Neurocritical Care & Multimodality Monitoring (MMM)

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Why neuro is so EASY😊

• Only 2 things can go wrong:
  • Too much stuff in there
  • Not enough blood flow

• *Change is the name of the game!*

• Figure out which problem you have and where & the basic management will follow
What Is Multimodality Monitoring

• Combined use of multiple monitors
  • Clinical evaluation correlated with:

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<tr>
<th>Systemic hemodynamics</th>
<th>Glucose and nutrition</th>
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<td>ICP &amp; CPP</td>
<td>Hemostasis and hemoglobin</td>
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<td>Cerebral autoregulation</td>
<td>Temperature and inflammation</td>
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<td>Systemic and brain oxygenation</td>
<td>Cellular damage and degeneration</td>
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<td>Cerebral blood flow</td>
<td>ICU processes of care</td>
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<td>Electrophysiology</td>
<td>Informatics, data integration, display, and analysis</td>
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<td>Cerebral metabolism</td>
<td>Monitoring in emerging technologies</td>
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Why Is MMM Important?

• Supplement to the clinical examination of the patient
  • Neuro exam is often confounded by disease progression, sedation/analgesia/neuromuscular blockade or coma
• Some monitors have strong anecdotal evidence of benefit
• Physiologic information from several monitors may translate into outcome differences for some patients
• Impact on prognostication, management and outcome
Why We Monitor Patients With Neurologic Disorders Who Require Critical Care

• Detect early neurological worsening before irreversible brain damage occurs
• Individualize patient care decisions
• Guide patient management
• Monitor the physiologic response to treatment and to avoid adverse effects
• Allow clinicians to better understand the pathophysiology of complex disorders
• Improve neurologic outcome and quality of life of survivors
• Begin to develop new mechanistically oriented therapies where treatments are currently lacking or are empiric in nature
The Consensus Group

• Who they are
• What they did
• How they came up with the consensus statements
• Intention of the consensus statements
  • Acute Brain Injury (ABI)
The Recommendations
Clinical Exam

• Still remains an essential key
**Pupillometer**

- Numerical value (index) of pupil size and reactivity
- Trend over time
- Important key assessment in clinical exam
- Removes clinician discrepancies/exam subjectivity

<table>
<thead>
<tr>
<th>Measured Value*</th>
<th>Assessment</th>
</tr>
</thead>
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<tr>
<td>3.0 – 4.9</td>
<td>Normal/“Brisk”</td>
</tr>
<tr>
<td>&lt; 3.0</td>
<td>Abnormal/“Sluggish”</td>
</tr>
<tr>
<td>0</td>
<td>Non- Reactive or Atypical Response</td>
</tr>
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</table>
GCS vs FOUR Score

• Use and accuracy of one over the other
Pain Scales

• NRS vs BPS vs CPOT vs NCS-R
Sedation Scales

• SAS and RASS
Delirium Prevention

- Wake-up tests
- CAM-ICU vs ICDSC
Systemic Hemodynamics

• BP, HR, pulse ox
• Baseline assessment of cardiac function with echocardiography
Skull is a rigid compartment
- Contains 3 components:
  - Brain tissue (80%)
  - Arterial and venous blood (10%)
  - Cerebrospinal fluid (10%)

Components are balanced in a state of dynamic equilibrium
- If an increase occurs in the relative volume of one component the volume of one or more of the other components must decrease or an elevation in ICP will result
- Small increases in volume result in large increases in ICP
- Slow vs rapid accumulations
ICP & CPP

• Fundamental to care of patients with ABI
• Threshold of 20 mmHg
• MAP and CPP
• Parenchymal vs EVD
BEST:TRIP

• Summary of study
• Challenges core beliefs in ICP monitoring
• ICP treatment is best guided by ICP monitoring, clinical imaging and clinical evaluation in combination and in the context of a structured protocol
BTF Algorithm For ICP Placement

ALGORITHM FOR THE MANAGEMENT OF INTRACRANIAL HYPERTENSION AND ISCHEMIA IN PATIENTS WITH SEVERE TBI

Place ICP monitor*

ICP > 20

- CSF drainage (continuous or intermittent)
- Hypertonic saline by bolus or continuous infusion
- High dose mannitol > 1.0g/kg bolus
- Moderate hyperventilation to PaCO2 30-35 (not recommended in the presence of ischemia)

Ischemia +

Tier 1

- Ventilation manipulation to maintain PaO2 > 60
- CPP manipulation to 50-70 with vasopressor medication

Tier 2

- Therapeutic mild hypothermia T 35-37

Tier 3

- High Dose barbiturates
- Neuronal blockade
- Decompressive craniectomy in the absence of surgical mass lesions
- Therapeutic Deep hypothermia T 32-34

Algorithm Options

- Use ICP-monitors and/or ischemic pathways as needed
- Treatments in a tier box can be used in any order
- It is not necessary to use all of the modalities in a given tier prior to moving to the next tier
- There is no rank ordering within a tier
- When considered advantageous, tiers can be skipped when advancing treatment (e.g., early decompressive craniectomy)

*Place ICP monitor* for GCS<9 and abnormal CT. Normal CT plus 2 out of 3 of the following parameters is an indicator for ICP monitoring: GCS motor 1 or 2, Age >60, or DBP < 60mmHg at any time. Follow the recommendations of the Guidelines for the Management of Severe TBI: www.braintrauma.org

+Ischemia in the algorithm is defined as the manuscript test of the algorithm for management of Severe TBI: A Systematic Approach for Achieving Cerebral.
Autoregulation

- PRx and CPPopt
- TCDs, NIRs
Systemic and Brain Oxygenation

- ABGs
- PaCO2 vs EtCO2
- PbtO2 vs SjvO2
NIRS Technology

- LED source on forehead emits near infrared light.
- Some light is “transflected” to detectors.
- “Shallow” detector is more sensitive to superficial light pathways.
- Light absorbance is converted into Hb oxygen saturation of tissue beneath sensor.
- “Regional O$_2$ Saturation” -- sensitive to both arterial and venous saturation.
  - Typically assumes 70% venous blood and 30% arterial blood. This ratio can vary with time.
- Can use two sensors to assess both hemispheres of brain.
Baseline rSO₂ Marker

rSO₂ Trend

Area Under the Curve

Delta (Difference) from Baseline rSO₂

Difference between rSO₂ and Peripheral SpO₂ (when used with the Radical-7 in Root)
ECMO Study with Brain Oxygenation
Cerebral Blood Flow

• TCD
• Transcranial color-coded duplex sonography
• Thermal dilution flowmetry
• Laser Doppler flowmetry
Electrophysiology

- Continuous EEG
- Evoked potentials
Brain Function Monitoring/Processed EEG

• SCCM Guideline recommendations
• Depth of sedation/anesthesia
  • Delirium prevention from oversedation prevention
• stroke patient on BFM/Sedline monitor (de-identified image)
• patient who is brain dead on BFM/Sedline monitor (de-identified image)
• Video of BFM/Sedline monitor of patient who goes into burst suppression (de-identified video)
Cerebral Microdialysis

- Key parameters
  - Lactate/pyruvate ratio
  - Glycerol
  - Brain glucose
  - Glutamate

- Metabolism assessment
  - Glucose

**Table 1** Normal and threshold values of metabolic parameters important in neuromonitoring of patients with traumatic brain injury

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal levels</th>
<th>Threshold value</th>
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<tbody>
<tr>
<td>Glucose, mean (SD), mg/dL</td>
<td>30.6 (16.2)</td>
<td>14.4</td>
</tr>
<tr>
<td>Pyruvate, mean (SD), mg/dL</td>
<td>1.46 (0.33)</td>
<td>0.27 (fatal)</td>
</tr>
<tr>
<td>Lactate mean (SD), mg/dL</td>
<td>26.1 (8.1)</td>
<td>80.2 (fatal)</td>
</tr>
<tr>
<td>Lactate to pyruvate ratio</td>
<td>23 (4)</td>
<td>30</td>
</tr>
<tr>
<td>Glycerol, mg/dL</td>
<td>184-460</td>
<td>21</td>
</tr>
</tbody>
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SI conversion factors: To convert glucose to mmol/L, multiply by 0.0555; pyruvate to μmol/L, multiply by 113.55; lactate to mmol/L, multiply by 0.111; glycerol to mmol/L, multiply by 0.1085.
Summary

• “Monitors alone cannot save patients, but wise application of the data from monitoring the injured brain can...”