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Burst-suppression ratio underestimates absolute duration of electroencephalogram suppression compared with visual analysis of intraoperative electroencephalogram

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Abstract

Background. Machine-generated indices based on quantitative electroencephalography (EEG), such as the patient state index (PSI^{TM}) and burst-suppression ratio (BSR), are increasingly being used to monitor intraoperative depth of anaesthesia in the endeavour to improve postoperative neurological outcomes, such as postoperative delirium (POD). However, the accuracy of the BSR compared with direct visualization of the EEG trace with regard to the prediction of POD has not been evaluated previously.
Methods. Forty-one consecutive patients undergoing non-cardiac, non-intracranial surgery with general anaesthesia wore a SedLine® monitor during surgery and were assessed after surgery for the presence of delirium with the Confusion Assessment Method. The intraoperative EEG was scanned for absolute minutes of EEG suppression and correlated with the incidence of POD. The BSR and PSI^{TM} were compared between patients with and without POD.
Results. Visual analysis of the EEG by neurologists and the SedLine®-generated BSR provided a significantly different distribution of estimated minutes of EEG suppression (P=0.037). The Sedline® system markedly underestimated the amount of EEG suppression. The number of minutes of suppression assessed by visual analysis of the EEG was significantly associated with POD (P=0.039), whereas the minutes based on the BSR generated by SedLine® were not associated with POD (P=0.275).
Conclusions. Our findings suggest that SedLine® (machine)-generated indices might underestimate the minutes of EEG suppression, thereby reducing the sensitivity for detecting patients at risk for POD. Thus, the monitoring of machine-generated BSR and PSI^{TM} might benefit from the addition of a visual tracing of the EEG to achieve a more accurate and real-time guidance of anaesthesia depth monitoring and the ultimate goal, to reduce the risk of POD.

Key words: depth of anaesthesia; burst-suppression ratio; confusion assessment method; patient state index; postoperative delirium

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Editor's key points

- Occurrence of EEG suppression during anaesthesia is associated with postoperative delirium.
- Commercially available depth-of-anaesthesia monitors commonly indicate the presence of burst suppression automatically.
- The authors compared the minutes of EEG suppression detected by visual EEG analysis and by a commercial monitor.
- The monitor significantly underestimated the amount of EEG suppression.

Postoperative delirium (POD) is common in older surgical patients, with a prevalence ranging from 11 to 60%.[1–3] Postoperative delirium is associated with prolonged hospitalization, increased rates of mortality and morbidity, long-term disability, and increased health-care cost.[1 4 5] Studies using intraoperative processed quantitative EEG monitoring suggest that POD can be decreased by maintaining the patient at a lighter level of anaesthesia, implying that POD is related to the depth of anaesthesia.[6–8] In particular, recent studies using machine-generated, processed EEG indices of intraoperative burst suppression (such as the burst-suppression ratio, BSR) indicate that burst suppression is an independent risk factor for POD, but none of these studies examined the raw EEG data.[9 10]

Two common quantitative EEG indices used to assess the depth of anaesthesia during surgery are the SedLine® Patient State Index (PSI™)[11] and the Medtronic/Covidien Bispectral Index™ (BIS™).[12] Both quantitative EEG systems use proprietary algorithms to generate a number between 0 and 100, with 100 being associated with wakefulness and 0 with an isoelectric (completely suppressed) EEG. These algorithms are complicated and typically involve a running power analysis of specific frequency bands combined with changes in symmetry and synchronization in various cortical regions.[12] Both the SedLine® and BIS™ monitoring systems also generate a second index called the BSR. The BSR represents the percentage of the previous 63 s epoch of EEG recognized as those periods longer than 0.5 s, during which the EEG voltage does not exceed approximately +5 to −5 μV. The BSR would be 1.0 for an isoelectric EEG signal and 0 for an EEG signal without any isoelectric periods. A burst-suppression pattern on EEG indicates a severe reduction in the brain's neuronal activity and metabolic rate, which puts the patient at risk for acute and subacute delirium and cognitive impairment.[9 10 13] Hence, devising accurate, reliable methods to quantify EEG suppression is an important clinical and research problem.

No previous study has evaluated the accuracy of BSR estimating the absolute time spent in complete EEG suppression in comparison with a direct visual analysis of the EEG trace. Hence, we conducted the first observational study to examine the relationship between the incidence of POD and the absolute time spent in EEG suppression as calculated by the machine-generated BSR and as identified through visual inspection of the EEG tracing by two experienced neurologists.

Methods

Participants and characteristics

This prospective, observational cohort study was conducted from May to December 2014 at the University of California San Francisco Medical Center. The study received approval from the institutional review board, and written patient informed consent was obtained. Inclusion criteria were consecutive adult patients (>40 yr of age) who were fluent in English and undergoing major, elective, non-cardiac surgery requiring general anaesthesia, with an expected postoperative hospital stay for ≥72 h. The age cut-off of 40 yr was chosen instead of the commonly used 60–70 yr as part of a pilot study that was also intended to determine whether there was an effect of age on intraoperative burst suppression that might have to be taken into account as part of a larger cohort study.

Patients were excluded if they were undergoing intracranial or neurovascular surgery. The characteristics of the study population are displayed in Table 1. The anaesthetic types and management were not controlled. There was no power analysis because this was a pilot study designed to determine the feasibility of measuring EEG suppression by off-line visual analysis of the EEG tracing compared with the commonly used indices (PSI™ and BSR) provided by the SedLine® monitoring system. Forty-eight patients consented to the study. For seven patients, there were incomplete EEG or POD data, resulting in a total of 41 patients for this analysis.

Study protocol and time line

The baseline cognitive status was measured ~1 week before surgery using the Telephone Interview of Cognitive Status instrument (TICS™), a measure of global cognitive functioning that is highly correlated with the Mini-Mental® State Examination (MMSE®).[14]

During surgery, the patients were monitored with a SedLine® brain monitor, which uses a four-lead strip placed over the forehead approximating the position of the F7, F8, FP1, and FP2 EEG electrodes of the international 10-20 system. The reference and earth for the EEG recording was placed in the midline, equidistant from electrodes FP1 and FP2. SedLine® records digital EEG waves in a referential montage, displays a number (the PSI™), and also calculates a BSR indicating depth of anaesthesia. The BSR was calculated in real time by the machine using a proprietary algorithm. Non-zero values of BSR indicate burst suppression on a minute-by-minute basis. Specifically, BSR represents the percentage of complete EEG suppression during the past minute, and was updated every 1.2 s. The anaesthetist was blinded to the PSI™ and BSR generated by SedLine® because both numbers are not used routinely for clinical care at our institution. Two board-certified and experienced neurologists (R.Z. and W.M.), who were blinded to the clinical data and the incidence of POD as the primary outcome, analysed the raw EEG tracing (as acquired by the SedLine® monitor) off-line and identified the amount of burst suppression present during each operation.

The patients were assessed daily for the presence of POD on the first 3 days after surgery by trained personnel using the Confusion Assessment Method (CAM).[15] The postoperative visits were conducted between 09.00 and 12.00 h at the patients' bedside. At each time point, the presence of delirium was measured using the CAM via a structured interview.[16] The CAM was developed as a screening instrument based on operationalization of Diagnostic and Statistical Manual of Mental Disorders 3rd Edition Revised (DSM-III-R) criteria for use by non-psychiatric clinicians in high-risk settings. This method has a sensitivity of 94–100% and a specificity of 90–95% for delirium. All research personnel administering the CAM were trained based on a detailed manual developed by Inouye and colleagues[17] for administration of the CAM. All instances of delirium were