Technology to monitor sedation during intensive care?

Tim Walsh
Professor of Critical Care
Edinburgh University
Disclosure

• Received grants from GE Healthcare to specifically work on sedation technology development

• Undertake consultancy work with GE Healthcare in relation to sedation technology
A systematic review of the impact of sedation practice in the ICU on resource use, costs and patient safety

Daniel L Jackson*1, Clare W Proudfoot2, Kimberley F Cann2 and Tim Walsh3

- Deeper sedation associated with:
  - duration of ventilation, ICU stay, hospital stay
  - higher illness cost
  - higher complication rates
  - possibly mortality
- Associations with neuropsychiatric outcomes
- No large studies of impact of technology
Early Intensive Care Sedation Predicts Long-Term Mortality in Ventilated Critically Ill Patients

Yahya Shehabi\textsuperscript{1,2}, Rinaldo Bellomo\textsuperscript{3,4,5,6}, Michael C. Reade\textsuperscript{7,8}, Michael Bailey\textsuperscript{5}, Frances Bass\textsuperscript{2}, Belinda Howe\textsuperscript{5}, Colin McArthur\textsuperscript{9}, Ian M. Seppelt\textsuperscript{10}, Steve Webb\textsuperscript{11,12}, and Leonie Weisbrodt\textsuperscript{13}; Sedation Practice in Intensive Care Evaluation (SPICE) Study Investigators and the ANZICS Clinical Trials Group* 

Am J Respir Crit Care Med Vol 186, Iss. 8, pp 724-731, Oct 15, 2012

\begin{itemize}
\item [\textbullet] Deep Sedation
\item [\textbullet] Light Sedation
\item [\textbullet] Agitated
\end{itemize}

\begin{itemize}
\item \textbf{Log rank P=0.04}
\end{itemize}

\begin{itemize}
\item \textbf{Number at risk}
\item Deeply sedated: 215, 172, 160, 158, 158, 157, 154
\item Not deeply sedated: 36, 34, 31, 31, 30, 30, 30
\end{itemize}
Sedation scales

- Rely on team “buy in”
- Insensitive during deep sedation (usually early in ICU stay or during most acute period)
- Challenging to implement
Existing “black box” technologies

**BIS (Aspect)**
Single number (0-100)
Derived from 3 components (SynchFast, Slow from Bispectrum)
Marketed for use in ICU

**Entropy (GE)**
Single number (0-100)
Based on spectral entropy (regularity) of EEG power spectrum
State (0-32 Hz)
Response (0-47 Hz)

**Narcotrend (Schiller AG)**
Single number (0-100)
Derived from patterns associated with 6 stages (A-F)
The EEG and EMG

\[
\begin{align*}
\beta & \ (13-30 \ Hz) \\
\alpha & \ (8-13 \ Hz) \\
\theta & \ (4-8 \ Hz) \\
\delta & \ (1-4 \ Hz)
\end{align*}
\]

EMG (>30 Hz but wide spectrum overlapping with \(\beta\) range especially)

Monitors designed for anaesthesia aim to detect hypnosis (awareness), not pain or nociceptive stimuli and largely “assume” abolition of most facial EMG activity
## Anaesthesia versus critical illness

### Anaesthesia
- Goal is deep anaesthesia with non-responsiveness
- Facial EMG activity useful as an index of arousal or “light anaesthesia”
- The goal is detection and avoidance of undersedation/hypnosis
- Limited range of nociceptive stimuli
- Movement rare

### Intensive Care
- Goal is light sedation with responsiveness
- Facial EMG problematic as optimum sedation infers active fEMG
- The goal is avoidance of oversedation/hypnosis
- Frequent and varied nociceptive stimuli
- Movement common
Anaesthesia versus critical illness

**Anaesthesia**
- Goal is deep anaesthesia with non-responsiveness
- Facial EMG activity useful as an index of arousal or “light anaesthesia”
- The goal is detection and avoidance of undersedation/hypnosis
- Limited range of nociceptive stimuli
- Movement rare

**Intensive Care**
- Goal is light sedation with responsiveness
- Facial EMG problematic as optimum sedation infers active fEMG
- The goal is avoidance of oversedation/hypnosis
- Frequent and varied nociceptive stimuli
- Movement common
### Anaesthesia versus critical illness

<table>
<thead>
<tr>
<th>Anaesthesia</th>
<th>Intensive Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal is deep anaesthesia with non-responsiveness</td>
<td>Goal is light sedation with responsiveness</td>
</tr>
<tr>
<td>Facial EMG activity useful as an index of arousal or “light anaesthesia”</td>
<td>Facial EMG problematic as optimum sedation infers active fEMG</td>
</tr>
<tr>
<td>The goal is detection and avoidance of undersedation/hypnosis</td>
<td>The goal is avoidance of oversedation/hypnosis</td>
</tr>
<tr>
<td>Limited range of nociceptive stimuli</td>
<td>Frequent and varied nociceptive stimuli</td>
</tr>
<tr>
<td>Movement rare</td>
<td>Movement common</td>
</tr>
</tbody>
</table>
## Anaesthesia versus critical illness

<table>
<thead>
<tr>
<th>Anaesthesia</th>
<th>Intensive Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Goal is deep anaesthesia with non-responsiveness</td>
<td>• Goal is light sedation with responsiveness</td>
</tr>
<tr>
<td>• Facial EMG activity useful as an index of arousal or “light anaesthesia”</td>
<td>• Facial EMG problematic as optimum sedation infers active fEMG</td>
</tr>
<tr>
<td>• The goal is detection and avoidance of undersedation/hypnosis</td>
<td>• The goal is avoidance of oversedation/hypnosis</td>
</tr>
<tr>
<td>• Limited range of nociceptive stimuli</td>
<td>• Frequent and varied nociceptive stimuli</td>
</tr>
<tr>
<td>• Movement rare</td>
<td>• Movement common</td>
</tr>
</tbody>
</table>
### Anaesthesia versus critical illness

<table>
<thead>
<tr>
<th><strong>Anaesthesia</strong></th>
<th><strong>Intensive Care</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal is deep anaesthesia with non-responsiveness</td>
<td>Goal is light sedation with responsiveness</td>
</tr>
<tr>
<td>Facial EMG activity useful as an index of arousal or “light anaesthesia”</td>
<td>Facial EMG problematic as optimum sedation infers active fEMG</td>
</tr>
<tr>
<td>The goal is detection and avoidance of undersedation/hypnosis</td>
<td>The goal is avoidance of oversedation/hypnosis</td>
</tr>
<tr>
<td>Limited range of nociceptive stimuli</td>
<td>Frequent and varied nociceptive stimuli</td>
</tr>
<tr>
<td>Movement rare</td>
<td>Movement common</td>
</tr>
</tbody>
</table>
Sedation, encephalopathy, delirium or underlying pathology

- Delirium is present in up to 80% of patients
- Encephalopathy is likely present in many patients concurrently during sedation
- These conditions cause slowing of frequencies and are likely confounders to EEG based algorithms
Relation between BIS and RASS scores
Ely EW et al 2003; 289; 2983
Comparison of two bispectral index algorithms in monitoring sedation in postoperative intensive care patients
Tonner, Peter H et al CCM 2005; 33: 580
BIS: importance of facial EMG
An assessment of the validity of spectral entropy as a measure of sedation state in mechanically ventilated critically ill patients

DOI 10.1007/s00134-007-0858-x
Log EMG power across different clinical sedation levels
Key Goals

• We do not need technology to inform the clinician that the patient is awake
• We need technology that could continuously alert the clinician that a patient may be over-sedated in order to prompt sedation review

• The “unresponsive patient”
Responsiveness algorithm

Features

• Summary measure of frequency and intensity of arousals (fEMG) compared to individual patients “baseline” state
• Averaging to create a representation of recent events (60 minutes)
• Continuous measure (running average)
• Weighting towards recent events
• Independence from “test related” stimulation
Effect of stimuli and the importance of averaging in algorithm
Responsiveness of the frontal EMG for monitoring the sedation state of critically ill patients

T. S. Walsh¹*, T. P. Lapinlampi², P. Ramsay¹, M. O. K. Särkelä², K. Uutela² and H. E. Viertio-Oja²
Cohort of patients regaining consciousness post routine cardiac surgery
Potential importance of encephalopathy

Pk for 1-4 versus 5-6:
“Low risk” encephalopathy 0.90 (0.02)
“High risk” encephalopathy 0.70 (0.04)
The “traffic light” concept

• Familiar warning colours to alert clinical staff to absolute values and trends

• Red (RASS -5) ⇒ “warning” “stop” “danger” “be alert” …etc

• Green (RASS ≥ -3) ⇒ “continue” “Go” “OK” …etc
Derivation of “best cut-off values” to discriminate “higher” from “lower” probability of over-sedation

In absence of likely encephalopathy:
Cut-off RI 35:
- Sensitivity 90%
- Specificity 79%

RED: ≤ 20
AMBER: 20-40
Responsiveness colour in relation to RASS score
Reasons for an “unresponsive “ patient based on fEMG activity (Red/Ampber)

- Muscle paralysis
- Normal sleep
- Illness associated coma
  - Liver failure
  - Hypoxic brain injury
  - Traumatic brain injury
  - Severe metabolic encephalopathy
- Drug-induced coma
  - Excessive dosing of sedative drugs
  - Accumulation of sedative drugs
- Decreased levels of patient stimulation
Day-night-time effects: the impact of reducing “therapeutic” stimulation
Excessive sedation
All patients

Patients with first responsiveness in “red” zone

Phase II “Proof of concept” trial (N = 74 patients)
Technology for sedation management

- Clinical rationale for monitors for deep or excessive sedation is high
- Novel approaches have potential as continuous objective “detectors” of possible excessive sedation
- Future effectiveness trials should assess these as quality improvement tools