Ultrasonographic Evaluation of Internal Jugular Vein for The Prediction of Post-Spinal Hypotension in Orthopedic Surgeries

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Background: Relative hypovolemia may predispose to severe or prolonged hypotension after spinal anesthesia in patients undergoing orthopedic surgeries. Empirical administration of fluid preload is time consuming, costly and might lead to volume overload, especially in elderly patients. Therefore, predicting post spinal hypotension is of great importance to reserve fluid infusion for susceptible patients. Ultra-sonographic evaluation of the internal jugular vein (IJV) diameter has been used to estimate intravascular volume in the ICU. Therefore, we investigated the efficacy of sonographic measurements of the internal jugular vein parameters for predicting post spinal hypotension in patients undergoing orthopedic surgeries.

Methodology: The study was conducted on 62 patients scheduled for orthopedic surgeries. Sonographic measurements of IJV diameter and cross-sectional area were recorded at supine and Trendelenburg position before spinal anaesthesia. Blood pressure was monitored for 15 minutes for all patients and hypotension was documented.

Results: Twenty-eight patients (45.2%) developed hypotension. The rate of increase in the diameter and cross-sectional area of the IJV with the change in patient's posture was significantly higher in hypotensive patients. According to ROC curves analysis, a rate of increase of 12.36% in IJV diameter, and a rate of increase of 25.55% in IJV cross sectional area showed moderate specificity and sensitivity in the prediction of spinal hypotension.

Conclusion: Preoperative sonographic measurements of the internal jugular vein diameter and cross-sectional area at supine and Trendelenburg position can predict the occurrence of post-spinal hypotension.

Key words: Internal jugular vein, ultrasound, post spinal hypotension, orthopedic surgeries, spinal anesthesia

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Introduction

Spinal anesthesia is frequently used in routine anesthesia practice. In literature, post spinal hypotension (PSH) revealed to be a common adverse effect with an incidence between 36% to 75%. Prolonged or severe hypotension could result in ischemia and organ hypoperfusion.[1,2] Intraoperative hypotension can be influenced by the sensory block level, age and preoperative volume status.[3,4]

Relative hypovolemia in patients undergoing orthopedic surgeries may be due to multiple factors such as decreased oral intake particularly in elderly patients due to impaired thirst sensation, increased fluid losses due to trauma and systematic inflammatory response and unplanned prolonged fasting in busy tertiary hospitals.

Prophylactic fluid administration or vasopressors have been advocated to prevent PSH.[5] However, these maneuvers might be associated with hazardous consequences. In spite that fluid co-load proved to decrease the incidence of PSH, empirical fluid infusion carries the potential of volume overload especially in cardiac patients.[6,7] Thus, the search for predictors of PSH is crucial in order to reserve fluid infusion only for patients who are suspected to such hypotensive events.

To date, various methodologies have been applied to estimate intravascular circulating volume. A reliable, non-invasive and simple method such as sonographic evaluation of the inferior vena cava (IVC) collapsibility index was recommended for assessment of intravascular volume in various studies.[8,9]

A systematic review published at 2019 documented that the internal jugular diameter has a role in non-invasive assessment of central venous pressure in spontaneously breathing patients.[10] Furthermore, internal jugular vein collapsibility index may be an attractive surrogate marker for the inferior vena cava vein collapsibility index in assessing fluid responsiveness.[11] Although post spinal hypotension is a common complication, spinal anesthesia remains the better choice for patients undergoing orthopedic surgeries. Therefore, non-invasive assessment of decreased intravascular volume is crucial especially in elderly traumatized patients, so we thought that preoperative ultrasonographic evaluation of the internal jugular vein parameters might be a reliable tool for estimating intravascular volume and prediction of post spinal hypotension.

Objective

This study aimed to evaluate the efficacy of preoperative sonographic measurements of the internal jugular vein diameter and area for predicting post spinal hypotension in patients undergoing orthopedic surgeries.

Methodology

This is a prospective observational study which was completed between March and September 2021 in Ain Shams University Hospital. Written informed consent was obtained from all participating patients. The study was approved by the Faculty of Medicine Research Ethics Committee, Ain Shams University (ref: FMASU R 25/2020/2021) and registered with Clinical Trials.Gov (ref: NCT04780139).

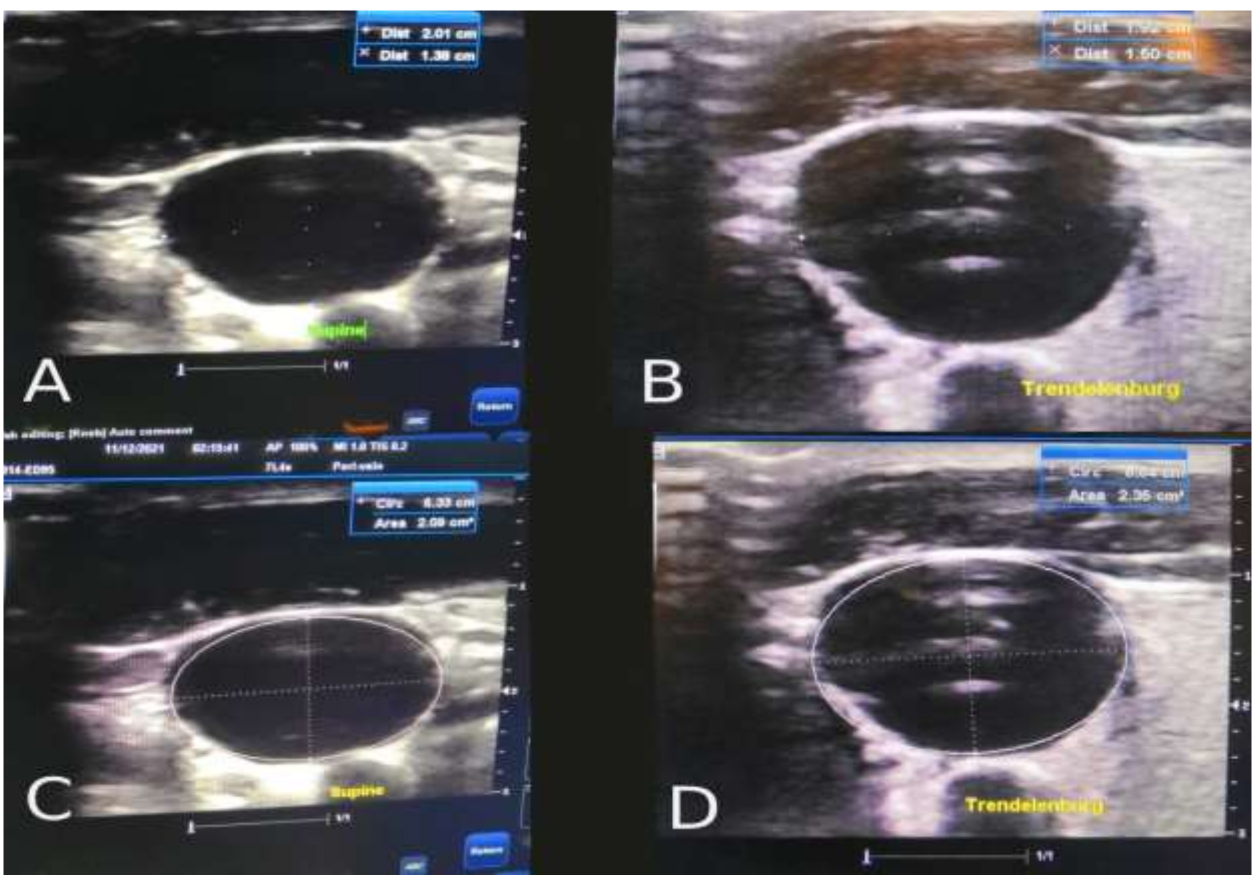
We included adult patients of both sexes more than 40 years of age and classified as the American Society of Anesthesiologists (ASA) physical status 1 or 2 who were scheduled for orthopedic surgery under spinal anesthesia in the supine position.

Exclusion criteria were BMI more than 35 kg/m^2, patients taking angiotensin converting enzyme inhibitors, pregnant women, emergency cases, absolute or relative contraindications to spinal anesthesia, Also, patients with a baseline arterial systolic blood pressure (SBP) less than 90 mmHg or mean arterial blood pressure (MBP) less than 70 mmHg were excluded.

After patients entered the operating room, standard monitors were applied. Baseline values of systolic, diastolic and mean blood pressures in the supine position were recorded.

We used a linear ultrasound probe, US machine Mindray M5 (Shenzhen Mindray Bio Medical Electronics Co., LTD. Shenzhen, China.). Patients lied down in the supine position with the head turned to the left side. After enough gel was applied, the probe was placed horizontally to the right of the middle level of the thyroid cartilage with minimum pressure. A clear and true transverse view of the right IJV was obtained, and both the diameter and area were recorded. Next, after changing the patient's position to Trendelenburg position (15^o), similar ultrasonographic measurements were again recorded as shown in figure 1. The biggest values obtained for the area or diameter during scanning for 20 seconds were adopted. The rate of change in IJV measurements with change in posture was calculated by the following formula (Measurement in Trendelenburg minus measurement in supine change, divided by measurement in the Trendelenburg position) presented as a percentage value(12). All the IJV measurements were performed on the right IJV at the same level by a single senior radiologist with more than 5 years of experience.

Image 1*: shows internal jugular view measurements. A: shows internal jugular diameter in supine position. B: shows internal jugular diameter in Trendelenburg position. C: shows internal jugular area in supine position. D: shows internal jugular area in Trendelenburg positionInside the induction room, an 18-G venous cannula was inserted and an infusion of 500 ml of Ringer Lactate solution was given to all patients with the administration of spinal anesthesia at a rate of 10 ml / kg /h*



Blood pressure values were recorded non-invasively every minute after spinal blockade for 10 minutes, and next then every 5 minutes till the end of the surgery. The incidence of hypotension was defined by a more than 20% decrease in MBP from the baseline level or any recorded value of MBP lower than 65 mmHg within the first 15 minutes after spinal anesthesia.

All the spinal block procedures were done by the same anesthesiologist, while the patient was in the sitting position. After sterilization of the back, the L3-4 or L4-L5 intervertebral space was identified, and local skin infiltration with lidocaine was done. Failure to perform the procedure through any of these intervertebral spaces was a reason for patient exclusion from the study. Spinal anesthesia was performed using a 25-G Quincke spinal needle, a 3 ml volume of local anesthetic was injected over 10 seconds. In all patients, the volume injected was 0.5 ml (25 ug) fentanyl added to 2.5 ml of hyperbaric 0.5% bupivacaine (Marcaine Spinal Heavy; AstraZeneca, Lund, Sweden). Then, the patient was immediately turned to the supine position with a pillow below the patient's head and neck to create an angle about 30° with the bed.

The sample size was calculated on the assumption that the incidence of hypotension is 50% and an area under ROC of 0.7 for internal jugular vein cross sectional area to predict hypotension whilst setting power at 80% and alpha error at 0.05, a sample size of 62 patients was needed.

Statistical analysis

Sample size was calculated using PASS program for sample size calculation which was based on a previous study conducted by Jie Zhang(12). The study detected that an area under the ROC curve (AUC) of 0.7 predicted more than 30% decrease in MBP. In addition, assuming that the incidence of hypotension is 50% and by setting the power at 80% and alpha error at 0.05, a sample size of 62 patients was determined.

Data of our study were analyzed using the Statistical Package for Social Science (SPSS) version 21.0. Chicago, Illinois, USA. Quantitative data were expressed as mean ± standard deviation, and qualitative data were expressed as count. The independent-samples t-test was used to compare between means in the two groups. Chi square test was used to compare proportions between two qualitative parameters. $P < 0.05$ was considered significant and the Receiver Operating Characteristic (ROC) curve analysis was performed to assess the ability of the two ultrasound-derived values; the rate of change in the IJV diameter and area of the change in posture, to predict clinically significant hypotension. The optimal cutoff values were identified as the values that maximize the Youden index (sensitivity + specificity − 1).[13]

Results

Initially, 76 patients were enrolled for the study. We excluded 6 patients not meeting our inclusion criteria, 3 failed spinal cases, and 5 patients could not tolerate Trendelenburg position. The demographic data of the 62 patients collectively were recorded. After induction of spinal anesthesia, 28 patients, representing 45.2% of all included patients, developed hypotension according to the predefined criteria of hypotension. We divided the patients into 2 groups: those who developed hypotension and those who didn't.

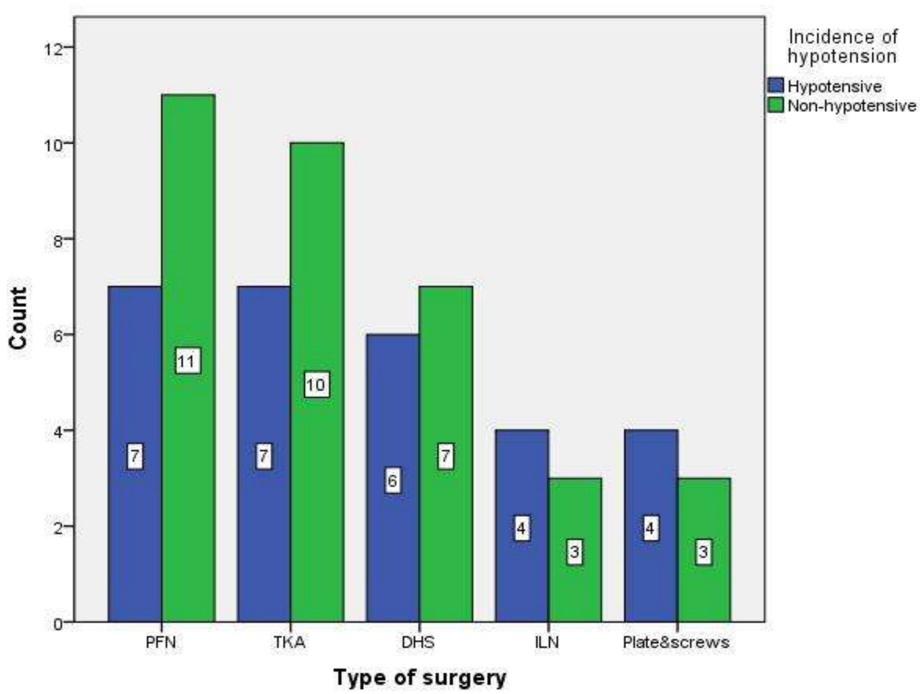
Table 1 demonstrates both demographic data and baseline blood pressure measurements of both groups. P value was measured by independent t-test except for gender which was measured by chi-square test. Data presented as count (%) or mean ± SD. Figure 2 represents the distribution of the different orthopedic surgeries.

***Table 1**: Patients' Demographics*

	All patients (62)	Hypotension group 28(45.2)	Non-hypotensive group 34(54.8)	P value
Age (years)	57.3±6.9	56.7±7.8	57.8±6.3	0.549
Gender (M/F)	32/30	15/13	17/17	0.779
BMI (kg/m^2)	27.3±1.7	27.5±1.6	27.3±1.9	0.638
Baseline SBP (mmHG)	129.9±6.4	131.4±4.6	128.6±7.5	0.095
Baseline DBP(mmHG)	79.1±4.6	78.9±4.6	79.1±4.7	0.854
Baseline MBP(mmHG)	96.1±3.8	96.4±3.2	95.6±4.3	0.429

SBP systolic blood pressure, DBP diastolic blood pressure, MBP mean blood pressure.

***Figure 2**: represents the distribution of the different orthopedic surgery done.*



The ultrasonographic measurements of the internal jugular vein in both groups are shown in Table 2. The results reveal that, in the Trendelenburg position, the IJV diameter and area are both significantly higher in the hypotensive group than in the other group. Also, with the change in patient's posture, the rate of change in the diameter and area of the IJV are significantly higher in the patients who developed hypotension after spinal anesthesia.

Table 2: *Ultrasonographic Measurements of Internal Jugular Vein*

	Hypotension group	Non-hypotensive	P value
IJV diameter (cm) at supine	1.58±0.07	1.61±0.08	0.232
At Trendelenburg(cm)	1.83±0.07	1.77±0.07	0.002
Rate of change with posture(%)	13.81±4.28	9.25±4.06	<0.001
IJV area(cm^2) at supine	1.51±0.16	1.51±0.12	0.901
At Trendelenburg(cm^2)	2.13±0.18	1.90±0.17	<0.001
Rate of change with posture(%)	28.83±4.12	20.19±5.57	<0.001

P value measured by independent t-test. Data presented as mean ± SD

The ROC curves for the rate of change in the diameter and area of the IJV are represented in figure 3. Table 3 represents the areas under the 2 curves (AUCs) and their confidence intervals. Both areas are statistically significant. The area under the ROC curve for the rate of change (%) in IJV area was 0.909(95% CI, 0.833,0.985), which is an outstanding level of discrimination between patients who will develop post spinal hypotension and those who won't.

However, the AUC for the rate of change (%) in IJV diameter was 0.779(95% CI,0.661,0.898) which represents an acceptable level of discrimination according to Hosmer et al.[14] We determined the cut-off values, that best discriminate between patients who will and those who will not develop hypotension after spinal anesthesia, by visual inspection of the curves.

These values were confirmed by the Youden index formula (sensitivity + specificity -1)(13). We found that a rate of change of 12.36% in IJV diameter, and a rate of change of 25.55% in IJV area have the optimal combination of sensitivity and false positive (1-specificity) rate. The sensitivity and specificity of the 2 cut-off values for the rate of change in IJV diameter and area are shown in table 4. The cut-off value for the rate of change in IJV area has a sensitivity of 89.3%, while that for the rate of change in IJV diameter is only 71.4%.

Figure 3: *shows the ROC curves of the rate of change in the diameter and area of the IJV.*

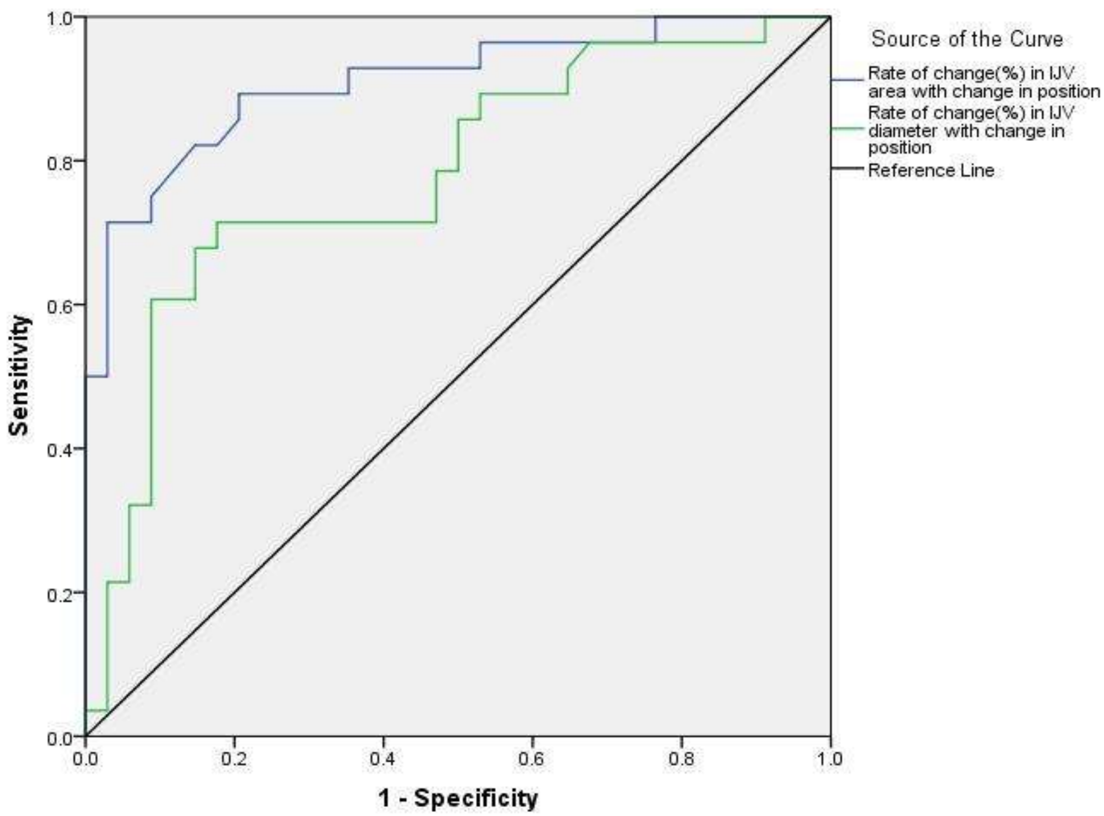


Table 3: *The Area Under the Curves of the ROC Curves and Their Statistical Analysis* (Null hypothesis: true area = 0.5)

Area Under the Curve					
Test Result Variables	Area	Std. Error	Sig.[a]	95% Confidence Interval	
				Lower Bound	Upper Bound
Rate of change (%) in IJV area with change in position	0.909	0.039	<0.001	0.833	0.985
Rate of change (%) in IJV diameter with change in position	0.779	0.061	<0.001	0.661	0.898

Table 4: *Sensitivity and Specificity and Their Confidence Intervals of the Cut-Off Values*

Cut-off value Of	**Diagnostic study**	**Value**	**95% confidence interval Lower and upper bounds**
Rate of change in IJV diameter (12.36%)	Sensitivity	0.714	0.529,0.847
	Specificity	0.824	0.665,0.917
Rate of change in IJV area (25.55%)	Sensitivity	0.893	0.728,0.963
	Specificity	0.794	0.632,0.879

Discussion

Hypotension after spinal anesthesia in orthopedic surgeries is a challenge faced anesthesiologists daily, as severe or prolonged hypotension may lead to myocardial injury, ischemic stroke or acute kidney injury[1]; therefore, prevention of such derangement is of great importance. Subclinical decrease of intravascular volume can predispose to severe hypotension after spinal anesthesia due to accompanying sympathetic blockade.[2] Patients undergoing orthopedic surgeries are usually geriatrics who may have latent hypovolemia due to chronic diseases, dehydration, medications or post traumatic systemic inflammatory response.[15,16]

Evaluation of preoperative volume status is traditionally approached via central venous catheter insertion, although routine insertion of central line owns its complications. Additionally, being invasive and time-consuming technique limits its usage in relatively short operations.[17]

In the last few years, ultrasound guided measurements of the inferior vena cava became an established non- invasive tool for predicting intravascular volume in intensive care units and operating theatres.[5,9]

Several studies demonstrated the ability of ultrasonographic measurements of the internal jugular vein (IJV) diameter to assess central venous pressure and intravascular volume.[18,19] Nejad et al showed that the ratio of internal jugular vein area to the common carotid artery area could be an alternative to central jugular line readings in accessing intravascular volume of critically ill patients.[20] Another study showed similar results and reported that a ratio less than 0.75 could predict central venous pressure <10 cm H_2o in ICU.[21]

On the other hand, a limited number of studies have investigated the role of sonographic IJV measurements in operating theaters. Okamura et al studied the ability of ultrasound evaluation of IJV area to predict hypotension after the induction of general anesthesia. Authors have found that IJV area in Trendelenburg position could predict postinduction hypotension[22], while another study has searched the feasibility of using

IJV collapsibility index in predicting hypotension after general anesthesia, and it has reported similar results.[23]

Regarding spinal anesthesia, Salama et al investigated the possible relationship between Inferior Vena Cava collapsibility index, IVC : aorta index and postspinal hypotension. Authors found that both indexes were reliable predictors for postspinal hypotension development(9). In contrary to that study, Singh et al found no positive correlation between IVC sonographic measurements and post spinal hypotension. However, participants were only young pregnant women which might be a limitation for generalizing their conclusion.[24]

To the best knowledge of the author's, yeliz et al.[25] conducted the only study which evaluated the reliability of IJV sonographic parameters in the prediction of post spinal hypotension. Yeliz et al. concluded that collapsibility index of IJV was a predictor of hypotension in young healthy adults undergoing different surgeries under spinal anesthesia with a cut-off value of 22.6%, whilst

the present study differed from the mentioned study because it contained older patients undergoing orthopedic surgeries. We chose to measure preanesthetic min/max diameters and area of IJV because it is easier than collapsibility index in elderly or fractured patients, as the collapsibility index needs tracking of inspiratory and expiratory changes in IJV.

In the current study, twenty-eight patients, representing 45.2% of all included patients, developed hypotension according to the predefined criteria of hypotension. Our results are consistent with the recorded general knowledge and literature[2], and they revealed that in the Trendelenburg position, the IJV diameter and area are both significantly higher in the hypotensive group than in the other group. Also, with the change in patient's posture, the rate of change in the diameter and area of the IJV are significantly higher in those patients who developed hypotension after spinal anesthesia.

Current study showed a higher area under the curve regarding the rate of change in the diameter and area of the IJV which indicates higher sensitivity and specificity rates in comparison to Yeliz's study.[25] We also found that a rate of change of 12.36% in IJV diameter, and a rate of change of 25.55% in IJV area have the optimal combination of sensitivity and false positive (1-specificity) rate. Differences in research population, surgical procedures and measured parameters may explain the variation in cut-off values recorded in their study.

This study concludes that preoperative sonographic measurements of the internal jugular vein diameter and area changes after Trendelenburg position might be reliable predictors of the occurrence of post spinal hypotension.

A large-scale study is required to generalize our statistical results because the present study was a single center study, and the participants were classified as ASA 1 or 2, which may have affected the cut-off values. Furthermore, the age range of the study population was a wide range, and we did not stratify our participants into age groups, which may have added another confounding factor for the study question. Another limitation for the present study is the various types of orthopedic surgeries included in the study.

Our recommendation is to investigate the ability of sonographic evaluation of the internal jugular vein parameters to guide fluid transfusion before spinal anesthesia.

Authors' contributions

W.H. did the analysis and interpretation of the data. N.S. contributed to the acquisition of data and drafted the manuscript. S.W. provided the idea of the research, helped in data acquisition and the interpretation and drafting of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

Please contact the corresponding author for data requests.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethics approval and consent to participate

The study was approved by the ethical committee of Ain Shams University (file reference no FMASU R 25/2020/2021)

A written consent for all patients was taken.

Trial registration

At ClinicalTrial.gov: NCT04780139).

References

1. Ferré, F., Martin, C., Bosch, L, et al. Control of Spinal Anesthesia-Induced Hypotension in Adults. Local and regional anesthesia,2020;13: 39–46.
2. Hartmann B, Junger A, Klasen J, et al. The incidence and risk factors for hypotension after spinal anesthesia induction: with an analysis automated data collection. Anesth Analg. 2002;94(6):1521-9,
3. Hofhuizen C, Lemson J, Snoeck M,et al. Spinal anesthesia-induced hypotension is caused by a decrease in stroke volume in elderly patients. Local Reg Anesth. 2019;12:19-26.
4. Kweon TD, Kim SY, Cho SA, et al. Heart rate variability as a predictor of hypotension after spinal anesthesia in hypertensive patients. Korean J Anesthesiol 2013; 65:317–321.
5. S. Ceruti, L. Anselmi, B. Minotti, D, et al. Prevention of arterial hypotension after spinal anaesthesia using vena cava ultrasound to guide fluid management. British Journal of Anaesthesia 2018; 120:101-108.
6. Khan MU, Memon AS, Ishaq M, et al. Preload versus coload and vasopressor requirement for the prevention of spinal anesthesia induced hypotension in nonobstetric patients. J Coll Physicians Surg Pak 2015; 25:851–855.
7. Minto G, Scott MJ, Miller TE. Monitoring needs and goal directed fluid therapy within an enhanced recovery program. Anesthesiol Clin 2015; 33:35–49.
8. Brennan JM, Ronan A, Goonewardena S, et al. Hand carried ultrasound measurement of the inferior vena cava for assessment of intravascular volume status in the outpatient hemodialysis clinic. Clin J Am Soc Nephrol 2006; 1:749–753.
9. Salama, Eman Ramadan, Elkashlan Mohamed. Preoperative ultrasonographic evaluation of inferior vena cava collapsibility index and caval aorta index as new predictors for hypotension after induction of spinal anaesthesia. A prospective observational study. European journal of Anaesthesiology. April 2019; 36(4): 297-302.
10. Nicola parenti, Marco Scalese, Carmela Palazzi, et al. Role of Internal Jugular Vein Ultrasound Measurement in the Assessment of Central Venous Pressure in Spontaneously Breathing patients: A Systematic Review. Journal of Acute medicine 2019; 9(2):39-48.
11. Broilo F, Meregalli A, Friedman G. Right internal jugular vein distensibility appears to be a surrogate marker for inferior vena cava vein distensibility for evaluating fluid responsiveness. Rev Bras Ter Intensiva. 2015 Jul-Sep;27(3):205-11.
12. Jie Zhang, M.B.B.S., Lester Augustus Hall Critchley. Inferior vena cava ultrasonography before general anesthesia can predict hypotension after induction (Anesthesiology 2016; 124:580-9)

13. Youden WJ: Index for rating diagnostic tests. Cancer 1950; 3:32–5.
14. Hosmer, D. W., Jr., Lemeshow, S., & Sturdivant, R. X. (2013). Applied logistic regression (3rd ed.). Hoboken, NJ: Wiley.
15. Kenney WL, Chiu P. Influence of age on thirst and fluid intake. Med Sci Sports Exerc. 2001 Sep;33(9):1524-32.
16. Singh, S., Shah, T. D., Gupta, R., et al. Postspinal hypotension in elderly patients undergoing orthopedic surgery, prophylactic ephedrine versus polygeline 3.5. Anesthesia, essays and researches, 2014; 8(3), 334–338.
17. Kornbau, C., Lee K. C., Hughes, G. D.,et al. Central line complications. International journal of critical illness and injury science,2015; 5(3), 170–178.
18. Unluer EE, Kara PH. Ultrasonography of jugular vein as marker of hypovolemia in healthy volunteers. Am J Emerg Med. 2013;31:173–7.
19. Avcil M, Kapci M, Dagli B, et al. Comparision of ultrasound-based methods of jugular vein and inferior vena cava for estimating central venous pressure. Int J Clin Exp Med. 2015;8:10586–94.
20. Hossein-Nejad H, Mohammadinejad P, Ahmadi F. Internal jugular vein/common carotid artery cross-sectional area ratio and central venous pressure. J Clin Ultrasound. 2016 Jun;44(5):312-8.
21. Bano, S., Qadeer, A., Akhtar, A.,et al. Measurement of Internal Jugular Vein and Common Carotid Artery Diameter Ratio by Ultrasound to Estimate Central Venous Pressure. Cureus,2018; 10(3).
22. Okamura K, Nomura T, Mizuno Y, et al. Pre-anesthetic ultrasonographic assessment of the internal jugular vein for prediction of hypotension during the induction of general anesthesia. J Anesth. 2019 Oct;33(5):612-619.
23. Yeliz Kılıç, Gülay Erdoğan Kayhan, Ayten Bilir, et al. Ultrasonographic measurement of the internal jugular vein as a predictor of hypotension following the induction of anesthesia. Int J Clin Exp Med 2020;13(10):7857-7864.
24. Singh, Y., Anand, R. K., Gupta, S., et al. Role of IVC collapsibility index to predict post spinal hypotension in pregnant women undergoing caesarean section. An observational trial. Saudi journal of anaesthesia,2019;13(4), 312–317.
25. Yeliz Kilic, Sema Sanal Bas, Gulay Erdogan Kayhan, et al. Internal Jugular Vein Ultrasonography in Prediction of Postspinal Hypotension." Journal of the College of Physicians and Surgeons Pakistan, vol. 30, no. 12, Dec. 2020, pp. 1256+