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ORIGINAL RESEARCH

Pre-anesthetic ultrasound assessment of subclavian vein collapsibility for predicting hypotension following induction after general anesthesia

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ABSTRACT

Background: The induction of anaesthesia is associated with risk of hypotension as anaesthetic agents have myocardial depressant and vasodilatory effects. These are more prevalent in patients with dehydration and an impaired compensatory response. The 'Collapsibility Index' of subclavian vein diameter (DSCV-CI) can predict general anesthesia-induced hypotension in deep inspiration. Our study aimed to assess the efficacy of pre-anaesthetic SCV collapsibility in supine and passive leg raising (PLR) to predict hypotension following induction of general anesthesia. **Methods**: Seventy-four patients belonging to the American Society of Anesthesiologists' physical status I and II in the age group 18-50 years of either gender scheduled to undergo elective surgeries under general anesthesia (GA) were selected for this study. An average of three ultrasonographic measurements of the subclavian vein (SCV) diameter in supine and passive leg raising (PLR) were taken. The maximum value of SCV diameter was recorded as $[DSCVmax]_{Supine}$ and the minimum as $[DSCVmin]_{Supine}$ in the supine position, and $[DSCVmax]_{PLR}$ and $[DSCVmin]_{PLR}$ during PLR respectively. The collapsibility index of SCV was further calculated from these values. Receiver operating characteristic curve (ROC) analysis, logistic regression, and p-value were used to project the use of DSCV and other parameters in predicting post-induction hypotension. **Results:** ΔDSCV had a significant difference in patients who developed post-induction hypotension and those who did not develop hypotension. The area under the curve for ΔDSCV in predicting hypotension after general anesthesia induction was 0.7 (95% CI: 0.53–0.87), while DSCV and CI were less than 0.7. **Conclusion**: ΔDSCV has better predictive value for hypotension that occurs following induction of general anesthesia.

Keywords: Collapsibility index; hypotension; induction; general anesthesia; passive leg raise; subclavian vein diameter.

INTRODUCTION

Various drugs used in general anaesthesia (GA) may promote vasodilation and/or myocardial depression, which frequently results in post-anaesthetic hypotension.[1] Approximately one-third of cases of intraoperative hypotension occurs during the period between the time of the induction of anaesthesia and surgical incision.[2] Consequently, during induction, anaesthesiologists should be alert to detect the onset of hypotension and prepared to treat the same.

Ultrasonography of inferior vena cava diameter (dIVC) and collapsibility index of inferior vena cava diameter (dIVC - CI) have been reported to be a useful tool for predicting post-GA hypotension.[3] Other independent predictor of hypotension during induction of GA is the pre-GA-induction ultrasonography of the internal jugular vein area (IJV-A) in the trendelenburg position.[4] The collapsibility index of subclavian vein diameter [CI] on deep inspiration was able to predict post-induction hypotension, which could be explained by enhanced cardiopulmonary interactions.[5] The subclavian vein (SCV) is located adjacent to the pleura and upstream of the superior vena cava and can be easily visualized in most patients using a linear probe. In patients with shock, PLR is useful in assessing intravascular volume depletion or fluid responsiveness. [6] Therefore, we assessed pre-anaesthetic subclavian vein ultrasonographic diameter

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variation with PLR and the SCV diameter collapsibility index [CI] in supine and in PLR position and the haemodynamic responses following induction of general anaesthesia were noted.

METHODOLOGY

After obtaining Institutional ethical committee approval (EC-324), the study was registered in the Clinical trial registry (CTRI/2023/10/058551). For this prospective, observational study, a total of seventy-four patients belonging to the American Society of Anesthesiologists' physical status I and II in the age group 18-50 years of either gender scheduled to undergo elective surgeries under general anaesthesia were selected. Written informed consent was obtained from all participants. Patients with peripheral vascular disease, cardiovascular disease, hepatic and renal complications, circulatory instability, and pregnant patients were excluded from the study.

Every patient underwent a regular pre-anaesthesia examination, and routine investigations were acquired and optimized as needed for the procedures. All the patients were kept nil by mouth as per Indian Society of Anaesthesiology (ISA) guidelines and were given oral ranitidine 150 mg and ondansetron 4 mg the night before surgery. After confirming nil by mouth status, an intravenous line was secured and crystalloids were administered at a rate of 10 ml/kg/hour. Baseline vitals were noted in the preoperative room while the patient was conscious, lying in a supine position for at least 5 minutes. Ultrasonographic measurements of the subclavian vein (SCV) were performed using a high frequency (13-6MHz) linear array probe (Sonosite© M Turbo machine) on M mode. With the marker point facing the head, the probe was positioned in the middle of the clavicle to find the optimal SCV view in the short axis.

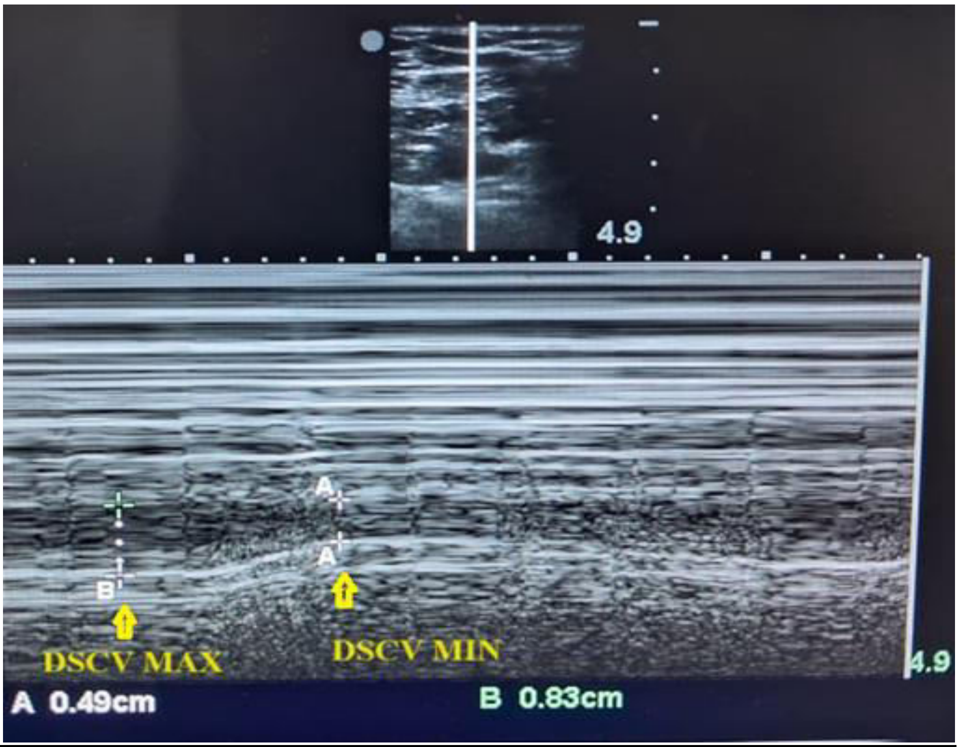

Figure 1: Ultrasound image showing assessment of SCV diameter

An average of three measurements of maximum and minimum diameters of the SCV were taken bilaterally in all patients during three spontaneous respirations both in supine and PLR. DSCV was determined by the average of the bilateral SCV diameters. The collapsibility index of SCV was calculated in the supine position - $[CI]_{Supine}$ and PLR - $[CI]_{PLR}$ with the following formula and recorded:

- CI = (DSCVmax - DSCVmin)/ DSCVmax *100

The rate of change of DSCV was expressed as ΔDSCV and calculated using the following formula:

- ΔDSCV = ($DSCVmax_{PLR}$ - $DSCVmax_{Supine}$)/ $DSCVmax_{PLR}$ *100

In the operating room, all patients were connected to an electrocardiogram, non-invasive blood pressure, and pulse-oximeter and values were recorded. All patients were premedicated with intravenous (IV) glycopyrrolate 0.004 mg/kg, ondansetron 0.1mg/kg, midazolam 0.01 mg/kg, fentanyl 2 mcg/kg, and were induced with IV propofol 2 mg/kg. Laryngoscopy and tracheal intubation were done following muscle relaxation with vecuronium 0.1 mg/kg. Anaesthesia was maintained with isoflurane in oxygen and air (FIO_2 0.5) and an intermittent dose of IV vecuronium 0.02 mg/kg for muscle relaxation was administered. Haemodynamic parameters such as heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and oxygen saturation

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(SpO_2) were measured every two minutes up to ten minutes after induction of anaesthesia. Patients who developed post-induction hypotension were identified. Hypotension was defined as a 20% or more fall in MAP from baseline or MAP less than 60 mmHg. The crystalloid infusion rate would be increased if the MAP was less than 60 mm Hg and if hypotension persists IV ephedrine 6 mg bolus was given. After completion of the surgery, IV neostigmine 0.05 mg/kg and glycopyrrolate 0.01 mg/kg were administered to reverse the residual neuromuscular blockade. Further, the association between ultrasonographic SCV measurements and post anaesthesia induction hypotension was analyzed.

Based on a previous study by Lijun Yang et al., [7] the area under the ROC curve of ΔDSCV was 0.75. Using the formula $Z\alpha^{2} * P(100 - P)]/d^2$, with a precision (d) of 10 and 95% CI (Zα) 1.96, the sample size was calculated to be 74.

STATISTICAL ANALYSIS

Data was analyzed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL) and the level of significance was set at $p < 0.05$. Descriptive statistics was used to assess the mean and standard deviation. The data - normality was assessed using the Shapiro-Wilkins test. Inferential statistics to find out the difference among patients were done using the Chi-square test. Logistic regression model, AUC curve with sensitivity and specificity was calculated for the risk estimation. For comparison of data, the Mann-Whitney U test was utilized.

RESULTS

A total of 83 patients were checked for eligibility, out of that seventy-four patients were enrolled in the study after considering inclusion and exclusion criteria.

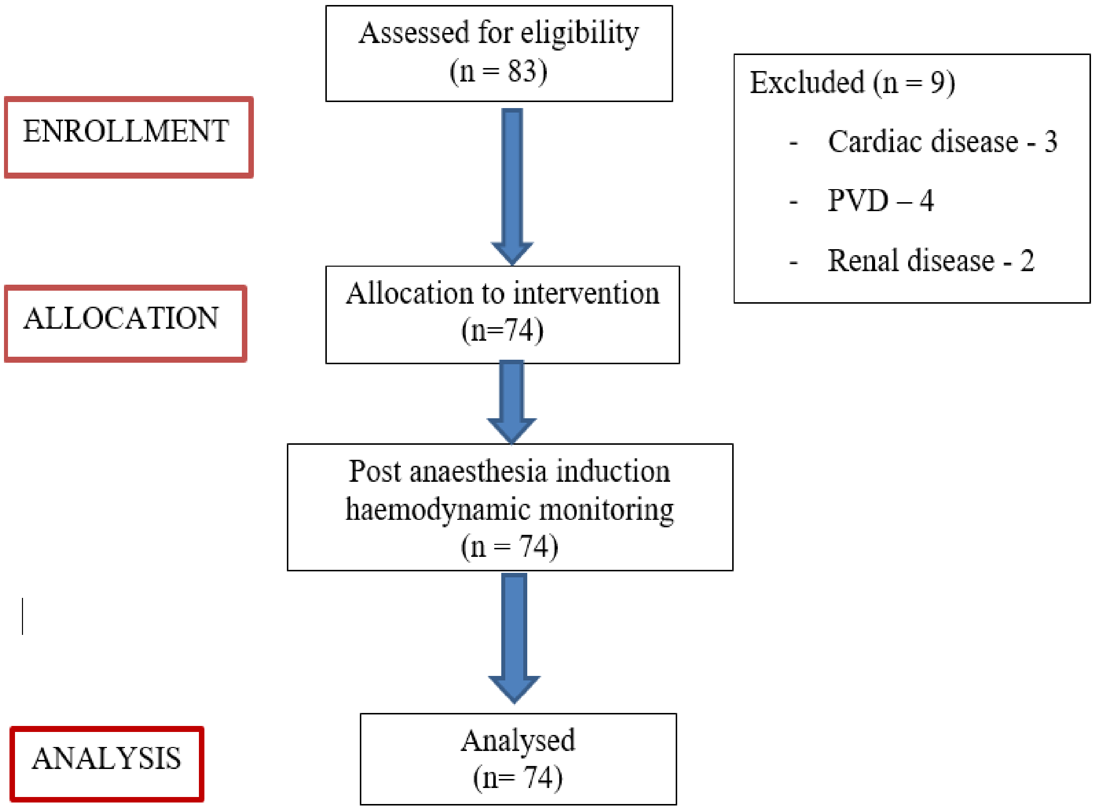

Figure 2: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) flowchart

The demographic parameters of the study participants are given in the table 1.

Table 1: Demographic data of study participants

Variables	Mean ± SD
AGE (years)	35.3 ± 2.184
BMI (kg/m^2)	24.1722 ± 0.558
Preoperative MAP (mmHg)	92.527 ± 1.902

The mean diameter of DSCVmax in the supine position in patients who developed hypotension was $(DSCVmax)_{Supine}$ 0.76 ± 0.12 cm, which increased to $(DSCVmax)_{PLR}$ 0.88 ± 0.17 cm after PLR position. The $(DSCVmax)_{Supine}$ was 0.83 ± 0.15 cm and it increased to $(DSCVmax)_{PLR}$ 0.95 ± 1.0 cm in patients who did not manifest hypotension. Out of 74 patients, only 17 patients (22.9%) developed hypotension after induction of anaesthesia, while the remaining 57 patients (77.1%) did not develop hypotension. It was

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noted that patients who developed post-anaesthesia induction hypotension had a higher MAP (96 ± 9.76 mmHg) when compared to those who did not develop hypotension (91 ± 7.55 mmHg). While analyzing measurements in both supine and PLR positions for all patients, only ΔDSCV exhibited a significant difference (p = 0.0026) between patients with and without post-induction hypotension.

Table 2: Ultrasonographic measurements of SCV diameter in supine and PLR

Variables	Patients with HYPOTENSION Mean ± SD (95% CI)	Patients WITHOUT HYPOTENSION Mean ± SD (95% CI)	p-value
$[\text{DSCV max}]_{\text{Supine}}$	0.76 ± 0.12 (0.56 - 0.87)	0.83 ± 0.15 (0.66 - 0.93)	0.06
$[\text{CI}]_{\text{Supine}}$	25.0 ± 10.04 (18.45 - 29.55)	29.20 ± 7.6 (17.55 - 34.98)	0.07
$[\text{DSCV max}]_{\text{PLR}}$	0.88 ± 0.17 (0.56 - 1.34)	0.95 ± 0.10 (0.75 - 1.22)	0.04*
$[\text{CI}]_{\text{PLR}}$	24.44 ± 7.66 (18.48 - 29.75)	22.12 ± 7.30 (17.56 - 26.98)	0.27
ΔDSCV	**16.22** ± 7.13 (13.56 - 23.46)	11.79 ± 4.41 (9.56 - 13.67)	**0.0026***

The area under the curve (ROC) for ΔDSCV in predicting hypotension following induction of general anaesthesia induction was 0.7 (95% CI: 0.53–0.87), while DSCV and CI were less than 0.7.

Table 3: Area Under the Curve (AUC) in ROC analysis

Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% CI Lower Bound	Asymptotic 95% CI Upper Bound
$[\text{DSVC max}]_{\text{Supine}}$	0.315	0.079	0.021	0.160	0.469
$[\text{CI}]_{\text{Supine}}$	0.377	0.088	0.126	0.205	0.550
$[\text{DSVC max}]_{\text{PLR}}$	0.359	0.088	0.078	0.185	0.532
$[\text{CI}]_{\text{PLR}}$	0.580	0.088	0.319	0.407	0.753
ΔDSCV	0.70	0.086	0.014	0.529	0.866
a. Under the nonparametric assumption					
b. Null hypothesis: true area = 0.5					

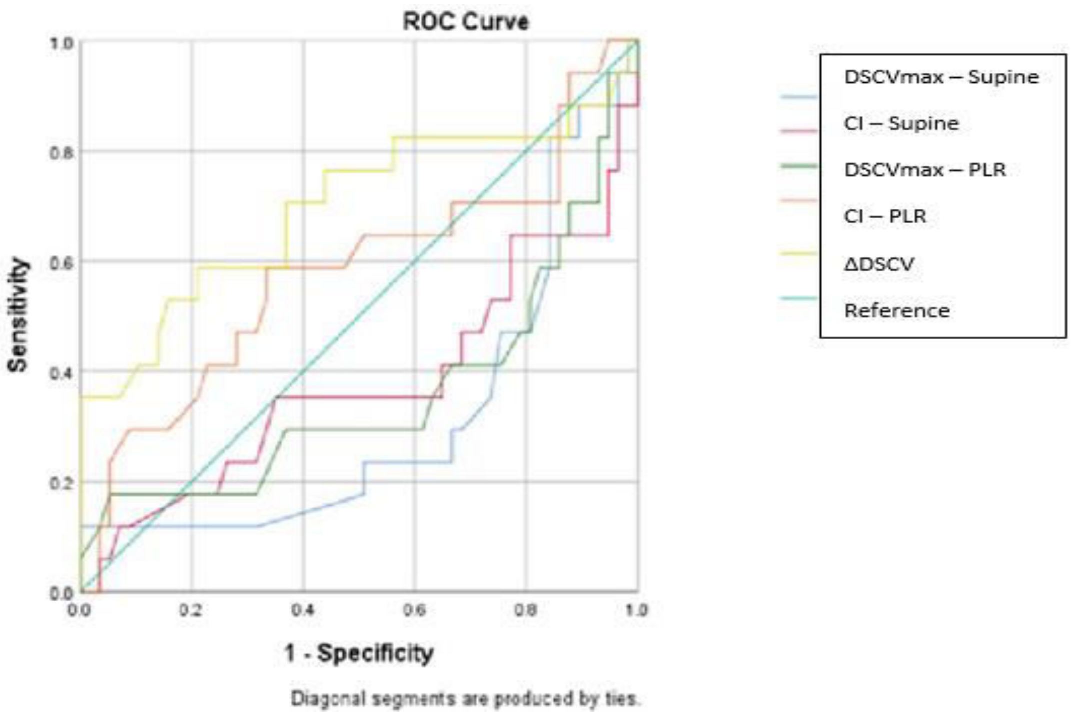

Figure 3: ROC curves with variables for prediction of hypotension

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ΔDSCV shows maximum positive predictive value (PPV) and negative predictive value (NPV) among all parameters. The critical value of ΔDSCV was determined to be 16.22%, with a sensitivity of 75% and specificity of 80%.

Table 4: Diagnostic accuracy of various variables in predicting post-induction hypotension

Variable(s)	Sensitivity	Specificity	PPV	NPV
$[\text{DSVC max}]_{\text{Supine}}$	39	43	19%	68%
$[\text{DSCV CI}]_{\text{Supine}}$	43	57	25%	75%
$[\text{DSVC max}]_{\text{PLR}}$	37	48	19.0%	69.0%
$[\text{DSCV CI}]_{\text{PLR}}$	63	74	45%	85.0%
ΔDSCV	**75**	**80**	**55.0%**	**90.0%**

After adjusting for all possible parameters using binary logistic regression, the odds ratio for ΔDSCV was found to be 1.235, making ΔDSCV the only independent predictor of hypotension after general anaesthesia induction in our study.

Table 5: Logistic regression analysis

Variables in the Equation								
							95% CI for EXP(β)	
	β	S.E.	Wald	df	Sig.	Exp (β)	Lower	Upper
$[\text{DSCVmax}]_{\text{Supine}}$	4.170	5.552	.564	1	.453	64.703	.001	3441077.234
$[\text{CI}]_{\text{Supine}}$	-.117	.049	5.576	1	**0.018**	**0.890**	**0.808**	.980
$[\text{DSCVmax}]_{\text{PLR}}$	-3.187	4.376	.530	1	.466	.041	.000	219.264
$[\text{CI}]_{\text{PLR}}$	.093	.061	2.350	1	.125	1.098	.974	1.237
ΔDSCV	.211	.096	4.783	1	**.029**	**1.235**	**1.022**	1.492
Constant	-3.493	3.708	.887	1	.346	.030		

DISCUSSION

Hypotension is a common threat every anaesthesiologist faces during anaesthesia induction. It may lead to serious consequences like acute renal injury or myocardial infarction if not treated early. Prevention of such complications by a reliable test that can predict hypotension, done before induction could be very helpful. Ultrasonographic evaluation of SCV diameter is supine and PLR has gained interest as a preliminary screening method for volume monitoring and has potential in clinical monitoring applications. Unlike invasive cardiac monitoring, ultrasound monitoring of the SCV is not hindered by surgical area disinfection and is easily accessible. Bedside USG measurements can be quickly done to obtain valuable information to recognize patients who could be at risk of post-induction hypotension. Also, unlike the inferior vena cava and internal jugular vein, the SCV is advantageous for measurement as it is supported by the clavicle, preventing deformation or compression. It is also not affected by pregnancy, obesity, or abdominal pain, and its anatomical position remains fixed. During PLR, around 300 ml of blood from the lower extremities returns to the right ventricle due to gravity, temporarily and rapidly increasing cardiac preload and stroke volume.[8] Since PLR supports blood redistribution through systemic autotransfusion, it is reasonable to observe an increase in DSCV and a decrease in CI after its implementation. Our data, confirmed this hypothesis, as we observed increased DSCV and decreased CI in both groups after PLR. Similarly, another study [9] showed that heart rate and blood pressure remained unchanged after PLR compared to the baseline values suggesting that blood pressure is not at all reliable for tracking changes in cardiac output.

A previous study [7] concluded that the rate of change of subclavian vein diameter with passive leg raising (ΔDSCV) can effectively predict hypotension with a cutoff value of 15.86%. Our study also confirms that ΔDSCV has significant predictive value, with a cutoff value of 16.22%.

Another study [5] found out the CI of the SCV during deep inspiration is a significant predictor of intraoperative hypotension occurrence but in our study, we found that the CI of the SCV at spontaneous respiration does not have much predictive value in post-induction hypotension.

In a study [9] done in sedated and mechanically ventilated patients undergoing kidney transplantation the researchers concluded that respiratory variations of the subclavian vein (ΔSCV) and pulse pressure variation (PPV) can be used interchangeably to assess preload dependency in these patients. ΔSCV was found to be a suitable tool due to its non-invasive nature, simplicity, ease of use, and high availability.

In a previous study [10], it was found that assessment using the SCV CI in the semi-recumbent position had a reasonable concordance with assessment using the IVC CI for both spontaneously breathing and mechanically ventilated patients with kidney disease, and can be used as an adjunct to assess intravascular volume in patients with kidney disease.

In a study [11] done in a surgical intensive care unit, it was concluded that SCV collapsibility assessment appears to be a reasonable adjunct to IVC-CI in the

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surgical intensive care unit patient population. The two techniques had an acceptable correlation and the overall measurement bias was low. Also, it took less time for SCV-CI measurements than IVC-CI measurements.

A study [12] done in full-term parturients scheduled for cesarean delivery under spinal anesthesia found that SCV US-guided volume management reduced the volume of the preload required before spinal anaesthesia but did not ameliorate post-spinal anaesthetic hypotension. Reducing preload volume did not have any effect on the incidence of maternal and neonatal adverse effects nor the total vasopressor dose. However, reducing preload volume could relieve the burden off of the parturient heart, which has a high clinical significance.

A study [13] done in patients undergoing general anaesthesia, suggests that in preoperative patients SCV-CI in deep breathing and IVC-CI are very sensitive and reliable in predicting post-induction hypotension. However, our study contradicts those findings; the CI in spontaneous breathing was not found to be a reliable predictor of post-induction hypotension. By excluding confounding factors such as changes in venous compliance, right atrial pressure, and intrathoracic pressure, volume is likely the primary determinant of hypotension in patients after general anaesthesia. Following PLR, the SCV diameter increased in the PLR position due to systemic blood redistribution, potentially benefiting from sympathetic innervation. However, general anaesthesia inhibits sympathetic nerves, leading to vasodilation and subsequent hypotension. [14] Thus, our findings indicated that alterations in SCV diameter resulting from PLR could serve as a predictive factor for post-anaesthesia hypotension.

Our study has several limitations. Firstly, the depth of anaesthesia was not continuously monitored during the anaesthesia period, which may introduce deviations in the results. Secondly, a direct assessment of systemic volume and haemodynamic parameters such as invasive cardiac output monitoring or non-invasive cardiac function parameter monitoring was not performed which could help correlate clinical outcomes; additionally, transthoracic echocardiographic monitoring was not done. Lastly, it is important to note that the sample size was small and the participants were all healthy individuals with good cardiac function. Therefore, further research is needed to validate these findings in larger and more diverse populations before definitive recommendations for clinical use can be made.

CONCLUSION

Pre-anaesthesia, ultrasound-guided monitoring of PLR-induced changes in subclavian vein diameter is a good predictor of hypotension following general anaesthesia.

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