

PLETH VARIABILITY INDEX PREDICTS EYE OPENING AFTER ISOFLURANE ANAESTHESIA

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ABSTRACT

Background: General anaesthesia allows pain-free surgery; however, predicting recovery can be challenging. The Pleth Variability Index (PVI), a non-invasive pulse oximetry parameter, reflects autonomic activity and may predict eye-opening time. This study evaluated the correlation between PVI and eye opening after isoflurane anaesthesia. **Materials and Methods:** This prospective observational study included 30 ASA I–II patients >18 years undergoing elective fibroadenoma surgery. Baseline perfusion index PVI, heart rate, and MAP were recorded before induction. Anaesthesia was induced with propofol (2 mg/kg) and fentanyl (2 µg/kg) and maintained with isoflurane 1.3% minimum alveolar concentration (MAC). Measurements were taken at 15 minutes after induction, end of surgery, and at eye opening, assessed by verbal or tactile response. **Result:** MAP decreased from 81±12 mmHg pre-anaesthesia to 60±6 mmHg at 15 min, 64±8 mmHg at the end of surgery, and returned to 80±8 mmHg at eye opening. Heart rate decreased from 88±12 bpm to 63±6 bpm at 15 min, 62±4 bpm at the end of surgery, and increased to 83±10 bpm at eye opening. Perfusion index increased from 2.2±1.6 pre-anaesthesia to 8.9±3 at 15 min and 10.1±3.6 at the end of surgery, then decreased to 2.5±1.6 at eye opening ($P<0.05$). PVI decreased from 15.5±8.8 pre-anaesthesia to 7.7±1.3 at 15 min, 4.6±0.9 at the end of surgery, and rose to 16.3±2.2 at eye opening ($P<0.05$). PVI at surgery end showed strong correlation with eye opening ($r^2=0.76\pm0.09$). **Conclusion:** PVI significantly decreased during isoflurane anaesthesia and increased eye opening, correlating with the return of consciousness. PVI may serve as a reliable, non-invasive predictor of eye opening, improving perioperative monitoring, and patient recovery.

INTRODUCTION

General anaesthesia is essential for modern surgeries because it makes procedures painless and safe for patients.^[1] Doctors usually check how deep the anaesthesia is by looking at clinical signs and using invasive monitors, but these methods can be subjective and may not always show how well a patient is recovering in real time.^[2] Recently, noninvasive monitors like the Pleth Variability Index (PVI) have been developed to give information about the autonomic nervous system during anaesthesia.^[3,4] studying how PVI values relate to recovery indicators, such as when a patient can open their eyes, could help improve patient care around the time of surgery.

PVI is a dynamic measure that comes from changes in the pulse oximeter waveform while the patient breathes. Blood flow in the limbs varies with changes in intravascular volume, vascular tone, and sympathetic activity.^[5] Studies have shown that the

PVI reflects a patient's response to fluid administration and assists anaesthesiologists in managing intraoperative fluids, particularly in mechanically ventilated patients. PVI has also been investigated as a marker for anaesthetic depth and recovery time, including the interval to eye opening after surgery.^[6,7]

Eye opening marks the return of consciousness and indicates the diminishing effect of anaesthetic drugs.^[8] Conventional parameters such as heart rate and mean arterial pressure (MAP) may not reliably represent this stage, as they can fluctuate due to pain, medication, or autonomic changes unrelated to anaesthetic depth.^[9] Identifying a non-invasive, objective measure that corresponds with eye opening could improve monitoring of recovery and enhance postoperative care.

Identifying early recovery indicators is clinically valuable, as delayed emergence may prolong operating room time and affect patient safety. Previous research has explored how the PVI relates

to postoperative recovery across different anaesthetic techniques. One report observed that the pulse perfusion component of PVI could serve as an indicator of recovery, as higher values were associated with earlier eye opening following sevoflurane anaesthesia.^[10] However, there is little information about how these results apply to isoflurane anaesthesia. Because anaesthetic drugs work differently in the body, it is important to check if PVI can also predict eye opening with isoflurane anaesthesia. This study looked at the link between PVI and the time it takes for patients to open their eyes after isoflurane anaesthesia in planned fibroadenoma surgeries, aiming to find out if PVI is a useful, non-invasive marker of recovery.

MATERIALS AND METHODS

Study design and setting: This prospective observational study took place in the operating theatre of the Department of Anaesthesia at Tirunelveli Medical College over two months. The study involved 30 patients scheduled for fibroadenoma surgery, all of whom underwent general anaesthesia with isoflurane. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was secured from each patient before inclusion in the study.

Inclusion criteria

Patients aged 18 years and above with an American Society of Anesthesiologists (ASA) physical status of I or II, scheduled for elective surface surgeries lasting approximately one hour, were included in the study.

Exclusion criteria

Patients with known cardiovascular or respiratory illness, diabetes mellitus, or peripheral vascular disease, receiving antihypertensive therapy, during surgery, any participant who developed hypotension, required vasoactive support to maintain blood pressure, or received a blood transfusion due to excessive blood loss were excluded.

Methods: Eligible participants were monitored continuously before, during, and after surgery with standard anaesthesia equipment. Baseline measurements included the perfusion index, PVI, heart rate, MAP, and oxygen saturation, recorded before induction of anaesthesia. Anaesthesia was induced with intravenous propofol (2 mg/kg) and fentanyl (2 µg/kg), followed by insertion of a laryngeal mask airway. Maintenance was achieved using isoflurane at 1.3% minimum alveolar concentration (MAC) in a gas mixture of oxygen and

nitrous oxide. Mechanical ventilation was set to deliver a tidal volume of 8 mL/kg at 12 breaths per minute with an inspired oxygen fraction of 50%.

PVI, perfusion index, heart rate, and MAP were recorded at four time points: before induction, 15 minutes after induction, at the end of surgery, and at the time of eye-opening following discontinuation of anaesthesia. If MAP fell below 60 mmHg during surgery, intravenous ephedrine was administered as required. Fluids were given at a rate of 20 mL/kg per hour to keep the patient well hydrated. To check if the patient had regained consciousness, they were asked to open their eyes in response to a voice or light touch. All this information was collected to find out how PVI was related to the time it took for patients to open their eyes after isoflurane anaesthesia.

Statistical analysis: Data are expressed as the mean $\pm$ standard deviation for continuous variables and as frequencies and percentages for categorical variables. Comparisons between time points were made using repeated-measures analysis of variance (ANOVA). Statistical significance was set at $P < 0.05$. Data analysis was performed using IBM SPSS Statistics v25.

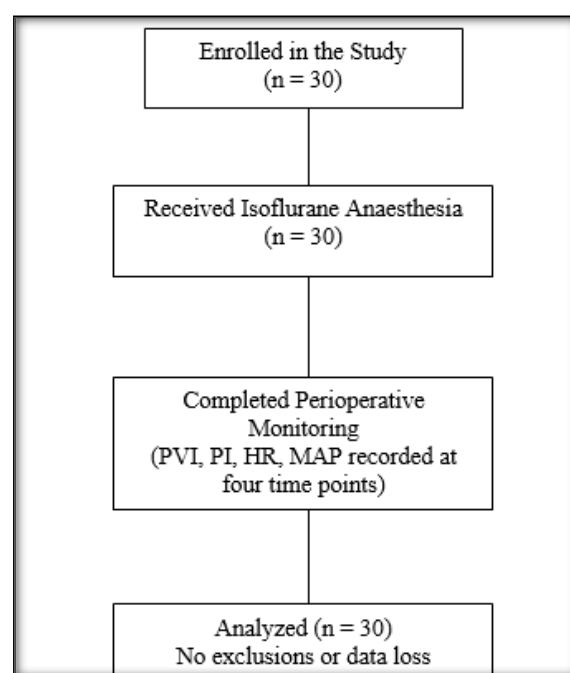


Figure 1: Consort diagram

RESULTS

The study included patients with a mean age of 20 ± 11 years and a mean weight of 53 ± 7 kg [Table 1].

Table 1: Patient characteristics

Variable	Mean $\pm$ SD
Age (years)	20 ± 11
Weight (kg)	53 ± 7

The MAP decreased from 81 ± 12 mmHg before anaesthesia to 60 ± 6 mmHg 15 min after induction and slightly increased to 64 ± 8 mmHg at the end of

surgery, returning to 80 ± 8 mmHg at eye opening. Similarly, the heart rate decreased from 88 ± 12 bpm pre-anaesthesia to 63 ± 6 bpm at 15 min after

induction and 62 ± 4 bpm at the end of surgery, and then rose to 83 ± 10 bpm at eye opening [Table 2].

Table 2: Comparison of non-invasive mean blood pressure and heart rate before and under anaesthesia and at eye opening

Parameter	Pre-anaesthesia	Anaesthesia 15 min	End of surgery	Eye opening	P value
MAP (mmHg)	81 ± 12	60 ± 6	64 ± 8	80 ± 8	<0.0001
Heart rate (bpm)	88 ± 12	63 ± 6	62 ± 4	83 ± 10	<0.0001

The perfusion index increased significantly from 2.2 ± 1.6 pre-anaesthesia to 8.9 ± 3 at 15 minutes after induction and 10.1 ± 3.6 at the end of surgery, and then returned to 2.5 ± 1.6 at eye opening ($P < 0.05$). The pleth variability index decreased from 15.5 ± 8.8 pre-anaesthesia to 7.7 ± 1.3 at 15 minutes and $4.6 \pm$

0.9 at the end of surgery, rising again to 16.3 ± 2.2 at eye opening ($P < 0.05$). A strong positive correlation was observed between PVI values at the end of surgery and at eye opening ($r^2 = 0.76 \pm 0.09$) (Table 3, Figures 2 and 3). No adverse events or data exclusions occurred during the study period.

Table 3: Comparison of perfusion value and Pleth variability index value before and under anaesthesia and at eye opening after the anaesthesia period

Parameter	Pre-anaesthesia	Anaesthesia 15 min	End of surgery	Eye opening	P value
Perfusion index	2.2 ± 1.6	8.9 ± 3	10.1 ± 3.6	2.5 ± 1.6	<0.0001
Pleth variability index	15.5 ± 8.8	7.7 ± 1.3	4.6 ± 0.9	16.3 ± 2.2	<0.0001

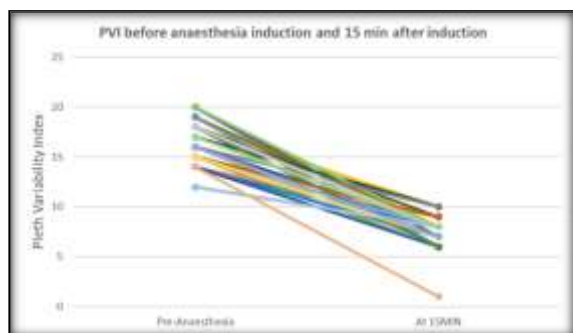


Figure 2: PVI values before and 15 min after anaesthesia induction

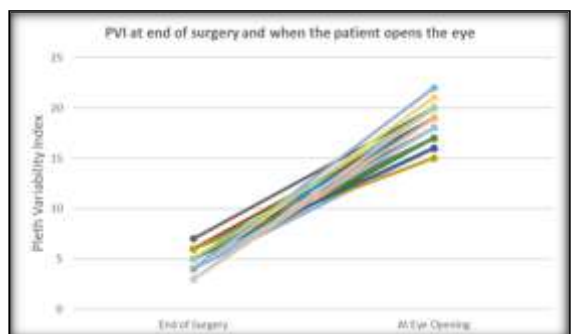


Figure 3: PVI index values at the end of surgery and when the patient opened their eyes.

DISCUSSION

This study examined whether the PVI could predict the return of consciousness, measured by eye opening, after isoflurane anaesthesia. PVI values declined during the maintenance phase of anaesthesia and rose again as patients regained responsiveness, whereas the perfusion index showed the opposite pattern. These changes reflect autonomic modulation during emergence from anaesthesia. The observed correlation between PVI at the end of surgery and at eye opening recommends its potential as a reliable indicator of awakening under isoflurane.

Conventional indicators such as heart rate and MAP often vary with multiple intraoperative factors; PVI appears to provide a more direct reflection of autonomic recovery. Clinically, integrating PVI into intraoperative monitoring could aid in anticipating patient awakening and optimizing anaesthetic titration.

In our study, the mean age of the patients was 20 ± 11 years and the mean weight was 53 ± 7 kg. In contrast, Enekvis et al. reported a mean age of 58 ± 11 years, a mean weight of 63 ± 9 kg, height of 1.64 ± 0.05 m, and BMI of 23.5 ± 2.9 among 20 patients.¹⁰ Similarly, Ryu et al. reported a mean age of 42 years (range, 19–65) in the desflurane group and 42 years (range, 22–61) in the sevoflurane group. The mean weight was 70 ± 10 kg in the desflurane group and 66 ± 12 kg in the sevoflurane group.^[11] Likewise, Bedi et al. reported a mean age of 46.6 years among 76 patients, with the majority of patients being middle-aged (52.6%).^[12] Compared to earlier reports, our patients were generally younger and had lower body weight.

In our study, MAP decreased after induction of anaesthesia, showed a slight increase by the end of surgery, and returned close to baseline at eye opening. Heart rate similarly decreased after induction, remained lower during surgery, and increased again at eye opening. Similarly, Enekvis et al. reported MAP of 81 ± 14 mmHg pre-anaesthesia, 63 ± 8 mmHg at 15 minutes, 66 ± 6 mmHg at the end of surgery, and 78 ± 10 mmHg at eye opening, with HR of 80 ± 11 bpm pre-anaesthesia, 65 ± 8 bpm at 15 minutes, 64 ± 6 bpm at the end, and 73 ± 8 bpm at eye opening.¹⁰ Likewise, Ajayan et al. reported baseline HR of 88.57 ± 20.01 bpm (isoflurane) and 80.41 ± 14.11 bpm (sevoflurane), MAP 94.10 ± 10.56 mmHg and 96.22 ± 12.36 mmHg, pre-noxious HR 78.23 ± 12.21 bpm and 71.45 ± 10.13 bpm, MAP 85.37 ± 8.05 mmHg and 81.88 ± 8.10 mmHg, and post-noxious HR 103.11 ± 15.17 bpm and $95.42 \pm$

9.08 bpm, MAP 100.36 ± 8.14 mmHg and 97.12 ± 9.86 mmHg.^[13]

In a study by Tsuchiya et al., a pre-anaesthesia HR of 74 ± 12 bpm was reported, which decreased to 68 ± 10 bpm during anaesthesia induction. SBP decreased from 135 ± 14 mmHg to 95 ± 13 mmHg, DBP decreased from 74 ± 10 mmHg to 57 ± 10 mmHg, and MAP decreased from 92 ± 9 mmHg to 68 ± 10 mmHg.^[14] The observed decreases in MAP and HR during induction, followed by recovery, reflect expected haemodynamic responses across anaesthetic agents, and study populations closely resemble the patterns reported by earlier studies.

In our study, the perfusion index increased after induction of anaesthesia, continued to rise by the end of surgery, and returned close to baseline at eye opening. The pleth variability index decreased after induction, remained lower during surgery, and increased again at eye opening. Same as ours, Enekvist et al. also reported perfusion values of 2.2 ± 1.6 pre-anaesthesia, 8.9 ± 3.0 at 15 minutes, 10.1 ± 3.6 at the end of surgery, and 2.5 ± 1.6 at eye opening. The BIS values were 96 ± 2.5 , 51 ± 7.6 at 15 minutes, 46 ± 7.7 , and 69 ± 13.7 , respectively, at the end of surgery and eye opening. PV values correlated with end of surgery and eye opening of $r^2 = 0.76 \pm 0.09$.¹⁰ Similarly, Ryu et al. reported PI values of 9.1 ± 2.8 (desflurane) and 5.8 ± 2.7 (sevoflurane) pre-stimulation, and 5.6 (4.6 – 6.8) and 2.8 (1.9 – 3.9) post-stimulation, respectively.^[11]

Similarly, Bedi et al. reported baseline PVI values of 22.3 ± 8.2 in responders and 10.1 ± 2.9 in non-responders ($P < 0.001$). PVI decreased over 30 minutes post fluid challenge in both groups, with higher baseline values in responders and a gradual decline over time.^[12] In Ajayan et al. reported baseline PI of 1.40 (1 – 1.7) in the isoflurane group and 1.41 (0.9 – 1.8) in the sevoflurane group. Pre-noxious stimulus PI increased to 4.71 (4 – 5.8) and 4.80 (4.2 – 5.5), while post-noxious stimulus PI decreased to 3.00 (2.3 – 4.2) and 2.70 (2.1 – 3.6).^[13]

Similarly, Abdel-Ghaffar et al. reported baseline median PI 0.7 (0.2 – 2.7), which increased during induction and intraoperatively, reaching 1.5 (0.5 – 5.2) at spontaneous eye opening. The AAI inversely changed with PI, decreased during anaesthesia, and increased during recovery. Correlation analysis showed a moderate negative correlation between PI and AAI at the 5th minute ($r = -0.457$, $P = 0.008$).^[15] Increases in PI and decreases in PVI during surgery, followed by reversal at eye opening, reflect predictable haemodynamic and autonomic changes under anaesthesia, align with findings from earlier studies. Factors such as temperature, ventilation settings, and peripheral perfusion may influence PVI readings and should be controlled in future studies.

Limitations: This study was conducted at a single centre, which may limit the generalisability of the findings. Additionally, the study involved a small sample size and short-term observations, preventing the assessment of long-term outcomes or broader patient populations.

CONCLUSION

PVI dropped noticeably while patients were under isoflurane anaesthesia but increased again when patients opened their eyes. The perfusion index changed in the opposite way. There was a strong positive link between PVI values at the end of the surgery and the time when patients opened their eyes. These results show that PVI measures are connected to when consciousness returns and could be a reliable, non-invasive way to predict eye opening after isoflurane anaesthesia. Further research with larger, multicentre samples and a variety of surgical procedures and anaesthetic agents is needed to confirm these results. Incorporating PVI assessment during recovery may enhance the objectivity and safety of anaesthetic emergence monitoring.

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