Neuromonitoring – What and When?

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Disclosures
• IP for monitoring technology licensed to Medtronic

Set up audience participation
1. Take out your silenced phone
2. Open a web browser
3. Go to: PollEv.com/kenbrady584

Test question

Outline
• NIRS
  – Fun with Beer-Lambert
• Autoregulation
  – Lassen’s curves...
• EEG
  – Fourier Transforms!!!

My opinion regarding NIRS monitoring

Take your beta blockers and buckle in.
Religion, Politics, and Neuromonitoring

"...we found no evidence that pulse oximetry affects the outcome of anaesthesia for patients."

"...a total of 22,992 participants had been allocated at random to be monitored or not monitored with a pulse oximeter."

"...does not affect a person's cognitive function and does not reduce the risk of complications or of dying after anaesthesia."

Pedersen: Pulse oximetry for perioperative monitoring. Cochrane Database of Systematic Reviews 2014

Cochrane Database Review of Pulse-Oximetry

Pascal’s Wager and Neuromonitoring

You're Right! You're Wrong!

Belief

Eternal Joy

Nothing

Atheism

Nothing

Eternal Suffering
Part I: Reflectance NIRS

Beer-Lambert Law: brains in cuvettes?

Borrowing from the pulse-oximeter

CMRO2/CBF: Jugular Sat and NIRS

What do you consider to be a low NIRS?

What is a low Cerebral Oximetry?
Case: Cardiopulmonary Bypass

- A 70 year old woman is having an aortic valve replacement and 2 vessel CABG for symptomatic valve insufficiency and CAD. She had left unilateral moderate carotid stenosis (<50% occluded). She is monitored with NIRS at initiation of bypass.
  - Baseline NIRS: R-65%; L-68% on 0.21 FiO2
  - After starting bypass: R-42%, L-44%
  - ABG: 7.35/37/150; Hb: 7.0; T: 35.9°C
  - Pump flow 100% (2.4 L/m²), ABP: 55 mmHg

- What is your intervention?

What causes low cerebral oximetry?

- Low CBF:
  - Hypotension
  - ICP
  - Hypocarbia

- Low Oxygen Content
  - Hypoxia
  - Anemia

- High Extraction
  - Hyperthermia

\[ \text{DO}_2 = \text{CBF} \times \text{CaO}_2 \]
\[ \text{CBF} = \frac{\text{ABP} - \text{ICP}}{\text{CVR}} \]
\[ \text{CaO}_2 = \left( \text{Hb} \times 1.39 \times \text{SaO}_2 \right) + \left( \text{PaO}_2 \times 0.003 \right) \]

Part II: The autoregulation curve

This is expected with pH-stat, but not alpha-stat management.

This is possibly due to a progressive hemorrhage under the sensor.

Abnormally high NIRS values are as dangerous as low NIRS values.

The sweep on the bypass oxygenator is too low.

None of the above- NIRS is bogus and these interventions are harmful!
The goal of autoregulation monitoring

The Cambridge Method

Single best answer: Cerebrovascular Pressure Autoregulation

Using PRx to find optimal pressure

Validated in animal models, replicated with modifications of NIRS

Autoreg monitoring in adult CPB

- RCCT
- R01 funded (Charles Hogue PI- year 8 of 10)
- Perfusionist to keep ABP>LLA vs standard
  - Increase flows primary
  - Vasoconstrictors secondary
- MRI data not yet available
Autoreg monitoring in adult CPB

- Post-op delirium

redacted

Part III: EEG

EEG Changes and Ischemia

Comparing Anesthetic Depth and Ischemic EEGs
**EEG 101: Greek waves**

<table>
<thead>
<tr>
<th>Wave Name</th>
<th>Wave Frequency (Hz)</th>
<th>Relevance to Anesthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow</td>
<td>&lt;1</td>
<td>Increase in Amplitude during anesthesia</td>
</tr>
<tr>
<td>Delta</td>
<td>1-4</td>
<td></td>
</tr>
<tr>
<td>Theta</td>
<td>5-8</td>
<td>Increase in Amplitude during anesthesia</td>
</tr>
<tr>
<td>Alpha</td>
<td>9-12</td>
<td></td>
</tr>
<tr>
<td>Beta</td>
<td>13-25</td>
<td>Decrease in Amplitude during anesthesia</td>
</tr>
<tr>
<td>Gamma</td>
<td>26-80</td>
<td></td>
</tr>
</tbody>
</table>

**The Secret in the Secret Sauce**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprocessed EEG</td>
<td>Requires a knowledge of all of the EEG waves, and how they change during anesthesia</td>
</tr>
<tr>
<td>Spectogram</td>
<td>Shows waves as power, frequency and time. Shows exact frequencies of dominant waves. Facilitates pattern recognition, but still requires profound knowledge of EEG.</td>
</tr>
<tr>
<td>Spectral edge frequency</td>
<td>The upper 95% frequency boundary of EEG wave power. Spectral edge decreases with Anesthesia</td>
</tr>
<tr>
<td>Burst Suppression Ratio</td>
<td>The % time (or probability) that EEG activity is silent.</td>
</tr>
<tr>
<td>Bispectral Coherence Index</td>
<td>Regression methods of selected EEG features correlated to observed states of patient arousal under anesthesia.</td>
</tr>
<tr>
<td>Narcotrend</td>
<td>Uses statistical classification of the awake state against visually categorised EEG recordings.</td>
</tr>
<tr>
<td>Entropy Algorithm</td>
<td>Quantifies the degree of disorder in the EEG; more entropy is more arousal.</td>
</tr>
</tbody>
</table>

**The EEG spectogram**

**What happens to the EEG under GA?**

**Spectral edge decreases with propofol anesthesia**

- **Propofol light sedation**
- **Propofol deep sedation**

**During CPB with deep hypothermia at 18 degrees the EEG spectral pattern is shown. What is your interpretation?**

- Anesthesia is too deep causing burst suppression
- The ABP is too low causing ischemic burst suppression
- The brain is inadequately cooled and there is too much EEG activity
Burst Suppression Ratio

A patient under volatile anesthetic with low ABP has the EEG spectrum in A. Due to movement ketamine is given, resulting in B. What is your interpretation?

- The increased EEG power at 30 Hz is indicative of increased arousal.
- The decreased EEG power at 10 Hz is indicative of increased arousal.
- The decreased EEG power at 30 Hz is due to ischemia from hypotension.
- This is the normal BIS effect of ketamine.

From: Clinical Electroencephalography for Anesthesiologists: Part I: Background and Basic Signatures

Summary

- NIRS: take it to church or leave it at home
  - Know how it works and how to respond to it.
- Autoreg: coming soon to an OR near you
  - Can only do 1 thing: support ABP optimization
- EEG: a contentious topic
  - Be careful with the confounders

From: Neuromonitoring - What and When?