Depth of Anesthesia Monitoring in Cardiac Surgery

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University of Ottawa Heart Institute
Depth of Anesthesia Monitoring in Cardiac Surgery

Because it’s not all about the heart.

“The anesthetist and surgeon could have before them on tape or screen a continuous record of the electric activity of both heart and brain.”
Disclosures

None
Objectives

• Review the general principles of monitoring
• Highlight the commercially available monitors
• Determine whether depth of anesthesia monitoring can allow us to prevent awareness
• Evaluate whether titrating anesthesia to a processed EEG value can promote positive outcomes
• Share our experience with processed EEG at the Ottawa Heart Institute
GENERAL PRINCIPLES OF MONITORING
Are you asleep?

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Verbal</th>
<th>Memory</th>
<th>Movement</th>
<th>Ventilation</th>
<th>Sudomotor</th>
<th>Hemodynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Implicit</td>
<td>Explicit</td>
<td>Purposeful</td>
<td>Involuntary</td>
<td>Tearing</td>
<td>Sweating</td>
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<td>Benign</td>
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<td>Calling name</td>
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<td>Light touch</td>
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<td>Shouting</td>
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<tr>
<td>Shouting and shaking</td>
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<td>Noxious</td>
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<td>Pinprick</td>
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<td>Electrical twitch</td>
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<tr>
<td>Electrical tetanus</td>
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<tr>
<td>Trapezius squeeze</td>
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<tr>
<td>Skin closure</td>
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<tr>
<td>Incision</td>
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<td>Abdominal exploration</td>
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<td>Rib retraction</td>
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<td>Laryngoscopy</td>
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<td>Intubation</td>
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</tbody>
</table>

Increasing anesthetic depth
Are you asleep?

A. Awake with Eyes Open: Beta and Gamma Oscillations

B. Paradoxic Excitation: Beta Oscillations

C. Sedative State: Alpha and Beta Oscillations

D. Unconsciousness at Surgical Level: Slow and Alpha Oscillations

E. Unconsciousness during Induction: Slow Oscillations

F. Unconsciousness: Burst Suppression

G. Unconsciousness: Isoelectricity

Purdon et al, 2015
General Principles of Monitoring

Awake?
Aware?
Are you asleep?

EEG

Power Spectrum

Near Suppression and Suppression Measurement

Bispectrum

Awake?
Aware?
Power analysis
Power analysis

\[
\begin{array}{cccc}
\delta & \theta & \alpha & \beta \\
\end{array}
\]
Power analysis in 3D!!! Or 4D?
Ok… Density Spectral Analysis
Anesthetic Signatures on DSA

Purdon et al, 2015
Limitations of (Processed) EEG

- Muscular activity
- Medical devices
  - Pacemakers, electrocautery, surgical navigation systems, forced air warmers
- Changes in cerebral metabolism
  - Cardiac arrest, hypovolemia, hypotension, hypoglycemia, hypothermia
- Seizures (or other abnormal EEG states)
- Medication limitations
  - Ketamine, nitrous oxide, etomidate, ephedrine
BIS = Depth of Anesthesia?

Whitlock et al, 2011
MAC ≠ Effect Site ≠ Anesthetic Depth

<table>
<thead>
<tr>
<th>Effect on MAC</th>
<th>Factors (Study Subjects)</th>
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</thead>
<tbody>
<tr>
<td>Decrease</td>
<td>Hypothermia (animals)</td>
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<tr>
<td></td>
<td>Severe hypotension (animals)</td>
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<tr>
<td></td>
<td>Advanced age (humans)</td>
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<tr>
<td></td>
<td>Opioids, ketamine (humans, animals)</td>
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<td></td>
<td>Chronic administration of amphetamine (animals)</td>
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<td></td>
<td>Reserpine, α-methyldopa (animals)</td>
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<td></td>
<td>Cholinesterase inhibitors (animals)</td>
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<td></td>
<td>Intravenous local anesthetics (humans, animals)</td>
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<td></td>
<td>Pregnancy (animals)</td>
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<td></td>
<td>Hypoxemia (PaO₂ &lt; 40 mm Hg) (animals)</td>
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<tr>
<td></td>
<td>Anemia (animals)</td>
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<tr>
<td></td>
<td>α₂-Agonists (animals, humans)</td>
</tr>
<tr>
<td>Increase</td>
<td>Hyperthermia (animals)</td>
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<tr>
<td></td>
<td>Hyperthyroidism (animals)</td>
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<td></td>
<td>Alcoholism (humans)</td>
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<td></td>
<td>Acute administration of dextroamphetamine (animals)</td>
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<tr>
<td></td>
<td>Young age (humans, animals)</td>
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<tr>
<td>No effect</td>
<td>Duration of anesthesia (humans, animals)</td>
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<tr>
<td></td>
<td>Sex (human, animals)</td>
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<tr>
<td></td>
<td>Metabolic acid-base status (animals)</td>
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<tr>
<td></td>
<td>Hypercapnia and hypocapnia (humans, animals)</td>
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<tr>
<td></td>
<td>Isovolemic anemia (animals)</td>
</tr>
<tr>
<td></td>
<td>Hypertension (animals)</td>
</tr>
</tbody>
</table>

Barash, 2013
COMMERCIALY AVAILABLE MONITORS
Commercially Available Monitors

- Bispectal Index
  - Covidien (Boulder, CO)
- Sedline
  - Masimo (Irvine, CA)
- State Entropy
  - GE Healthcare (Helsinki, Finland)
- Narcotrend
  - Narcotrend-Gruppe (Hannover, Germany)
Bispectral Index
Sedline
# State Entropy

![EEG signal](image)

## RE and SE

<table>
<thead>
<tr>
<th>RE</th>
<th>SE</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>90</td>
<td>Awake</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
<td>Low probability of recall</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
<td>Clinically adequate level for most surgical operations</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>Suppressed EEG</td>
</tr>
</tbody>
</table>

- **RE** is a fast reacting parameter, which may be used to detect the activation of facial muscles.
- **SE** is a more stable parameter, which may be used to assess the hypnotic effect of anesthetic drugs on the brain.
Narcotrend stage

A  B₀  B₁  B₂  C₀  C₁  C₂  D₀  D₁  D₂  E₀  E₁  F₀
First… Do No Harm.

PREVENTING AWARENESS
Awareness

• Incidence is likely 1-2/1000

• Cardiac surgical procedures
• Obstetrical surgical procedures
• ASA III or IV
• Use of neuromuscular blocking agents

• ? Older
• ? Longer case

Sebel et al, 2004
Pollard et al, 2007
**B – Aware**

- **Awareness:** BIS 0.17% vs Routine 0.91%
  - NNT of 138

- **Anesthetic technique differences**
  - Less midazolam in the BIS group (2mg vs 2.5mg)
  - Lower target plasma propofol concentration (2mg/L vs 2.4mg/L)

- No significant differences in nearly all post operative parameters and complications

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_Bispectral index monitoring to prevent awareness during anaesthesia: the B-Aware randomised controlled trial_

Myles _et al_, 2004
BAG - RECALL

- Goal was to determine whether BIS guided anesthetic management was superior to end tidal anesthetic concentration (ETAC) for awareness prevention
  - Alarms used to guide therapy

- BIS was not superior to ETAC for preventing awareness
  - BIS 0.24% compared to ETAC 0.07%

- No difference in median BIS

- No difference in median ETAC

Avidan et al, 2011
MACS

• Patients with no particular risk for awareness were included
• Very large (n=21,601) effectiveness study
  • Planned for 30,000 patients – terminated for futility at interim endpoint

• Based on randomization, practitioners received alerts
  • MAC < 0.5 (age adjusted)
  • BIS > 60

Mashour et al, 2012
• Significant differences when analyzed by intention to treat vs post hoc grouping

• Technical malfunction

Mashour et al, 2012
The Holy Grail of Cochrane

- Decreases the risk of awareness in high risk patients
  - But ETAC may be as effective
- No clinically relevant difference in discharge readiness
- Less anesthetic use
  - Especially consistent and relevant for TIVA
- Impact of BIS on outcome was not evaluated

Punasawadwong et al, 2014
PROMOTING OUTCOMES
The Holy Grail of Cochrane, Round 2

- Non Cardiac Surgery

- Probably reduces risk of postoperative delirium in first 7 days
  - NNT – 17
  - Moderate quality evidence

- No support for other outcomes
  - All cause mortality
  - Length of stay

Punasawadwong et al, 2018
B – Aware

• Long term follow-up was done with included patients
  • Median follow-up time of 4.1 years

• No difference in post-30 day death rates in the BIS monitored compared to routine care

• Patients who had BIS < 40 for more than 5 minutes were less likely to be alive at follow-up (HR=0.66, p=0.003)

Leslie et al, 2010
B – Unaware – Duration of BIS < 45

Log-rank test, $p = 0.02$

Kertai et al, 2010
Burst Suppression and Delirium

- A single centre prospective observational study
- 81 patients enrolled with identical anesthetic management
  - Divided into delirious and non-delirious groups
- No difference in mean BIS values
- No other statistically significant risk factors identified
- Burst suppression duration was associated
- Burst suppression ratio was associated

Soehle et al, 2015
High BIS vs Low BIS – Possible?

- Anesthetic management at discretion of provider
  - Except no nitrous oxide

Short et al, 2014
BIS AND THE OTTAWA HEART INSTITUTE
Our Experience – Use of Processed EEG

Yearly Average BIS
Yearly Average PSI
Our Experience – Average BIS
Summary

- Depth of anesthesia is not a number

- The use of depth of anesthesia monitors, in high risk patients, can prevent awareness

- Preventing excessive anesthetic depth is an area of very active investigation
My Conclusions, Predictions and Bias

• The threshold value for “deep anesthesia” is suspect…
  • Burst suppression/suppression ratio may prove to be useful signal
• Low numerical depth of anesthesia indicates frailty
  • The expected low BIS in a critically ill patient
  • The unexpected low BIS in a “well” appearing patient
• Excessive anesthetic depth is harmful
  • Neurologic specific outcomes
  • Outcomes related to vasoactive agent use
  • Will be easier to demonstrate in vulnerable patients
• Sedation and anesthetic depth perioperatively is as, or more important than intraoperatively
Questions
Selected References


