Advances in Anesthesia Monitoring Technology

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Technology

- Structured Interview – simple, effective
- TransCranial Doppler
- Precordial Doppler
- JVC SaO$_2$
- Cerebral Oximetry
- EEG – EP
- BIS and other Brain Monitors
TransCranial Doppler

- Not always Possible
- Measures velocity, not actual flow
- Detects emboli during CEA and CPB
- Detects vasospasm after SAH
- Detects vertebro-basilar insufficiency
- ↑ ICP ⇒ No diastolic velocity
- Allows immediate assessment of therapy
TCD: Sites of Examination
Advanced TCD Imaging

Schematic of the Circle of Willis visualized from the transtemporal approach:
- Middle cerebral artery (M1 and M2);
- Anterior cerebral artery (A1 and A2);
- Posterior cerebral artery (P1 and P2)

MCA Velocity Reflects CBF Changes

The Doppler signal from the Middle Cerebral Artery (MCA). The mean velocity is 56 cm/sec.
TCD Changes during CEA

CONTROL PHASE
V=76.36  P=127.71  T=1:16 pm

CROSS CLAMP PHASE
V=37.27  P=108.43  T=1:39 pm

RELEASE PHASE
V=130.89  P=117.54  T=2:40 pm

5 MINUTE POST-RELEASE PHASE
V=230.120  P=140.45  T=2:45 pm

10 MINUTE POST-RELEASE PHASE
V=190.105  P=115.45  T=2:50 pm

CLOSING PHASE
V=135.70  P=97.49  T=3:02 pm

Correlation between TCD change and Stroke Incidence

<table>
<thead>
<tr>
<th>TCD</th>
<th>Shunt Incidence</th>
<th>None Incidence</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe</td>
<td>0%</td>
<td>46%</td>
<td>&lt;0.0001</td>
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<tr>
<td>Mild</td>
<td>3.9%</td>
<td>0.6%</td>
<td>&lt;0.1</td>
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<tr>
<td>None</td>
<td>4.4%</td>
<td>0.7%</td>
<td>&lt;0.001</td>
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</tbody>
</table>

Halsey, Stroke 23:1583, 1992
## Doppler MicroEmbolic Signals During CEA

<table>
<thead>
<tr>
<th>Phase</th>
<th>Preval</th>
<th>DMES/min*</th>
<th>n</th>
<th>DMES/min*</th>
<th>n</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-op</td>
<td>(5 min) 19%</td>
<td>0.043</td>
<td>20</td>
<td>0.029</td>
<td>423</td>
<td>.95</td>
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<tr>
<td>Intra-op</td>
<td>93%</td>
<td>0.68</td>
<td>22</td>
<td>0.37</td>
<td>439</td>
<td>.02</td>
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<tr>
<td>PACU</td>
<td>36%</td>
<td>0.67</td>
<td>22</td>
<td>0.30</td>
<td>389</td>
<td>.06</td>
</tr>
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</table>

* Average rate over all minutes monitored
Precordial Doppler Device
Precordial Doppler

- Sensitive and early VAE detection
- Non-invasive and rapid application
- Moderate cost
- Signal analysis can produce semi-quantitative estimate of severity
Wavelet Analysis and Venous Air Embolism

Linear relationship (solid line) between the cumulative embolic power (CEP) at scale = 1 (y axis) and air volumes (x axis) injected by bolus and continuous infusion on the natural log-log scale for seven dogs. The region bounded by the dotted lines contains approximately two thirds of the total number of data points. Regression statistics: $y = 1.08x + 7.89; Y = 0.75, P < 0.001$. The 95% confidence intervals for the slope and intercept are 0.89-1.27 and 7.65-8.13, respectively.
Jugular Bulb Venous Saturation ($S_{jv}O_2$)

- Reflects the balance of supply and demand for $O_2$
- Continuous monitoring possible, but usually done by venous blood gas
- Technically demanding placement (Now easier with ultrasonic guidance)
- Also useful to evaluate hyperventilation and perfusion
- Helps to assess ICP therapy
Near Infra-red Spectroscopy

Cerebral Oximetry

- Regional ischemia detector
- Limited sample volume
- Non-invasive, but limited by hair
- Detects CO$_2$ reactivity similarly to TCD
- Possible non-invasive alternative to $S_{jv}O_2$
Simultaneous recording of three measures of cerebral oxygenation during four inspired oxygen fractions (FiO₂) in a single patient. The pattern of changes was similar in all patients. Tissue oxygenation index (TOI) and brain tissue oxygen tension (PbrO₂) are shown as real-time continuous traces. Jugular venous saturation (SjO₂) is shown as a mean value for the stable period at each FiO₂ because the noise from the continuous signal obscured the other traces.

Neurophysiologic Monitoring

- Useful for identifiable structures at risk
- Technically demanding
- Equipment can be complex and costly
- Interpretive training is hard to get
- Now usually by a separate service
EEG & Evoked Potentials

- Detection of ischemia or injury
- Early intervention (while reversible?)
- Assessment of therapy
- Guide to ‘protection measures’
EEG in Anesthesia

- Signal processing – much in development, but little applied yet.
- Low morbidity rates make cost-justification difficult
- CEA – many approaches, all with low stroke rates
- Cardiac surgery – many ‘disturbances’ lead to neuropsychiatric deficits
- Monitoring vulnerable to noise
Monitoring of spinal cord
Separate Motor & Sensory Pathways

- Sensory tests are well defined
- SSEP’s are unable to monitor the anterior column
- Motor tests are still emerging
- Cranial nerve tests are very specific, but vary in sensitivity
Figure 2: Equipment and electrode positions for motor evoked potential monitoring. SCEP: Spinal cord evoked potential; NMEP: Neurogenic motor evoked potential; CMAP: Compound muscle action potential.
EEG Monitoring in ICU

- Assure adequate sedation during relaxant use
  - BIS can guide sedative infusions
- Follow progression of coma
  - upward or downward
  - detect effective or detrimental therapy
- Detect Seizures
  - rapidly adjust therapy dosages
Advanced Processing of EEG during Anesthesia

Techniques continue to improve and expand
Drug dosing Schemes
(in most clinical practice)

- Choose a standard dose (e.g. ED\textsubscript{50} or ED\textsubscript{95}),
- Guess the degree to which a patient is tolerant or sensitive to the drug,
- Then adjust the dose by trial and error
- Avoid toxicity.
Several Components to "Anesthetic Depth"

- Sedative/Hypnotic
  - BIS – most tested
  - Others in development – SedLine, NarcoTrend, Mid-latency AEP, Chaos or Entropy, SNAP

- Analgesic
  - BIS variability
  - Heart rate variability

- Autonomic
  - HRV, RSV, Anemon-L, others
Bispectral Index (BIS)

- Derived statistically
- Optimized to classify EEG of observed sedation states
- Sedation states defined behaviorally
- Validated for many drugs (except Ketamine)
Effect Monitoring
Individualizes Management

- Shows lower drug needs if obtunded
- Shows higher drug needs if patient is enzyme-induced
- Allows rapid assessment at end of surgery
- Facilitates non-relaxant anesthetic management
Documented Anesthesia Benefits

Drug Savings
(Gan, 1997; Bannister, 2001; Wong 2002; White 2004; Liu 2004)

- Isoflurane: 26%
- Propofol: 23%
- Sevoflurane: 19%
- Desflurane: 18%

Decreased PONV
(Nelskya, 2001; Lugnibuhl, 2003)

- Control: 40%
- BIS Titrated: 16%

Faster Wake-Ups
(Gan, 1997)

- Standard Practice: 23%
- BIS-Titrated: 43%

- 87% decrease

Shorter PACU Stays
(White, 2004)

- Standard Practice: 195 minutes
- BIS-Titrated: 132 minutes

- 32% decrease
BIS is NOT

- a MAC-meter
- a predictor of future behavior
- a reliable detector of cerebral ischemia
- a replacement for clinical judgment
Control of the opiate infusion

- without feedback control
- by front-loading and then
  - Fixed rate or
  - Kinetic-modeled infusion,
- variance in the BIS appears to have useful information for adjusting the opiate infusion
- an "opiate EEG index" similar to BIS can possibly be developed.
Pitfalls of BIS application

- Overdosing for BIS elevated by artifact
- Depending on BIS to prevent movement without relaxant
- Running “too light” before a strong stimulus
- Overdosing opiate to lower BIS
- “Learning” to use lower dosages even without BIS
What use is a measure of sedative effect

- Avoid awareness
- Avoid overdosage - 25-40% less drug
- Speed emergence - faster into & out PACU
- Detect tolerance and over-sensitivity
- Manage unstable patients
- Learn the real time-course of drug effects (pharmaco-dynamics)
Statistically-derived multi-parametric indices

- Bispectral Index (BIS) - most successful so far
- Entropy & Sedline – less studied
- Auto-regressive model of Guedel stages – NarcoTrend (not in USA)
- More? - Cerebral State Index, - SNAP II
- Mid-latency Auditory Evoked Response Index (Europe)
Consciousness Monitoring Technologies

- Aspect BIS
- Danmeter CSM
- GE Entropy
- Hospira SEDLine
- Narcotrend
- Stryker SNAP II
<table>
<thead>
<tr>
<th>Index</th>
<th>Hardware Availability</th>
<th>Sensor for children</th>
<th>Recommended ranges for general anesthesia</th>
<th>Reduced incidence of intraoperative awareness with recall in adults</th>
<th>Perioperative outcome benefits</th>
<th>Pediatric outcome benefits</th>
<th>Published meta-analysis of randomized clinical outcomes trials</th>
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<tbody>
<tr>
<td>Bispectral Index (BIS)</td>
<td>Standalone (BIS Vista or A-2000) Integrated module with many monitors</td>
<td>Yes</td>
<td>40-60</td>
<td>Yes (8.9)</td>
<td>Yes (10-24) Reduced primary anesthetic use Reduced emergence, extubation and recovery times Reduced PONV</td>
<td>Yes (28) Reduced anesthetic use Reduced emergence time</td>
<td>Yes (32) Ambulatory Anesthesia</td>
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<tr>
<td>Entropy (SE, RE)</td>
<td>Module only (M-Entropy)</td>
<td>No</td>
<td>40-60</td>
<td>No</td>
<td>Yes (25) Reduced primary anesthetic use Reduced emergence, extubation and recovery times</td>
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<td></td>
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<tr>
<td>Patient State Index (PSI)</td>
<td>Standalone only (SEDLine)</td>
<td>No</td>
<td>25-50</td>
<td>No</td>
<td>Yes (27) Reduced primary anesthetic use Reduced emergence, extubation and recovery times</td>
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<tr>
<td>SNAP Index</td>
<td>Standalone only (SNAP II Monitor)</td>
<td>No</td>
<td>N/A</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Narcotrend Index</td>
<td>Standalone only (Narcotrend)</td>
<td>No</td>
<td>Stage DO-2 Index 40-60</td>
<td>No</td>
<td>Yes (26) Reduced primary anesthetic use Reduced emergence, extubation and recovery times</td>
<td>Yes (31) Reduced primary anesthetic use</td>
<td></td>
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<td>Cerebral State Index (CSI)</td>
<td>Hand-held only (Cerebral State Monitor)</td>
<td>No</td>
<td>40-60 (+15 bias from BIS)</td>
<td>No</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
The End