

PREOPERATIVE ULTRASONOGRAPHIC EVALUATION OF SUBCLAVIAN VEIN AND INFERIOR VENA CAVA FOR PREDICTING HYPOTENSION ASSOCIATED WITH INDUCTION OF GENERAL ANAESTHESIA

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ABSTRACT

Background: Perioperative hypotension after induction is a serious complication associated with poor outcomes, with preload status being a key determinant. Ultrasonographic assessment of inferior vena cava (IVC) and subclavian vein (SCV) collapsibility indices (CI) provides a simple, noninvasive method for predicting anaesthesia-induced hypotension. This study aimed to evaluate the ability of ultrasonographic measurement of SCV and IVC diameters and CI to predict hypotension after the induction of general anaesthesia. **Materials and Methods:** This prospective observational study included 94 patients at the Institute of Anaesthesiology, Government Rajaji Hospital, Madurai, over 1 year. Patients were premedicated, baseline ASA monitoring was applied, and IVC and SCV diameters were measured using ultrasound to calculate the collapsibility indices. Anaesthesia was induced using a standard protocol, with hypotension defined as a MAP <60 mmHg or a $\geq 30\%$ fall from baseline. **Result:** Among the 94 patients, 26.6% developed post-induction hypotension. Baseline age, BMI, HR, and MAP were comparable, although hypotensive patients had a longer NPO duration ($p = 0.006$). Both SCV and IVC diameters were smaller, with significantly higher collapsibility indices in the hypotension group (all $p < 0.001$). The SCV CI during deep inspiration (cutoff 37.8%) showed excellent predictive accuracy (AUC 0.99), comparable to that of the IVC CI (cutoff 38.9%, AUC 0.98). SCV-CI and IVC-CI were moderately correlated ($r = 0.55$, $p < 0.001$). SCV imaging was faster than IVC (42.39 vs. 50.86 seconds, $p < 0.0001$). **Conclusion:** Respiratory-dependent SCV and IVC ultrasonography can enhance pre-anaesthesia assessment, with SCV collapsibility during deep inspiration emerging as a reliable and practical predictor of post-induction hypotension.

INTRODUCTION

Perioperative hypotension following the induction of general anaesthesia is a common and potentially serious complication linked to myocardial injury, acute kidney injury, and increased postoperative morbidity and mortality, particularly in high-risk populations.^[1] Identifying patients vulnerable to haemodynamic instability remains challenging. Among the haemodynamic variables influenced by anaesthetic agents, preload status is important. Preload-dependent patients often experience marked blood pressure decreases when agents such as propofol or thiopental are administered owing to their vasodilatory and myocardial depressant effects.^[2] This risk is especially relevant in clinically stable

patients with unrecognised hypovolaemia. Therefore, an objective preoperative assessment of intravascular volume status could help guide anaesthetic management and prevent hypotensive episodes.

Point-of-care ultrasound (POCUS) is a useful bedside method for assessing intravascular volume. Ultrasonographic evaluation of the inferior vena cava (IVC) and subclavian vein (SCV) offers dynamic information on central venous pressure and preload.^[3] The IVC, being highly compliant, shows respiratory variation in diameter; inspiration reduces its size due to increased venous return. This change is quantified by the collapsibility index (CI), calculated as the percentage difference between maximum and minimum diameters. Increased IVC collapsibility is associated with hypovolaemia and

has been shown to predict post-induction hypotension.^[4] However, IVC assessment has its limitations. Obesity, bowel gas, surgical scars, and patient positioning can obscure optimal imaging, whereas mechanical ventilation or increased intra-abdominal pressure can reduce reliability.^[5] These challenges have prompted interest in alternative venous markers, notably the SCV.

The SCV, located outside the abdominal cavity, is easily visualised in most patients using a high-frequency linear probe. Similar to the IVC, it proves respiratory fluctuation, and its CI has been correlated with intravascular volume status.^[6] For patients in whom subxiphoid imaging is difficult, the SCV may recommend a more practical option. Growing evidence supports the use of pre-induction IVC and SCV ultrasonography as predictors of anaesthesia-induced hypotension (AIH). A study reported that an IVC CI > 43% was associated with a higher risk of post-induction hypotension in ASA I–II surgical patients.^[7] Respiratory variation in SCV diameter correlated strongly with right atrial pressure, highlighting its potential role in volume assessment.^[8] Similarly, SCV CI had predictive value comparable to IVC CI for estimating central venous pressure in spontaneously breathing patients, with the advantage of easier imaging.^[9]

Despite these promising findings, most available studies are single-centre, small-scale, and heterogeneous, with limited direct comparisons between IVC and SCV within the same patient cohort. Variations in the study design and definitions of hypotension further limit generalisability. Given these gaps, a systematic comparison of SCV and IVC ultrasonographic parameters is needed to predict post-induction hypotension. Evaluating the maximum and minimum diameters, collapsibility indices, and time required for image acquisition may help determine a more practical and reliable approach in the operating theatre. This study aimed to address this gap by directly comparing SCV and IVC ultrasonographic measurements as predictors of post-induction hypotension. The findings may suggest anaesthesiologists a simple and reliable bedside test with implications for fluid management, patient safety, and preoperative risk stratification.

Aim

This study aimed to evaluate the ability of ultrasonographic measurement of SCV and IVC diameters and CI to predict hypotension after the induction of general anaesthesia.

MATERIALS AND METHODS

This prospective observational study was conducted in 94 patients at the Institute of Anaesthesiology, Government Rajaji Hospital, Madurai, over 1 year. The study was approved by the Institutional Ethics Committee of Madurai Medical College. All eligible patients were informed of the study procedures, and written informed consent was obtained.

Inclusion Criteria

Patients aged 18–60 years, ASA Physical Status Grade I and II, scheduled for elective surgery under general anaesthesia, and willing to provide written informed consent were included.

Exclusion Criteria

Patients <18 or >60 years of age, ASA Grade III–IV, with congestive cardiac failure, portal hypertension, significant valvular disease, major peripheral arterial disease, anticipated difficult airway, baseline systolic BP >180 or <90 mmHg, or undergoing emergency surgery were excluded.

Methods

Preoperative preparation

Patients were kept nil per oral as per institutional protocol and premedicated with tablet alprazolam 0.5 mg on the night before surgery. In the operating room, the patients were positioned supine, and baseline parameters, including heart rate (HR), oxygen saturation (SpO₂), and noninvasive blood pressure (NIBP), were recorded using standard ASA monitors.

Ultrasonographic measurements

The IVC was assessed using a curvilinear probe (2–5 MHz) with a portable ultrasound machine. A subxiphoid long-axis view was obtained 1–2 cm caudal to the hepatic vein–IVC junction, and the diameters were measured in M-mode over a single respiratory cycle. The CI was calculated as the percentage difference between the maximum and minimum diameters. SCV measurements were performed using a high-frequency linear probe (6–13 MHz) placed in the sagittal plane at the right deltopectoral groove. SCV diameters were recorded during spontaneous breathing and deep inspiration, and the collapsibility index was calculated for both the respiratory phases.

Anaesthetic induction and monitoring

Anaesthesia was induced using a standard intravenous protocol. Patients were continuously monitored for HR and blood pressure, which were recorded every minute with invasive methods or every two minutes with non-invasive methods for 10 min post-induction, before surgical incision. Hypotension was defined as a mean arterial pressure (MAP) decrease of $\geq 30\%$ from baseline or an absolute MAP <60 mmHg. The documented parameters included the maximum and minimum diameters of the IVC and SCV, CI, and incidence of post-induction hypotension.

Statistical Analysis

Data were analysed using SPSS version 25. Continuous variables were presented as mean $\pm$ standard deviation and categorical variables as frequency and percentage. Chi-square test, Student's t-test, and ROC analysis were applied, with $p < 0.05$ considered statistically significant.

RESULTS

The mean age was 41.35 ± 9.68 years, with the majority aged 31–50 years (59.6%). Females constituted 56.4% of patients. The mean BMI was 26.32 ± 3.02 kg/m², with most patients in the overweight category (45.7%), followed by those with normal weight (30.9%). Surgical cases were predominantly from general surgery (43.6%),

followed by spine surgery (24.5%), gynaecology, and urology (both 20.2%). Comorbidities were present in 48.9% of patients, with hypertension (22.3%) and diabetes mellitus (20.2%) being the most common comorbidities. Post-induction hypotension occurred in 26.6% of the patients. Preoperatively, the mean NPO duration was 10.5 ± 1.3 h, with baseline HR and MAP averaging 77.9 ± 7.5 bpm and 95.7 ± 9.1 mmHg, respectively. [Table 1]

Table 1: Patient demographics, anthropometry, comorbidities, surgical profile, and preoperative characteristics

Parameter	Category/Value	N (%) / Mean $\pm$ SD
Age group (years)	18-30	15 (16.0%)
	31-40	29 (30.9%)
	41-50	27 (28.7%)
	51-60	17 (18.1%)
	>60	6 (6.4%)
Mean age		41.35 ± 9.68
Gender	Male	41 (43.6%)
	Female	53 (56.4%)
BMI (kg/m ²)	<18.5	3 (3.2%)
	18.5-24.9	29 (30.9%)
	25-29.9	43 (45.7%)
	30-34.9	13 (13.8%)
	≥ 35	6 (6.4%)
	Mean BMI	26.32 ± 3.02
Surgical specialty	General surgery	41 (43.6%)
	Spine surgery	23 (24.5%)
	Gynaecology	19 (20.2%)
	Urology	19 (20.2%)
	ENT	9 (9.6%)
	Neurosurgery	3 (3.2%)
Comorbidities	Hypertension	21 (22.3%)
	Diabetes mellitus	19 (20.2%)
	Thyroid disorders	5 (5.3%)
	Epilepsy	1 (1.1%)
	No comorbidity	48 (51.1%)
Post-induction hypotension	Developed hypotension	25 (26.6%)
	Did not develop hypotension	69 (73.4%)
	NPO duration (hours)	10.5 ± 1.3
	Baseline HR (bpm)	77.9 ± 7.5
	Baseline MAP (mmHg)	95.7 ± 9.1

Table Footer: Data are presented as frequencies (percentages) or means $\pm$ standard deviations, as appropriate. BMI: body mass index; ENT: ear, nose, and throat; NPO: nil per oral; HR: heart rate; MAP: mean arterial pressure.

Among the 94 patients, 25 (26.6%) developed post-induction hypotension. Age, BMI, baseline HR, and MAP were comparable between the groups ($p > 0.05$). However, patients with hypotension had a significantly longer NPO duration (11.31 ± 1.33 vs.

10.11 ± 1.33 hours, $p = 0.006$). Both SCV and IVC measurements demonstrated smaller minimum and maximum diameters in the hypotension group, with higher collapsibility indices under spontaneous and deep inspiration conditions (all $p < 0.001$). The minimum IVC diameter was significantly lower in the hypotension group (1.13 ± 0.17 vs. 1.49 ± 0.35 cm, $p = 0.0001$), whereas the maximum diameter did not differ significantly ($p = 0.42$). [Table 2]

Table 2: Comparison of baseline, SCV, and IVC parameters between hypotension

Parameter		Hypotension		p-value
		Yes (N=25)	No (N=69)	
Baseline variables	Age (years)	41.73 ± 9.37	41.07 ± 10.13	0.89
	BMI (kg/m ²)	27.31 ± 3.11	25.73 ± 2.91	0.31
	NPO duration (hours)	11.31 ± 1.33	10.11 ± 1.33	0.006
	Baseline HR (bpm)	79.33 ± 7.57	77.11 ± 7.91	0.29
	Baseline MAP (mmHg)	95.31 ± 9.13	96.13 ± 8.53	0.47
SCV measurements-spontaneous	Min (cm)	0.55 ± 0.15	0.69 ± 0.17	0.0001
	Max (cm)	0.73 ± 0.17	0.87 ± 0.19	0.001
	CI (%)	24.27 ± 5.31	19.51 ± 6.49	0.001
SCV measurements-deep inspiration	Min (cm)	0.47 ± 0.13	0.67 ± 0.15	0.0001
	Max (cm)	0.77 ± 0.19	0.91 ± 0.21	0.0005
	CI (%)	42.23 ± 6.35	26.29 ± 7.81	0.0001

IVC measurements	Minimum diameter (cm)	1.13 ± 0.17	1.49 ± 0.35	0.0001
	Maximum diameter (cm)	1.89 ± 0.27	1.95 ± 0.39	0.42
	CI (%)	40.41 ± 3.59	23.33 ± 9.43	0.0001

Table footer: Data are presented as the mean ± standard deviation. Abbreviations: BMI: body mass index; NPO: nil per oral; HR: heart rate; MAP: mean arterial pressure; SCV: subclavian vein; IVC: inferior vena cava; Min: minimum diameter; Max: maximum diameter; CI: collapsibility index. Statistical comparisons between groups were performed using Student's t-test, and a p-value of <0.05 was considered significant.

The SCV CI during deep inspiration (cutoff 37.8%) demonstrated excellent predictive value for post-induction hypotension, with a sensitivity of 94.5%,

specificity of 91.4%, and highest AUC (0.99, $p < 0.0001$). Similarly, IVC CI (cutoff 38.9%) showed very high accuracy (sensitivity 98.7%, specificity 88.2%, AUC 0.98, $p < 0.0001$). The maximum SCV diameter during spontaneous and deep inspiration had good sensitivity (92.4%) but lower specificity (52.5% and 46.2%, respectively). The SCV CI during spontaneous breathing also showed reasonable diagnostic accuracy (AUC 0.75, $p = 0.0018$). In contrast, the IVC maximum diameter (cutoff 2.07 cm) had poor discriminatory ability (AUC 0.65, $p = 0.176$) and was not significant (Table 3 and Figure 1).

Table 3: ROC analysis for predicting postinduction hypotension (PIH)

Parameter	Optimal cutoff	Sensitivity (%)	Specificity (%)	AUC	p-value
SCV Max (Spontaneous)	0.73 cm	92.4	52.5	0.78	0.0012
SCV Max (Deep inspiration)	0.74 cm	92.4	46.2	0.77	0.0003
SCV CI (Spontaneous)	24.61%	67.2	80.8	0.75	0.0018
SCV CI (Deep inspiration)	37.80%	94.5	91.4	0.99	<0.0001
IVC CI	38.90%	98.7	88.2	0.98	<0.0001
IVC max diameter	2.07 cm	46.2	77.7	0.65	0.176

Table Footer: Data are presented as optimal cutoff values with corresponding sensitivity, specificity, and area under the curve (AUC). Abbreviations: SCV: subclavian vein; IVC: inferior vena cava; CI: collapsibility index; Max: maximum diameter. Statistical significance was set at $p < 0.05$.

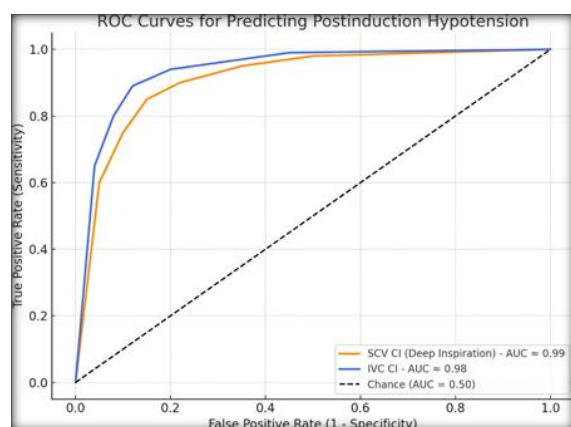


Figure 1: ROC curve for predicting PIH

The analysis of the correlation between the SCV collapsibility index (SCV-CI) and IVC collapsibility index (IVC-CI) revealed a moderate positive correlation with a correlation coefficient (r) of 0.55 and an R^2 value of 0.32 ($p < 0.001$). [Table 4 and Figure 2]

Table footer: Data are presented as Pearson's correlation coefficient (r) and coefficient of

determination (R^2). Abbreviations: SCV-CI: subclavian vein collapsibility index; IVC-CI: inferior vena cava collapsibility index; r : Pearson correlation coefficient; R^2 : coefficient of determination. Statistical significance was set at $p < 0.05$.

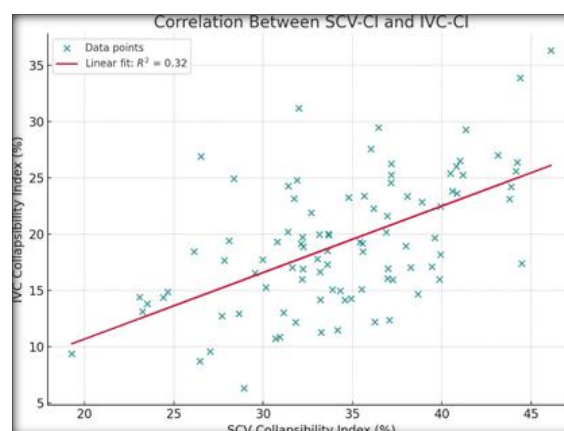


Figure 2: Correlation between SCV-CI and IVC-CI

The mean time for SCV measurement was 42.39 ± 3.15 s, and for IVC measurement 50.86 ± 4.02 s ($p < 0.0001$) (Table 5).

Table footer: Data are presented as the mean ± standard deviation. Abbreviations: SCV: subclavian vein; IVC: inferior vena cava. Statistical comparisons between groups were performed using Student's t-test, and statistical significance was set at $p < 0.05$.

Table 4: Correlation Between SCV-CI and IVC-CI

Variable pair	Correlation coefficient (r)	R^2 value	p-value
SCV-CI vs IVC-CI	0.55	0.32	< 0.001

Table 5: Time taken for ultrasound measurements

Vein measured	Mean time (seconds)	p-value
SCV	42.39 ± 3.15	< 0.0001
IVC	50.86 ± 4.02	

DISCUSSION

In our study, the SCV spontaneous minimum and maximum diameters were significantly lower in hypotensive patients, in line with Rose et al., who reported smaller diameters in hypotensive patients (minimum: 0.549 ± 0.15 cm vs. 0.686 ± 0.16 cm, $p = 0.0001$; maximum: 0.72 ± 0.17 cm vs. 0.85 ± 0.18 cm, $p = 0.001$).¹⁰ In contrast, Chaudhary et al. observed larger, non-significant values (minimum: 0.82 ± 0.25 cm vs. 0.86 ± 0.19 cm, $p = 0.30$; maximum: 0.98 ± 0.22 cm vs. 0.96 ± 0.18 cm, $p = 0.53$).⁶ The SCV collapsibility index was also higher in hypotensive patients in our study, comparable to Rose et al. (spontaneous: $24.27 \pm 5.28\%$ vs. $19.54 \pm 6.47\%$, $p = 0.001$; deep inspiration: $42.21 \pm 6.31\%$ vs. $26.30 \pm 7.80\%$, $p = 0.0001$) and Chaudhary et al. (spontaneous: $17.88 \pm 12.79\%$ vs. $11.69 \pm 7.73\%$, $p = 0.001$; deep inspiration: $46.33 \pm 21.91\%$ vs. $34.32 \pm 18.86\%$, $p = 0.001$).^{10,6} However, Yang et al. did not find a significant difference, which may be attributed to methodological or positional variations.^[11]

Regarding IVC parameters, the minimum diameter was significantly smaller in hypotensive patients ($p=0.0001$), in line with Rose et al. (1.1 ± 0.17 cm vs. 1.48 ± 0.35 cm, $p=0.0001$).¹⁰ Chaudhary et al. also reported significant differences (quiet breathing: 1.13 ± 0.3 cm vs. 1.46 ± 0.4 cm; deep breathing: 0.77 ± 0.48 cm vs. 1.02 ± 0.39 cm, both $p=0.001$).⁶ Liu et al. confirmed this pattern in a meta-analysis, finding a pooled mean difference of -0.28 cm ($p=0.001$).¹² In contrast, IVC maximum diameter did not differ significantly ($p=0.42$), aligning with Rose et al. ($p=0.419$) and Khaled et al. ($p=0.437$), though some studies reported significant differences, showing variability across populations.^{10,13} IVC CI was markedly higher in hypotensive patients ($p = 0.0001$) in our study, supported by Rose et al. ($40.44 \pm 3.58\%$ vs. $23.32 \pm 9.42\%$, $p=0.0001$), Fathy et al. ($49 \pm 8\%$ vs. $33 \pm 8\%$, $p<0.001$).^{10,14} Chaudhary et al. (2024) also demonstrated significant differences across both quiet and deep breathing ($35.32 \pm 13.9\%$ vs. $27.06 \pm 14.3\%$ and $60.19 \pm 18.03\%$ vs. $49.64 \pm 16.82\%$, both $p=0.001$).⁶ Liu et al. (2024) provided further confirmation through meta-analysis, reporting a pooled mean difference of 10.47% ($p<0.001$), indicating that IVC CI is associated with post-induction hypotension across multiple studies.^[12]

ROC analysis in our study demonstrated the high predictive performance of the SCV and IVC indices. Rose et al. reported an optimal SCV max cutoff of 0.69 cm with 88% sensitivity, 50% specificity, and an AUC of 0.78 , while Zheng et al. reported a slightly higher cutoff of 0.86 cm with 88% sensitivity, 66% specificity.^[10,15] SCV CI during spontaneous

breathing had a cutoff of 23.44% with 64% sensitivity, 77% specificity, according to Rose et al., whereas Chaudhary et al. suggested a $\geq 10\%$ cutoff with 68% sensitivity, 56% specificity, and an AUC of 0.659 .^[6,10] Zheng et al. reported a 33% cutoff with 86% sensitivity, 39% specificity.^[15] SCV CI during deep inspiration was reported by Bharath et al. with a cutoff $>45\%$, yielding 87.5% sensitivity, 84.6% specificity, and an AUC of 0.9116 . Rose et al. observed a 36% cutoff with 90% sensitivity, 87% specificity, and an AUC of 0.944 .^[10]

For IVC CI, Fathy et al. proposed a cutoff $>39\%$, achieving 90.32% sensitivity, 80.22% specificity, and an AUC of 0.908 , while Bharath et al. reported a cutoff $>40\%$ with 85.7% sensitivity and 82.3% specificity.^[14,16] In contrast, Khaled et al. and Mohammed et al. reported lower predictive utility with AUCs of 0.59 and 0.51 , respectively.^[13,17] IVC maximum diameter showed limited diagnostic value across studies, with Rose et al. reporting a cutoff of 1.97 cm (44% sensitivity, 74% specificity).^[10] Bharath et al. reporting >17.5 mm (72.4% sensitivity, 74.2% specificity, AUC 0.80), and Liu et al. finding pooled sensitivity and specificity of 66% and 75% , respectively (AUC 0.77).^[16,12]

A moderate positive correlation was observed between SCV-CI and IVC-CI ($p<0.001$), suggesting that SCV-CI is a reliable surrogate for IVC-CI when visualisation is limited. This correlation was stronger than that reported by Rose et al. (R^2 0.16 during spontaneous breathing), showing stronger correlation values.¹⁰ SCV ultrasound measurements were faster than IVC in our study ($p<0.0001$). Bharath et al. reported SCV measurements took 41.4 ± 9.99 seconds versus 69.6 ± 11.2 seconds for IVC ($p<0.001$), while Rose et al. observed SCV at 40.37 ± 3.16 seconds versus IVC 48.44 ± 19.40 seconds ($p<0.0001$), in line with previous reports of shorter measurement times for SCV compared with IVC.^[16,10]

Limitations

As this was a single-centre study with a modest sample size, the findings may not be generalisable to diverse populations. Inter- and intra-operator variability in ultrasonographic measurements were not assessed, which may have affected reproducibility. This study focused only on elective surgical patients, limiting its applicability to emergency settings or patients with significant comorbidities. Clinical outcomes beyond the immediate post-induction period, such as intraoperative haemodynamic instability or postoperative morbidity, were not evaluated. Larger multicentre trials are required to validate these results and establish standardised protocols.

CONCLUSION

Respiratory-dependent SCV and IVC ultrasonography show significant promise in enhancing the detection and prevention of post-induction hypotension when integrated into routine pre-anaesthesia assessments. Among the evaluated parameters, SCV collapsibility during deep inspiration was the most reliable predictor. Given its accessibility, rapid assessment, and predictive accuracy, SCV ultrasonography could be a valuable adjunct in anaesthesia practice, especially in resource-limited or time-sensitive settings.

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