Pre-operative Ultrasonographic Evaluation of the Internal Jugular , Inferior Vena cava and Femoral Veins collapsibility Indices in supine position to predict post spinal hypotension during cesarean delivery.

Abstract

Background: Spinal anesthesia (SA) is commonly employed for elective cesarean section (CS); however, it is frequently complicated by post-SA hypotension (PSAH), which may adversely influence maternal and fetal outcomes. ***Objective:*** to determine the predictive performance of the collapsibility indices of internal jugular vein (IJV), inferior vena cava (IVC), and femoral vein (FV) in detecting PSAH CS. ***Methods:*** A cross-sectional study was conducted at Benha University Hospital. Ultrasonographic assessment of venous collapsibility indices was performed prior to SA in women scheduled for elective CS. Hemodynamic parameters, including heart rate and mean arterial pressure, were documented at three-minute intervals during the first 15 minutes following SA. ***Results:*** There were highly statistically significant differences between patients with and without PSAH, and the mean collapsibility indices of the internal jugular, inferior vena cava, and femoral veins demonstrated high sensitivity and specificity in predicting PSAH. ***Conclusions:*** IJV, IVC, and FV collapsibility indices were effective and reliable predictors of PSAH in pregnant women undergoing CS, with FVCI demonstrating the highest specificity and sensitivity.

Key-Words: Ultrasonographic ; Collapsibility; spina; Hypotension; Cesarean.

Introduction

The daily practice of obstetric anesthesia frequently involves post-spinal anesthesia hypotension (PSAH), which has been documented to occur as frequently as to 71% [(1)]. PSAH results primarily from a reduction in systemic vascular resistance due to vasodilation following spinal anesthesia (SA), along with decreased preload caused by compression of the inferior vena cava (IVC) by the gravid uterus [(2)].

In addition, prenatal hypovolemia further increases the likelihood of CV instability in pregnant patients. PSAH may be associated with serious maternal and fetal complications; accordingly, pre-anesthetic identification of intravascular volume

(IVV) deficiency may contribute to reducing intraoperative blood pressure (BP) reduction [3].

Substantial progress has been achieved in hemodynamic monitoring approaches in recent years [4], Ultrasound (US) is a practical, safe, and noninvasive tool for the assessment of hemodynamic status [5]. Several investigations have underscored the practical utility of point-of-care US when applied by anesthesiologists in perioperative and critical care settings [6].

US-based assessment of the internal jugular vein (IJV) or IVC has been shown to offer valuable insight into IVV status ([7].

Preventive measures for PSAH include left uterine displacement, vasopressor use, crystalloid or colloid preloading or coloading, and elastic compression of the lower limbs.[8] However, no single strategy has been shown to completely prevent maternal hypotension. [9] **Objective:** to assess the predictive values of IJV, IVC and Femoral Veins collapsibility indices in identifying PSAH during cesarean section (CS).

Methods:

Following approval from the Research Ethics Committee (REC) of the Faculty of Medicine, Benha University (approval number: MD-9-5-2023), this cross-sectional study was conducted at the Anesthesia Department of Benha University Hospital over a period extending from June 2023 to May 2024.

A total of 30 parturients aged between 18 and 40 years with singleton pregnancies at full term (>37 weeks' gestation), classified as American Society of Anesthesiologists (ASA) physical status II, and scheduled for elective CS under SA were enrolled in the study. Written informed consent was obtained from all parturients.

ASA physical status III or IV; multiple gestation or prolonged pregnancy exceeding 42 weeks; placenta previa or placenta accreta; pre-existing hypertension or pregnancy-induced hypertension, including preeclampsia; evidence of fetal distress or congenital fetal anomalies; emergency cesarean section; inadequate sensory block below the T6 dermatome at the commencement of surgery; or morbid obesity defined as a body mass index ≥36 kg/m² were excluded.

Additional exclusion criteria included a documented history of IJV thrombosis; neck pathology that could interfere with ultrasonographic visualization of the IJV, such as neck masses, large goiter, or local infection; IVC thrombosis; moderate to severe ascites; femoral vein (FV) thrombosis; groin infection; femoral hernia; groin mass; or a history of femoral vascular surgery.

Based on the occurrence of PSAH, participants were subsequently classified into two groups: patients who developed PSAH (12 patients) and patients who did not develop PSAH (18 patients).

All enrolled patients underwent a standardized preoperative evaluation that included comprehensive history taking, complete physical examination, and review of routine laboratory investigations. Patients were instructed to fast for a minimum of six hours prior to surgery.

Ultrasonographic evaluation was performed approximately 15 minutes before SA while parturients were positioned on the transfer bed in the post-anesthesia care unit; upon arrival in the operating room, standard monitoring was initiated, including pulse oximetry, five-lead electrocardiography, and non-invasive blood pressure. All ultrasonographic assessments were conducted with parturient in the supine position by the same anesthesiologist via a LOGIQ e US system to minimize inter-observer variability. The IVC was examined with a curvilinear probe, whereas the IJV and FV were assessed via a high-frequency linear vascular transducer, with both B-mode and M-mode imaging utilized during data acquisition.

a. IJVCI Estimation

For assessment of the IJV, the US transducer was positioned transversely on the neck approximately 2 cm above the sternoclavicular joint. Care was taken to avoid excessive probe pressure in order to prevent artificial compression of the vein. via M-mode imaging, the maximum and minimum anteroposterior diameters of the IJV were estimated during the respiratory cycle. The IJV collapsibility index (IJVCI) was estimated via the following equation: Maximum diameter - lowest diameter/ maximum diameter) 100% [(10)].

b. IVCCI Estimation

The IVC was visualized in the longitudinal plane via a curvilinear US probe placed in the subxiphoid region, in accordance with the guidelines of the American Society of Echocardiography [(3)] . Estimations were obtained approximately 3–4 cm distal to the junction of the hepatic veins with the IVC, just inferior to the right atrium. The maximum and minimum IVC diameters during respiration were documented, and the IVC collapsibility index (IVCCI) was estimated via the same formula applied for IJVCI.

c. FVCI Estimation

The FV was identified at a level 2–5 cm below the inguinal ligament via a high-frequency linear transducer. Particular attention was given to avoid exerting pressure that could alter the venous diameter. The maximum and minimum diameters of the FV during the respiratory cycle were estimated, and the FV collapsibility index (FVCI) was estimated via the same equation utilized for IJVCI [(11)]. After completion of all ultrasonographic estimations, SA was administered at the L2–L3 or L3–L4 intervertebral space via a 25-gauge spinal needle following confirmation of free and unobstructed cerebrospinal fluid flow. A total volume of 2.5 mL of 0.5% hyperbaric bupivacaine combined with 20 µg fentanyl was injected intrathecally. Simultaneously, all parturients received a coload of Ringer's lactate solution at a dose of 10–12 mL/kg administered over 15 minutes. Surgical intervention was initiated once a sensory block level corresponding to the T6 dermatome was achieved.

Heart rate (HR) and mean arterial pressure (MAP) were documented at three-minute intervals during the first 15 minutes following the administration of SA.

Hypotension was defined as a reduction in mean arterial pressure exceeding 20% of the baseline value or an absolute MAP value less than 65 mmHg. Management of hypotension included intravenous ephedrine administered in 6-mg increments in addition to a 250-mL bolus of Ringer's lactate solution. The total dose of ephedrine administered was documented for each parturient. Bradycardia, defined as a HR below 50 beats per minute, was treated with 0.6 mg of intravenous atropine.

Sample size calculation was performed via G*Power software based on data exhibited by Singh et al., with a 95% confidence level, 80% statistical power, and a two-tailed alpha error of 0.05. The estimated minimum sample size was 27 parturients. Allowing for an anticipated dropout rate of 10%, a 30 parturients were enrolled.

IV- Data management and statistical analysis: -

We employed SPSS 25.0 for Windows (SPSS Inc., Chicago, IL, USA) to code, input, analyze, and display the obtained data in appropriate tables and graphs. We employed quantitative measures like Mean and SD to describe the data we gathered. The student t test (t-test) was employed to compare quantitative data. A ROC curve and screening tests were conducted.The tests were all two-sided, and the accepted threshold of significance for this study was $p < 0.05$. A p-value of less than or equal to 0.01 was deemed highly significant statistically.

Results

In the present investigation, 60 parturients were evaluated for eligibility; 30 were excluded, including 20 who did not meet the criteria, 2 who exhibited a sensory level below T6 at the onset of surgery, and 8 who declined to participate in the study. The remaining 30 parturients were monitored, analyzed, and categorized into two categories according to the incidence of PSAH: those with PSAH (12 cases) and those without PSAH (18 cases) **(Figure 1).**

This investigation indicates statistically significant variations between patients with PSAH and patients without PSAH regarding height in cm (159.67±1.67 Vs.164.0±3.80) respectively, Total IV fluid administered in ml (2225.0±194.81Vs.1611.1±114.47)respectively, and Interoperative pressors consumption, (44.17±12.94 Vs. 3.06±7.1) respectively ($P < 0.001$) **(Table 1).**

The current investigation noticed a highly statistically significant differences between Patients with PSAH and Patients without PSAH regarding; the mean percentage of IVCCI (46.46 ±9.55 Vs. 28.83 ±16.33) respectively, the mean percentage of IJVCI (41.817±6.2104 Vs. 18.42±7.30) respectively and the mean percentage of FVCI (41.02 ± 6.27 Vs. 16.37 ± 4.94) respectively ($P < 0.001$) **(Table 2).**

This study demonstrates a highly statistically significant differences between patients with PSAH and Patients without PSAH regarding; the mean of HR at 3 minutes (109.33±9.41 Vs. 97.06±12.28) respectively (P = 0.007), the mean of HR at 12 minutes (110.83±11.46 Vs. 93.06±9.22) respectively (P < 0.001) and the mean of HR at 15 minutes (106.00±14.61 Vs. 90.50±7.46) respectively (P = 0.004) **(Table 3).**

This work notes a highly statistically significant differences between patients with PSAH and Patients without PSAH regarding; the mean of MAP at 3 minutes (56.67±7.57 Vs. 81.72±6.75) respectively, the mean of MAP at 12 minutes (63.33±2.87 Vs. 83.61±4.29) respectively and the mean MAP at 15 minutes (72.00±5.91 Vs. 83.72±4.11) respectively (P < 0.001) (**Table 4).**

This work demonstrated that an IVCCI cut-off of 39% predicted PSAH with a sensitivity of 83.3% and specificity of 77.8%. IJVCI, via a cut-off value of 25.7%, predicted PSAH with 100% sensitivity and 83% specificity. Furthermore, an FVCI cut-off of 27.65% showed 100% sensitivity and 100% specificity in predicting PSAH. **(Table 5 and Figure 2).**

Discussion

Venodilation commonly occurs after SA. Several factors contribute to the increased susceptibility of parturients to hypotension. During uncomplicated pregnancy, SVR typically decreases by nearly 20%, mainly due to the vasodilatory effects of progesterone and prostaglandins [(12)].

Venodilation occurs frequently after SA. Parturients are particularly vulnerable to hypotension due to physiological changes inherent to pregnancy. In uncomplicated pregnancy, SVR typically decreases by nearly 20%, a change largely attributed to the vasodilatory effects of progesterone and prostaglandins [(13)].

Aortocaval compression (AoCC) represents an additional contributor to hypotension in pregnant females. At term, when parturients are positioned supine, the IVC may become almost completely compressed, resulting in a marked reduction in VR and further aggravation of hypotension following SA [(14)].

Because PSAH remains a frequent and clinically relevant complication, numerous studies have focused on identifying reliable methods for its prediction. Several approaches have been explored with the aim of improving early identification of patients at risk for PSAH [(15)].

In the present study, IVCCI proved useful in estimating IVV status and predicting hemodynamic responses in obstetric patients (Table 2). These findings, however, are not entirely concordant with reports suggesting that IVCCI is not a reliable predictor of PSAH in parturients undergoing elective CS with infra-umbilical surgery.[(16)(17)] . This inconsistency may reasonably be attributed to pregnancy-related changes in VT, the mechanical effects of uterine compression, and physiological hemodynamic adaptations that may limit the predictive accuracy of a single dynamic venous index.

PSAH was observed in 12 cases in the current study, corresponding to an incidence of 40% (Table 1). This incidence is partially comparable to that exhibited in a cross-sectional study conducted at Tanta University, in which PSAH occurred in 26 cases, with an incidence of 47.27% [(18)] .

Nevertheless, the incidence observed in this study was lower than that exhibited by Chekol et al., who documented PSAH rates of 80% during the 5–15 min interval and 83% during the 15–25 min interval following SA [(19)] .

In addition, a systematic review and meta-analysis conducted in Ethiopia exhibited pooled PSAH incidence rates ranging from 56.8% to nearly 80% [(20)] . Such variability may be explained by differences in PSAH definitions, patient characteristics, anesthetic techniques and dosages, preventive measures, and methodological differences between single-center studies and pooled analyses.

Patients who developed PSAH in the present study demonstrated significantly higher IVCCI values than those who remained normotensive (46.46% ± 9.55 vs. 28.83% ± 16.33, $P < 0.001$) (Table 2). This observation is consistent with findings exhibited by Elbadry and Sabaa (2022), who also noted significantly higher IVCCI values in PSAH patients compared with non-PSAH patients (38.27% vs. 23.97%, $P < 0.001$) [(18)]

Conversely, an observational study exhibited comparability in IVCCI values between hypotensive and non-hypotensive patients (26.32 ± 13.3 vs. 31.6 ± 12.3, $P = 0.22$),

suggesting limited reliability of IVCCI for predicting PSAH in parturients undergoing elective CS[16][21].

With regard to IJVCI, patients who developed PSAH in the current study exhibited significantly higher values compared with those who did not ($P < 0.001$) (Table 2). via a cut-off value of 25.7%, IJVCI predicted PSAH with a sensitivity of 100% and a specificity of 83%. Comparable findings were exhibited by Wang et al. (2022), who demonstrated that IJVCI values exceeding 39% predicted hypovolemia with high sensitivity and specificity in critically ill patients [22].

Comparability was observed in baseline HR between patients with and without PSAH (Table 3). Mean baseline HR values were 91.83 ± 10.04 bpm in the PSAH group and 95.22 ± 13.38 bpm in the non-PSAH group ($P = 0.462$). This finding contrasts with reports suggesting baseline HR as a predictor of PSAH in parturients undergoing CS [23] .

These results also differ from those exhibited by Yao et al. (2021), who proposed that a baseline HR > 90 bpm could predict PSAH [24], , as well as from another study reporting higher baseline HR values in PSAH patients with a cut-off of 92 bpm[25].

An IVCCI cut-off value of 39% predicted PSAH with a sensitivity of 83.3% and a specificity of 77.8% in the present study (Table 5). These results are broadly consistent with those exhibited by Elbadry and Sabaa (2022), who identified a 33% cut-off with a sensitivity of 84.6% and a specificity of 93.1% off [18]. On the other hand, another research found that IVCCI at a 33% cut-off predicted PSAH with 84.6% sensitivity and 93.1% specificity [16].

IJVCI demonstrated excellent diagnostic performance in the current study, achieving a sensitivity of 100% and a specificity of 83% at a cut-off value of 25.7% (Table 5). This finding aligns with data from a cohort study conducted in India, which exhibited an IJVCI cut-off value of 29.5% associated with a sensitivity of 70% and a specificity of 23% for predicting PSAH during spontaneous breathing [26]

This research had a number of limitations, the first of which was that it was conducted at a single tertiary care institution. The multicenter trial can have a different outcome than expected. Our research did not take into account the issue of preoperative anxiety

concerns. Furthermore, we have only recruited individuals who were getting elective LSCS, which means that our findings cannot be generalized to patients who are undergoing emergency LSCS.

Conclusion:

IVCCI, FVCI, and IJVCI were effective and reliable predictors of PSAH in pregnant women undergoing CS, with FVCI demonstrating the highest specificity and sensitivity.

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Table (1): Demographic data of the studied group according to PSAH occurrence:

Variable	Patients with PSAH (n=12) Mean ± SD	Patients without PSAH (n=18) Mean ± SD	T-test	P
Age (years)	27.33 ± 6.60	29.89 ± 7.22	0.98	0.33
Weight (kg)	86.33±4.66	86.22±5.71	-.06	0.96
Height (cm)	159.67±1.67	164.0±3.80	4.26	**<0.001****
BMI (kg/m2)	33.27±1.21	31.99±2.44	-1.90	0.07
Gestational Age (weeks)	38.0±1.04	37.94±0.80	-.165	0.87
Induction delivery interval (min)	17.50±2.69	19.11±3.66	1.31	0.20
Total IV fluid administered (ml)	2225.0±194.81	1611.1±114.47	-9.84	**<0.001****
Interoperative pressors consumption	44.17±12.94	3.06±7.1	-10.04	**<0.001****
Neonatal body weight(kg)	3.40±0.21	3.27±0.21	-1.556	0.13

**PSAH: Post Spinal Anesthesia Hypotension

Table (2): The IVCCI, IJVCI and FVCI of the studied group according to PSAH occurrence.

Variable		Patients with PSAH (n=12) Mean ± SD	Patients without PSAH (n=18) Mean ± SD	T-test	P
IVC	**Max. IVC diameter**	19.50 ±2.54	17.50 ±2.33	-2.221	**0.03***
	Min. IVC diameter	10.55 ± 2.86	12.56 ±3.80	1.553	0.13
	IVCCI(%)	46.46 ±9.55	28.83 ±16.33	-3.724	**0.001****
IJV	**Max. IJV diameter**	13.17 ±2.125	15.11 ± 2.56	2.173	**0.03***
	Min. IJV diameter	7.60 ±1.08	12.24 ± 1.91	7.612	**<0.001****
	IJVCI(%)	41.817 ±6.21	18.42 ± 7.30	-9.105	**<0.001****
FV	**Max. FV diameter**	14.00 ±2.000	14.44 ± 2.31	0.544	0.59
	Min. FV diameter	8.20 ±1.03	12.11 ± 2.29	6.334	**<0.001****
	FVCI(%)	41.02 ± 6.27	16.37 ± 4.94	-12.014	**<0.001****

** IVCCI: Inferior Vena Cava collapsibilty Index ** IJVCI. Internal Jugular Vein Collapsibility Index

** FVCI: Femoral Vein Collapsibility Index ** PSAH. Post Spinal Anesthesia Hypotension

Table (3): The Heart Rate of the studied group according to PSAH occurrence:

HR (beat/min.)	Patients with PSAH (n=12) Mean ± SD	Patients without PSAH (n=18) Mean ± SD	T-test	P
Baseline	91.83±10.04	95.22±13.38	0.746	0.462
3 min.	109.33±9.413	97.06 ±12.28	-2.930	**0.007****
6 min.	112.17±11.94	96.00±11.31	-3.750	**0.001****
9 min.	112.67±13.34	93.33±9.31	-4.687	**<0.001****
12 min.	110.83±11.46	93.06±9.22	-4.695	**<0.001****
15 min.	106.00±14.61	90.50±7.46	-3.392	**0.004****

**PSAH: Post Spinal Anesthesia Hypotension

Table (4): The MAP of the studied group according to PSAH occurrence:

MAP (mmHg)	Patients with PSAH (n=12) Mean ± SD	Patients without PSAH (n=18) Mean ± SD	T-test	P
Baseline	85.67±3.28	86.33±4.690	0.43	0.673
3 min.	56.67±7.57	81.72±6.75	9.49	**<0.001****
6 min.	62.17±5.73	83.06±5.29	10.25	**<0.001****
9 min.	65.67±6.05	84.72±5.37	9.06	**<0.001****
12 min.	63.33±2.87	83.61±4.29	14.34	**<0.001****
15 min.	72.00±5.91	83.72±4.11	6.42	**<0.001****

**MAP:Mean Arterial Pressure

**PSAH: Post Spinal Anesthesia Hypotension

Table (5): The Diagnostic Profile for IVCCI , IJVCI and FVCI in Predicting PSAH:

Variable	AUC	Cut-off	Sensitivity	Specificity
IVCCI	0.806	39.00	83.3	77.8
IJVCI	0.972	25.7	100.00	83.0
FVCI	1	27.65	100.00	100.00

**IVCCI Inferior Vena Cava collapsibilty Index

**IJVCI. Internal Jugular Vein Collapsibility Index

**FVCI. Femoral Vein Collapsibility Index

**PSAH. Post Spinal Anesthesia Hypotension

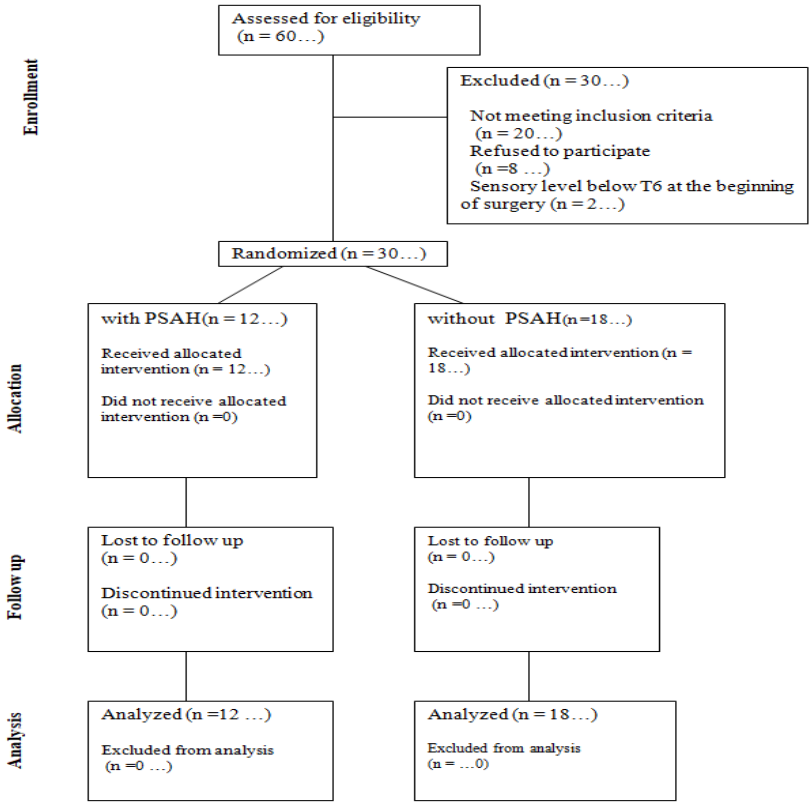

Figure (1): Enrolment flowchart (according to the CONSORT statement).

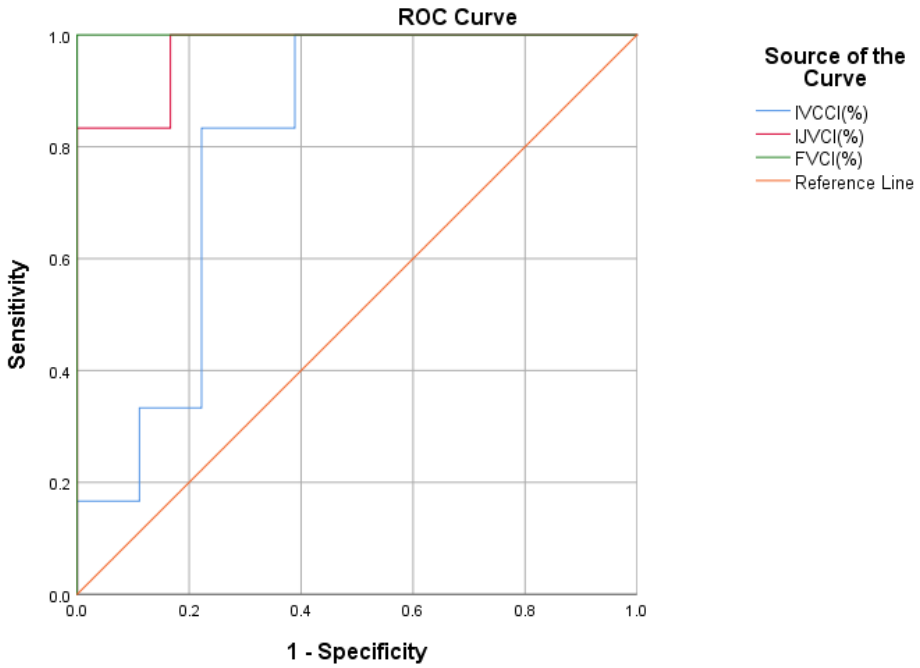

Figure (2): The ROC curve for IVCCI, IJVCI and FVCI in predicting PSAH.