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Research Article

An Evaluation of the Relationship between the Pleth Variability Index with Bleeding and Volume Responsiveness in Patients Undergoing Lumbar Spine Surgery Under General Anesthesia

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ABSTRACT

Background: Pulse oximetry is essential for monitoring patients during surgery, which display SPO2, as well as the plethysmographic variability index. Volume responsiveness is also indicated by this index. Considering the non-invasiveness of the PVI index and its predictive value, its use could be highly beneficial. Thus, we decided to evaluate the correlation between Pleth Variability Index in prone position and bleeding and volume responsiveness in patients undergoing lumbar spine surgery under general anesthesia.

Methods: 119 patients who were candidates for lumbar spine fixation surgery were studied in the prone position during surgery. Aside from demographic information, vital signs and PVI levels were recorded after induction of anesthesia, 5 minutes after induction of anesthesia, immediately after changing position from supine to prone, 5 minutes after changing position from supine to prone, at the end of the operation, immediately after shifting position from prone to supine, and after switching position from prone to supine for 5 minutes. Accordingly, the amount of bleeding and the type and amount of fluid received during the operation were recorded.

Results: Results revealed that demographic factors (gender, age, weight, height), hemodynamic factors (heart rate, blood pressure, SPO2), cardiac EF, and initial Hb levels, and changes in position from supine to prone did not affect the PVI process. In contrast, PVI has decreased due to an increase in intraoperative fluid intake. Notably, the amount of fluid received by different people (taking into consideration weight, bleeding, etc.) had no effect on PVI decreasing.

Conclusion: The PVI provides a cheap and readily accessible way to determine volume responsiveness, which is unaffected by various individual variables and can be performed in a prone position.

Introduction

Anesthesia care relies heavily on monitoring. There are a number of standard ASA patient monitoring devices, including a pulse oximeter, electrocardiogram (ECG), a noninvasive blood pressure device, and a temperature monitor. The World Health Organization's preoperative safe surgery checklist recommends pulse oximetry as one of the most convenient and non-invasive tools for monitoring oxygenation during anesthesia [1-2].

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A crucial aspect of any anesthesia is monitoring the mentioned parameters and considering blood and fluid management [3]. Patients can suffer adverse effects if their fluids are administered inappropriately; therefore, accurately identifying their hemodynamics can provide a patient with a better prognosis (for example, less serum lactate, shorter hospital stays, and fewer postoperative organ complications) [4-5]. A static and invasive method for fluid management is to measure the central venous pressure (CVP), the pulmonary artery occlusion pressure (PAOP), and the cardiac output [6-10].

Moreover, in pleth waveform analysis, advanced clinical information can similarly be gleaned from them. As an alternative to invasive testing, pulse oximetry plethysmographic wavelength amplitude variables have recently proven to be an effective noninvasive method for assessing fluid responsiveness in operating rooms and intensive care units [10-11]. As a result of this method, pleth variability index (PVI) values are derived in comparison with maximum and minimum perfusion amplitudes measured in a finger during the respiratory cycle. PVI evaluation is impacted by diverse factors, such as cardiac dysrhythmia, hemoglobin disorders, norepinephrine, and the position of the patient during surgery [12-15].

Most spine surgeries are performed with the patient in a prone position. Nonetheless, mechanical ventilation may be affected by increased intra-abdominal and intra-thoracic pressures caused by the prone position. Due to physiological changes caused by prone positioning, dynamic indices such as PPV and PVI may be less accurate in predicting fluid responsiveness. Therefore, it is not recommended to expand their validity to surgical procedures involving a prone position. These parameters have rarely been studied in patients undergoing spinal surgery in the prone position in order to predict fluid responsiveness [16-19].

Taking into account the noninvasive nature of the PVI index and its predictive value, we investigated in this study how this criterion correlated with bleeding and volume responsiveness to changing positions, as well as individual factors affecting PVI.

Methods

This cross-sectional, descriptive analytical study was conducted at Imam Khomeini Hospital, Tehran, Iran from May 2023 to Jan 2024. This study was approved by the Research Ethics Committee of Tehran University of Medical Sciences (Ethics no.: IR.TUMS.IKHC.REC.1402.047). Before the participant's enrollment, the freely informed written consent was taken from all eligible participants.

The target population was 119 patients who were candidates for spine fixation surgery and being in the prone position during surgery. Patient eligibility criteria include mechanical ventilation without spontaneous breathing, normal heart rhythm, EF> 50%, TV≥8 ml/kg of ideal body weight, ASA Class I or II, age between 20 and 70 Year, and Heart Rate / Respiratory Rate > 3.6. The following conditions are excluded from enrollment: hemoglobinopathies, heart dysrhythmias, anemia, Hb <8 g/dl, use of nail polish, intra-aortic balloon pump (IABP), and blood product requirements during surgery. Pre-medications were administered to all patients with midazolam (0.05 mg/kg) and fentanyl (2 mcg/kg). Three minutes later, propofol (1-2.5 mg/kg) and atracurium (0.5 mg/kg) were administered as muscle relaxants. After 3 minutes, the patient underwent a laryngoscopy with a Macintosh blade and tracheal intubation. Propofol (50-150 mcg/kg) was prescribed as a maintenance drug to all patients who underwent mechanical ventilation with a volume of at least 8 ml/kg. The desired parameters in the study namely vital signs (HR, BP, and SPO2) and PVI level in the supine position were observed and recorded immediately after induction of anesthesia and 5 minutes after that. In addition, the parameters were recorded immediately after switching from supine to prone, after five minutes of changing from supine to prone, after receiving 500 ml of normal saline, after receiving 1500 ml of normal saline, and after receiving 2500 ml of normal saline. Upon completion of the operation, all parameters were recorded in the prone position, immediately after the prone position was changed to supine, and five minutes after the supine position was modified. Additionally, to routine monitoring for patients, PVI was also compared in supine and prone positions in this study. A Massimo pulse oximeter of Saadat company was also used to record the changes in PVI as a result of receiving fluids for each patient according to their weight, bleeding amount, and other considerations. By examining the suctioned blood during the operation and counting the sterile gases used, the bleeding rate was measured and interpreted.

The data were analyzed using SPSS software version 16. Descriptive statistics including distribution and frequency were performed. In analytical statistics, correlation tests, univariate and multiple linear regression were used.

Results

119 people (48 women and 71 men) participated in this study with an average age (standard deviation) of 53.01 (10.61) years, a height of 1.69 (0.10) meters, weight of 83.44 (75.66) kg, a cardiac output of 54.49 (3.87) %, hemoglobin of 13.30 (1.57) g/dL, intraoperative bleeding of 396.63 (82.27) ml, and intraoperative fluid intake of 2962.18 (299.43) ml (Table 1). A total of 16 patients who had bleeding beyond the MABL assessment and required blood product injections were excluded from the study.

Table 1-Distribution of age, height, weight, ejection fraction, hemoglobin, and fluid intake during surgery

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Age (Year)	119	22.00	68.00	53.00	10.61
Height (m)	119	1.53	1.84	1.69	0.10
Weight (Kg)	119	65.00	101.00	83.44	7.56
Cardiac Ejection Fracture (%)	119	50.00	65.00	54.49	3.87
Hemoglobin (g/dl)	119	9.80	16.50	13.30	1.57
Whole Blood Loss During Operation (ml)	119	300.00	750.00	396.63	82.26
Whole Fluid (Normal Saline) Recieved During Operation (ml)	119	2500.00	4000.00	2962.18	299.43

Table 2-Average distribution of PVI at various timeframes during and after surgery

Variable	Mean	Std. Deviation	N
Immediately After Induction	19.30	3.85	119
5min After Induction	17.89	3.17	119
Immediately After Changing Position (Before Start of Operation)	17.94	3.28	119
5min After Changing Position	16.91	3.27	119
After Recieving 500ml NS	14.64	3.36	119
After Recieving 1500ml NS	12.55	3.54	119
After Recieving 2500ml NS	10.76	3.60	119
End Of Operation	9.48	3.72	119
Immediately After Changing Position (End of Operation)	9.42	3.57	119
5min After Changing Position (End of Operation)	9.63	3.55	119

The time points are as follows: immediately following induction of anesthesia, 5 minutes after induction of anesthesia, instantly after switching positions from supine to prone, 5 minutes after changing positions from supine to prone, after taking 500 ml serum, after receiving 1500 ml serum, after receiving 2500 ml serum, at the end of the operation, right after the position shift from prone to supine, and 5 minutes after that shift.

Throughout all the specified periods, the average PVI declined (Table 2). As well, the average PVI diminishes significantly after the procedure ends (F=477.9, P<0.001, Figure 1).

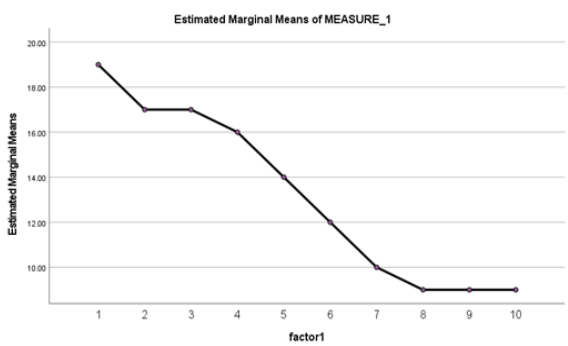

Figure 1-Variations in PVI during and after anesthesia

Individual characteristics of the subjects were evaluated. It was confirmed that age did not influence the average PVI trend, and it tended to deteriorate regardless of the subjects' age (F=40.18, P<0.001). There was no difference between women and men in the PVI trend (F=0.583, P=0.447) (Figure 2), and it still tended to decline even with the gender variable present (F=823.12, P<0.001, The height of the subjects was also not found to have any effect on the process of PVI changes (F=0.523, P=0.471) and the trend was still declining and significant (F=3.63, P=0.0018) as well.

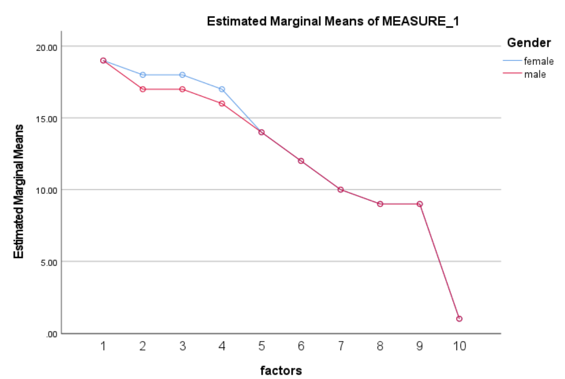

Figure 2-Effects of gender during and after anesthesia on average PVI

Individual characteristics of the subjects were evaluated. It was confirmed that age did not influence the average PVI trend, and it tended to deteriorate regardless of the subjects' age (F=40.18, P<0.001). There was no difference between women and men in the PVI trend (F=0.583, P=0.447), and it still tended to decline even with the gender variable present (F=823.12, P<0.001, The height of the subjects was also not found to have any effect on the process of PVI changes (F=0.523, P=0.471) and the trend was still declining and significant (F=3.63, P=0.0018) as well.

Upon examining the relationship between people's weight and PVI trend, it was demonstrated that this parameter did not affect the PVI variation (F=0.004, P=0.951) and the trend change was still significant (F=7.18, P<0.001).

PVI changes in this study were not correlated with cardiac output (F =0.527, P=0.469).

At any recorded stage, SPO2 was always 100%, and the PVI trend was not altered (F=0.888, P=0.413).

Additionally, the recorded heart rate of the patients did not fluctuate PVI throughout the study (F=248, P=0.001). PVI does not appear to be affected by blood pressure (F=7.11, P<0.001).

Also, the PVI declined with an increase in fluids received during the operation. However, the amount of fluid received by different people (depending on weight, bleeding, etc.) had little effect on this decreasing trend in PVI (F=541.126, P<0.001, Figure 3).

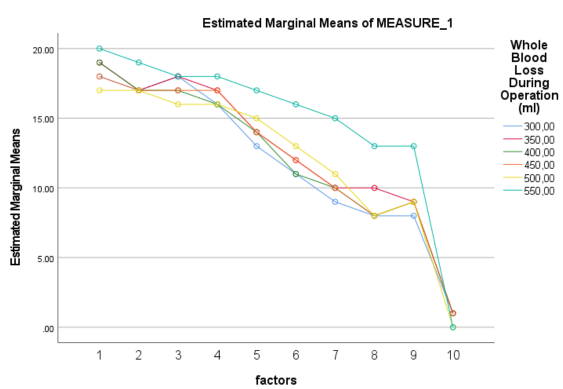

Figure 3-Fluid intake and average PVI trends during different periods of anesthesia

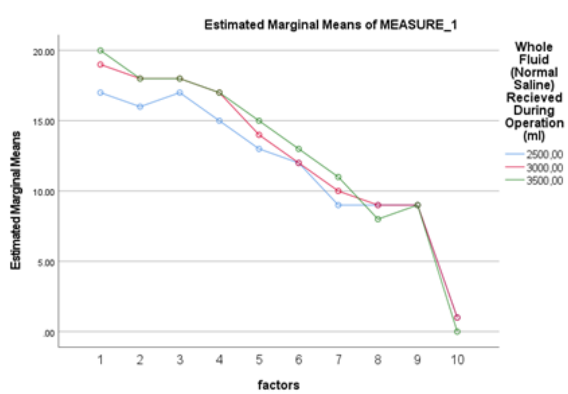

Figure 4-Intraoperative bleeding effect on PVI trend

PVI changes were not significantly influenced by the amount of bleeding during surgery, either (F=109, P<0.001, Figure 4).

Discussion

This study investigated the relationship of the Pleth Variability Index in the prone position with bleeding and volume responsiveness in patients under general anesthesia during spine surgery. Prior studies did not explore the influence of individual factors such as gender, age, weight, height, and paraclinical evaluations of each person (hemoglobin and ejection fraction before surgery) on PVI. Based on the present study's outcomes, these factors do not influence PVI variations during surgery in patients with mechanical ventilation.

Position change has been mentioned in previous studies as a confounding factor for PVI evaluation. However, the process of PVI changes during surgery was not affected by changing position from supine to prone. The aforementioned studies define position alteration as shifting the patient's position to one that causes CO changes (leg raising). Meanwhile, in the present study, the patient was turned from supine to prone, which wouldn't modify CO status [13,20]. It is worthwhile to mention that several studies have confirmed that supine to prone position shifts do not interfere with PVI assessment [19,21-22]. Interestingly, Mireskandari et al found that changing position from supine to lateral did not affect PVI. This conclusion can also be supported by the present study since ventilation and cardiovascular factors did not differ in prone or lateral positions. Nevertheless, given that PVI changes in this position were not explored, further research will be required in the future [23].

In another part of this study, the relationship between PVI and volume responsiveness was investigated. As a result of increased fluid intake during surgery, overall PVI changes decreased during the present study. As well as PVI changes decreasing with fluid intake during surgery, other studies consider that PVI is a suitable criterion for estimating volume responsiveness [3,24,28].

Furthermore, blood loss during surgery does not affect the process of PVI changes. This result can likely be attributed to the study's exclusion of patients who were bleeding severely during surgery and required blood products.

Conclusion

PVI is an inexpensive and accessible measure of Volume Responsiveness, which is also easy to interpret. Individual factors such as age, gender, weight, and height do not influence the changes. It is also possible to evaluate and interpret this criterion in the prone position.

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