ORIGINAL ARTICLE

# Awareness during anaesthesia for surgery requiring evoked potential monitoring: A pilot study

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## Abstract

**Background:** Evoked potential monitoring such as somatosensory-evoked potential (SSEP) or motor-evoked potential (MEP) monitoring during surgical procedures in proximity to the spinal cord requires minimising the minimum alveolar concentrations (MACs) below the anaesthetic concentrations normally required (1 MAC) to prevent interference in amplitude and latency of evoked potentials. This could result in awareness. Our primary objective was to determine the incidence of awareness while administering low MAC inhalational anaesthetics for these unique procedures. The secondary objective was to assess the adequacy of our anaesthetic technique from neurophysiologist's perspective. **Methods:** In this prospective observational pilot study, 61 American Society of Anesthesiologists 1 and 2 patients undergoing spinal surgery for whom intraoperative evoked potential monitoring was performed were included; during the maintenance phase, 0.7–0.8 MAC of isoflurane was targeted. We evaluated the intraoperative depth of anaesthesia using a bispectral (BIS) index monitor as well as the patients response to surgical stimulus (PRST) scoring system. Post-operatively, a modified Bruce questionnaire was used to verify awareness. The adequacy of evoked potential readings was also assessed. **Results:** Of the 61 patients, no patient had explicit awareness. Intraoperatively, 19 of 61 patients had a BIS value of above sixty at least once, during surgery. There was no correlation with PRST scoring and BIS during surgery. Fifty-four out of 61 patient's evoked potential readings were deemed 'good' or 'fair' for the conduct of electrophysiological monitoring. **Conclusions:** This pilot study demonstrates that administering low MAC inhalational anaesthetics to facilitate evoked potential monitoring does not result in explicit awareness. However, larger studies are needed to verify this. The conduct of SSEP electrophysiological monitoring was satisfactory with the use of this anaesthetic technique. However, the conduct of MEP monitoring was satisfactory, only in patients with Nurick Grade 1 and 2. The MEP response was poor in patients with Nurick Grade 4 and 5.

**Key words:** Anaesthesia, anaesthesia depth monitor, awareness, evoked potential monitoring, spine

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## INTRODUCTION

Evoked potential monitoring has become imperative to monitor the integrity of neural pathways when surgeries are performed on the spine. These monitoring made the high risk, more extensive procedures possible and safe from a surgical perspective.[1] With the evoked



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potential monitoring, a decrease in amplitude of 50% or more and an increase in latency of 10% or more imply a loss of integrity of a neural pathway during surgery provided; there is no anaesthetic or temperature or blood pressure induced changes at that particular time.[2] One minimum alveolar concentration (MAC) of isoflurane causes 50% decrease in amplitude and 15% increase in latency.[1] Therefore, lower concentrations of MAC are required while monitoring the evoked potential during the conduct of general anaesthesia (GA) with this agent. Regarding motor-evoked potential (MEP) monitoring, a MAC of more than 0.87 causes inconsistencies and is difficult to interpret.[3] This entails the conduct of GA for a procedure requiring evoked potential monitoring such as somatosensory evoked potential (SSEP) and MEP with lower MAC of inhalational anaesthetic agents that could potentially lead to awareness.

Till date, there are no studies available in the literature which examined the existence of awareness in surgical procedures requiring low MAC of isoflurane (<0.8) to facilitate the evoked potential monitoring. Total intravenous anaesthesia (TIVA) with bispectral (BIS) monitoring is an alternative technique which is used to avoid the inhalational anaesthetics induced interference in evoked potential monitoring. However, it has obvious disadvantages of inability to monitor continuous blood concentration of intravenous agents as opposed to titrating the volatile agents with end-tidal concentrations, and the problem of delayed awakening when compared to volatile anaesthetics. In certain group of patients, TIVA can cause severe hypotension compared to volatile agents; finally, the cost GA with TIVA is higher when compared to volatile-based GA.

We conducted a prospective observational pilot study with a primary objective to verify the incidence of awareness related to these procedures. Our secondary outcome was to assess the adequacy of the anaesthetic technique to facilitate the evoked potential monitoring from the neurophysiologist point of view. The neurophysiologist was asked to grade the quality of evoked potential reading as 'good', 'fair' or 'poor'.

## MATERIALS AND METHODS

The study was carried out after the approval of Institutional Review Board and the Ethics Committee clearance. The internal fluid research grant of our institution funded the study. All patients of the American Society of Anesthesiologists (ASA) 1 and 2, aged between 15 and 80 years who underwent spine surgeries required MEP or SSEP monitoring, were included. Furthermore, we selected patients who spoke and understood either one of these languages such as Hindi, Tamil, Bengali or English. The study was carried out between December 2008 and September 2009. Patients with hearing defects, psychiatric illness and those who are unable to communicate were excluded from the study.

The day before surgery, the principal investigator visited the patients who met the inclusion criteria and informed about the study plan, details of the procedure and obtained the informed consent. On the day of surgery, all patients were brought to the operating room, and standard anaesthesia monitors such as electrocardiogram, pulse oximetry, invasive arterial pressure, end-tidal $CO_2$ and anaesthetic agent analyser, temperature, neuromuscular monitor and BIS were connected. Patients were induced and intubated with propofol (2 mg/kg), fentanyl (2–3 μg/kg), vecuronium (0.1 mg/kg). Maintenance of anaesthesia was carried out by air, oxygen, isoflurane (0.7–0.8 MAC), fentanyl (0.5–1 μg/kg/h) and vecuronium infusion (1–1.5 mg/h) to ensure a minimum of the 3–4 twitches in the train-of-four monitor. Soon after positioning the patient prone, headphones were placed in both ears of the patient and a pre-recorded story was played in his or her native language. Each story was an original one, made up by the investigators. Each story was about 3 min long and was repeatedly played throughout the surgery. The story had an unexpected ending to avoid guessing the storyline during the post-operative questionnaire in the absence of intraoperative recall. When the patient was ready to turn to supine position, the headphones were removed.

Supplemental analgesia included infiltrations of the surgical site with 2% lignocaine with adrenaline before surgical incision, intravenous paracetamol (20 mg/kg) or diclofenac (1–1.5 mg/kg). Blood pressure and heart rate and BIS were continuously monitored for every 5 min till the end of surgery. Since the patient was positioned prone and the head was away from the anaesthesiologist, we could only monitor the sweating not the lacrimation. The skin was examined for sweating for every 5 min. The warming device was switched off when the core temperature exceeded >36.5°C to avoid sweating which can be a misleading sign while recording the patients response to surgical stimulus (PRST) scoring.

PRST scoring[4] which takes into account of blood pressure (P) changes, heart rate (R) changes, the presence of sweating (S) and tears (T) was done with the previous 5$^{th}$ min reading as 'control' reading [Table 1]. If the score was more than two at any time, the corresponding BIS value was noted. If PRST score was >2, it was considered as positive PRST response which was treated with 0.5 mg/kg of propofol. The number of times propofol given was noted. The number of times the BIS value went more than sixty was also observed, but this was not treated. Episodes of hypotension were treated with phenylephrine (25 μg each) boluses. Hypertensive patients on antihypertensive medication were included

in this study, and a Fisher's exact test was planned to demonstrate whether PRST response would be affected by these drugs.

Since the occurrence of awareness is a relatively rare event, the sample size required to detect the incidence in any study is usually large. However, as the incidence of awareness for these specific procedures is unknown and needed to be verified, we planned to do a pilot study based on the number of cases performed per month at our institute. For this pilot study, we targeted a sample size of sixty (with the assumption of six cases per month for 10 months).

The neurophysiologist was consulted for each case regarding the strength of current used and the adequacy of the evoked potential response. Subjectively, the electrophysiological recordings were judged as 'good', 'fair' or 'poor' depending on recorded waveform. The reading was done to verify if this method of anaesthetic administration was conducive to monitor SSEP/MEP.

After the surgery, all patients were extubated and shifted to the ward or the Neurosurgical Intensive Care Unit according to the discretion of the anaesthesiologist and neurosurgeon. Patients were interviewed post-operatively between 24 and 48 h for awareness. During the post-operative interview, patients were enquired about his or her anaesthetic experience and asked for any relevant complaint regarding the operation. After the general discussion, specific questions were asked based on a modified Brice questionnaire[5] [Table 2] and some other questions related to the story were also asked. Based on the patient's response, the interviewer decided whether the patient had awareness or not. Explicit awareness was declared if patients came forward in saying they were awake during the procedure and could remember clearly excerpts from the story. Implicit awareness was reported if patients did not primarily remember being awake during the surgery, but after clues or prompts could recall parts of the story or if their responses to the Brice questionnaire suggested implicit awareness. If patients had unexplainable emotional disturbances or nightmares following the procedure, it was also considered as 'implicit awareness'. Patients were categorised into 'Definite' or 'Possible' category or 'absent' according to their answers. If they belonged to the 'Definite' or 'Possible' category, they were to be interviewed by the consultant anaesthesiologist and if necessary by a psychiatrist.

Patient data such as type of surgery and intraoperative details including BIS and PRST as well as the post-operative questionnaire were initially tabulated onto individual data sheets. Data were then transcribed into Microsoft Excel 2010 (©Microsoft 2010). Statistical analysis was performed using the programme Stata version 10 (Stata Inc., Texas, USA). Pearson's correlation coefficient ($r$) was used to verify the correlation between BIS and PRST.

**Table 1: Patient response to surgical stimulus scoring system**

| Index | Condition | Score |
|---|---|---|
| Systolic blood pressure (mmHg) | <Control* + 15 | 0 |
| | >Control + 15 and < control | 1 |
| | >Control + 30 and < control | 2 |
| Heart rate (beats/min) | <Control + 15 | 0 |
| | >Control + 15 and < control + 30 | 1 |
| | >Control + 30 | 2 |
| Sweating | Nil | 0 |
| | Skin moist | 1 |
| | Visible beads of sweat | 2 |
| Tears | No excess tears in open eyes | 0 |
| | Excess tears in open eyes | 1 |
| | Tears overflowing | 2 |

*Measurement at baseline (at commencement of maintenance of anaesthesia)

**Table 2: Post-operative questionnaire**

| |
|---|
| 1. Do you remember going to the operation theatre? |
| 2. What is the last thing you remember before going to sleep? |
| 3. What is the first thing you remember after waking up? |
| 4. Where did you wake up after the operation? |
| 5. Do you remember hearing anything or hearing anyone? |
| If yes, do you have any recollection of what was being said or what were they talking about? |
| 6. Did you have any dream during your operation or after the operation? |
| If yes, what type of dreams? |
| 7. What is your experience of the operation and anaesthesia? |
| 8. What would you say about your emotional state now as compared to before operation? |
| 9. If you have to have another operation, would you be happy to have the same anaesthetic? |
| 10. Do you remember feeling any pain? |
| If yes, when did you feel the pain and how severe - describe |

## RESULTS

There were 61 patients in total; 34 were male, 27 were female. The most of the patients (43 out of 61 [70.49%]) were ASA Grade 1 patients. The remaining 18 were ASA Grade 2 patients with comorbidities that included diabetes mellitus Type 2, essential hypertension and

chronic kidney disease. The most common indication for surgery in these patients was for removal of a tumour ($n$ = 53; 86.89%); five patients had surgery for trauma and three for surgical correction of a skeletal abnormality (e.g., spondylolisthesis, atlanto-occipital dislocation, kyphoscoliosis). Most of these surgeries lasted for 2–6 h (81.97%).

No patient reported being awake during the surgery (explicit awareness). Despite being given clues or prompts from the interviewer, no patient recalled any part of the story that was repeatedly played to them during their surgery. No patient reported any emotional change or disturbance post-operatively (awareness without recall). None of the patients had a recall of having any form of pain during the surgical period. Fifty-eight out of the 61 remember an IV line, arterial line, monitor or mask being placed before being anaesthetised. All 61 patients reported that they would like the same anaesthetic if they had to undergo another surgery.

Of the 61 patients in total, the PRST score became positive (PRST score >2) in 31 patients; about 55 times (more than once in some patients) [Figure 1]. Twenty-nine patients did not have a positive PRST response. Figure 2 depicts that 19 patients (31%) had a BIS value of more than sixty, two patients had BIS values of 75.

The PRST scoring system and BIS index monitoring had a poor correlation. Although the PRST score became positive 55 times, only in 5 out of these 55 episodes did the BIS score cross 60 at the same time (Pearson's correlation coefficient $r$ = 0.3). It is possible that underlying diseases (such as hypertension) and its medication (such as antihypertensive medication) may have influenced the PRST response. However, there was also no statistical difference in the PRST responses between those on antihypertensive medication and those not on anti-hypertensive medication [Table 3].

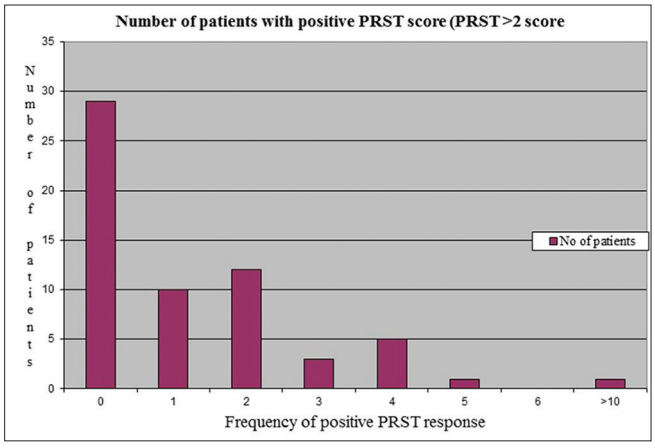


**Figure 1:** Bar graph depicting the frequency of patients response to surgical stimulus-response during surgery

Of total 61 patients, 22 had SSEP and 39 had MEP monitoring. Of 22 patients who had SSEP monitoring, 21 (96%) patient's readings were deemed to be 'good' and one patient's (4%) response was not readable because of technical error. Of 39 who had MEP monitoring, 30 (78%) had 'good' response and 3 (7%) had 'fair' and 6 (15%) had 'poor' response. Table 4 shows the details of evaluation about the quality of evoked potential monitoring.

## DISCUSSION

In this pilot study, we aimed to verify whether awareness could be present while administering low MAC (0.7–0.8) isoflurane anaesthesia to enhance the quality of evoked potential monitoring in patients undergoing spine surgeries. Evoked potential monitoring is often useful[6] and imperative for surgical procedures that are done in proximity to the spinal cord. Various anaesthetics such as

**Table 3: Difference in patients response to surgical stimulus responses between hypertensives and non-hypertensives**

| Anti-hypertensive | PRST response absent | PRST response present | Fisher's exact test ($P$<0.05) |
|---|---|---|---|
| No | 26 | 25 | 0.31 |
| Yes | 3 | 7 | |

PRST=Patients response to surgical stimulus

**Table 4: The details of evaluation about the quality of evoked potential monitoring**

| Type of neurophysiological monitoring | Quality of neurophysiological monitoring (%) | | |
|---|---|---|---|
| | Good | Fair | Poor |
| SSEP (22/61) | 21 (96) | - | 1 (4) technical error |
| MEP (39/61) | 30 (78) | 3 (7) | 6 (15) |

SSEP=Somatosensory-evoked potential, MEP=Motor-evoked potential

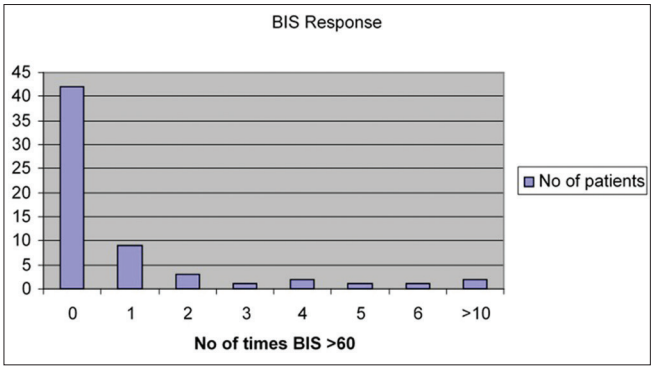


**Figure 2:** Bar graph depicting the frequency of bispectral responses more than sixty during surgery

the higher concentration of volatile anaesthetics, nitrous oxide, bolus doses of propofol and midazolam all can impede their smooth conduct.[7-9] This entails restricting their use which could lead to awareness during the surgical procedure. Awareness during the conduct of evoked potential monitoring has not been investigated. Therefore, we felt a need to verify its presence or absence by conducting this pilot study.

Awareness is a phenomenon that is hard to detect, and there is no standard intraoperative monitoring technique[10] available due to lack of our understanding of consciousness and memory. Explicit awareness may be relatively straight forward to elicit when the patient declares that he or she has definitely experienced the sense of being awake during the procedure. Implicit memory, however, is not so easy to elicit and often only subtle behavioural or hormone level changes may be the only clue.[11,12] The PRST scoring was devised to detect the intraoperative awareness in patient undergoing surgery.[4] The presence of awareness or light plane of anaesthesia often detected by surges in the heart rate, blood pressure and by the presence of sweating/tearing. Isolated forearm technique is an another reliable technique, but it is hard to employ this tool for long surgeries.[13] Mid-latency auditory-evoked potentials although promising, it is complex and not widely used. In our study, we had used the PRST score along with BIS during surgery, and the modified Brice interview - a post-operative questionnaire,[14] was used to detect the intraoperative awareness. In our pilot study, none of the patients had either explicit or implicit recall of the events in the operating room when standard tests were used for testing awareness in the post-operative period. However, the study was a small-scale pilot study; larger studies are needed to verify this when inhalational agents are delivered at low MAC to facilitate the neurophysiological monitoring.

Haemodynamic changes may not be very precise in detecting the light plane in patients undergoing surgery on the spinal cord or close to spinal cord because of root stimulation or spinal cord manipulation.[15] Our study result also confirmed that haemodynamic perturbations as represented by the positive PRST score are frequent during spine surgery, but it was not always associated with the light plane of anaesthesia as indicated by low BIS value during the positive PRST score. While correlating all the positive PRST scores (>2) with positive BIS responses (>60), only five values of high BIS recordings had a corresponding simultaneous positive PRST response indicating that PRST scoring is not reliable for detecting awareness in spine surgery.

While evaluating the adequacy of the anaesthetic technique on patient satisfaction, all patients claimed that they would like the same anaesthetic if they had to have another procedure. From the neurophysiologist point of view, recordings deemed to be 'good' for all patients who had SSEP monitoring except in one (technical error), indicating that this technique is satisfactory for SSEP monitoring. While the conduct of MEP monitoring, 6 out of 39 patients had poor response. While evaluating the cause for the poor response, we have found that all six patients had poor Nurick grading (Grade 4 and 5). Our study results indicate that this anaesthetic technique is satisfactory for MEP monitoring in patients with good Nurick grading (Grade 0–2) but not for patients with poor Nurick grading (Grade 4 and 5). Table 5 shows the Nurick grading.[16] Our success rate is similar to that of other studies.[17]

There are several limitations in our study; first of all, assessment of the depth of anaesthesia using PRST scoring will not be very reliable in the surgeries involving spinal cord. Furthermore, it is possible that underlying diseases (such as hypertension, long-standing diabetes) and its medication could have influenced the PRST response. Second, a long-term follow-up of patients was not done. This follow-up may have been useful in detecting awareness as some studies indicate.[18] Finally, this study is only a pilot study, and a large number of patients are required to make a conclusion whether the incidence of awareness is higher in these procedures requiring evoked potential monitoring compared to the overall incidence reported in other studies.

## CONCLUSIONS

This pilot study demonstrates that administering anaesthesia with low MAC (0.7–0.8) of inhalational anaesthetics to facilitate evoked potential monitoring does not result in explicit awareness. However, larger studies are needed to verify this. The conduct of SSEP electrophysiological monitoring was satisfactory with the

**Table 5: Nurick scale: A six grade system (0-5) based on the 'difficulty in walking'**

| Grade | Level of neurological involvement |
|---|---|
| Grade 0 | Signs or symptoms of root involvement but without evidence of spinal cord disease |
| Grade 1 | Signs of spinal cord disease but no difficulty in walking |
| Grade 2 | Slight difficulty in walking which does not prevent full-time employment |
| Grade 3 | Difficulty in walking which prevented full-time employment or the ability to do all housework, but which was not so severe as to require someone else's help to walk |
| Grade 4 | Able to walk only with someone else's help or with the aid of a frame |
| Grade 5 | Chair bound or bedridden |

use of this anaesthetic technique. However, the conduct of MEP monitoring was satisfactory only in patients with Nurick Grade 1 and 2 and it is not satisfactory or poor for patients with Nurick Grade 4 and 5.

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## Conflicts of interest

There are no conflicts of interest.

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