Cerebral state index: comparison between pairwise registrations from the left and the right sides of the brain

R. E. Anderson¹ and J. G. Jakobsson²*

¹Department of Cardiothoracic Anaesthetics and Intensive Care, Karolinska Hospital, Stockholm, Sweden. ²Department of Anaesthesiology and Intensive Care, The Karolinska Institute, Stockholm, Sweden

*Corresponding author: Department of Anaesthesiology, Sabbatsberg Hospital, S-113 24 Stockholm, Sweden. E-mail: jan.jakobsson@ki.se

Background. Lateralization of cerebral blood flow and EEG activity is known to vary during cognition, sleep and waking. In spite of this, electrode placement for the cerebral state index (CSI) monitor is not specified to a particular side of the brain. This study is designed to determine if pairwise registrations differ for CSI measured simultaneously from the left or right sides of the brain.

Methods. In total, 25 ASA I–II patients undergoing elective day surgery under general anaesthesia were recruited. Pairwise recordings were made every minute from two CSI monitors (Cerebral State Monitor, Danmeter A/S; Odense, Denmark) connected to the left and the right side of the head. Sedation was graded according to the observer’s assessment of alertness/sedation rating scale and correlated with CSI.

Results. A large overlap of indices, of similar magnitude, for each side of the brain was seen between different levels of sedation. The agreement between pairwise registrations was high, correlation between the 584 CSI pairs of recordings left/right was $r^2=0.92$.

Conclusions. Despite known lateralization of the EEC, this study found a very high correlation in CSI derived simultaneously from the left and right sides of the brain by two independent monitors.

Br J Anaesth 2006; 97: 347–50

Keywords: anaesthetics i.v., propofol; anaesthetics volatile, sevoflurane; monitoring, depth of anaesthesia; surgery, day-case

Accepted for publication: May 3, 2006

New devices are being introduced for determining the depth of anaesthesia. These devices all calculate a numerical index from either the passively reiterated EEG or evoked EEG potentials using different algorithms for signal processing of the raw EEG. While the electrodes for the various devices all serve the same function, they differ greatly both in design, cost and placement on the skull.

The cerebral state index (CSI) monitor is one of the latest developments in monitoring the depth of anaesthesia. One important economic factor is that the CSI electrodes are among the least expensive. The CSI monitor processes passive EEG from three electrodes: two are placed on the forehead and one behind the ear on the mastoid process. The manufacturers do not specify which side of the brain should be monitored. As the left side of the brain is dominant for most patients, one might expect that the CSI measured on the two sides of the brain would differ as EEG lateralization has been demonstrated in sleep studies.¹⁻⁴

We hypothesized that the differences in EEG power derived from the left or the right side of the brain during anaesthesia would result in the differences in the CSI registered from the two different sides. The study was designed to determine if the CSI would differ when registered from the right or the left side of the brain using two identical CSI monitors.

Methods

This study included, after informed written consent, 25 ASA I–II patients undergoing elective day surgery (majority arthroscopy) under general anaesthesia. Patients were anaesthetized according to standard departmental protocol. The premedication was oral cyclizine 50 mg. Anaesthesia was induced by one of the investigators who was blinded to the cerebral state monitoring. Propofol and fentanyl (0.1 mg) were used to induce anaesthesia and these were followed...
by the placement of a laryngeal mask airway. Anaesthesia was maintained using sevoflurane, nitrous oxide and oxygen. No predefined minimum alveolar concentration value was sought, sevoflurane was titrated as per clinical needs and the adequacy of anaesthesia was judged clinically by the attending anaesthetist. Standard monitoring included single channel ECG, non-invasive blood pressure, pulse oximetry and end-tidal anaesthetic gas concentration.

Anaesthetic depth was monitored using two identical monitors for CSI version 1.1 (CSI™ Cerebral State Monitor, Danmeter A/S; Odense, Denmark). Two sets of three special composite electrodes were applied according to manufacturer’s instructions for recording the CSI. Two electrodes were placed on the forehead midline, one behind each ear, and one each on the left and the right sides of the forehead. Each set of three electrodes was connected to one of the two identical CSI monitors. After an initial control for electrode impedance, the monitor calculates an index from the raw EEG signals using an algorithm based on power analysis of the $\beta$, $\alpha$ and $\beta$–$\alpha$ ratio in conjunction with estimation of burst suppression ratio. The monitor provides a single numerical index from 0 to 100. Patients were interviewed for awareness just before discharge from the recovery room.

Sedation level was evaluated and graded according to the observer’s assessment of alertness/sedation (OAAS) rating scale:

- OAAS score 5—awake and responds readily to name spoken in normal tone.
- OAAS score 4—lethargic responses to name in normal tone.
- OAAS score 3—responds only after name is called loudly and/or repeatedly.
- OAAS score 2—responds only after name called loudly and mild shaking.
- OAAS score 1—does not respond when name is called loudly and mild shaking or prodding.
- OAAS score 0—does not respond to noxious stimulation.

The level of sedation and CSI were manually registered simultaneously by a nurse (not otherwise involved in the study) every minute from preinduction until emergence when the patient could communicate his/her name and date of birth. The data are presented as mean (SD). The correlation and comparison between the pairwise registrations of CSI from each individual were analysed using Pearson coefficient of correlation and Bland–Altman plot, respectively.

Results

In total 10 males and 15 females of mean age 50 (20–70) yr and weight 76 (16) kg were studied. Surgery was uneventful for all patients without any complications during either anaesthesia or recovery. Of the 25 patients, 3 were left-handed.

A total of 584 pairwise readings were registered. CSI decreased with increasing sedation with a large overlap between OAAS levels (Fig. 1). No difference in the CSI was seen between the difference in CSI from the left and the right sides with respect to OAAS values. No difference was observed between CSI registered on the right and left side (Tables 1 and 2). The correlation between left and right side registrations was $R^2=0.92$ (Fig. 2). Only six pairs (1%) showed a difference in CSI.

Table 1 The cerebral state index (CSI) registered separately from both the right or the left side of the brain in relation to the level of sedation graded according to the observer’s assessment of alertness/sedation (OAAS) rating scale. $n$, number of paired registrations at each OAAS level.

<table>
<thead>
<tr>
<th>OAAS level</th>
<th>Right (n)</th>
<th>Left (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OAAS 5</td>
<td>93 (6)</td>
<td>92 (5)</td>
</tr>
<tr>
<td>OAAS 4</td>
<td>88 (4)</td>
<td>87 (5)</td>
</tr>
<tr>
<td>OAAS 3</td>
<td>79 (12)</td>
<td>78 (11)</td>
</tr>
<tr>
<td>OAAS 2</td>
<td>73 (13)</td>
<td>74 (15)</td>
</tr>
<tr>
<td>OAAS 1</td>
<td>61 (15)</td>
<td>63 (14)</td>
</tr>
<tr>
<td>OAAS 0</td>
<td>51 (10)</td>
<td>52 (10)</td>
</tr>
</tbody>
</table>

Table 2 The cerebral state index (CSI) registered separately from both the right or the left side of the brain in relation to clinical events. LMA, laryngeal mask airway.

<table>
<thead>
<tr>
<th>Event type</th>
<th>Right (n)</th>
<th>Left (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMA insertion</td>
<td>45 (3)</td>
<td>46 (4)</td>
</tr>
<tr>
<td>Surgical incision</td>
<td>45 (5)</td>
<td>44 (6)</td>
</tr>
<tr>
<td>During surgery</td>
<td>50 (9)</td>
<td>51 (10)</td>
</tr>
<tr>
<td>End surgery</td>
<td>55 (8)</td>
<td>55 (9)</td>
</tr>
<tr>
<td>LMA out</td>
<td>83 (11)</td>
<td>83 (9)</td>
</tr>
<tr>
<td>Verbal communication</td>
<td>87 (3)</td>
<td>87 (5)</td>
</tr>
</tbody>
</table>
Discussion

This study sought to determine if CSI differed when measured from the right and the left sides of the brain. The principle finding is that CSI from the left and right brain halves during general anaesthesia for routine day surgery shows a high degree of agreement between pairwise registrations with no consistent differences.

While one may argue that pairwise registrations from anaesthetic depth monitors should correlate well, a number of studies comparing two or more indices have shown poor congruence and even huge degrees of disagreement between simultaneous readings. Niedhart and colleagues showed that even two identical BISxp monitors gave conflicting results over 10% of the time. One recent study found, however, a relatively good correlation between CSI and the bispectral index. Large inconsistencies have also appeared between simultaneous determinations of the auditory evoked response index (AAI) and the bispectral index, although it may not be that surprising as the two actually explore different neuronal modalities.

This study compares the same model and version of the cerebral state monitor. Thus the agreement between the two readings may seem obvious if it were not for studies showing that lateralization of EEG activity and cerebral blood flow differ during cognition, REM sleep and waking.

All our patients received standardized anaesthesia. Anaesthetic depth was adjusted according to the clinical signs in spontaneously breathing patients. We have shown earlier that CSI, similar to other EEG-based depth anaesthesia monitors, is not sensitive to the effects of nitrous oxide as sole agent. The extensive overlap between different levels of sedation is also in agreement with earlier studies of BIS and entropy.

There are some limitations to our study design. We did not use computerized registration and therefore our results may not accurately reflect rapid changes, as for example during induction of anaesthesia, but the lack of such fast extractions of data does not affect the clinical question. The majority of data pairs were registered during surgery with a stable level of anaesthesia. It might have been of value to study more explicitly the changes in depth of sedation/anaesthesia with a slower induction. While the present correlations only apply to the anaesthesia protocol used, it is reasonable to extrapolate these conclusions to even other forms of anaesthesia. This study is not powered to make any conclusions about the clinical relevance of the CSI.

This study has shown that the EEG differences between hemispheres known to occur during sleep do not confound the algorithm calculating the CSI. Pairwise registrations from the left and right side of the forehead provide reassuringly high congruence in CSI.

References

10 Niedhart DJ, Kaiser HA, Jacobsohn E, Hantler CB, Evers AS, Avidan MS. Intrapatient reproducibility of the BISxp(R) monitor. *Anesthesiology* 2006; 104: 242–8