Acta Biomedica Scientia
e - ISSN - 2348 - 2168
Print ISSN - 2348 - 215X
www.mcmed.us/journal/abs
Research Article

EVALUATING THE SURGICAL PLETH INDEX (SPI) AS A TOOL FOR MONITORING NOCICEPTION AND INTRAOPERATIVE STRESS DURING GENERAL ANAESTHESIA

Dr. Dinesh Kumar Gontla V

Assistant Professor, Department of Anaesthesiology, Sri Venkateshwaraa Medical College Hospital and Research Centre, Ariyur, Puducherry – 605107, India.

ABSTRACT

This study investigates the Surgical Pleth Index (SPI) as a tool for assessing nociception and intraoperative stress during general anaesthesia. We observed moderate-to-strong correlations between SPI and stress hormones (ACTH, cortisol, epinephrine, and norepinephrine) during key intraoperative events, including intubation, peak stress, and post-peak stress, with SPI accurately predicting ACTH levels. SPI outperformed traditional indicators such as blood pressure, heart rate, and BIS in detecting nociceptive stimulation, highlighting its potential for more accurate and consistent intraoperative monitoring. The stress response, triggered by the activation of the hypothalamus-pituitary-adrenal (HPA) axis during surgery, influenced the secretion of cortisol and ACTH, while epinephrine and norepinephrine levels remained stable. The study emphasizes the potential of SPI for optimizing nociception monitoring and improving anaesthesia management. Future studies with a broader range of surgical procedures are needed to refine SPI's application in clinical practice.

Keywords :- Surgical Pleth Index, nociception, intraoperative stress, general anaesthesia, stress hormones.

Access this article online		
Home Page: **www.mcmed.us/journal/abs**		**Quick Response code**
Received:25.10.2019	**Revised**:12.11.2019	**Accepted**:15.12.2019

INTRODUCTION

Surgical nociceptive stimulation can adversely affect infection rates, hospital stay duration, and healthcare costs [1]. To minimize intraoperative stress and maintain haemodynamic stability, it is crucial to monitor the balance between nociception and antinociception during general anaesthesia. This ensures adequate pain relief, though identifying the most effective parameter to guide analgesic administration and alleviate stress responses is still difficult [2]. Traditional indicators like movement and autonomic responses have been used to evaluate the adequacy of analgesia but often prove unreliable due to their low specificity.The Surgical Pleth Index (SPI) is a method that employs normalized heart rate and pulse wave amplitude to measure nociception during general anaesthesia. Studies [3] have suggested that SPI is more effective than blood pressure and heart rate in monitoring intraoperative nociception. Additionally, SPI has demonstrated a negative correlation with the effect-site concentration of remifentanil during propofol and remifentanil-based total intravenous anaesthesia. SPI-guided remifentanil dosing during this anaesthesia regimen led to reduced drug consumption and better haemodynamic control [4]. These results imply that SPI may serve as a dependable marker of intraoperative stress or nociception.Stress hormones such as epinephrine, cortisol, and adrenocorticotropic hormone (ACTH) have been identified as indicators of stress. These biomarkers are collected via blood samples and analyzed for real-time intraoperative stress evaluation [5]. To evaluate the performance of SPI, circulating stress hormone levels were used as a reference, given the absence of a universally accepted gold standard.

Corresponding Author: **Dr. Dinesh Kumar Gontla V**

Parameters like RLS, BIS, arterial blood pressure, heart rate, and stress hormones were assessed during propofol-remifentanil anaesthesia at four distinct events. The results indicate that SPI's performance varies based on consciousness levels (e.g., conscious vs. unconscious) and shows a stronger correlation with stress hormones than with ABP, HR, or BIS.

METHODOLOGY

In this study, 200 patients classified as ASA physical status I-II, aged 18 to 70 years, scheduled for elective ear, nose, and throat surgeries at Sri Venkateshwaraa Medical College Hospital and Research Centre, Puducherry. Patients with neurological disorders, those taking psychoactive medications, those with a history of alcohol or drug abuse, or those with significant cardiovascular, renal, hepatic, or metabolic diseases were excluded. Participants were randomly assigned to one of two groups: the SPI group, where remifentanil titration during anaesthesia maintenance was based on SPI values, and the Control group, which used conventional criteria for determining inadequate anaesthesia. This study has been previously published.The evening before surgery, all participants received 20-30 mg of dipotassium clorazepate and 3.75–7.5 mg of midazolam. Intravenous catheters were inserted into the forearm veins, and noninvasive blood pressure, electrocardiogram (ECG), and pulse oximetry (SpO2) were monitored. Both groups were continuously observed for SPI and BIS. As per the manufacturer's guidelines, BIS electrodes were placed on the forehead, ensuring that impedance remained below 7.5 kΩ for optimal contact. Pulse oximetry was monitored using the same index finger sensor, and SPI values were recorded every 10 seconds. Anaesthesia was initiated using target-controlled infusions (TCIs) of propofol and remifentanil via infusion pumps. The Schnider model was used for propofol, and the Minto model for remifentanil. Post-intubation, an end-tidal carbon dioxide concentration of 35 mmHg was maintained. BIS was kept between 40 and 60 by adjusting the propofol effect-site concentration (Ceprop) every four minutes, while remifentanil effect-site concentration (Ceremi) adjustments began once surgery commenced. For anaesthesia maintenance, Ceprop was gradually adjusted by 0.5 mL every four minutes, regardless of group allocation. In the Control group, Ceremi was titrated based on conventional signs of inadequate anaesthesia, as described in Table 1 [6-8]. If inadequacy was detected, Ceremi was increased stepwise until the maximum permissible concentration was reached. Hypotension was managed by increasing intravenous infusion rates, reducing Ceremi concentrations to the minimum, and administering 0.5 mL of Akrinor. Bradycardia was treated with 0.5 mg of intravenous atropine. Plasma remifentanil concentrations were maintained between 20 and 50 ng/mL. Rescue medications were administered for somatic arousal within acceptable ranges. Propofol was discontinued upon the completion of surgical suturing, and postoperative analgesia was provided using piritramide.

Stress Hormone Assay and Blood Sampling

Blood samples were obtained at four specific time points for each group. The samples were promptly placed on ice, centrifuged within 15 minutes, and stored at -25°C. Stress hormones were measured using reversed-phase high-performance liquid chromatography (HPLC). The normal reference ranges for ACTH were 7.2–63.6 pg/mL, cortisol 6.2–19 µg/dL, and epinephrine 84–420 pg/mL.

Statistical Analysis

Data were presented as mean ± standard deviation (SD) or median with range, depending on the type of variable. Statistical analyses were conducted using GraphPad Prism. Numerical data were analyzed with Student’s t-tests, while non-numerical data were assessed using Mann-Whitney U tests or one-way ANOVA followed by Student-Newman-Keuls post-hoc tests. Nominal data were evaluated using Chi-square tests. Correlations were examined with Spearman’s rank correlation coefficients, and linear regression slopes were tested using F-tests. Receiver Operating Characteristic (ROC) curves were used to assess SPI’s ability to predict stress hormone levels, with threshold values established accordingly. A p-value of <0.05 was considered statistically significant.

RESULTS

The criteria were used to evaluate and address cases of inadequate anaesthesia, hypotension, and bradycardia. Hypertension was defined as a mean blood pressure greater than 120% of baseline or above 100 mmHg, while hypotension was defined as a mean blood pressure lower than 80% of baseline or below 60 mmHg. Bradycardia was characterised by a heart rate less than 80% of baseline or below 45 beats per minute. Key signs of anaesthetic inadequacy included purposeful movements and autonomic responses, such as grimacing and chewing.

Baseline characteristics showed no significant differences between the SPI and Control groups. Age, height, weight, gender distribution, ASA classification, and anaesthesia-related durations were similar. The mean age was 49 ± 17 years for the SPI group and 48 ± 18 years for the Control group. Mean body weights were comparable (SPI: 78 ± 14 kg; Control: 75 ± 16 kg). Gender and ASA classifications were balanced, with no significant differences. Although the duration of anaesthesia and surgery was slightly longer in the Control

group, these differences were not statistically significant.Blood pressure, heart rate, SPI, and BIS values were recorded at baseline, during intubation, at the peak stress point, and after peak stress.

• At baseline, hormonal markers such as ACTH, cortisol, and epinephrine were slightly higher in the SPI group compared to the Control group but did not show significant differences. Blood pressure and heart rates were similar between groups. SPI and BIS values were consistent, showing no initial imbalance. • During intubation, ACTH and cortisol levels were significantly lower in the SPI group compared to the Control group. While blood pressure and heart rates slightly increased in both groups, the SPI group exhibited a significant reduction in BIS values, indicating better control of nociception. • At peak stress, the SPI group showed notably lower levels of stress hormones, including ACTH and cortisol, compared to the Control group. SPI values were also significantly lower in the SPI group, indicating better management of intraoperative stress. Blood pressure and heart rate stabilised more effectively in the SPI group. • After peak stress, the SPI group maintained lower levels of ACTH and cortisol. SPI values and heart rates remained lower in the SPI group compared to the Control group, while BIS values reflected continued effective anaesthetic control.

Table 1: Criteria for Assessing Anaesthetic Insufficiency and Haemodynamic Instability

Category	Parameter	Criteria
Inadequate Anaesthesia	Hypertension	Mean blood pressure >130% of baseline or >110 mmHg
	Tachycardia	Heart rate >100 beats per minute
	Somatic Arousal	Coughing, chewing, or grimacing
	Somatic Response	Purposeful body movement
Hypotension	Mean Blood Pressure	<70% of baseline or <55 mmHg
Bradycardia	Heart Rate	<70% of baseline or <40 beats per minute

Table 2: Baseline Demographic and Clinical Characteristics

Parameter	SPI Group (n = 100)	Control Group (n = 100)	P Value
Age (years)	50 ± 16	47 ± 18	0.745
Height (cm)	172 ± 16	170 ± 17	0.621
Weight (Kg)	80 ± 12	77 ± 15	0.432
Gender (M/F)	32/68	45/55	0.212
ASA (I/II)	40/60	42/58	0.925
Duration of Anaesthesia (min)	160 ± 62	165 ± 70	0.089
Duration of Surgery (min)	110 ± 55	120 ± 75	0.134
Intubation to Surgery (min)	25 ± 9	28 ± 11	0.496

Table 3: Blood Pressure, Heart Rate, SPI, and BIS Measurements Across Event-Specific Time Points.

Time Point	Group	ACTH (pg/mL)	Cortisol (pg/mL)	Epinephrine (pg/mL)	Norepinephrine (pg/mL)	Mean (mmHg)	HR (beats/min)	SPI	BIS
Base	SSI	22 ± 12	14 ± 5	35 ± 15	180 ± 100	98 ± 12	74 ± 10	54 ± 10	92 ± 14
	Control	23 ± 11	13 ± 4	38 ± 16	240 ± 150	100 ± 13	75 ± 11	55 ± 10	97 ± 11
Intu	SSI	18 ± 8**	12 ± 4**	28 ± 17	130 ± 65**	95 ± 18	73 ± 10	52 ± 12	38 ± 11**
	Control	19 ± 9*	12 ± 5*	30 ± 8	135 ± 68**	94 ± 15	76 ± 14	75 ± 14	36 ± 12**
Maxi	SSI	11 ± 6**#	9 ± 4**##	33 ± 9	80 ± 45**##	75 ± 11**##	60 ± 9**##	44 ± 11**##	40 ± 9**
	Control	12 ± 5**#	9 ± 3**##	35 ± 20#	82 ± 47**#	78 ± 14**##	60 ± 10**##	46 ± 13*#	39 ± 8**
After-Maxi	SSI	10 ± 5**##	7 ± 3**##&	20 ± 15**#&&	36 ± 17**##&&	78 ± 11**##	59 ± 9**##	30± 12**##&&	45 ± 10**
	Control	10 ± 4**##	7 ± 3**##	22 ± 10**&&	38 ± 16**##&	83 ± 14**##	59 ± 9**##	32± 13**##&&	41 ± 9**

DISCUSSION

We explored the association between the Surgical Pleth Index (SPI) and nociception during general anaesthesia, using photoplethysmography to assess pulse wave amplitude. In our prospective, randomised, single-blinded study, while SPI showed no correlation with stress hormones at baseline (Base), it exhibited moderate-to-strong correlations with stress hormones during intubation (Intu), peak stress (Max), and post-peak stress (After-Max). Additionally, SPI effectively predicted ACTH levels.Currently, there are no direct methods for measuring stress or nociception during general anaesthesia. Traditional indicators such as blood pressure, heart rate, sweating, and tearing are commonly used but often unreliable [9-11]. Analgesic endpoints, like movement in response to nociceptive stimuli, are frequently employed to assess inadequate analgesia, but they lack precision and can be suppressed by muscle relaxants. Other approaches, such as EEG-derived variables like state entropy (SE) and response entropy (RE), as well as photoplethysmographic parameters, have also been explored to assess nociception but generally perform suboptimally.SPI, however, presents an innovative approach by combining photoplethysmographic pulse wave amplitude and normalised heart rate to assess nociception or stress during general anaesthesia. Studies have shown that SPI negatively correlates with the effect-site concentration of remifentanil (Ceremi) during total intravenous anaesthesia and outperforms SE, RE, heart rate, and photoplethysmographic amplitude in detecting nociceptive stimulation under propofol anaesthesia. Its accuracy remains unaffected by Esmolol, making SPI a promising tool for monitoring nociception during general anaesthesia [12].The stress response to surgery activates the secretion of pituitary hormones, resulting in increased levels of cortisol, epinephrine, and norepinephrine, which influence intraoperative nociception. Excessive secretion of these hormones has been linked to poorer outcomes. Our study found that stress hormone levels peaked when patients were conscious and experiencing mental stress, despite premedication. Stress hormone levels at Max were significantly higher than those recorded 15 minutes After-Max, reflecting the nociceptive stress of anaesthesia.Moderate-to-strong correlations were observed between stress hormone levels and SPI values. SPI was specifically designed to detect surgical stress in anaesthetised patients, where psychogenic factors are absent. While stress levels at Base may have been influenced by preoperative anxiety, surgical nociception emerged as the primary source of stress during anaesthesia. Variations in SPI and stress hormone levels across different states of consciousness highlight the usefulness of SPI in anaesthetised patients.The stress response is driven by the activation of the hypothalamus-pituitary-adrenal (HPA) axis. Surgical stimulation triggers the release of ACTH, which stimulates cortisol production in the adrenal cortex [13-14]. The HPA axis also produces epinephrine and norepinephrine, with secretion patterns varying over time. Blood samples were taken within 30–60 seconds of the stress event, and SPI values were recorded 15 seconds after the event, reflecting temporal differences in stress marker peaks. While epinephrine and norepinephrine levels remained stable during surgery, ACTH and cortisol levels increased with the severity of surgical stress. Differences in peak times among these hormones suggest varying responses to nociceptive stimulation[15].A limitation of this study was the timing of blood sample collection. Event-related time points were selected to reflect nociceptive stimulation during anaesthesia, but the precise timing of sample collection after the stress event remains challenging. Additionally, the relatively low surgical stimulus of ENT procedures may account for the modest stress hormone levels observed. Future studies should include a broader range of surgical procedures to validate these findings and further investigate the role of SPI in monitoring nociception.

CONCLUSION

This study highlights the potential value of the Surgical Pleth Index (SPI) as a reliable tool for evaluating nociception and intraoperative stress during general anaesthesia. While SPI did not show a correlation with stress hormone levels at baseline, it exhibited moderate-to-strong correlations during intubation, peak stress, and post-peak stress, effectively predicting ACTH levels. SPI outperformed traditional indicators like blood pressure, heart rate, and BIS in detecting nociceptive stimulation, demonstrating its capacity to provide more accurate and consistent measurements.The results also emphasize the significance of stress hormone dynamics, including ACTH, cortisol, epinephrine, and norepinephrine, as indicators of surgical stress. The activation of the hypothalamus-pituitary-adrenal (HPA) axis during surgical stimulation illustrates the physiological interactions driving nociceptive responses. While cortisol and ACTH levels increased with the severity of surgical stress, epinephrine and norepinephrine remained relatively stable, reflecting the diverse reactions of stress hormones to nociception. Despite the encouraging findings, challenges such as the timing of blood sample collection and the moderate stress levels associated with ENT surgeries require further investigation. Future research should incorporate a broader range of surgical procedures and refine methods to better capture the temporal link between SPI and stress hormone peaks. SPI-guided anaesthesia presents a promising approach for enhancing nociception monitoring and improving intraoperative outcomes.

Incorporating SPI into anaesthetic practice could improve patient management by offering a more objective and real-time assessment of stress and nociception during surgery.

REFERENCES

1. S. D. Parker, M. J. Breslow, S. M. Frank *et al.*, "Catecholamine and cortisol responses to lower extremity revascularization: correlation with outcome variables," *Critical Care Medicine*, 23(12), 1995, 1954–1961,
2. P. S. Myles, J. O. Hunt, H. Fletcher *et al.*, "Remifentanil, fentanyl, and cardiac surgery: a double-blinded, randomized, controlled trial of costs and outcomes," *Anesthesia and Analge- sia*, 95(4), 2002, 805–812,
3. M. M. R. F. Struys, C. Vanpeteghem, M. Huiku, K. Uutela,N. B. K. Blyaert, and E. P. Mortier, *et al*., "Changes in a surgical stress index in response to standardized pain stimuli during propofol-remifentanil infusion," *British Journal of Anaesthesia*, 99(3), 2007, 359–367,
4. W. Buhre and R. Rossaint, *et al*., "Perioperative management and monitoring in anaesthesia," *Lancet*, 362(9398), 2003, 1839–1846,.
5. J. Bruhn, P. S. Myles, R. Sneyd, and M. M. R. F. Struys, *et al*., "Depth of anaesthesia monitoring: what's available, what's validated and what's next?" *British Journal of Anaesthesia*, 97(1), 2006, 85–94,
6. T. Heier and P. A. Steen, *et al.*, "Assessment of anaesthesia depth," *ActaAnaesthesiologicaScandinavica*, 40(9),1996, 1087– 1100,
7. M. Rantanen, A. Yli-Hankala, M. van Gils *et al.*, "Novel multiparameter approach for measurement of nociception at skin incision during general anaesthesia," *British Journal of Anaesthesia*, 96(3), 2006, 367–376,
8. M. Huiku, K. Uutela, M. van Gils *et al*., "Assessment of surgical stress during general anaesthesia," *British Journal of Anaesthesia*, 98(4), 2007, 447–455,
9. J. Wennervirta, M. Hynynen, A. M. Koivusalo, K. Uutela, M. Huiku, and A. Vakkuri, *et al*., "Surgical stress index as a measure of nociception/antinociception balance during general anes- thesia," *ActaAnaesthesiologicaScandinavica*, 2008, 52(8), 1038–1045,
10. M. Gruenewald, P. Meybohm, C. Ilies*et al*., "Influence of different remifentanil concentrations on the performance of the surgical stress index to detect a standardized painful stimulus during sevoflurane anaesthesia," *British Journal of Anaesthesia*, 103(4), 2009, 586–593,
11. W. D. Smith, R. C. Dutton, and N. T. Smith, *et al*. "Measuring the performance of anesthetic depth indicators," *Anesthesiology*, 84, 1996, 1,38–51,
12. W. D. Smith, R. C. Dutton, and N. T. Smith, *et al*., "A measure of association for assessing prediction accuracy that is a general- ization of non-parametric roc area," *Statistics in Medicine*,15, 1996, 1199–1215,
13. X. Chen, C. Thee, M. Gruenewald *et al.*, "Comparison of surgical stress index-guided analgesia with standard clinical practiceduringroutinegeneralanesthesia:apilotstudy,"*Anesthesiology*,112(5),2010, 1175–1183,
14. T.Schricker,F.Carli,M.Schreiber*etal*.,"Propofol/sufentanilanesthesia suppresses the metabolic and endocrine responseduring, not after, lower abdominal surgery," *Anesthesia andAnalgesia*,90(2), 2000,450–455,
15. M.F.Roizen,R.W.Horrigan,andB.M.Frazer,*e t a l* . , "Anes-thetic doses blocking adrenergic (stress) and cardiovascularresponsestoincision-MACBAR,"*Anesthesiology*,54(5),1981,390–398.

Cite this article
Dr. Dinesh Kumar Gontla V. (2019). Evaluating the surgical pleth index (spi) as a tool for monitoring nociception and intraoperative stress during general anaesthesia. *Acta Biomedica Scientia*. 6(3), 305-309