO, Thallium</td>
<td></td>
</tr>
<tr>
<td>200 Drugs</td>
<td>4 Drugs</td>
</tr>
</tbody>
</table>

*Current Neurological Monitoring is Limited!!*
Acute Brain Injured Patients

The Black Box!!

Outcome?
- Good?
- Poor?

- Intracranial Pressure ventricular (ICP)
- Cerebral Perfusion Pressure (CPP)
- Systemic oxygen (PaO)
- Systemic CO₂ (PaCO₂)
- Blood oxygen saturation (SO₂)
- Blood oxygen (PbtO₂)
- Brain oxygen (PbtO₂)
- EEG/SSEP
- Cerebral Blood Flow (CBF)
Cerebral Oximetry Technologies

1. Jugular Bulb (JvO$_2$)
2. Extracranial/Scalp Monitors
   - Near Infrared Spectroscopy
     • Somanetics (rSO$_2$)
     • Hamamatsu (TIO)
3. Parenchymal Monitors
   - LICOX, (PbO$_2$)
   - Neurotrend
Jugular Bulb Oximetry

- Much literature in conjunction with ICP directed therapy in TBI, not a new technology
- Global measure of cerebral oxygenation
- Therapy aimed at keeping $\text{JvO}_2 > 50\%-55\%$
- Poor outcome increased with multiple desaturations below 50% for >10 min
- Early identification and potential therapeutic target to treat following TBI
- Disadvantage in location of placement of sensor
Near Infrared Spectroscopy (NIRS)

- Surface monitor of underlying regional cerebral parenchyma
- Regional oxygen saturation (rSO₂) > 55% (Somanetics)
- Measures of oxyhemoglobin, deoxyhemoglobin and cytochrome oxidase; Tissue Oxygenation Index (TOI) = oxyhemoglobin/total hemoglobin (Hamamatsu NIRO)
  - Significant change with reduction by 20% from “baseline”
- Most often used to guide the anesthesia plan during cardiac surgery (reduced morbidity and mortality)
- Has not been as good in correlation with other monitors (i.e. JvO₂) or outcome in trauma patients
PbtO$_2$

- Recent literature showing efficacy of PbtO$_2$ monitoring in adults in trauma
- Disadvantage: small regional area of measure
- Combined ICP and PbtO$_2$ monitoring were compared to historical controls
- Therapy aimed at ICP < 20 mm Hg; CPP > 60; PbtO$_2$ > 25
When should we start using a new technology?
Implementing a New Technology

Evaluation of a New Technology

Four **key** questions **prior** to implementation:

1. Are the studies supporting this new technology or strategy **valid**?
2. Is this valid technology or strategy potentially **useful** (or important)?
3. Is this technology or strategy **applicable in your practice**?
4. How **easily** can it be implemented?
Is the Technology for Cerebral Oximetry Valid?

• Many studies have evaluated brain oxygenation following acute brain injury and TBI

• Little information of direct correlates of cerebral oxygenation to other physiological factors (i.e. \( \text{PaO}_2 \), \( \text{PaCO}_2 \), etc.), pathophysiologic factors (i.e. ICP, CBF, etc.) and patient outcome.

• Much information of indirect correlates of these parameters
Is Cerebral Oximetry Potentially Useful (or Important)? Clinically Applicable?

Does brain oxygenation levels provide insight into the physiology of secondary responses/injuries following TBI?

- Improved care with monitoring of potential iatrogenic insults (e.g.) $\downarrow$ PaO$_2$ or $\downarrow$ PaCO$_2$ though unlikely lead to increased ICP but could $\downarrow$ PbO$_2$.

- Early detection system?

- Autoregulation?

- Prognosis?

- Potential endpoint for intervention?
Is Cerebral Oximetry Ready for Widespread Application?
(Ready for Prime Time?)
Widespread Application?

NO

• Monitors only regional area of potential cerebral function
• Does not provide one number of “good” or “bad”
• Limited understanding of relationship to other parameters
• Long learning curve
• More studies necessary
  – Minimal correlative data
  – Minimal data that management will alter outcome
Widespread Application?

YES

- Safe and valid, proven technology
- Provides new information in the monitoring of cerebral physiology and potentially assist in the complex management of TBI or other cerebral injuries
- Further use will lead to better understanding of relationship between other parameters and cerebral oxygenation
- Potentially improve outcomes
Summary

- Cerebral oximetry is a safe and valid technology that has reached the threshold for widespread use as part of a multimodality approach to evaluating cerebral function.
- Useful for determining cerebral oxygen physiology in the normal and pathologic state.
- Limited in that further rigorous (and controlled) studies are needed to better understand the optimal approach for its application.
- Further widespread use will increase the knowledge base and experience necessary to enhance its efficacy.
ICU Monitoring for Severe TBI

- Standard physiology - MAP, HR, PaO$_2$, PaCO$_2$, Serum laboratories
- Neurologic monitoring (Standard)
  - ICP, CPP
- Neurologic monitoring (Available, low utilization)
  - CBF - Xe$^{133}$, XeCT, laser doppler, TCD
  - Jugular bulb
  - CSF/ Microdialysis
  - Brain oxygenation - Licox, NIRS
- Imaging - MR, MRS, PET, SPECT
- Electrophysiologic - EEG, SSEP, BAER

Cannot treat 2nd insults if they cannot be detected!!
Recent literature showing efficacy of PbO$_2$ monitoring in adults in trauma

Combined ICP and PbO$_2$ monitoring were compared to historical controls

Therapy aimed at ICP < 20 mm Hg; CPP > 60; PbO$_2$ > 25

Outcomes - Mortality:
  - Conventional ICP and CPP management 44%.
  - Addition of PbO$_2$ monitoring 25% (p < 0.05).

Cerebral Oximetry (Pediatric)

STUDY PATIENTS

- Children with PbtO$_2$/ BT monitoring
- N = 46
- Mean age = 9.4 y
- Gender = 72% male
- Mean GCS = 6.9
- GOS = 70% good

Adelson et al. 2006, Ortiz et al. 2009
Physiological Parameters with Clinical Correlations

- Daily mean PbO$_2$ trended *higher* PID #0-3 in patients with a good outcome
- Daily mean PbO$_2$ $> 30-33$ mmHg had highest sensitivity and specificity for good outcome
- PbO$_2$ tended to have a *negative* correlation with ICP early (higher ICP resulted in lower PbO$_2$) but *positive* correlation with ICP after PTD #3
- PbO$_2$ tended to have a *positive* correlation with CPP throughout the monitoring period
Additional Modalities

- Hypothermia/Hyperthermia
- Microdialysis
- Blood enzymes
- Decompressive craniectomy
- Continuous EEG
- Transcranial Doppler's
Hypothermia

• Level II – Moderate Hypothermia (32-33°C) beginning early after severe TBI for only 24 hrs duration should be avoided

• Level II – Moderate Hypothermia (32-33°C) beginning within 8 hrs after severe TBI for up to 48 hrs duration should be considered to reduce ICP

• Level II – If hypothermia is induced for any indication, rewarming at a rate of >0.5°C per hr should be avoided

• Level III - Moderate Hypothermia (32-33°C) beginning early after severe TBI for 48 hrs duration may be considered

Kochanek et al., 2012
Hyperthermia

• 2004 guidelines - Level III recommendation to avoid hyperthermia (extrapolated from adult data)

• 2012 guidelines – No recommendation
  – General consensus is to avoid hyperthermia
  – What is hyperthermia?
  – How long should it be avoided?
Microdialysis

- Bedside analyzer approved by the FDA
- Dialysate of tissue obtained from injured brain to look at biochemistry
- May help understand other modalities
Biochemistry

Multiple studies looking at brain specific enzymes which may be an easy blood test for brain injury

- Neuron specific enolase (NSE), S100B, myelin basic protein (MBP)
Decompressive Craniectomy

- Level III recommendation – 2012
  - DC with duraplasty, leaving the bone flap out, may be considered for pediatric patients with TBI who are showing early signs of neurologic deterioration of herniation or are developing intracranial hypertension refractory to medical management during the early stages of their treatment. Kochanek et al., 2012

- Fronto-temporo-parietal or a bifrontal bone flap
• DECRA Trial
  – International multisite RCT
  – reduction of ICP but worse outcome in adults with DC

• RESCUEicp Trial – ongoing

• No current pediatric trial
Continuous EEG

• Seizure detection
  – Paralyzed child
  – Sub-clinical seizure

• Spreading Cortical Depression
  – Occur after ischemic, hemorrhagic, and traumatic brain injury
  – Effect the penumbra
  – Associated with poor outcome after TBI
Transcranial Doppler's

- Measures the velocity of blood flow through the brain's blood vessels
- Used to detect vasospasm
  - Post SAH
  - Post trauma
- Intermittent or continuous
Outcomes Research

• Important for adaptation to any deficits
• Optimize functioning
• Include family structure
Functional Outcomes

• Test the child’s functional recovery at 3, 6, and 12 months post injury

• Use a battery of tests to look at different types of recovery/impairment

• Improves knowledge of recovery patterns and limitations of tests
Our greatest natural resource is the minds of our children.

-Walt Disney
THANK YOU!