Original Article

Comparison between perfusion index, pleth variability index, and pulse pressure variability for prediction of hypotension during major abdominal surgery under general anaesthesia: A prospective observational study

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ABSTRACT

Background and Aims: Short-term hypotension after general anaesthesia can negatively impact surgical outcomes. This study compared the predictive potential of the pleth variability index (PVI), pulse pressure variability (PPV), and perfusion index (PI) for anaesthesia-induced hypotension. This study's primary objective was to evaluate the predictive potential of PI, PVI, and PPV for hypotension. **Methods:** This observational study included 140 adult patients undergoing major abdominal surgery under general anaesthesia. Mean arterial pressure, heart rate, PVI, PPV, and PI were collected at 1-min intervals up to 20 min post anaesthesia induction. Hypotension was assessed at 5-min and 15-min intervals. Receiver operating characteristic (ROC) curves were plotted to determine the diagnostic performance and best cut-off for continuous variables in predicting a dichotomous outcome. Statistical significance was kept at $P < 0.05$. **Results:** Hypotension prevalence within 5 and 15 min of anaesthesia induction was 36.4% and 45%, respectively. A PI cut-off of <3.5 had an area under the ROC curve (AUROC) of 0.647 ($P = 0.004$) for a 5-min hypotension prediction. The PVI's AUROC was 0.717 ($P = 0.001$) at cut-off >11.5, while PPV's AUROC was 0.742 ($P = 0.001$) at cut-off >12.5. At 15 min, PVI's AUROC was 0.615 (95% confidence interval 0.521–0.708, $P = 0.020$), with 54.9% positive predictive value and 65.2% negative predictive value. **Conclusion:** PVI, PPV, and PI predicted hypotension within 5 min after general anaesthesia induction. PVI had comparatively higher accuracy, sensitivity, specificity, and positive predictive value than PI and PPV when predicting hypotension at 15 min.

Keywords: Anaesthesia, haemodynamics, hypotension, perfusion index, pleth variability index, prediction, pulse pressure variability

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INTRODUCTION

Induction of general anaesthesia can sometimes lead to changes in the body's haemodynamics, resulting in significant decreases in blood pressure (severe hypotension) and heart rate (bradycardia).[1] The occurrence of initial hypotension just before and after tracheal intubation warrants particular attention as anaesthesiologists may be preoccupied with airway maintenance and ventilatory adjustments during this

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crucial time, potentially delaying the identification and treatment of hypotension. Nevertheless, even short-term hypotension following anaesthesia induction can have adverse effects on patient outcomes and overall haemodynamic stability.[2] Factors such as the patient's cardiac performance, the type and dosage of anaesthetic drugs used, and the degree of hypovolaemia resulting from pre-operative fasting are crucial in determining the likelihood of hypotension. Therefore, accurately assessing the risk of anaesthesia-induced hypotension is paramount for ensuring safe anaesthesia management.

In patients without significant comorbidities, anaesthesia-induced hypotension is often associated with the patient's volume status. Therefore, determining the patient's volume status may help predict the occurrence of anaesthesia-induced hypotension.[3] Various studies have explored both non-dynamic parameters, such as systolic blood pressure (SBP), mean arterial pressure (MAP), perfusion index (PI), and inferior vena cava diameter, and dynamic parameters, such as pleth variability index (PVI), pulse pressure variability (PPV), and stroke volume variation (SVV), as potential predictors of volume status.[4,5] However, in mechanically ventilated patients, blood pressure can fluctuate in response to ventilator cycles, especially in hypovolaemic patients, making prediction more challenging.[6]

Several studies have investigated using PI, PVI, and PPV as independent parameters to predict hypotension, yielding mixed results.[7-9] However, there is a lack of literature explicitly comparing perfusion indices such as PI, PVI, and PPV for predicting hypotension following anaesthesia induction in major abdominal surgeries.

The present study aimed to compare the predictive capabilities of PI, PVI, and PPV in determining hypotension after general anaesthesia induction. The primary objective was to establish cut-off values for these parameters to predict hypotension, and the secondary objective was to compare their positive and negative predictive values within 15 minutes of induction.

METHODS

This prospective observational study was conducted at a tertiary centre from June 2020 to February 2022 after obtaining approval from the institutional ethics committee (vide approval number 214/IEC/PGM/2018 dated 29 December 2018). The trial was registered under the Clinical Trials Registry-India (CTRI/2020/05/025263, www.ctri.nic.in).

All consenting patients of either gender, 18–60 years of age, belonging to the American Society of Anesthesiologists (ASA) physical status I/II scheduled for open major abdominal surgery under general anaesthesia requiring at least 2 hours of arterial blood pressure monitoring, were enroled. Patients with hypertension, cardiac, hepatic, or renal dysfunction, bilateral pulmonary disease, and difficult airway were excluded from the study. Written informed consent was obtained for participation in the study and use of the patient data for research and educational purposes. The study was carried out according to the principles of the Declaration of Helsinki, 2013, and good clinical practice.

According to our institutional preoperative fasting protocol, patients completed at least 6 h of fasting for solid foods before anaesthesia. Standard ASA monitors (non-invasive blood pressure, pulse oximeter, electrocardiogram, and temperature probe) were attached to the patient after transfer to the operating room. After securing the intravenous (IV) cannula, a left radial arterial line was inserted after applying local anaesthesia to alleviate the pain due to the needle prick. The Mindray Beneview T5 monitor (Mindray Bio-medical Electronics Co. Ltd., India) was connected to the arterial line to measure PPV. The Masimo Radical 7 co-pulse oximetry monitor and Mindray Beneview T5 pulse oximeter were put on the same side to get PVI and PI values, respectively.

Intravenous (IV) fluid loading and maintenance of the ringer's lactate infusion was started after calculating the total volume deficit using the Holiday Segar formula (4:2:1 rule). IV fentanyl 2 μg/kg, followed by IV propofol 2 mg/kg and vecuronium 0.1 mg/kg, was administered. The trachea was intubated with the appropriate-sized endotracheal tube by the same anaesthesiologist for all the patients. Maintenance of anaesthesia was established with nitrous oxide and oxygen in a ratio of 60%:40% and 1.5% sevoflurane. Volume control mode of ventilation was started with 6–8 mL/kg tidal volume and was titrated according to end-tidal carbon dioxide in the 30–35 cmH_2O range. After the surgery, the trachea was extubated once the extubation criteria were fulfilled.

Data was recorded by an anaesthesiologist unaware of the study protocol. Heart rate (HR), SBP, diastolic blood pressure (DBP), MAP, PI, PVI, and PPV were recorded at baseline and then at 1-minute intervals till 15 minutes after tracheal intubation. Blood pressure was recorded for the whole surgical duration as per standard patient care. However, for the study, we included a BP recording of only 15 minutes in the manuscript.

Hypotension was defined as a drop in SBP to >30% below the baseline value. If needed, hypotension was treated immediately by rapid IV fluid administration (10 mL/kg) and IV mephentermine 6 mg boluses. Bradycardia was defined as a decrease in the HR by >30% below baseline value[10] and was treated with IV atropine 0.6 mg boluses.

The primary outcome was to identify the cut-off values of PI, PVI, and PPV to predict hypotension by 5 minutes after induction of general anaesthesia. In addition, the secondary outcome was to compare the positive and negative predictive values of PI, PVI, and PPV with established cut-off values 15 min post induction.

In the present study, we monitored vital signs and various parameters up to 15 min post induction. We specifically focused on this time frame because pre-induction volume depletion was identified as a significant risk factor for subsequent hypotension.[11] We also considered the transition from spontaneous to mechanical breathing during the initial 15 minutes post-induction. This transition can alter intrathoracic pressure, potentially influencing the monitored parameters and emphasising the importance of studying this critical period in detail.

The pathophysiology of hypotension in spinal anaesthesia is different. However, as no prior research paper had been published at the time of initiation of a study to calculate the sample size in general anaesthesia induction for comparing PI, PVI, and PPV, the sample size was calculated based on a study on hypotension in spinal anaesthesia. The sample size was based on a study by Duggappa DR *et al*.,[2] who reported PI as a predictor of hypotension following spinal anaesthesia. For $\alpha = 1.96$ with a 95% confidence interval and power of 99%, the proposed sample size for the study was calculated to be 127. Assuming 10% attrition, the total sample size calculated was 140.

Data were coded and recorded in MS Excel spreadsheet program. Statistical Package for the Social Sciences (SPSS) statistics software version 23.0 (Armonk, NY: International Business Machines Corp, USA) statistical software was used for data analysis. Descriptive statistics were elaborated as means (standard deviation [SD]) and median (interquartile range [IQR]). Group comparisons for continuously distributed data (PI, PVI, PPV) were made using independent sample *t-test* and one-way analysis of variance (ANOVA) when comparing more than two groups. Post-hoc pairwise analysis was performed using Tukey's HSD test in the case of one-way ANOVA. Non-parametric tests (Wilcoxon and Kruskal–Wallis tests) were used to compare non-normal distribution (blood pressure and MAP). The Chi-squared test was used for group comparisons for categorical data such as types of surgeries and gender. Fisher's exact test was used instead if the expected frequency in the contingency tables was <5 for >25% of the cells. Paired variables PI, PVI, and PPV from different time frames were continuously distributed and were compared using the paired *t-test* and ANOVA when comparing more than two variables. The Friedman test was used if the variables were not continuously distributed (BP changes). For the hypotension, categorical variables were compared using McNemar's test. Linear correlation between two continuous variables was explored using Pearson's and Spearman's correlation. Receiver operating characteristic (ROC) curves were plotted to determine the diagnostic performance and the best cut-off for continuous variables in predicting a dichotomous outcome. Statistical significance was kept at $P < 0.05$.

RESULTS

A total of 140 patients were included in the study [Figure 1]. Demographic data is represented in Table 1. In total, 83 (59.3%) participants were male, and 57 (40.7%) were female. The patients' mean (SD) age was 39.56 (11.00) years. The different major surgeries included in this study were gastro-surgeries (41.4%), general surgeries (30%), gynaecological surgery (6.4%), and onco-surgeries (22.1%). There were no significant differences in demographic variables. Post-induction hypotension developed in 63 patients.

Prevalence of hypotension by 5 min of anaesthesia induction was 36.4%, and by 15 min of induction was 45% (63 patients). Area under ROC (AUROC) curve of PI, PVI, and PPV at 5 min is represented in Figure 2a-c, respectively. A PI cut-off value of <3.5 showed 64% sensitivity and 73% specificity in predicting hypotension by 5 min and statistically insignificant results by 15 min [Tables 2 and 3].

A cut-off value of 11.5 for PVI yielded a sensitivity of 68.6%, specificity of 75.3%, and modest diagnostic accuracy by 15 minutes [Table 3]. A PPV cut-off of 12.5 yielded statistically insignificant results by 15 min [Table 3]. The mean propofol dose was 93 mg in patients who developed post induction hypotension and 90 mg in those who did not develop post induction hypotension ($P > 0.05$).

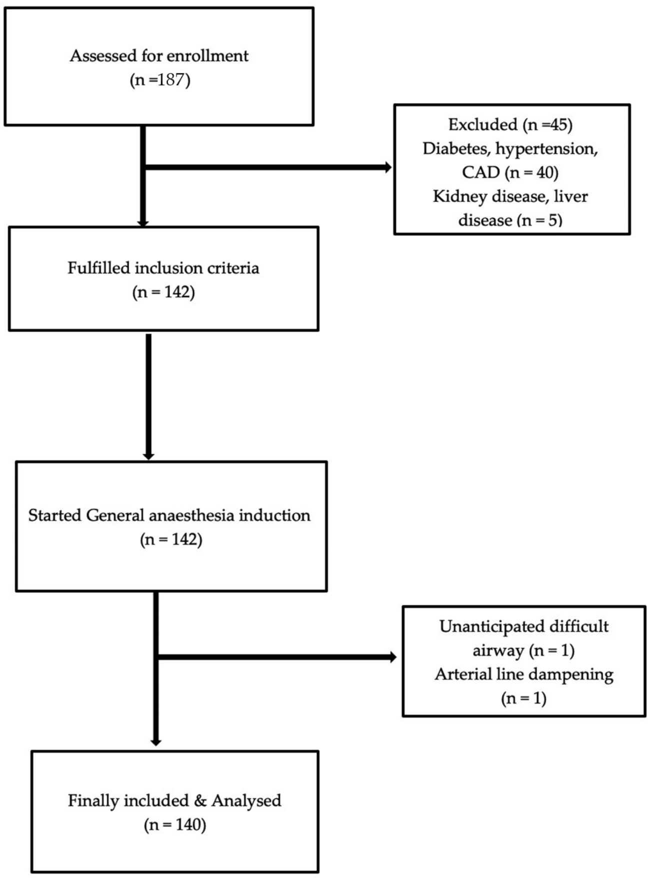

Figure 1: Study participants flow diagram. CAD=coronary artery disease, n=number of patients

DISCUSSION

In the present study, PI showed a positive correlation with SBP with a significant AUROC (0.647) at 5 min for hypotension prediction, but its performance diminished at 15 min (AUROC: 0.501). PVI displayed a negative correlation with SBP, presenting an AUROC of 0.717 at 5 min and 0.615 at 15 min. In contrast, PPV exhibited poor predictive performance at 15 min (AUROC: 0.524), questioning its reliability in this context.

Our findings suggest that PPV may not be a reliable predictor of hypotension related to anaesthesia induction in this study setting. In contrast, PPV is the predictor of volume status.[12] Enevoldsen *et al*.[13] reported decreased PPV values with lower tidal volumes, the relative best tidal volume being 10 mL/kg.

In this study, we induced anaesthesia while the patient was breathing normally with a 6 mL/kg tidal volume. We believe baseline PPV values may have been influenced by the patient's forced inspiratory breathing and the tidal volume set after induction. Intrathoracic pressure and the capacitance of pulmonary vasculature, influenced by the intensity of inspiratory effort, may lead to unpredictable heart-lung interactions.[14] These complex interactions could explain our study's lack of predictive value of PPV.

Table 1: Demographic data

Parameters	Values *n*=140
Age (years)	39.56 (11)
Height (cm)	164.69 (7.47)
Weight (kg)	58.37 (9.11)
Body Mass Index (kg/m^2)	21.54 (3.24)
Duration of surgery (h)	4.53 (1.94)

Data expressed as mean (standard deviation)

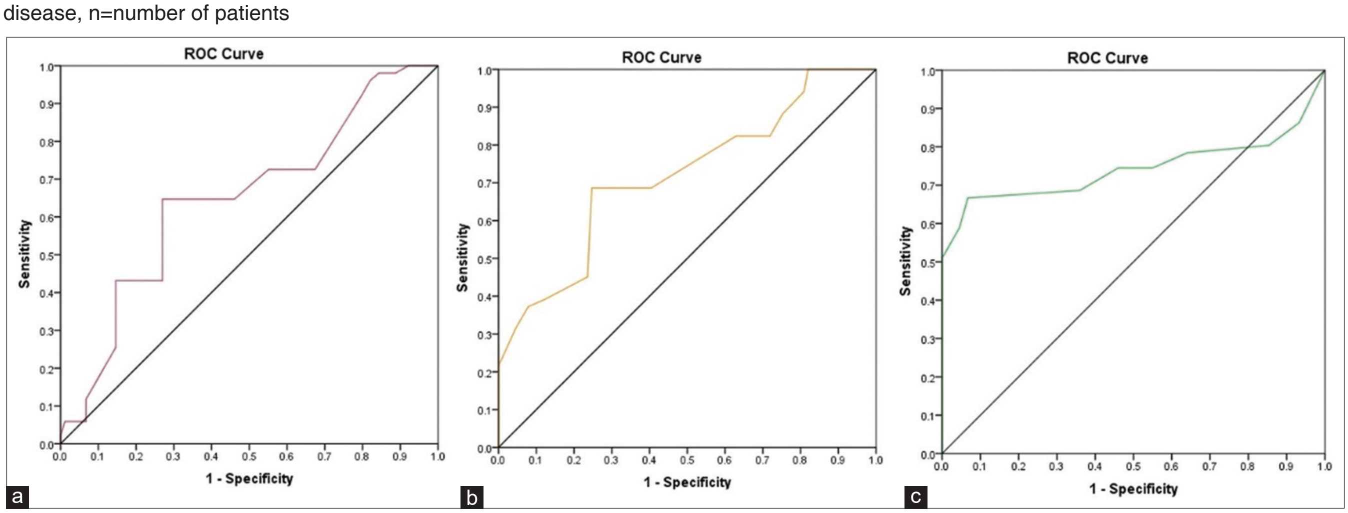

Figure 2: Receiver operating characteristic (ROC) curve: perfusion index at 5 minutes (a), pleth variability index at 5 minutes (b), pulse pressure variation at 5 minutes (c)

Table 2: Comparison of the diagnostic performance of various predictors in predicting hypotension by 5 minutes

Predictor	Cut off	AUROC	95% CI	*P*	Sn	Sp
PI (Baseline)	3.5	0.647	0.551–0.744	0.004	64.7%	73%
PVI (%) (Baseline)	11.5	0.717	0.626–0.807	0.001	68.6%	75.3%
PPV (%) (Baseline)	12.5	0.742	0.636–0.848	0.001	68.6%	64%

AUROC: Area under receiver operating characteristic curve; CI: Confidence interval; P: P value; Sn: Sensitivity; Sp: Specificity; PI=perfusion index, PVI=pleth variability index, PPV=pulse pressure variation

Table 3: Comparison of the diagnostic performance of various predictors in predicting hypotension by 15 minutes

Predictor	Cut off	AUROC	95% CI	*P*	Sn	Sp	PPV*%	NPV%	DA%
PI (Baseline)	3.5	0.501	0.403-0.598	0.992	47.6	42.9	40.5	50	45
PVI (%) (Baseline)	11.5	0.615	0.521-0.708	0.02	61.9	58.4	54.9	65.2	60
PPV (%) (Baseline)	12.5	0.524	0.421-0.627	0.629	49.2	53.2	46.3	56.2	51.4

AUROC: Area under receiver operating characteristic curve; CI: Confidence interval; P: P value; Sn: Sensitivity; Sp: Specificity; PPV*: Positive predictive value; NPV: Negative predictive value; DA: Diagnostic Accuracy

Hypotension during the post-induction phase involves action on the autonomic nervous system, affecting the sympathetic and parasympathetic components.[15] There is evidence for propofol's direct effect through endothelium-dependent and endothelium-independent pathways.[16] Both culminate in vasodilatation. If the patients have significant peripheral vasoconstriction, that is, low PI, they are more likely to have hypotension after induction. Similarly, suppose the patient already has low vascular tone (vasodilated and relatively compensated blood volume), indicated by higher PI. The current study demonstrates that hypotension is less possible in that case. Because volume depletion before induction is the major risk factor for developing significant hypotension during the post-induction phase, it is reasonable that the hypotension is greater in patients with higher PVI and lower PI values. In addition to patient volume status, it is also significant to consider the influence of patient mental status while collecting baseline values of parameters. The period before anaesthesia induction is a time when surgical patients would be anxious, which might cause a rise in baseline blood pressure and sympathetic tone.[17] To diminish such adverse effects, we administered oral alprazolam 0.5 mg and permitted the patient to rest comfortably in the pre-operative area. Despite these techniques, patients can continue to be in a state of anxiety, and an increase in baseline blood pressure may induce a more significant decrease in blood pressure post-anaesthesia induction. However, increased sympathetic tone might decrease baseline PI values and consequently increase PVI. It should be noted that patients received not merely propofol but also fentanyl and vecuronium. As these two drugs have little or feeble pharmacological effects on circulation,[18] we considered that their administration did not substantially impact circulation.

In a prospective cohort study conducted by Abdelhamid *et al*.[8] in 2022, pre-anaesthetic PI <3.03 and PVI >17 were effective predictors of post-induction hypotension in adult patients undergoing elective surgery with general anaesthesia. Our study aligns partly with these findings, although the present study had a larger sample size, with a high power of 99%.

Strengths of this study include a robust sample size (140 patients) and a focused assessment of primary and secondary outcomes. However, limitations include the inability to control respiratory variables and lack of consideration for certain patient-specific factors, such as varied sensitivity to induction agents. In addition, the induction process involving laryngoscopy and intubation can lead to changes in blood pressure, potentially affecting the predictive capabilities of the studied parameters. However, the same anaesthesiologist performed laryngoscopy and intubation in every patient to avoid subjective bias. PVI measurements may be susceptible to false readings due to ambient light. Our findings support the predictive potential of PVI for hypotension within 15 minutes post-induction, outperforming PI and PPV. PI's predictive capability diminished over time, while PVI maintained a significant association with hypotension. These results suggest the clinical relevance of PVI monitoring in preventing adverse outcomes related to hypotension post-anaesthesia induction.

This study raises questions about the reliability of PPV as a predictor for hypotension in this specific setting, contrasting its established role in predicting fluid responsiveness. Future research should explore comprehensive models incorporating multiple parameters to enhance predictive accuracy for post-induction hypotension. In addition, considering the impact of patient-specific factors such as anxiety and varying responses to induction agents may improve predictive models.

CONCLUSION

We conclude that all three parameters (PI, PVI, and PPV) could predict hypotension following induction of general anaesthesia by 5 min. PVI demonstrated more diagnostic accuracy in predicting hypotension after 15 min of induction. PVI had a statistically significant association with hypotension and showed higher sensitivity, specificity, and positive predictive value than PI and PPV.

Study data availability

De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared after approval as per the authors' institutional policy.

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Conflicts of interest

There are no conflicts of interest.

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