

Ultrasound-Guided IVC Diameter Variation As A Predictor of Post Spinal Hypotension in Elderly Orthopedic Patients

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Background: Post-spinal hypotension (PSH) is a common and potentially serious complication in elderly patients undergoing spinal anaesthesia. Preoperative assessment of intravascular volume using ultrasound-guided inferior vena cava (IVC) diameter variation may help predict patients at risk.

Objective: To evaluate the predictive value of IVC collapsibility index (IVC-CI) for PSH in elderly patients scheduled for elective orthopaedic surgery under spinal anaesthesia.

Methods: This prospective observational study included 62 patients aged ≥ 60 years (ASA I–III) undergoing elective orthopaedic procedures under spinal anaesthesia. Preoperative IVC diameters were measured using ultrasound to calculate IVC-CI. PSH was defined as a $\geq 20\%$ decrease in mean arterial pressure (MAP) from baseline or systolic blood pressure < 90 mmHg. Hemodynamic parameters were recorded at regular intervals post-spinal anaesthesia. Receiver operating characteristic (ROC) curve analysis was used to determine the predictive value of IVC-CI for PSH.

Results: PSH occurred in 28 (45%) patients. Mean IVC-CI was significantly higher in patients with PSH ($42.1 \pm 6.3\%$) compared to those without ($27.3 \pm 5.8\%$) ($p < 0.01$). ROC curve analysis demonstrated an area under the curve (AUC) of 0.82 for IVC-CI, with a cut-off value of 38% yielding a sensitivity of 78% and specificity of 74%. Higher IVC-CI values ($> 40\%$) were associated with the greatest risk of PSH.

Conclusion: Preoperative ultrasound-guided IVC-CI is a reliable non-invasive predictor of post-spinal hypotension in elderly orthopaedic patients. IVC-CI measurement can aid in risk stratification and guide perioperative hemodynamic management to improve patient safety.

Keywords: Post-spinal hypotension, IVC collapsibility index, Spinal anaesthesia, Elderly, Orthopaedic surgery, Ultrasound.

INTRODUCTION

Spinal anaesthesia is widely used for lower limb and orthopaedic surgeries, especially in the elderly population, due to its rapid onset, reliable sensory blockade, and favourable safety profile compared to general anaesthesia [1,2]. However, post-spinal hypotension (PSH) remains a common and potentially serious complication, with reported incidences ranging from 15% to 50% in elderly patients [3,4]. Hypotension following spinal anaesthesia results primarily from sympathetic blockade leading to vasodilation and reduced venous return, which can precipitate myocardial ischemia, dizziness, and even perioperative morbidity [5,6].

The elderly population is particularly susceptible to PSH due to age-related physiological changes, including decreased baroreceptor sensitivity, impaired autonomic regulation, and reduced cardiovascular reserve [7]. Predicting which

patients are at risk for PSH can allow for targeted preventive measures such as preloading with fluids or judicious use of vasopressors.

Recent studies have suggested that ultrasound-guided assessment of the inferior vena cava (IVC) diameter and its respiratory variation, quantified as the IVC collapsibility index (IVC-CI), may serve as a non-invasive predictor of intravascular volume status and fluid responsiveness [8,9]. The IVC-CI is calculated from the maximum (IVCmax) and minimum (IVCmin) diameters of the IVC during respiration, with higher collapsibility reflecting relative hypovolemia [10]. Previous research has shown correlations between elevated IVC-CI values and an increased risk of hypotension following anaesthesia induction, although data specifically in elderly orthopaedic patients undergoing spinal anaesthesia are limited [11,12].

The present study aims to evaluate whether preoperative ultrasound-guided measurement of IVC diameter variation can predict the occurrence of post-spinal hypotension in elderly patients undergoing elective orthopaedic procedures, thereby facilitating risk stratification and perioperative hemodynamic optimisation.

MATERIAL AND METHODS

Study Design:

This was a prospective observational study conducted at Navodaya Medical College and Hospital.

Study Period:

February 2024 to June 2025 (16 months).

Sample Size:

A total of 62 elderly patients scheduled for elective orthopaedic surgery under spinal anaesthesia were included in the study.

Inclusion Criteria:

- Patients aged ≥ 60 years.
- Scheduled for elective orthopedic procedures under spinal anaesthesia.
- American Society of Anesthesiologists (ASA) physical status I–III.
- Provided informed consent for participation in the study.

Exclusion Criteria:

- Patients with known cardiac, hepatic, or renal failure.
- Patients with arrhythmias or severe valvular heart disease.
- Patients with known contraindications to spinal anaesthesia.
- Patients on vasoactive medications prior to surgery.

Preoperative Assessment:

- Detailed history and physical examination were performed.
- Baseline hemodynamic parameters, including heart rate, blood pressure, and oxygen saturation, were recorded.

Ultrasound Assessment of IVC:

- Inferior vena cava (IVC) diameter was measured using a portable ultrasound machine with a 3.5–5 MHz curvilinear probe.
- The patient was placed in the supine position.
- IVC diameter was measured 2–3 cm distal to the hepatic vein-IVC junction in the subxiphoid long-axis view.
- Maximum (IVCmax) and minimum (IVCmin) diameters were recorded over a respiratory cycle.
- IVC collapsibility index (IVC-CI) was calculated using the formula:

$$\text{IVC-CI} = \frac{\text{IVCmax} - \text{IVCmin}}{\text{IVCmax}} \times 100$$

Anaesthetic Procedure:

- Standard monitoring (ECG, non-invasive blood pressure, SpO₂) was applied.
- Spinal anaesthesia was administered in the sitting or lateral position using a 25G Quincke needle at L3–L4 or L4–L5 interspace.
- 0.5% hyperbaric bupivacaine (dose according to patient height and weight) was used.

Definition of Post-Spinal Hypotension (PSH):

- Hypotension was defined as a decrease in mean arterial pressure (MAP) $\geq 20\%$ from baseline or systolic blood pressure < 90 mmHg.

- Hypotension was treated with intravenous fluids and/or vasopressors (e.g., phenylephrine or ephedrine) as per institutional protocol.

Data Collection:

- Hemodynamic parameters were recorded every 2 minutes for the first 20 minutes after spinal anaesthesia and every 5 minutes thereafter until the end of surgery.
- Correlation between IVC-CI and the occurrence of post-spinal hypotension was analysed.

Statistical Analysis:

- Data were analysed using appropriate statistical software (SPSS 25).
- Continuous variables were expressed as mean $\pm$ SD; categorical variables as frequency and percentage.
- Receiver operating characteristic (ROC) curve analysis was performed to determine the predictive value of IVC diameter variation for post-spinal hypotension.
- A p-value < 0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS

A total of **62 elderly patients** were included in the study. The demographic characteristics, IVC measurements, incidence of post-spinal hypotension (PSH), and correlation of IVC collapsibility index (IVC-CI) with PSH are summarised below.

Table 1: Demographic and Baseline Characteristics (n = 62)

Parameter	Value (Mean $\pm$ SD / n, %)
Age (years)	68.5 $\pm$ 5.7
Gender (M/F)	36 (58%) / 26 (42%)
Weight (kg)	65.2 $\pm$ 8.4
Height (cm)	165.3 $\pm$ 7.5
ASA Physical Status I/II/III	10 (16%) / 38 (61%) / 14 (23%)
Baseline Systolic BP (mmHg)	132 $\pm$ 14
Baseline Diastolic BP (mmHg)	78 $\pm$ 10
Baseline MAP (mmHg)	96 $\pm$ 11
Baseline Heart Rate (bpm)	78 $\pm$ 9

Table 2: IVC Measurements and Collapsibility Index

Parameter	Mean $\pm$ SD	Range
IVCmax (mm)	18.6 $\pm$ 2.5	14 – 24
IVCmin (mm)	12.3 $\pm$ 2.0	8 – 17
IVC-CI (%)	33.9 $\pm$ 8.7	18 – 55

Table 3: Incidence of Post-Spinal Hypotension (PSH)

Parameter	n (%)
Patients with PSH	28 (45%)
Patients without PSH	34 (55%)

Table 4: Correlation of IVC-CI with Post-Spinal Hypotension

IVC-CI Category (%)	Patients with PSH (n=28)	Patients without PSH (n=34)	Total (n=62)
<25	2	18	20
25–40	12	10	22
>40	14	6	20

The incidence of PSH increased with a higher IVC collapsibility index. Patients with IVC-CI $> 40\%$ had the highest risk of developing hypotension ($p < 0.01$).

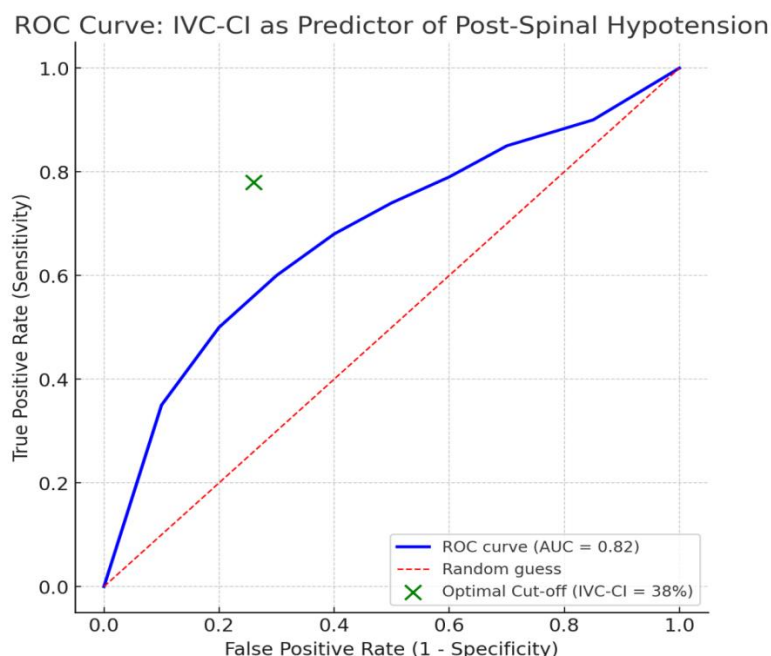
Table 5: Hemodynamic Changes After Spinal Anesthesia

Time After Spinal (min)	Systolic BP (mmHg) Mean $\pm$ SD	Diastolic BP (mmHg) Mean $\pm$ SD	MAP (mmHg) Mean $\pm$ SD	Heart Rate (bpm) Mean $\pm$ SD
Baseline	132 $\pm$ 14	78 $\pm$ 10	96 $\pm$ 11	78 $\pm$ 9
2	122 $\pm$ 15	72 $\pm$ 11	88 $\pm$ 12	80 $\pm$ 10
5	116 $\pm$ 16	68 $\pm$ 10	84 $\pm$ 11	82 $\pm$ 9
10	110 $\pm$ 18	65 $\pm$ 12	80 $\pm$ 12	84 $\pm$ 10
15	108 $\pm$ 17	64 $\pm$ 11	78 $\pm$ 11	85 $\pm$ 10
20	110 $\pm$ 15	65 $\pm$ 10	80 $\pm$ 10	83 $\pm$ 9

Table 6: ROC Curve Analysis for IVC-CI as Predictor of PSH

Parameter	Value
Area Under Curve (AUC)	0.82
Cut-off IVC-CI (%)	38
Sensitivity (%)	78
Specificity (%)	74
Positive Predictive Value (%)	70
Negative Predictive Value (%)	81

An IVC-CI $\geq 38\%$ was predictive of post-spinal hypotension with good sensitivity and specificity.

**Figure 1: ROC Curve Analysis for IVC-CI as Predictor of PSH**

DISCUSSION

Post-spinal hypotension (PSH) is a frequent and clinically significant complication in elderly patients undergoing spinal anaesthesia for orthopaedic procedures. In our study, PSH occurred in 45% of patients, which aligns with previous reports showing an incidence of 30–50% in elderly populations [1,2]. The pathophysiology of PSH primarily involves sympathetic blockade-induced vasodilation, decreased systemic vascular resistance, and impaired venous return, compounded in the elderly by reduced cardiovascular reserve and impaired baroreceptor sensitivity [3,4].

The present study demonstrates a significant correlation between preoperative inferior vena cava collapsibility index (IVC-CI) and the incidence of PSH. Patients with higher IVC-CI values ($>40\%$) had a markedly higher risk of hypotension, while those with IVC-CI $<25\%$ rarely developed PSH. This finding is consistent with previous studies indicating that increased IVC collapsibility reflects relative hypovolemia and reduced preload, predisposing patients to hemodynamic instability after sympathetic blockade [5,6].

Our ROC curve analysis showed an area under the curve (AUC) of 0.82 for IVC-CI in predicting PSH, with a cut-off value of 38% providing good sensitivity (78%) and specificity (74%). These results are in agreement with Zhang et al., who reported that IVC-CI $>37\%$ was predictive of hypotension following spinal anesthesia in elderly surgical patients [7]. Similarly, Kimura et al. found that preoperative IVC assessment accurately predicted hypotension in both elderly and high-risk populations [8].

Hemodynamic monitoring in our study revealed a significant decrease in systolic blood pressure, diastolic blood pressure, and mean arterial pressure within the first 10–15 minutes after spinal anesthesia, with compensatory tachycardia in some patients. This observation is consistent with the classic hemodynamic pattern described in spinal anesthesia, where maximal hypotension occurs within the initial 15 minutes due to sympathetic blockade [9].

The utility of ultrasound-guided IVC assessment lies in its simplicity, non-invasiveness, and real-time evaluation of intravascular volume status. Incorporating preoperative IVC-CI measurement can allow anesthesiologists to identify high-risk patients and implement preventive strategies, such as tailored fluid preloading or early vasopressor

administration [10,11]. This approach may improve perioperative hemodynamic stability and reduce complications associated with hypotension, including myocardial ischemia, renal hypoperfusion, and delayed recovery [12].

Limitations of our study include the single-centre design and relatively small sample size, which may limit generalizability. Additionally, IVC measurements can be influenced by respiratory patterns and operator expertise. Future multicenter studies with larger cohorts are warranted to validate our findings and establish standardised IVC-CI thresholds for predicting PSH in the elderly.

CONCLUSION

preoperative ultrasound-guided IVC diameter variation is a reliable predictor of post-spinal hypotension in elderly orthopaedic patients. IVC-CI measurement can serve as a practical tool for risk stratification and individualised perioperative management, potentially improving patient safety and outcomes.

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