Original Article

The effect of prone positioning on surgical pleth index in patients undergoing spine surgery under general anesthesia – A prospective observational study

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Abstract

Background and Aims: Surgical Pleth Index (SPI) provides an objective assessment of nociception - anti-nociception balance but is influenced by multiple confounders. The effect of change of position on SPI, has not been studied extensively. The aim of the study was to observe the effect of prone positioning on SPI and its correlation with hemodynamic variables, in patients undergoing lumbar and thoracic spine surgery.

Material and Methods: This prospective observational pilot study included 14 patients. In addition to hemodynamic monitoring, SPI, entropy and pulse pressure variability (PPV) were monitored. Propofol and Fentanyl infusions were used for maintenance of anesthesia. The patients were made prone on bolsters and all the variables were recorded every 5 minutes in supine position and after making prone for 20 minutes, before and after incision, muscle splitting and laminectomy.

Results: Comparing the last value of the variables in the supine position with those immediately after making prone, SPI increased by 16.36 units ($P = 0.003$), followed by gradual reduction over the next 20 minutes. Mean arterial pressure and heart rate increased transiently (Pvalue = 0.028 and 0.025, respectively) without any significant change in PPV. Surgical incision also led to a significant increase in SPI.

Conclusion: Prone positioning leads to significant increase in SPI, probably due to increased sympathetic tone.

Keywords: Confounders, prone position, spine surgery, surgical pleth index

Introduction

Surgical Pleth Index (SPI) is as an objective tool to measure nociception-anti nociception balance under anesthesia. SPI is derived from combined measurement of central (heart beat interval- HBI) and peripheral (plethysmographic pulse wave amplitude- PPGA) sympathetic tone. The SPI ranges from 0-100; high values indicate pain, values between 20-50 indicate acceptable level of analgesia and an SPI value of 50 indicates a balance of nociceptive and anti-nociceptive factors. SPI correlates with the intensity of surgical stimuli and anti-nociceptive effects of opioids.[1] SPI has also been shown to be a better predictor of response to noxious stimulation than the standard monitoring variables.[2] However, there are certain confounding factors which should be considered while interpreting SPI values. These include rhythm disturbances, intravascular volume status, autonomic dysfunction, change of body position, quality of plethysmograph and age of the patient.

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The effect of patient's body position on SPI has not been studied extensively. Effect of position change on SPI is probably mediated by autonomic nervous system (ANS).Ilies *et al.*[3]randomly assigned 45 patients to receive either general anesthesia (n = 15) or spinal anesthesia with (n = 15) or without sedation (n = 15) and another 15 patients were included as awake volunteers as controls. Values of the SPI reduced in all the anesthetized patients after change to lithotomy position (from supine). However, in healthy volunteers, the SPI increased after head-up and reduced after head-down tilt.

In neurosurgical cases during insertion of head holder, SPI was observed to be comparable to mean blood pressure (MAP) and heart rate (HR) in assessing nociception-remifentanil concentration. The interpretation of SPI is improved when all the variables are in concordance, taking into account the low intravascular volume status and the fact that patients with chronic hypertension are under treatment.[4]If the intravascular volume is adequate, fluid challenge does not bring about any change in SPI. However, in the presence of hypovolemia, SPI tends to decrease by mechanism of increase in PPGA.[5]

Prone positioning is frequently required for surgical access, particularly in neurosurgery. To the best of our knowledge, there is no literature examining the effect of prone position on values of SPI. The primary aim of this study was to observe the effect of change of position, i.e., from supine to prone under anesthesia on SPI. The secondary objective was to study the correlation of SPI with hemodynamic variables; HR, MAP and pulse pressure variation (PPV). We hypothesized that changing the position from supine to prone would affect the SPI values.

Material and Methods

This prospective observational cohort study was conducted at a tertiary care centre for patients with neurological diseases. Institutional Ethics Committee approval was obtained and patients were recruited after obtaining written informed consent. The study was registered with Clinical Trials Registry-India (CTRI/2019/09/021228). All patients with American Society of Anesthesiologists' (ASA) classification grade I and II, aged between 18-65 years undergoing lower thoracic and lumbar spine surgeries were included. Patients with uncontrolled diabetes mellitus, significant cardiac arrhythmias causing hemodynamic instability and hypertensive patients on ACE inhibitors were excluded from the study. Patient recruitment was done over a period of 4 months (September 2019 – January 2020).

After taking the patient into operation theatre, electrocardiogram (ECG), non-invasive blood pressure monitor (NIBP), pulse oximeter and SPI monitoring (GE Medical Systems, Freiburg, Germany) were commenced. Anesthesia was induced with Fentanyl 2mcg/kg, Propofol (dose titrated to loss of consciousness) and Vecuronium 0.1mg/kg followed by endotracheal intubation. Anesthesia and analgesia were maintained with Propofol infusion (using target-controlled infusion pump, Orchestra Base Primea-Fresenius Kabi, France) titrated to achieve a state entropy of 40-60 (GE Health Care, Helsinki, Finland) and Fentanyl infusion at 1μg/kg/hour, respectively. The infusions were started after intubation and continued throughout the surgery. Arterial cannula was secured in radial artery of the non-dominant hand for continuous monitoring of MAP and PPV and the recording was started in the supine position. Thereafter, patient was positioned prone. The arterial monitoring system and pulse oximeter were in place while positioning to ensure un-interrupted data recording. For lower thoracic and spine surgeries, we routinely position the patient with head turned to one side and rested on a head ring. The thorax and abdomen were supported by bolsters and pressure points were padded.

The values of HR, MAP, PPV and SPI were recorded in supine position every 5 minutes. After placing the patient in prone position, values were recorded at 0, 5, 10, 15, 20 minutes; time point 0 being immediately after prone position. The last values of HR, MAP, PPV and SPI in supine position were compared with those after placing in prone position. All the above variables were also noted at specific time points during surgery – just before skin incision and after skin incision at 0, 2, 5 minutes, just before muscle splitting and after muscle splitting at 0, 2, 5 minutes, and just prior to laminectomy and post laminectomy at 0, 2 and5 minutes.

Statistical analysis

Data was analyzed using R software ver. 3.5.2. The timeline of data collection was segregated into four sets – at prone positioning, at incision, during muscle splitting and during laminectomy. Outcome variables (SPI, PPV, MAP and HR) were analyzed using linear mixed effect models for main effect of time and random intercept by subject (package "*lmerTest*"). Unstructured covariance structure was assumed. Descriptive data are presented as means ± standard deviations and hypothesis test results are presented as estimates with P values. Correlation between SPI and other outcome variables was conducted using repeated measures correlations (package "*rmcorr*"). Power of individual hypotheses tested was calculated post-hoc using package "simr" using 1000 simulations. A P value of < 0.05 was considered as level for statistical significance.

Results

Twenty-five patients met the inclusion criteria, out of which 14 patients were recruited. (flow diagram- Figure 1). There were 11 male and 3 female patients. The mean age of the study sample was 44.2 years. The study was conducted as a pilot study and cases available during the study period were included. Descriptive data of outcome variables across the time points is presented in Table 1.Results of mixed effect model testing are presented in Table 2. Percentage change of variables over study time points is depicted in Figure 2. This form of representation was chosen for scale-free visualization of trend of change for all variables in one image.

Effect of prone positioning

The last value of the variables in supine position were taken as the baseline to determine the effect of change in position from supine to prone. SPI was found to have a mean increase of 16.36 units ($P = 0.003$) immediately after positioning prone, followed by a gradual reduction over the next 20 minutes. MAP (mean increase 9.43 mmHg, $P = 0.028$) and HR (mean increase = 6.21 beats/min, $P = 0.025$) had a transient increase followed by reduction. PPV was not found to have a significant change after prone positioning [Table 2 and Figure 2].

SPI was found to increase significantly after incision (compared to the value before incision) and the increase was sustained for 5 minutes. PPV had a transient increase, MAP had a delayed increase at 2 minutes which was sustained while HR did not change significantly [Table 2 and Figure 2].

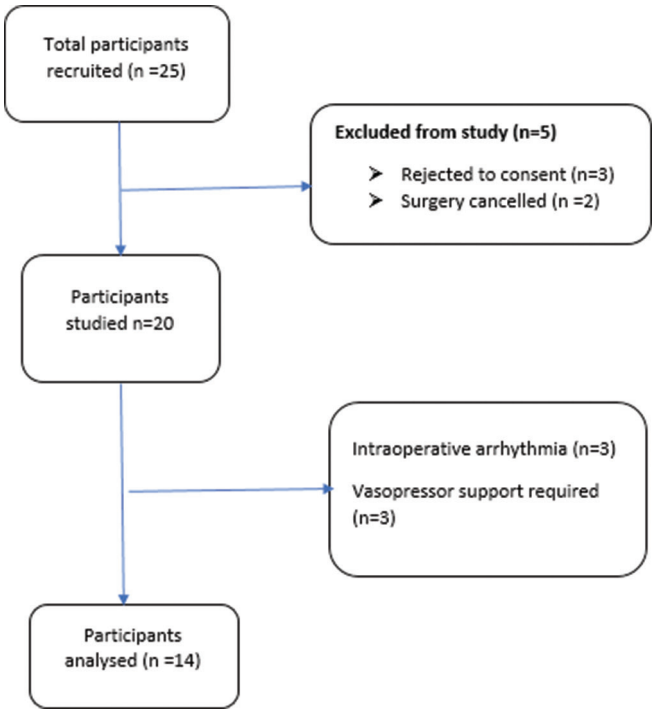

Figure 1: Flow diagram showing the recruitment of patients at various steps

Muscle splitting and laminectomy

None of the variables had a clinically significant change over these time points [Table 2 and Figure 2].

Correlation

SPI was not found to be correlated with PPV (r=-0.0029; 95% confidence limits -0.103 to 0.099, $P = 0.975$). HR (r = 0.196; 0.096 – 0.291) and MAP (r = 0.348; 0.256 – 0.434) showed a mild positive correlation with SPI (both $P < 0.001$).Post-hoc power analysis revealed 0.89, 0.91, 0.28 and 0.3 power for detection of change in SPI over prone positioning, incision, muscle splitting and laminectomy respectively.

Discussion

SPI has been used extensively as a measure of nociceptive-antinociceptive balance. SPI has been found to strongly relate to Remifentanil effect-site concentration during Propofol-Remifentanil anesthesia but is only minimally influenced by Propofol effect-site concentration.[6,7]SPI has a higher probability of predicting a nociceptive stimulus when compared to hemodynamic parameters or the difference between RE and SE.[1]SPI is derived from a balanced of sum of normalised HBI and PPGA by the following equation, SPI = 100-(0.3 X HBInorm+ 0.7X PPGAnorm).[7]

Therefore, SPI will increase with decrease in HBI as in tachycardia or with decrease in PPGA as in situations of increased sympathetic tone. Pulse wave amplitude depends on distensibility factor which in turn is determined by the vascular tone. The vascular tone is strongly affected by ANS. Therefore, any condition causing change in HR or pulse wave amplitude, not necessarily caused by pain, may affect SPI.A few examples of such scenarios would be chronic hypertension, diabetes, change in body temperature, change in volume status or medications such as anti-hypertensives. SPI has been shown to change in response to noxious stimulation even in patients who are receiving beta blockers.[8]

SPI can also be affected by change of body position such as with lithotomy position, head-up or head-down.[3]In our study, we found that with change of position from supine to prone, there was an increase in SPI by 16 units accompanied by transient increases in BP and HR. Increase in BP indicates sympathetic stimulation which could have led to decrease in pulse wave amplitude. Since the PPV did not change (ruling out change

Table 1: Descriptive Statistics (mean±standard deviation) of Relevant Variables at all Study Time Points

Stage	Time Point	SPI	PPV	MAP	HR
Prone Positioning	Baseline	40.64±20.33	12.21±7.47	73.43±15.92	76.86±17.81
	Prone	57±16.85	13.86±7.44	82.86±16.67	83.07±18.28
	5 min	53.07±21.03	13.43±4.42	72.43±15.5	78.86±12.5
	10 min	48.36±22.07	13.21±5.78	76.07±16.9	75.71±17.13
	15 min	42.14±20.61	10.93±3.12	71.29±13.74	75.71±17.13
	20 min	41.86±20.3	11.29±4.39	70.57±10.79	72.36±15.46
Incision	Baseline	35.07±14.07	9.79±2.83	68.93±10.75	71.71±16.03
	Incision	41.86±13.33	10.86±4.31	71.57±13.54	73.43±17.37
	2 min	43.57±15.42	11.07±3.99	74.21±13.09	73.36±16.83
	5 min	44.14±14.96	10.5±3.96	74.21±12.29	73.07±18.07
Muscle Splitting	Baseline	45.79±14.31	10±3.8	77.43±15.92	71.21±18.03
	Muscle Splitting	45.43±15.06	9.71±3.65	75.29±10.48	69.93±15.79
	2 min	42.21±12.49	9.86±3.23	74.21±10.98	68.29±14.79
	5 min	41.5±10.66	9.79±2.81	72.79±9.34	70.07±16.11
Laminectomy	Baseline	45.5±11.13	11.29±3.69	70.5±8.5	70±17.65
	Laminectomy	50.71±13.85	9.43±4.38	73.5±10.93	72.29±17.56
	2 min	47.43±11.86	10.14±3.7	73±7.63	70.14±15.84
	5 min	50.71±15.07	10.71±4.08	73.64±10.68	73.43±16.02

SPI – Surgical Pleth Index, PPV – Pulse Pressure Variability, MAP – Mean Arterial Pressure, HR – Heart Rate

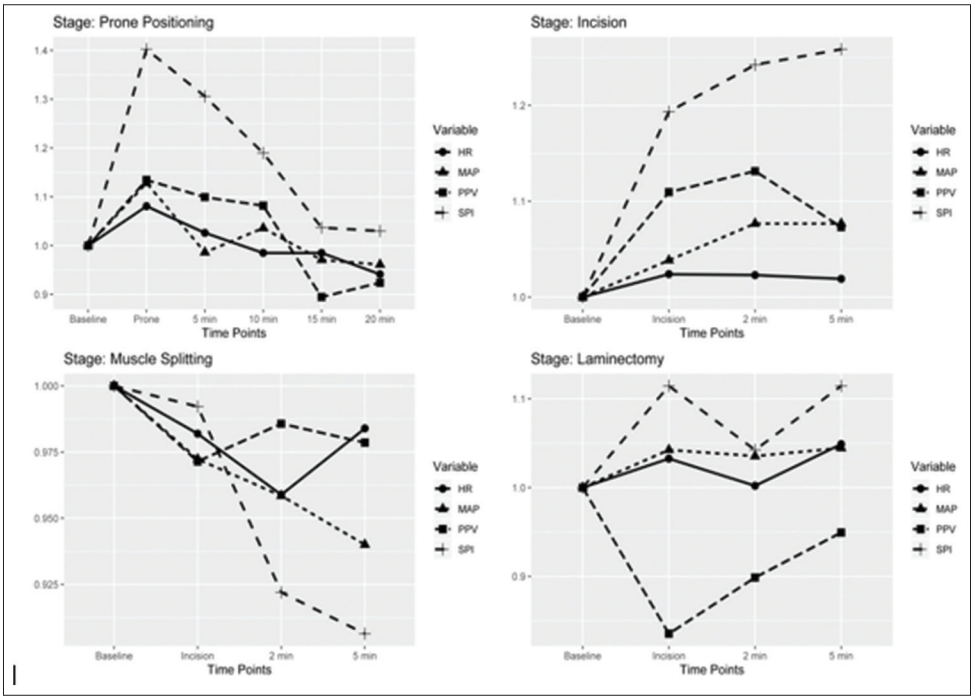

Figure 2: Percentage change in means of outcome variables over respective time durations

in intravascular volume status), it is probably the tachycardia and reduction in pulse wave amplitude that are responsible for the increase in SPI. As is evident from this discussion, without extraction of constitutive components of SPI, it is difficult to elucidate the exact mechanisms responsible for change in SPI.

Prone positioning usually leads to decrease in cardiac index and stroke volume due to raised intra-thoracic pressures causing reduced left ventricular compliance and decreased venous return.This leads to sympathetic activation and increase in SVR causing vasoconstriction.[9,10]The type of prone position employed also influences the magnitude of hemodynamic disturbances encountered. The flat prone position usually does not interfere with cardiac function, unlike positions where heart is above the level of head and limbs.

In our study, the patients were placed at level, pelvis and chest were supported by pillows and abdomen was free.[11,12]Our patients

Table 2: Estimates of Within Subject Fixed Effects of Time on Variables

Stage	Time Point	SPI		PPV		MAP		HR	
		Estimate	*P*	Estimate	*P*	Estimate	*P*	Estimate	*P*
Prone Positioning	Intercept	40.64	<0.001	12.21	<0.001	73.43	<0.001	76.86	<0.001
	Prone	16.36	0.003*	1.64	0.342	9.43	0.028*	6.21	0.025*
	5 min	12.43	0.02*	1.21	0.482	-1.00	0.813	2.00	0.463
	10 min	7.71	0.143	1.00	0.562	2.64	0.532	-1.14	0.674
	15 min	1.50	0.774	-1.29	0.457	-2.14	0.612	-1.14	0.674
	20 min	1.21	0.816	-0.93	0.591	-2.86	0.5	-4.50	0.101
Incision	(Intercept)	35.07	<0.001	9.79	<0.001	68.93	<0.001	71.71	<0.001
	Incision	6.79	0.015*	1.07	0.09	2.64	0.227	1.71	0.198
	2 min	8.50	0.003*	1.29	0.044*	5.29	0.019*	1.64	0.217
	5 min	9.07	0.002*	0.71	0.254	5.29	0.019*	1.36	0.306
Muscle Splitting	(Intercept)	45.79	<0.001	10.00	<0.001	77.43	<0.001	71.21	<0.001
	Muscle Splitting	-0.36	0.908	-0.29	0.593	-2.14	0.318	-1.29	0.208
	2 min	-3.57	0.249	-0.14	0.789	-3.21	0.137	-2.93	0.006
	5 min	-4.29	0.169	-0.21	0.688	-4.64	0.034	-1.14	0.262
Laminectomy	(Intercept)	45.50	<0.001	11.29	<0.001	70.50	<0.001	70.00	<0.001
	Laminectomy	5.21	0.135	-1.86	0.018	3.00	0.118	2.29	0.143
	2 min	1.93	0.576	-1.14	0.135	2.50	0.19	0.14	0.926
	5 min	5.21	0.135	-0.57	0.45	3.14	0.102	3.43	0.031

SPI – Surgical Pleth Index, PPV – Pulse Pressure Variability, MAP-Mean Arterial Pressure, HR– HeartRate

were scheduled for thoracic and lumbar spine surgeries and therefore, did not experience skull pin fixation which is associated with significant pain. Therefore, the effects on SPI seen in our study were purely the result of position change. Total intravenous anesthesia causes greater decrease in CI and increasedSVR compared to inhalational anesthesia.[10]We used Propofol and Fentanyl infusions intra-operatively for maintenance of anesthesia.

Interpretation of SPI is improved when the patient's volume status is taken into account. Therefore, in our study we used PPV to monitor the intravascular volume. However, the smaller sample size precludes statistical covariate adjustment during analysis.We also observed that SPI increased with surgical incision which isknown to be a painful stimulus. This is also in accordance with previous literature that SPI increases with intubation or surgical incision, but is not predictive of hemodynamic responses.[13]

Strengths and limitations

This is probably the first study to evaluate change in SPI with change of position from supine to prone. Our study is not without limitations. Firstly, our small sample was not large. Secondly, we did not monitor cardiac output, which could have provided information on contribution of CI and stroke volume to changes in SPI. Thirdly, without availability of constituent variables used in SPI calculation, causality is difficult to estimate.

Conclusion

SPI increased significantly when position is changed from supine to prone. The study findings are likely to have implications in day-to-day practice of balanced anesthesia, since we frequently encounter different positions in anesthesia practice. While this monitor is frequently used for guiding the administration of intraoperative analgesics, it is also important to be aware of the limitations of SPI, when SPI values may change in the absence of noxious stimulation. Although SPI correlates with ANS activity, whether it reflects 'nociception' or some other variables that are associated with nociception is not well understood. There is a mild correlation of HR and MAP with SPI. Interpretation of SPI as a surrogate measure of nociception–anti-nociception balance, can therefore be confounded by change of position.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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