Effect of sevoflurane/nitrous oxide versus propofol anaesthesia on somatosensory evoked potential monitoring of the spinal cord during surgery to correct scoliosis

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Background. Use of intraoperative somatosensory evoked potential (SSEP) monitoring is helpful in spinal corrective surgery but may be affected by anaesthetic drugs. An anaesthetic technique that has less effect on SSEP or allows faster recovery is an advantage. We compared the effects on SSEP and the clinical recovery profiles of sevoflurane/nitrous oxide and propofol anaesthesia during surgery to correct scoliosis.

Methods. Twenty adolescent patients were randomized into two groups of 10. One group received sevoflurane–nitrous oxide anaesthesia and the other received propofol i.v. anaesthesia. An alfentanil infusion was used for analgesia in both groups.

Results. Changes in anaesthetic concentration produced little effect on the latency of SSEP, but the effect on the variability of SSEP amplitude was significant (P<0.05). Sevoflurane produced a faster decrease in SSEP and a faster recovery than propofol (P<0.05). On emergence, patients who received sevoflurane tended to have shorter recovery times to eye opening (mean 5.1 vs 20.6 min, P=0.09) and toe movement (mean 7.9 vs 15.7 min, P=0.22). Those who had received sevoflurane were significantly more lucid and cooperative in recovery.

Conclusions. Sevoflurane produces a faster decrease and recovery of SSEP amplitude as well as a better conscious state on emergence than propofol.


Keywords: anaesthetics volatile, sevoflurane; anaesthetics i.v., propofol; monitoring, somatosensory evoked potential; surgery, spinal

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The use of continuous or intermittent intraoperative electrophysiological spinal cord monitoring provides information concerning the neurological structures at risk during spinal corrective surgery. The Scoliosis Research Society has published a position statement concerning the use of intraoperative monitoring during spinal surgery, and made recommendations concerning standard monitoring techniques.¹ Somatosensory evoked potentials (SSEP) remain the most widely used monitoring method for spinal surgery.² This is largely related to familiarity with the method, comparative ease of application and its proven sensitivity to an array of surgical variables. SSEPs are signal-averaged data, elicited by stimulating a peripheral nerve and recording the response at points along the afferent pathway and across the somatosensory cortex. They are small-amplitude responses that are not identifiable with a single stimulus. Instrumentation used to record these data amplifies and filters the signal over multiple trials to produce a response that can be measured and duplicated. Typically, 300–500 samples are averaged to create one SSEP response and take about 60 s to obtain. They are, therefore, a measure of neural transmission in afferent spinal cord pathways. However, anaesthetic drugs can affect SSEP findings. Sevoflurane can increase the latency and
decrease the amplitude of SSEP in a dose-dependent fashion. Propofol–sufentanil total i.v. anaesthesia has also been shown to influence SSEP monitoring. Anaesthesia may, therefore, affect the interpretation of an unfavourable intraoperative SSEP and a drug that has less effect on SSEP or allows a faster recovery of SSEP after readjustment of anaesthetic dose is advantageous.

Although electrophysiological monitoring is an important breakthrough, the Stagnara ‘wake-up’ test has largely remained the gold standard for assessment of neurological status during spinal surgery. The wake-up test may be required in circumstances in which SSEP signals are undetectable or abnormal. However, timely completion of an intraoperative wake-up test can be difficult and the critical time window for reversal of a deficit can be lost while waiting for a patient to recover consciousness. Should a wake-up test become necessary, an anaesthetic technique that facilitates more rapid, lucid recovery can be helpful. The low blood–gas partition coefficient of sevoflurane or the short, context-sensitive half-time of propofol may confer advantages in such scenarios. Previous studies have shown that recovery after sevoflurane is faster than after isoflurane, halothane and propofol.

The aims of this study were (i) to compare inhalational sevoflurane/nitrous oxide anaesthesia with total i.v. anaesthesia (TIVA) with propofol for their abilities to preserve SSEP monitoring signals during corrective scoliosis surgery, and (ii) to compare the wake up profiles of these techniques.

Patients and methods

Approval for this prospective, randomized study was obtained from the research ethics committee of the University of Hong Kong. Twenty patients with adolescent idiopathic scoliosis undergoing spinal fusion and instrumentation at the Duchess of Kent Children’s Hospital were enrolled. All patients were ASA class II. Patients with neurological deficit, congenital musculoskeletal disease, learning difficulties or cerebral palsy were excluded. Informed consent was obtained from all patients and their parents.

Patients were allocated randomly into two groups of 10. Randomization was done by drawing lots from an envelope containing 20 small pieces of paper, 10 marked ‘S’ and 10 marked ‘P’. Group 1 (lots marked S) received sevoflurane/nitrous oxide inhalational anaesthesia and Group 2 (lots marked P) received propofol TIVA. EMLA cream (AstraZeneca LP, Wilmington, USA) was applied to facilitate painless insertion of an i.v. cannula and patients were not premedicated. Anaesthesia was induced with alfentanil 40 mg kg⁻¹ and propofol 2–3 mg kg⁻¹. Atracurium 0.5 mg kg⁻¹ was given for muscle relaxation and was followed by tracheal intubation and intermittent positive pressure ventilation. Maintenance of anaesthesia in the sevoflurane group was provided with a mixture of 65% nitrous oxide and 35% oxygen with 0–3% sevoflurane [<1.5 minimum alveolar concentration (MAC)], titrated to clinical requirement. Anaesthesia was maintained in Group 2 by target-controlled infusion (TCI) of propofol (Diprifusor; AstraZeneca) at a plasma concentration of 2–5 µg ml⁻¹, titrated to clinical requirement while the patient was ventilated with 35% oxygen in air. Muscle relaxation was maintained with atracurium 0.3–0.5 mg kg⁻¹ h⁻¹. Intraoperative analgesia was provided by an alfentanil infusion of 0.4–1.0 µg kg⁻¹ min⁻¹, with intermittent boluses of 150–500 µg as required. No other opioid was given until after completion of the study. The infusion of atracurium was discontinued towards the end of surgery and reversed using neostigmine 40 µg kg⁻¹ and atropine 20 µg kg⁻¹. Patients were kept normothermic with forced air warmers.

Intraoperative monitoring included intraradial invasive arterial blood pressure, rectal temperature, capnography, end-tidal sevoflurane concentration, pulse oximetry, central venous pressure, urine output and peripheral nerve stimulation. Arterial blood gases and haematocrit were checked intermittently. SSEP signals were collected over Cz’ (2 cm posterior to Cz; 10–20 international system of EEG electrode placement) and Cv (over the cervical spinal process of C2) vs the Fz of the 10–20 system (Fig. 1). To elicit SSEPs, a pair of stimulating electrodes was applied over the posterior tibial nerve behind the medial malleolus. The stimulation current used ranged from 10 to 30 mA and was kept constant once selected for a particular patient. The normal current density was adjusted to produce a small movement of the toes. Single-pulse stimulation with a frequency between 5.1 and 5.7 Hz and duration of 200 µs was applied. An intraoperative spinal cord monitoring
system (Viking IV; Nicolet Biomedical, Madison, WI, USA) was employed to record the responses with a 20–3000 Hz bandpass filter. Continuous 100 times averaging was used. The initial negative and positive waves were identified in the SSEP tracings so that the latency and the peak-to-peak amplitude could be measured. The intensity changes related to anaesthesia were also noted during surgery. The mean values and standard deviations of these variables were calculated for each patient. The within-patient variability was calculated from the ratio of the standard deviation to the mean \[(SD/mean) \times 100\%\].

The results for the two groups were analysed statistically with the paired Student’s \(t\)-test, with the level of significance set at \(P<0.05\). Statistical analysis was performed using SPSS 8.0 for PC Windows (SPSS, Chicago, IL, USA). The changes in SSEP amplitude in response to changes in anaesthetic dose were analysed with a scatter chart corresponding to time, where the trend lines of SSEP amplitude and anaesthetic dose changes were plotted with a best-fit polynomial function. The delay period was measured between the inflection points of the trend line of anaesthetic dose and SSEP variables. The delay periods were defined as two types of change in anaesthetic dose. One was the dose-increase period, i.e. decrease in SSEP amplitude with increasing anaesthetic dose. The dose-increase period was measured from the time the dose was increased by 30% from the baseline to the time that the SSEP amplitude reached a plateau. The other was the ‘dose-decrease’ period, measured from the time that the dose was decreased back to baseline to the time that the SSEP amplitude increased to 70% of its baseline value.

Anaesthetic agents were stopped when the patient had been turned to the supine position after completion of surgery. Recovery was assessed with a simulated wake-up test. The patients were asked to open their eyes and move their toes and the time interval from cessation of anaesthesia was recorded. A behavioural score was determined at this point. As the physicians could not be blinded to the anaesthesia technique, it was necessary to provide a simple classification of the level of consciousness in order to decrease observer bias: 1=calm/cooperative/good; 2=confused/restless/disorientated; 3=drowsy/unable to obey commands.

**Results**

There were 10 patients in each group. All patients were female and Chinese. There was no significant difference between the groups with respect to age and weight. Table 1 shows the within-patient variability of SSEP variables related to the changes of doses of the different anaesthetic agents. Changing the anaesthetic dose produced little effect...
on the latency of SSEP. The effect on the variability of Cz’ SSEP amplitude was statistically significant (P<0.05) compared with Cv SSEP amplitude, suggesting that Cv SSEP is more resistant to the effects of anaesthesia. There was no difference between the two anaesthetic techniques in this regard.

The dose-increase and dose-decrease delay periods were both shorter in the sevoﬂurane group (P<0.05, Table 2), indicating a faster decrease in SSEP and faster recovery than for propofol. The recovery times are also shown in Table 2. There was no correlation between duration of anaesthesia or total dose of alfentanil and time to toe movement or eye opening (Table 3). A contingency table was constructed to compare the behavioural scores on emergence between the two groups (Table 4). Patients in the sevoﬂurane group were significantly more lucid and cooperative.

### Discussion

Spinal cord monitoring with SSEP has become a routine technique for detecting cord injury during spinal surgery, allowing early intervention to avoid permanent impairment. Its use has been found to correlate with neurosurgical outcome [13–15]. The effects of anaesthetic drugs on SSEP are, therefore, an important consideration. Our study shows that propofol and sevoﬂurane/nitrous oxide affect the amplitude of SSEP to a similar extent, assuming that the depth of anaesthesia is comparable in the two groups. Such a comparison, however, is difficult as it is not possible to measure the actual plasma concentration of propofol in real time (unlike end-tidal sevoﬂurane concentration) and, therefore, to make a direct comparison between sevoﬂurane MAC and the median effective concentration of propofol (EC50). The bias and accuracy of the TCI system used has, however, been shown to be satisfactory,¹⁶ ¹⁷ and clinical signs of anaesthetic depth were the same in both groups. Processed EEG modalities, such as the bispectral index (BIS) and the middle latency auditory evoked response (AEP), can be helpful in monitoring anaesthetic depth but neither has the sensitivity nor specificity to allow the clinician to draw conclusions about the depth of anaesthesia in individual patients. Furthermore, the values seen at similar clinical levels of anaesthesia vary according to the anaesthetic drug used.¹⁸ However, the possibility that sevoﬂurane has a lesser effect on SSEP because of differences in the depth of anaesthesia cannot be discounted.

A sevoﬂurane concentration up to 1.0 MAC was still compatible with SSEP recording.² Other studies have found that propofol/alfentanil TIVA provides a better signal-to-noise ratio than enﬂurane or isoflurane anaesthesia, thereby allowing more frequent and reliable intraoperative SSEP recordings.¹⁹ The TCI plasma propofol concentration that can preserve SSEP signals adequately is still to be determined. Our results also show that there is a significant change in SSEP Cz’ amplitude in response to changes in anaesthetic concentration when compared with SSEP Cv amplitude. This may reflect the cerebral effect of anaesthetic drugs rather than their effect on the spinal cord.

Sometimes a higher concentration of anaesthetic may be required during surgical manipulation and a drug that allows faster recovery of SSEP after readjustment therefore permits more accurate interpretation of the data. In this regard, we found that sevoﬂurane had significantly shorter dose-increase and dose-decrease periods than propofol. Also, the smaller standard deviation suggests that the recovery time required is more predictable than that with propofol. In interpreting SSEP, however, it is important to realize that false negative results may occur because monitoring is pathway-specific and an injury not involving the pathway may not be detected. Failure to monitor both latency and

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**Table 1** Within-patient variability of SSEP latency and amplitude in relation to changes in doses of sevoﬂurane and propofol. Values are mean percentage (SD). *P<0.05 compared with SSEP Cv amplitude (*t*-test)

<table>
<thead>
<tr>
<th>Dose variation</th>
<th>SSEP Cz’ Latency</th>
<th>SSEP Cz’ Amplitude*</th>
<th>SSEP Cv Latency</th>
<th>SSEP Cv Amplitude*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol</td>
<td>23.7 (11.4)</td>
<td>2.2 (1.0)</td>
<td>18.0 (8.2)</td>
<td>1.9 (0.9)</td>
</tr>
<tr>
<td>Sevoﬂurane</td>
<td>34.4 (13.4)</td>
<td>3.5 (1.8)</td>
<td>34.9 (11.7)</td>
<td>2.6 (2.0)</td>
</tr>
</tbody>
</table>

**Table 2** Anaesthetic effects on delay periods and the interval in minutes from cessation of anaesthetic to toe movement and eye opening. Values are mean (SD)

<table>
<thead>
<tr>
<th></th>
<th>Sevoﬂurane</th>
<th>Propofol</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose-increase period</td>
<td>9.0 (1.7)</td>
<td>13.5 (5.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dose-decrease period</td>
<td>16.1 (3.0)</td>
<td>35.0 (11.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Toe movement</td>
<td>7.9 (6.5)</td>
<td>15.7 (17.9)</td>
<td>0.22</td>
</tr>
<tr>
<td>Eye opening</td>
<td>5.1 (6.7)</td>
<td>20.6 (25.8)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

**Table 3** Pearson correlation coefficient (C) between duration of anaesthesia, total dose of alfentanil and eye opening and toe movement

<table>
<thead>
<tr>
<th></th>
<th>Toe movement</th>
<th>Eye opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of anaesthesia</td>
<td>C=−0.003</td>
<td>C=−0.03</td>
</tr>
<tr>
<td>Alphentanil</td>
<td>(P=0.99)</td>
<td>(P=0.89)</td>
</tr>
<tr>
<td></td>
<td>C=0.17</td>
<td>C=0.14</td>
</tr>
<tr>
<td></td>
<td>(P=0.47)</td>
<td>(P=0.55)</td>
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</table>

**Table 4** Contingency table showing numbers of patients with different behavioural scores on emergence (P<0.03, Fisher’s exact test)

<table>
<thead>
<tr>
<th>Score</th>
<th>Sevoﬂurane</th>
<th>Propofol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
amplitude or use of an insufficient number of recording electrodes can be responsible for false negative responses.20 Also, patients with preoperative deficits may not have detectable SSEPs. More and colleagues reported six patients in a series of 158 who had no detectable potentials before anaesthesia.21 False positive SSEP results may also occur as a result of changes in anaesthetic dose or technical problems, although the consequences are less serious. A large multicentre study of SSEPs for spinal cord monitoring found a sensitivity of 92%, specificity 98.9%, positive predictive value 42% and negative predictive value 99.93%.22 Changes in SSEP may also be produced by physiological factors such as severe hypotension, hypoxia, hyperthermia and a large decrease in haematocrit (to less than 15%).23 These did not occur in any of the patients in our study.

As well as a faster recovery time, our data from the behavioural scores showed that sevoflurane produces a better conscious state on emergence. As both groups were homogeneous with respect to age, sex, body weight, ethnicity and surgery, we can assume that this is related to the anaesthetic technique. Although there was some variation in the duration of anaesthesia and individual consumption of alfentanil, there was no correlation between the duration of anaesthesia or total dose of alfentanil per unit body weight and the recovery indices, i.e. times from cessation of anaesthesia to toe movement and eye opening. This is interesting, considering recent reports of restlessness in paediatric patients recovering from sevoflurane anaesthesia.24 25 A calm and cooperative patient is obviously preferable after spine stabilization surgery and in the event of a wake-up test being required.

Sevoflurane has been associated with more nausea and vomiting than propofol.11 In our study, two patients in the sevoflurane group developed postoperative nausea and vomiting, but none in the propofol group did so before commencement of patient-controlled anaesthesia with morphine. Although propofol appears to have intrinsic antiemetic properties, the number of patients in this study was too small to demonstrate this. One patient receiving sevoflurane had involuntary movement on wakening, but this was transient with no clinical consequence.

In conclusion, this study showed that both sevoflurane and propofol produced a significant change in SSEP amplitude but sevoflurane produced this change more quickly and with faster recovery than propofol. Patients receiving sevoflurane also had a faster, more predictable recovery from anaesthesia and a calmer, more cooperative state on emergence.

References


11 Smith I, Thwaites AJ. Target-controlled propofol vs sevoflurane: a double-blind, randomised comparison in day-case anaesthesia. Anaesthesia 1999; 54: 745–52


21 More RC, Nuwer MR, Dawson EG. Cortical evoked potential


