RESEARCH PAPER

Pre-Anesthetic Venous Excess Ultrasound Score for Predicting Spinal Anesthesia-Induced Hypotension in Geriatric Patients Undergoing Elective Lower Body Surgeries: A Prospective Observational Study

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ABSTRACT

Background: Spinal anesthesia-induced hypotension (SAIH) complications are still prevalent in 16–33% of cases.

Objectives: To assess the correlation between the pre-anesthetic venous excess ultrasound (VExUS) grading system and the prediction of SAIH in elderly patients, as well as the correlation between internal jugular vein (IJV) measurements and SAIH prediction in geriatric patients.

Methods: This prospective observational investigation included 127 patients aged ≥ 65 years at Tanta University Hospitals over one year. All patients were divided into two groups: Group A (n = 56) with no SAIH and Group B (n = 71) with SAIH. A comprehensive evaluation of prominent systemic veins, including hepatic, portal, renal, and internal jugular veins, was performed on all patients.

Results: Delta IJV diameter (ΔIJV-D), delta IJV area (ΔIJV-A), and IJV collapsibility index (IJV-CI) were significantly predictive of hypotension. ΔIJV-D showed an area under the curve (AUC) of 0.697 (P<0.001) at a cutoff >0.11, with 77.46% sensitivity, 57.14% specificity, 69.62% positive predictive value (PPV), and 66.67% negative predictive value (NPV). ΔIJV-A had an AUC of 0.635 (P=0.009) at a cutoff >0.17, with 78.87% sensitivity, 55.36% specificity, 69.14% PPV, and 67.39% NPV. IJV-CI demonstrated an AUC of 0.739 (P<0.001) at a cutoff >19, with 80.28% sensitivity, 76.79% specificity, 81.43% PPV, and 75.44% NPV.

Conclusions: Predictors of SAIH in geriatric patients include the simplicity and noninvasiveness of pre-anesthetic IJV-CI, ΔIJV-A, and ΔIJV-D. In contrast, VExUS did not predict SAIH during perioperative assessment.

Keywords: Geriatric Patients, Pre-Anaesthetic Venous Excess Ultrasound Score, Spinal-Induced Hypotension

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INTRODUCTION

Spinal anesthesia-induced hypotension (SAIH) is the most prevalent adverse event associated with spinal anesthesia (SA), with reported incidences ranging from 15% to 30%. [1] In older individuals, advancing age is associated with increased resting sympathetic nerve activity and decreased baroreceptor reflex activity, resulting in marked hypotension following sympathetic blockade.

The venous excess ultrasound (VExUS) score is a four-staged validated protocol that evaluates the presence and severity of systemic venous congestion in the IVC and organs (liver, gut, and kidneys) by assessing the IVC diameter, venous waveforms of HV, PV, and interlobar renal veins via pulsed wave Doppler (PWD) and colour Doppler (CD). [2] After general anesthesia (GA), intravascular volume status and hypotension can be expected through ultrasonographic evaluation of the IJV, which has had promising results. [3]

This investigation aimed to assess the preoperative condition of the venous system via the VExUS score and examine its correlation with the incidence of SAIH in geriatric patients undergoing surgery under SA.

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METHODOLOGY

This prospective observational study involved 127 patients aged 65 or older, both sexes, with body mass index (BMI) less than 30 kg/m^2, with American Society of Anesthesiologists class (ASA) I–III, scheduled for elective lower-body surgeries under SA.

Patients were divided into two groups based on the occurrence of SAIH: Group A (n = 56), without SAIH, and Group B (n = 71), with SAIH.

We conducted this investigation from July 2023 to July 2024, following approval by the Ethics Committee of the Faculty of Medicine at Tanta University Hospitals (ID: 36264MD71/4/23). The patients have provided informed written consent.

Patients who had a history of cardiovascular conditions, such as uncontrolled arrhythmias, tricuspid or mitral regurgitation, heart failure, atrial fibrillation, respiratory disorders, dilated right atrium or ventricle, liver cirrhosis, pulmonary hypertension, or renal diseases, atients experiencing arterial hypotension associated with bone cement application, tourniquet deflation, blood loss >150 mL, or blood transfusion, significant bloody surgeries (class C), or patient refusal were excluded.

All patients underwent a comprehensive history and physical examination, as well as laboratory investigations, and were fasted for six hours before surgery, with a two-hour fast for clear fluids.

Intraoperative monitoring included electrocardiography, non-invasive arterial blood pressure, pulse oximetry, and a temperature probe. Baseline heart rate (HR), arterial oxygen saturation (SaO_2), and mean arterial pressure (MAP) were recorded.

Ultrasonographic examination

All examinations were performed in the supine position via an ultrasound device (Philips CX50, Extreme Edition, Amsterdam, The Netherlands) equipped with phased array (2–7.5 MHz) or curvilinear (2–5 MHz) transducers.

Assessment of the inferior vena cava (IVC)

The IVC diameter was measured 2 cm below the right atrial junction in long-axis and/or short-axis views via lateral transhepatic or subxiphoid approaches.

Assessment of the hepatic veins (HVs)

HVs were visualized via subxiphoid or lateral mid-axillary transhepatic windows. CD and PWD were applied, with the sample volume placed 1 cm within the HV.

Assessment of the portal veins (PVs)

PVs were evaluated via subxiphoid or lateral transhepatic windows using CD and PWD at a baseline velocity of 20 cm/s.

Assessment of the renal veins

Interlobar veins were assessed in the lateral mid-axillary window at the 10th intercostal space. The Nyquist limit was reduced to 10–15 cm/s, and color gain was increased for optimal visualization. Venous congestion was graded via the VExUS score: grade 0: no congestion (IVC not plethoric; Doppler of HV, PV, renal veins not used), grade 1 (Mild): plethoric IVC, no severely abnormal waveforms (S-wave reversal in HV, >50% pulsatility in PV, monophasic intrarenal veins), grade 2 (Moderate): plethoric IVC with at least one abnormal waveform and grade 3 (Severe): plethoric IVC with two or more abnormal waveforms. [4]

VExUS assessment does not differentiate between pressure and volume overload; findings were interpreted in the clinical context.

Internal jugular vein ultrasonography

Patients were supine with the neck rotated 40° to the left. A linear probe (7–12 MHz, depth 3 cm) was positioned over the right IJV, immediately below the sternal and clavicular heads of the sternocleidomastoid muscle. M-mode was used to measure IJV diameter (IJV-D) and cross-sectional area (IJV-A) over three respiratory cycles. The exact measurements were repeated in a 10° Trendelenburg position. The change rate in IJV-D with the change in posture (ΔIJV-D) was calculated as follows: ΔIJV-D = IJV-D in Trendelenburg position ÷ IJV-D in supine position ÷ IJV-D in Trendelenburg position. Also, the change rate in IJV-A with the change in posture (ΔIJV-A) was calculated via the same formula. IJV collapsibility index (IJV-CI, %) was calculated by comparing the percentage decrease in IJV-D during inspiration relative to expiration while the patient was supine: IJV-CI (%) = (Maximum IJV-D – Minimum IJV-D) / Maximum IJV-D × 100. [3]

Spinal anesthesia

SA was administered via the median approach at L3–L4 or L4–L5 in sitting patients after local infiltration with 2.5 mL of 0.5% heavy bupivacaine and 25 µg fentanyl (time 0 min). Ringer's lactate was co-loaded at 15 mL/kg over 20 minutes. HR and non-invasive blood pressure were recorded at baseline and every 2.5 minutes until 15 minutes post-SA. Block height was assessed via cold sensation, typically T6–T8. [5] Surgical positioning was completed 15 minutes after the injection. Post-spinal hypotension (PSH) was defined as a MAP decrease of≥20% from baseline within 15 minutes post-injection. [6] PSH was treated with a maximum of two intravenous (IV) boluses of ephedrine, 6 mg each, administered every 5 minutes. If hypotension persisted despite vasopressors, a 500 mL Ringer's lactate fluid bolus was administered. Bradycardia was managed with IV atropine at 0.01 mg/kg.

The primary outcome was to detect a correlation between the pre-anesthetic VExUS grading system and the prediction of SAIH occurrence in elderly patients. The secondary outcomes included the detection of a correlation between IJV measurements and the prediction of SAIH occurrence in elderly patients, as well as the assessment of sensitivity, specificity, and positive predictive value of both the VExUS grading system and IJV measurements.

Sample size

The sample size calculation was performed using the EpI-Info 2002 statistical software package, designed by the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC). The sample size was calculated based on the following considerations: 95% confidence level, and the incidence of SAIH was 66.2% according to a previous study [7] ± 9% confidence limit.

Twenty cases were added to compensate for dropouts. Therefore, we recruited 127 cases.

Statistical analysis

The statistical analysis procedure was conducted using SPSS v27, developed by IBM (Armonk, NY, USA). When checking for data normality, the Shapiro-Wilk test and histograms proved helpful. Statistical measures of central tendency were given as means and standard deviations (SD). When dealing with quantitative, non-parametric data, the IQR and median were used. The percentage and frequency of the qualitative qualities were shown graphically. A two-tailed P value less than 0.05 was used to define statistical significance. We employed the following tests: the chi-square test, the Mann-Whitney test, and the unpaired Student's t-test. The receiver operating characteristic (ROC) curve was used to assess the overall diagnostic performance of each test. The AUC is a critical metric for evaluating a test's overall success; an AUC of more than 50% is considered acceptable, while an AUC close to 100% is considered optimal.

RESULTS

A preliminary assessment was conducted on 159 individuals to determine their eligibility for participation in the study. After screening, 19 individuals were excluded because they did not meet the inclusion criteria, and 13 declined participation. The remaining 127 patients were divided into two groups based on the occurrence of SAIH: Group A (n = 56), without SAIH, and Group B (n = 71), with SAIH. All participants were followed up, and statistical analysis was performed. **Figure 1**

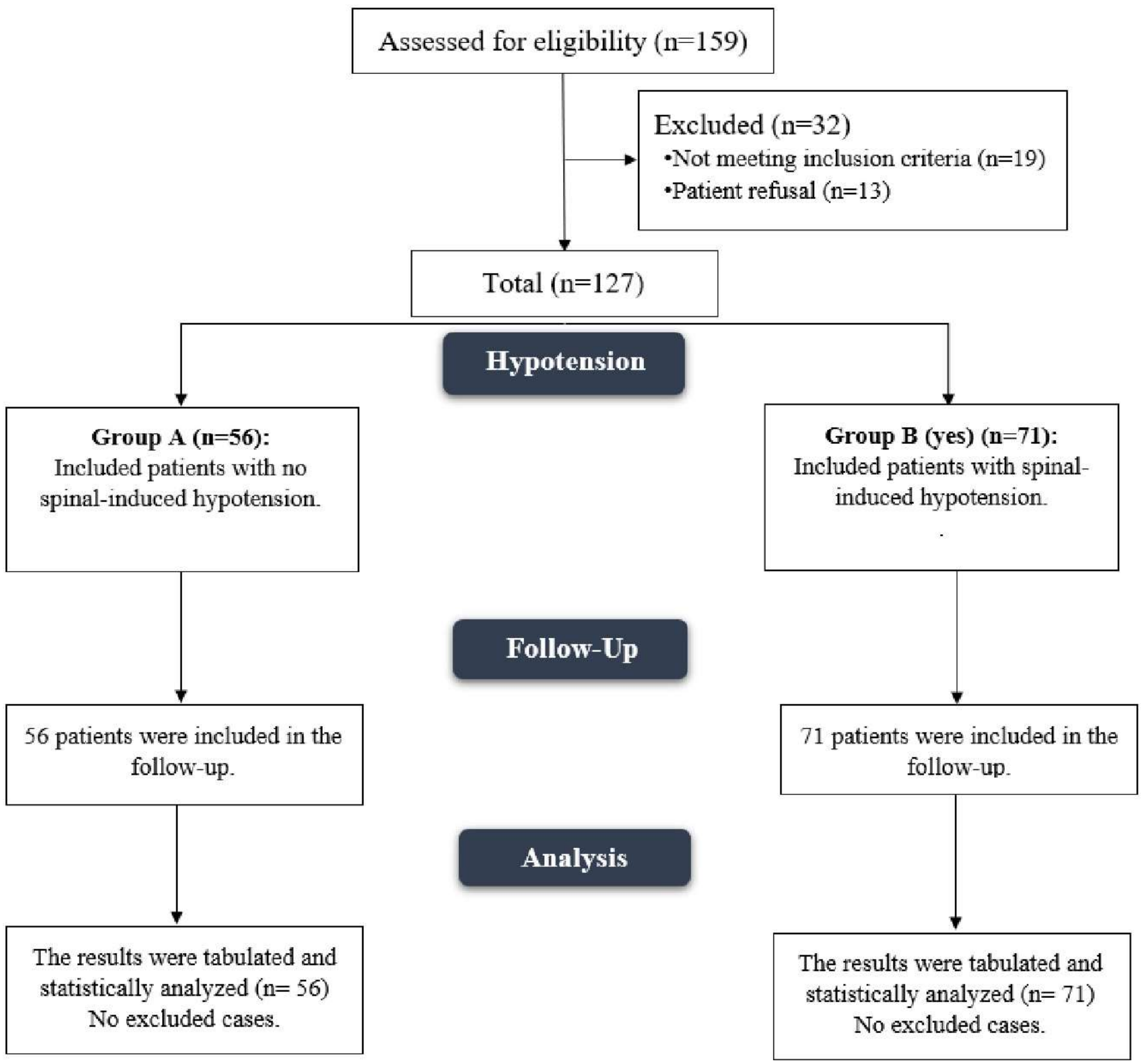

Figure 1: STROBE flowchart of the studied patients

Demographic data, type of surgery, and surgery duration were comparable between the two groups. **Table 1**

Table 1. Comparison of the two studied groups according to the demographic data and duration of surgery

		Group A (n = 56)	Group B (n = 71)	p
Age (years)		68.27± 2.76	68.27± 2.74	0.999
Sex	**Male**	40 (71.43%)	48 (67.61%)	0.643
	Female	16 (28.57%)	23 (32.39%)	
BMI (Kg/m^2)		26.45± 2.81	27± 2.76	0.266
ASA physical status	**I**	29 (51.79%)	48 (67.61%)	0.058
	II	17 (30.36%)	19 (26.76%)	
	III	10 (17.86%)	4 (5.63%)	
Type of surgery	**Orthopedic surgery**	25 (44.64%)	33 (46.48%)	0.774
	General surgery	9 (16.07%)	14 (19.72%)	
	Genito-urinary	22 (39.29%)	24 (33.8%)	
Duration of surgery (min)		101.43± 57.13	105± 55.49	0.723

Data are presented as mean ± SD or frequency (%). ASA: American Society of Anesthesiologists, SD: Standard deviation, p: p-value for comparing between the studied groups.

The MAP was significantly lower immediately after spinal anesthesia, at 2.5, 5, 7.5, and 10 min in group B compared to group A ($P < 0.05$). Neither group exhibited any significant differences at baseline, 12.5 minutes, 15 minutes, or at the end of surgery. **Table 2**

Table 2. Comparison of the two studied groups according to the mean arterial blood pressure

	Group A (n = 56)	Group B (n = 71)	p
Baseline	95.82± 10.11	97.04± 9.52	0.486
After spinal	95.5± 10.18	77.63± 7.62	**<0.001***
2.5 min	96.04± 10.1	76.66± 7.52	**<0.001***
5 min	96.14± 10.53	75.69± 7.42	**0.001***
7.5 min	95.04± 10.19	74.72± 7.33	**0.003***
10 min	96.2± 10.31	76.82± 7.58	**0.002***
12.5 min	95.57± 10.25	78.85± 12.23	0.108
15 min	96.18± 10.35	82.76± 10.68	0.141
End of surgery	96.21± 10.6	90.08± 8.91	0.215

Data are presented as mean ± SD. SD: Standard deviation, MAP: mean arterial blood pressure p: p value for comparing between the studied groups, *: statistically significant as p value <0.05.

Delta internal jugular vein diameter (Δ IJV-D), delta internal jugular vein diameter's area (Δ IJV-A), and delta IJV collapsibility index were significantly higher in group B than group A (P<0.001, 0.009, and <0.001, respectively). The VEXUS score was insignificantly different between the two groups. **Table 3**

Table 3. Comparison between the two studied groups according to IJV ultrasonography

		Group A (n = 56)	Group B (n = 71)	p
Δ IJV-D	Mean ± SD.	0.11 ± 0.09	0.19 ± 0.21	**<0.001***
	Median (IQR)	0.10 (0.05 – 0.15)	0.17 (0.13 – 0.28)	
Δ IJV-A	Mean ± SD.	0.16 ± 0.13	0.23 ± 0.31	**0.009***
	Median (IQR)	0.15 (0.09 – 0.25)	0.22 (0.19 – 0.35)	
IJV-CI	Mean ± SD.	17.98 ± 11.55	28.35 ± 11.42	**<0.001***
	Median (IQR)	13.50 (11.0 – 19.0)	29.0 (21.50– 37.50)	
VEXUS score	Mean ± SD.	0.0 – 1.0	0.0 – 1.0	0.694
	Median (IQR)	0.0 (0.0 – 0.0)	0.0 (0.0 – 0.0)	

Data are presented as mean ± SD or Median (IQR). VEXUS: Venous Excess Ultrasound, Δ IJV-A: Delta internal jugular vein diameter's area, Δ IJV-D: Delta internal jugular vein diameter, IJV-CI: Internal jugular vein collapsibility index, IQR: Inter quartile range, SD: Standard deviation, U: Mann Whitney test, p: p value for comparing between the studied groups, * Significant as P-value ≤ 0.05.

Δ IJV-D with AUC of 0.697 can significantly predict the specificity cases (P<0.001), at a cutoff value of >0.11, with 77.46% sensitivity, 57.14% specificity, 69.62% PPV, and 66.67% NPV. Δ IJV-A with AUC of 0.635 can significantly predict the specificity cases (P=0.009), at a cutoff value of >0.17, with 78.87% sensitivity, 55.36% specificity, 69.14% PPV, and 67.39% NPV. JV-CI with an AUC of 0.739 can significantly predict the specificity cases (P<0.001), at a cutoff value of >19, with 80.28% sensitivity, 76.79% specificity, 81.43% PPV, and 75.44% NPV. **Figure 2**

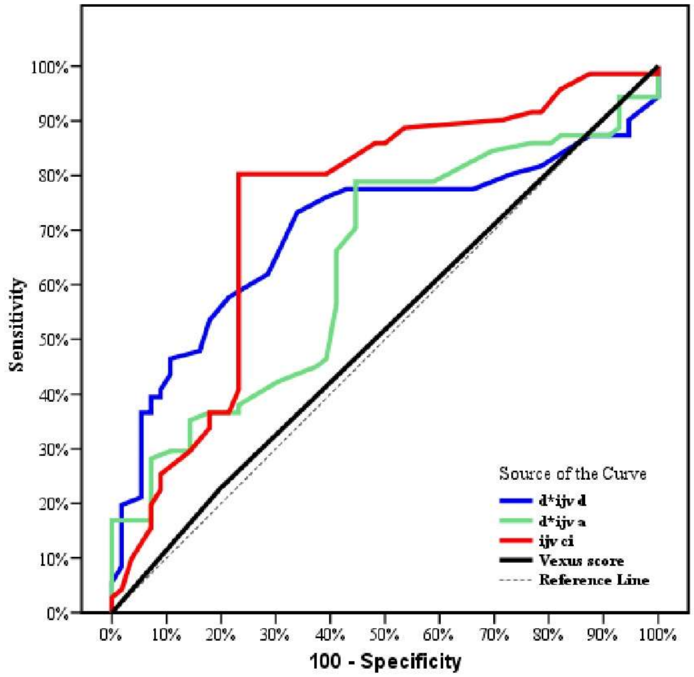

Figure 2: ROC curve for ΔIJV d, Δ IJV a, and IJV ci and Vexus score to predict hypotension cases group B (n = 71) from non-hypotension cases group A (n = 56)

DISCUSSION

For geriatric patients, SA continues to be the preferred anesthetic procedure; however, SAIH is a frequent complication. The report indicates that SAIH development, which was subsequently accompanied by ischemic myocardial, cerebrovascular, and acute renal lesions, was independently predicted by an increase in age. This injury ultimately extends the hospital stay and elevates the likelihood of postoperative morbidity and mortality. [8] SAIH prevention, which is associated with volume excess risk, is frequently implemented through empirical volume preloading, especially in renal and cardiac patients. [9]

Regarding IJV ultrasound measurements, group B had significantly increased Δ IJV-D, Δ IJV-A, and ΔIJV- CI than group A (P<0.001, 0.009, and <0.001, respectively). The VEXUS score was insignificantly different between the two groups. Additionally, Magin et al. [10] discovered that VexUS grading and complications had an insignificant correlation. Venous congestion at first 24 hours preoperatively is frequently noticed; however, no venous congestion was observed preoperatively. Our research did not reveal a correlation between the grade of VexUS and the number of complications that occurred within 30 days.

Further, Nofal et al. [11] reported in patients undergoing orthopedic surgery. Hypotension was acquired by twenty-eight patients (45.2%). Hypotensive patients experienced a higher incidence of increases in IJV diameter and cross-sectional area as a result of postural modifications. Spinal hypotension was predicted by a rate of increase of 25.55% in IJV cross-sectional area and a rate of growth of 12.36% in IJV diameter, as indicated by the ROC curves analysis.

In our study, Δ IJV-D with an AUC of 0.697 can significantly predict the specificity cases (P<0.001), at a cutoff value of >0.11, with 77.46% sensitivity, 57.14% specificity, 69.62% PPV, and 66.67% NPV. Δ IJV-A with AUC of 0.635 can significantly predict the specificity cases (P=0.009), at a cutoff value of >0.17, with 78.87% sensitivity, 55.36% specificity, 69.14% PPV, and 67.39% NPV. IJV-CI with AUC of 0.739 can significantly predict the specificity cases (P<0.001), at a cutoff value of >19, with 80.28% sensitivity, 76.79% specificity, 81.43% PPV, and 75.44% NPV.

In line with our results, Kaur et al. [12] showed that the hypotensive group had significantly greater IJVCI values, with mean values of 53.11±11.52, compared to the non-hypotensive group's 40.96±12.20. With a sensitivity of 89.7% and a specificity of 69.6%, the ROC curve yielded an AUC of 0.769.

Similarly, Shah et al. [13] reported that IJV measurements significantly correlated with the occurrence of SAIH. However, they demonstrated that IVC collapsibility index-guided fluid preloading was more effective than IJV measurements in preventing SAIH. This difference may be attributed to their studying young, healthy parturients, whose highly compliant central veins allowed IVC collapsibility-guided fluid preloading to prevent SAIH effectively.

As well, Khaled et al. [14] demonstrated in 163 adult patients who went for elective surgery under GA, the incidence of protracted hypotension was higher than that of severe hypotension. Prolonged post-induction hypotension was predicted by an IJV change rate greater than 0.28, with a specificity of 76% and a sensitivity of 55%. Severe post-induction hypotension was predicted by an IJV change rate greater than 0.35, with a specificity of 72% and a sensitivity of 75%.

Regarding the MAP, the MAP in group A was insignificantly different at all time measurements (just after spinal, at 2.5, 5, 7.5, 10, 12.5, and 5 min, and at the end of the operation) compared to baseline. The MAP in group B was significantly reduced at all time measurements (after spinal, at 2.5, 5, 7.5, 10, 12.5, and 15 minutes, and at the end of surgery) compared to baseline ($P < 0.05$). Group B had significantly lower MAP after spinal at 2.5, 5, 7.5, and 10 min than group A ($P<0.05$); both groups did not exhibit any significant differences in other measurements.

Reduced MBP that is ≥ 20% of the baseline within 15 minutes of the medication injection into the subarachnoid space, known as PSH. That happened at (just after spinal,2.5, 5, 7.5, and 10 min after spinal) in group B.

Also, Nofal et al. [11] reported hypotension in twenty-eight patients out of 62 patients scheduled for orthopedic surgeries. Also, Kaur et al. [12] Noted that out of 52 patients, 29 developed PSH.

In alignment with our results, Abdelzaher et al. [15] conducted a clinical study that found that hypotension occurred in 48 patients

Further, Moschovaki et al. [16] found that the basal MAP was statistically indifferent between the hypotensive group and the normotensive group ($P=0.09$).

Additionally, regarding demographics, Elbadry et al. [17] encompassed cases with and without PSAH. The two groups were comparable in terms of age, BMI, and ASA. Liked our investigation.

Further, Nefeli et al. [18] found the same as they saw in elderly orthopedic-trauma patients that patients (manifested hypotension after spinal anesthesia and one who experienced hypotension in the post–anesthesia care unit was excluded (Before SA, a transthoracic echocardiogram examination was performed). The study found that age and sex were not significantly different between the two groups ($P=0.27$, 0.8, respectively). The SAIH incidence in elderly patients was similar to that in our study.

The limitations of the study included the absence of a correlation between VexUS and IJV measurements and post-operative complications, a lack of correlation between pre-operative fluid status and the level of intraoperative sensory and motor blood loss with SA, a single-centre study, which limits the generalizability of the results, and the absence of follow-up on post-operative complications.

It is recommended that further studies and additional research be conducted to determine the potential of VexUS as a diagnostic tool and for perioperative patient management. Furthermore, it is imperative to conduct a multicenter study and follow up on postoperative complications. Additional research should be conducted on other groups, such as paediatrics and other adult geriatric patients with different comorbidities, and should be considered.

CONCLUSIONS

The simplicity and noninvasiveness of pre-anesthetic IJV-CI, ΔIJV-A, and ΔIJV-D are predictors of post-SA in geriatric patients. VEXUS couldn't be used to predict SAIH in geriatric patients during perioperative examination.

AUTHORS' CONTRIBUTIONS

Study concept and design: E.M.A.
Acquisition of data: H.G.
Analysis and interpretation of data: S.M.A.
Drafting of the manuscript: E.S.E.M.
Critical revision of the manuscript for important intellectual content: H.B
Statistical analysis: E.M.A.
Administrative, technical, and material support: H.G.
Study supervision: H.B

CONFLICTS OF INTEREST

There are no conflicts of interest.

SUPPORT AND FUNDING

Not applicable

CONSENT

An informed written consent was obtained from all patients.

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Nil

DATA AVAILABILITY:

Data is available on reasonable requests from corresponding authors

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