The utility of the pleth variability index in predicting anesthesia-induced hypotension in geriatric patients

Abstract

Background/aim: Anesthesia induced hypotension may have negative consequences in geriatric patients. Therefore, predicting hypotension remains an important topic for anesthesiologists. Pleth Variability Index (PVI) measurement provides information about the fluid status and vascular tonus of the patients. In our study, the ability of Pleth Variability Index to predict hypotension after general anesthesia induction was evaluated.

Materials and methods: PVI values obtained from pulse oximetry were recorded in addition to preoperative standard anesthesia monitoring. The correlation between the PVI value and mean arterial pressure (MAP), systolic arterial blood pressure (SAP) changes and the power of PVI values to predict the incidence of hypotension after anesthesia induction (>20% MAP decrease) was tested.

Results: Eighty patients over 65 years of age who were operated under general anesthesia were included in the study. Hypotension was observed in 20 patients (25%). PVI values were mild and positively correlated with MAP changes (r = 0.195 and p=0.041). According to the ROC analysis, the incidence of hypotension increased in patients with PVI values above 15.45%. We also found the following diagnostic results for PVI value for predicting hypotension: p=0.044 and Area Under ROC Curve 0.651 ± 0.073 (95%, Confidence Interval: CI 0.507–0.794), Sensitivity of 40%, specificity of 80%, PPV of 40%, NPV of 80%, cut-off value of 15.45, positive likelihood ratio of 2, negative likelihood ratio of 0.75, Youden Index of 0.2.
Conclusion: Predicting hypotension in geriatric patients is an important issue for anesthesiologists. As an easily applicable test, The Pleth Variability Index is useful in predicting MAP reduction in patients. This practical technique can be used routinely in all geriatric patient groups.

Key words: Pleth variability index, geriatric assessment, hypotension

1. Introduction

The average age in developed countries is increasing; as such, geriatric anesthesia is an emerging field of study that aims to better serve this special patient population [1]. General anesthesia in geriatric patients is a high-risk procedure due to the effects of drugs, mechanical ventilation, and possible co-morbidities [2].

Hypotension due to the cardio depressant and vasodilator effects of anesthetic drugs in the induction of general anesthesia may cause decreased critical organ perfusion and increase cardiac and cerebral complications [3]. The risk for complications increases, even with short-term hypotension [4]. Moreover, because laparoscopic surgeries have a suppressive effect on the respiratory and circulatory systems, it is important to be able to predict the development of hypotension in these patients before surgery [2]. Increased fluid shortage in patients due to prolonged waiting times for operation may also lead to the development of hypotension.

Peripheral perfusion index (PI) reflects the amplitude of the pulse oximeter waveform and is calculated as the pulsatile infrared signal (variable component), indexed against the non-pulsatile infrared signal (constant component). PI is expressed as a percentage (0.02-20%). The pleth variability index (PVI) is a measure of the dynamic changes in the PI that occur during one or more complete respiratory cycles.
PVI may show changes that reflect physiologic factors such as vascular tone, circulating blood volume, and intrathoracic pressure excursions [5]. In this way PVI provides information about the fluid status of patients through decreasing or increasing peripheral perfusion according to changes in respiration [6]. The ratio of pulsatile to non-pulsatile pulse oximetry measurements corresponds to the peripheral perfusion index, and the ratio of the highest and lowest perfusion index values corresponds to the PVI, there is no defined reference range [7, 8].

Tsuchiya et al. demonstrated that the PVI could be used to evaluate anesthesia-induced hypotension in patients undergoing general anesthesia without age group classification [8]. Similar studies have been conducted in pregnant women undergoing spinal anesthesia and, again, PVI was found to be a successful tool for predicting hypotension [9, 10]. This technique has been used in patients undergoing mechanical ventilation in the intensive care unit to detect fluid responsiveness through changes in respiratory patterns and peripheral perfusion [11]. It is a relatively new area of interest in the use of spontaneous breathing before anesthesia.

Predicting hypotension in geriatric patients with many co-morbidities is valuable for early intervention and the reduction of complication rates. However, the PVI and its predictive power in anesthesia-induced hypotension have not been extensively studied in geriatric patient populations. The aim of this study, therefore, was to test the utility of PVI in predicting anesthesia-induced hypotension in geriatric patients undergoing laparoscopic surgery. To the best of our knowledge, this is the first study on the use of PVI on anesthesia induction-induced hypotension in geriatric patients.

2. Materials and Method
Previous studies involving similar patient populations were examined, and power analyses revealed that at least 50 patients were required [9,12]. After approval from the local ethics committee (2017-KAEK-189_04), American Society of Anesthesiology (ASA) class 1 and class 2 patients, who underwent laparoscopic surgery at a university hospital and agreed to participate, were included in the study. The protocol adhered to the principles of the Declaration of Helsinki. This study was carried out prospectively and observationally between November 2018 and December 2019.

Patients with known cardiovascular diseases (all arrhythmias, including atrial fibrillation, and uncontrolled hypertension and congestive heart failure), those using vasoactive drugs (beta-blockers, etc), and those with peripheral vascular diseases or neuropathy were excluded from the study.

Non-invasive blood pressure, heart rate, pulse oximetry, and PVI values which automatically calculated from pulse oximetry were measured in the operating room after the patients rested for 5 min. The preoperative PVI value taken at this point was recorded as basal PVI. Preoperative total fasting times were also recorded.

After standard monitoring, an intravenous balanced crystalloid solution was started at a standard rate of 100 ml/h and was adjusted according to patient condition after intubation. Induction of anesthesia was performed using 2 mg/kg propofol and 0.6 mg/kg rocuronium, in accordance with hospital standards. After induction, the patients were intubated after being ventilated with a mixture of 80% oxygen and 20% air for 3 minutes with a peak pressure below 30 cmH2O. Hypotension was defined as a decrease in mean arterial pressure (MAP) > 20% after anesthesia induction and treated with intermittent bolus doses of 5 mg ephedrine. The values in patients with hypotension were not recorded after ephedrine administration. The definition of hypotension was
based on previous studies [13]. Non-invasive blood pressure measurements were performed at 30s intervals during the first 3 min after induction. The lowest systolic arterial blood pressure (SAP) was recorded; oxygen saturation and heart rate values were also recorded at this point. Apart from our study protocol, we did not perform postoperative follow-up related to outcomes in hypotensive patients.

Patients were divided into two groups (hypotensive and normotensive) and the correlation between preoperative anesthetic baseline PVI value and preoperative heart rate, preoperative SAP, preoperative MAP, SAP after induction, and changes blood pressure values were analyzed for these two groups.

SPSS version 22.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analysis. The Kolmogorov-Smirnov normality test was performed to examine the distribution of the measured values. The correlation between PVI and preoperative and postinduction systolic arterial pressure values was investigated using Pearson correlation analysis. The predictive power of PVI for hypotension was evaluated by using receiver operating characteristic (ROC) curve analysis, and the independent samples t-test was used to analyze normally distributed quantitative data and the chi-square (χ2) test was used to compare qualitative data. A value of p<0.05 was accepted as statistically significant [14].

3. Results

Eighty patients over 65 years of age who underwent laparoscopic surgery were included in the present study. No patient refused to participate in the study after enlightenment. The mean age of the patients was 72.97±5.20 years (range, 65–87 years), and there was no difference in age, sex, height, weight, or ASA classification between the hypotensive
and normotensive patients. The demographic data of the patients included in the study are summarized in Table 1. The mean fasting times of hypotensive and normotensive patients were 9.17 ±2.43 and 9.80 ± 2.09 hours, respectively. There was no significant difference in fasting time between groups (p=0.271).

Hypotension, which we accepted as more than twenty percent reduction in MAP was observed in 20 (25%) patients after anesthesia induction. The mean systolic arterial pressure change was 19.63% in all patients and 36.41% in hypotensive patients. Although there was a difference between hypotensive and normotensive patients in terms of PVI values (p=0.022), there was no significant difference in MAP, SAP and HR values. The difference between variables in hypotensive and normotensive patients is shown in table 2.

The mean baseline PVI of the patients before anesthesia was 12.29±4.15. When the relationship between preoperative MAP, preoperative SAP, and preoperative heart rate was examined, both in hypotensive and normotensive patients, as expected, a positive and significant correlation was observed between preoperative MAP and SAP values (p<0.001). Neither MAP nor SAP correlated with preoperative heart rate (p>0.05). Table 3 shows the significant correlation of SAP and MAP values.

Pearson correlation test was used for correlation analysis between basal PVI value and parameters that may be a risk factor in the development of hypotension. A positive and mild correlation was found between basal PVI value and MAP change (r = 0.195 and p = 0.041). There was no significant correlation between preoperative MAP value and PVI (r = 0.137 and p = 0.062), between preoperative SAP and PVI (r = 0.164 and p =
0.146), and between preoperative heart rate and PVI (r = 0.112 and p = 0.321). MAP, SAP, and pleth variability index correlations are summarised at table 4. The ability of the basal Pleth variability index value to differentiate hypotension was examined using ROC analysis, the mean area under the ROC curve (AUC) was 0.651 ± 0.073 (95%, Confidence Interval: CI 0.507–0.794) and was found to be statistically significant in predicting hypotension (p=0.04). The cut-off PVI value was calculated to be 15.45. Positive predictive value (PPV) was calculated as 40% and negative predictive (NPV) value was calculated as 80%. Hypotension was observed in 42% of patients with a basal PVI >15.45 and 23% in patients with a basal perfusion index <15.45. There were 8 hypotensive and 12 normotensive patients with a PVI value above the threshold value, and 12 hypotensive and 48 normotensive patients with a PVI value below the threshold value. Likelihood ratios in diagnostic testing calculated as LR+: 2 and LR-: 0.75. Also youden index calculated as 0.2. The power of the basal PVI values to predict the incidence of hypotension, according to ROC analysis, is shown in Figure.

When MAP, SAP and HR values and their ability to predict hypotension development were analyzed by ROC analysis; for MAP; AUC 0.738 sd: 0.002 CI 95% (0.628-0.847) and p = 0.056, for SAP; AUC 0.659 sd: 0.034 CI 95% (0.525-0.793) and p = 0.068, and for HR; AUC 0.311sd:0.012 CI 95% (0.174-0.447) and p = 0.070, these parameters were not predictive.

4. Discussion

Geriatric patients require more surgical procedures than the general population. General anesthesia provides greater hemodynamic stability than spinal anesthesia, however, there is a risk for hypotension with vasodilator and the cardio depressant effects of
anesthetic drugs. Older age alone is a risk factor for the development of hypotension [14]. In this patient group, hypotension should be recognized early and treated quickly to reduce the complication rate.

The PVI uses photoplethysmographic data obtained from pulse oximetry and perfusion index data, providing a ratio of pulsatile to non-pulsatile signals. Increased intrathoracic pressure with respiration will lead to more immediate reductions in peripheral perfusion in patients with a fluid deficit. In this case, a decrease in the perfusion index value of the patient will be observed. As a result of these changes with respiration, the ratio of the highest and lowest perfusion index corresponds to the PVI. High PVI values are observed in patients with a high fluid deficit or in those who do not respond to fluid application with changes in the perfusion index [11]. PVI was used in the regulation of perioperative fluid therapy in geriatric patients [15]. This was the first purpose of this technique. However, predicting hypotension in anesthesia induction and being able to do this especially in a risky group of patients such as geriatric patients will contribute to our anesthesia practice. In this sense, we think that our study can also contribute to geriatric anesthesia.

According to findings from our study, with preoperative baseline values, the PVI can predict the development of hypotension in geriatric patients undergoing laparoscopic surgery as a noninvasive and easily applicable test. Similar studies have been conducted for pregnant patients under spinal anesthesia or with those under general anesthesia without age limitations. These results are also consistent with our study [8, 10, 16].

In our study, the incidence of hypotension was increased in patients with PVI>15.45 before general anesthesia. This value was calculated to be 18 in the study by
Kuwata et al. and 15 in the study by Tsuchiya [8, 10]. Previously, PVI was used in studies investigating the relationship between respiratory movements and changes in peripheral perfusion index in patients undergoing mechanical ventilation. PVI has significant predictive power in terms of fluid deficit or non-response to fluid treatment. Since PVI is a ratio of PI values, there is no defined reference range. However, we think that the value of 15.45 in our study and the results in similar studies will make sense in clinical practice and that a new threshold can be drawn which can be defined as high or low pleth variability with new data [8, 10, 16]. Hypotension was observed in 42% of patients with a basal PVI >15.45 and 23% in patients with a basal perfusion index <15.45. Calculating positive and negative predictive values as 40 and 80 percent indicates that the predictive power is at medium levels. These values were 80% in PPV and 61.4 in NPV in the S. Sun’s study and in Kuwata's study, this value was calculated as PPV 78% and NPV 83%. However, these studies evaluated patients undergoing elective cesarean surgery. When our study results and predictive values are evaluated together, it supports our idea of using PVI results as an early warning system instead of a sharp distinction.

Systemic diseases, especially vascular problems and hypertension, may affect the results obtained with PVI. The fact that these problems are also commonly seen in geriatric patients, may limit the use of PVI. We think that it may be necessary to carry out new studies on the use of PVI in systemic diseases. Although some recent studies indicate that preoperative or basal heart rate has a predictive value for hypotension and cardiac complications, there was no significant relationship between basal heart rate and hypotension development in our study groups (Table 3) [17-19].
It is noteworthy that there was a correlation between PVI and MAP change (p = 0.042), but there was no significant relationship between PVI and preoperative MAP values. (r^2 = 0.062) (Table 4). We believe that the relationship between these two variables should be supported by more studies.

In our study, it was observed that this test was easily used in awake patients in the preoperative waiting room. Our study involving geriatric patients undergoing general anesthesia and previous studies in cesarean section patients undergoing spinal anesthesia conclude that the routine use of this test may be beneficial [16]. Positive features of this test include its non-invasiveness, it is easy to perform, and is inexpensive. However, there are insufficient data to distinguish the cause of hypotension due to peripheral vasodilatation and fluid redistribution, or due to cardiac output decrease after general anesthesia. In this distinction, our patients were selected from non-heart disease participants to investigate hypotension that may result from a fluid deficit or decreased vascular tone. However, the extent to which this highly selected patient group represents all geriatric patients is controversial, and this may be considered one limitation of our study. Polypharmacy and malnutrition, which are more common in geriatric patients, were not considered in the study. We think that this issue should also be mentioned as a limitation of our study. We believe that it may be misleading to add multivariate analysis without examining all possible factors. It may even be an advantage to detect increased risk without having to identify possible causes of hypotension. Regardless of risk factors, its use in finding patients with increased hypotensive risk supports the hypothesis.

5. Conclusion
The ability to predict hypotension in all patients, especially geriatrics, would be highly convenient for anesthetists and provide safety to patients. As an easily applicable test, PVI is useful in predicting the development of hypotension. It can be used as an early warning system. High PVI values can be interpreted as the incidence of MAP decrease will be higher after anesthesia induction in geriatric patients.

Acknowledgement and/or disclaimers: None

References


5. Forget P, Lois F, de Kock M. Goal-directed fluid management based on the pulse oximeter-derived pleth variability index reduces lactate levels and improves fluid...


### Table 1. Demographic data

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Hypotensive (n=20)</th>
<th>Normotensive (n=60)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>75.1±6.17</td>
<td>72.26±4.68</td>
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</tr>
<tr>
<td>Sex (F/M), n/n</td>
<td>12/8</td>
<td>35/25</td>
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<tr>
<td>Height (cm)</td>
<td>162.21±3.92</td>
<td>168.12±4.4</td>
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</tr>
<tr>
<td>Weight (kg)</td>
<td>72.0±5.8</td>
<td>69.8±6.4</td>
<td>0.073</td>
</tr>
<tr>
<td>ASA class I/II, n/n</td>
<td>10/10</td>
<td>34/26</td>
<td>0.080</td>
</tr>
</tbody>
</table>

Data presented as mean ± standard deviation unless otherwise indicated. ASA, American Society of Anesthesiologists.
Table 2. Variables in hypotensive and normotensive patients

<table>
<thead>
<tr>
<th></th>
<th>Hypotensive</th>
<th>Normotensive</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVI</td>
<td>14.12± 4.51</td>
<td>11.68±3.87</td>
<td>0.022</td>
</tr>
<tr>
<td>MAP</td>
<td>107.30±10.48</td>
<td>89.20±12.60</td>
<td>0.066</td>
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<tr>
<td>SAP</td>
<td>135.20±12.42</td>
<td>119.35±14.01</td>
<td>0.112</td>
</tr>
<tr>
<td>HR</td>
<td>74.15±12.09</td>
<td>82.65±13.73</td>
<td>0.241</td>
</tr>
</tbody>
</table>

PVI; Pleth variability index, MAP; Mean arterial pressure, (mmHg). SAP; Systolic arterial blood pressure (mmHg), HR; Heart rate, beats per minute (bpm).
Table 3. Correlations among MAP_1, SAP_1 and HR_1

<table>
<thead>
<tr>
<th>Measurement</th>
<th>MAP_1</th>
<th>SAP_1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypotensive</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR_1</td>
<td>$r$</td>
<td>-0.049</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>0.663</td>
</tr>
<tr>
<td>SAP_1</td>
<td>$r$</td>
<td>0.910</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Normotensive</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR_1</td>
<td>$r$</td>
<td>0.121</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>0.287</td>
</tr>
<tr>
<td>SAP_1</td>
<td>$r$</td>
<td>0.887</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>&lt;0.001</td>
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</table>

*Pearson correlation test, significant at 0.01 level. HR_1=preoperative heart rate (bpm); SAP_1 and MAP_1=preoperative systolic and mean arterial blood pressure (mmHg), respectively.
**Table 4.** MAP, SAP, and pleth variability index correlations

<table>
<thead>
<tr>
<th>Pathological parameter</th>
<th>Correlation coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAP change</strong></td>
<td>r 0.195</td>
<td>p 0.041*</td>
</tr>
<tr>
<td><strong>Preoperative MAP</strong></td>
<td>r 0.137</td>
<td>p 0.062</td>
</tr>
<tr>
<td><strong>Preoperative SAP</strong></td>
<td>r 0.164</td>
<td>p 0.146</td>
</tr>
<tr>
<td><strong>Preoperative HR</strong></td>
<td>r 0.112</td>
<td>p 0.321</td>
</tr>
</tbody>
</table>

*Correlation significant at 0.05 level. HR= Heart rate (bpm), SAP and MAP=Systolic and mean arterial blood pressure (mmHg), respectively.
Figure legend

Figure. Receiver operating characteristic (ROC) curve analysis for pleth variability index to predict the incidence of hypotension. Mean ± SD, Area under the ROC curve, 0.651±0.073 (95% CI 0.507–0.794; p=0.044). Sensitivity of 40%, specificity of 80%, PPV of 40%, NPV of 80%, cut-off value of 15.45