Original Article

The diagnostic accuracy of preoperative perfusion index as a predictor of postspinal anesthesia hypotension in parturients undergoing cesarean delivery: A prospective non-blinded observational study

ABSTRACT

Background and Objectives: Spinal anesthesia is the technique of choice for elective cesarean section with a prominent side effect of postspinal anesthesia hypotension (PSH). This needs an early prediction to avoid feto-maternal complication. This study aimed to assess the diagnostic accuracy of perfusion index (PI) and inferior vena cava collapsibility index (IVCCI) in the prediction of PSH.

Material and Methods: Thirty parturients of American Society of Anesthesiologists Physical Status (ASA-PS) 1 and two undergoing cesarean delivery participated in the study. IVCCI, PI, baseline systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), and heart rate (HR) were noted in the preoperative period. The fall of MBP by 20% from baseline or below 65 mm Hg was considered PSH. After spinal anesthesia, SBP, DBP, MBP, and HR were noted again for diagnosing PSH.

Results: It did not show any statistical difference when comparing the PI between the PSH and non-PSH groups in both the PSH definition groups. IVCCI was significantly higher when PSH was considered MBP <65 mm Hg ($P = 0.01$). However, IVCCI was found to be statistically insignificant if PSH was considered a 20% reduction in baseline MBP. The correlation matrix between IVCCI and PI showed Pearson's r-value of 0.525, indicating a substantial relationship between the two ($P = 0.003$). Multivariate logistic regression analysis had shown that neither IVCCI nor PI was a good predictor of PSH in parturients for both definition groups for PSH.

Conclusion: Although there is a modest correlation between PI and IVCCI, both cannot be used to predict postspinal hypotension in parturients undergoing elective lower-segment cesarean section (LSCS).

Key words: Elective surgery, inferior vena cava collapsibility index, LSCS, parturient, perfusion index, postspinal hypotension, pregnancy

Access this article online	
Website: https://journals.lww.com/sjan	Quick Response Code
DOI: 10.4103/sja.sja_378_23	

How to cite this article: Kesavankutty MP, Panda C, Karim HM, Singha S, Agrawal S. The diagnostic accuracy of preoperative perfusion index as a predictor of postspinal anesthesia hypotension in parturients undergoing cesarean delivery: A prospective non-blinded observational study. Saudi J Anaesth 2024;18:23-30.

Manu P. Kesavankutty, Chinmaya Panda, Habib M. R. Karim[1], Subrata Singha, Sarita Agrawal[2]

Departments of Anaesthesia and Critical Care, [1]Anaesthesiology and [2]Obstetrics and Gynaecology, All India Institute of Medical Sciences, Raipur, Chhattisgarh, India

Address for correspondence: Dr. Chinmaya Panda, Faculty Room A003, Block A, All India Institute of Medical Sciences, Raipur, Tatibandh, Chhattisgarh – 492 099, India.
E-mail: chinmaya.panda06@gmail.com

Submitted: 08-May-2023, **Accepted:** 06-Jun-2023, **Published:** 02-Jan-2024

Introduction

Spinal anesthesia is the preferred technique for cesarean section worldwide.[1] It has a faster onset of action with a reliable neural blockade, less feto-maternal transfer, and lesser incidence of a failed block. However, postspinal anesthesia hypotension (PSH) is a prominent side effect of spinal anesthesia due to sympathetic vasomotor blockade, with an incidence varying from 15.3 to 33%.[2,3] Patients with poor preoperative fluid status, prolonged fasting period, comorbidities, and medications are also susceptible to PSH.[4] Hypotension may lead to several maternal complications such as transient brainstem ischemia, nausea, vomiting, and cerebral hypoxia. It also produces fetal acidosis and bradycardia if it persists longer than 2 minutes.[5,6] Although several measures, such as intravenous fluid administration (preloading/co-loading) and prophylactic vasopressor administration, have been attempted to reduce hypotension, none altogether avoid PSH.[7,8] Accurate prediction of PSH preoperatively may lead to appropriate therapeutic intervention, thus avoiding complications related to fluid loadings such as anaphylaxis, coagulopathy, and pulmonary edema.[9] Various methods have been applied to predict PSH risk, such as heart rate (HR) variability index, passive leg raise test, and central venous pressure, each having varied sensitivity and specificity. Minimally invasive and noninvasive cardiac output monitors have a better predictive value than static parameters.[10] However, these are time-consuming and need expertise for calculation. Recently, ultrasound (USG) has been adopted as a point-of-care tool to assess fluid responsiveness in emergency departments, intensive care units (ICUs), and operation theaters (OT) because of its noninvasive, rapid, and easily reproducible nature.[11] The inferior vena cava collapsibility index (IVCCI) is favored as a dynamic method of fluid assessment by USG, which requires a moderate level of training in obstetric patients.[12,13] Another noninvasive method of interest is the perfusion index (PI), that is, pulsatile strength at a specific monitoring site, measured with a pulse oximeter, and has also been widely studied for predicting PSH.[14] This modality does not require special training and can be easily interpreted by nonexpert clinicians, leading to early intervention.

The study's primary outcome was to assess the sensitivity and specificity of the PI in predicting PSH. The cutoff value for PI was established to maximize sensitivity at an optimal level of specificity. Finally, the performance of PI was compared to that of IVCCI. The results were presented as per the Standards for Reporting Diagnostic Accuracy Studies (STARD) guidelines.

Methods

Study design and setting

The institute ethical committee approved the study of All India Institute of Medical Sciences, Raipur (No. AIIMSRPR/IEC/2019/336), and registered it with the Clinical Trials Registry, India (CTRI/202003/024270). We enrolled patients from the obstetrics and gynecology (OG) department of a 1000-bed tertiary hospital from April 2020 to April 2021. It was a single-center prospective cohort study.

Selection of participants

The residents in the OG department OT were involved in screening patients planned for routine caesarian sections during the regular hours (9.00 AM to 5.00 PM) from Monday to Friday. The inclusion criteria were as follows: (1) grades 3 and 4 as per Lucas' classification of the urgency of caesarian section, (2) singleton pregnancy, (3) age between 18 and 40 years, (4) gestational age >34 weeks, and (5) American Society of Anesthesiologists Physical Status (ASA-PS) 1 and 2. The exclusion criteria were as follows: (1) any pathological pregnancy such as pregnancy-induced hypertension, gestational diabetes, abruption placenta, or placenta previa; (2) any previous medical diseases such as diabetes mellitus, hypertension, cardiac diseases, severe anemia, and peripheral vascular diseases; (3) body mass index >35 kg/metre2; (4) hemoglobinopathies; (5) contraindication for spinal anesthesia; (6) partial spinal block; and (7) patient refusal.

Measurements

After obtaining informed consent from patients posted for cesarean section under spinal anesthesia, a routine pre-anesthesia checkup was done. Patients were advised to fast from midnight. After shifting to the OT holding area, vital parameters and PI were obtained by the nursing officer (not a part of the study) in the supine position (Crawford's wedge, 55 * 30 *10 cm) placed below the right hip, using a pulse oximeter probe (BeneView T8, Shenzhen Mindray Bio-Medical Electronics Co., Ltd., China) before spinal anesthesia. The probe was attached to the left index finger of all patients to ensure uniformity.

Soon after noting the PI, the monitors were removed (to keep the investigator blinded), and IVC measurements were obtained before spinal anesthesia using the SonoSite M-Turbo™ (SonoSite, Inc., Bothell, WA, USA) ultrasonography machine. All the IVC measurements for all the patients were performed by an experienced anesthesiologist (CP) who had done at least 100 such scans. Measurements were made by a curvilinear probe (3–5 MHz). The IVCCI was measured in a recumbent position with the same wedge (Crawford's

wedge, 55 * 30 *10 cm) in place. The transducer was placed in the subxiphoid position in a longitudinal position. Measurements were made just distal to the IVC–hepatic vein junction, approximately 3 to 4 cm distal to the right atrium. IVC was identified by the Doppler waveform and its respiratory collapsibility nature. The maximum (IVCdmax) and minimum (IVCdmin) internal anteroposterior diameter at the end of expiration and inspiration were measured, respectively, over the same respiratory cycle. IVCCI was derived as per the equation [IVCCI = (IVCdmax - IVCdmin/IVCdmax) *100)]. The video loops were saved for further verification by an expert cardiologist for interobserver reliability.

After noting the preoperative measurements, patients were shifted to the operation theater and standard American Society of Anesthesiologists monitors (noninvasive blood pressure, pulse oximeter, and 3-lead electrocardiography) were attached. An intravenous 18-gauge catheter was secured, and co-loading of Ringer's lactate was done with 2 ml/kg body weight during the anesthesia procedure. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), and HR were noted before the spinal anesthesia and considered a baseline reading. Spinal anesthesia was performed in a sitting position at the level of L3-4 or L2-3 intervertebral space by a 25-gauge Quincke's needle, and 8–12 mg of 0.5% hyperbaric bupivacaine was given after confirming free flow of cerebrospinal fluid to achieve a sensory level of T5. Patients were immediately returned to the supine position, with the same wedge in place. An adequate level of anesthesia was confirmed with a cold swab test.

Meanwhile, SBP, DBP, MBP, and HR were noted every 3 minutes for the first 20 minutes and, after that, every 5 minutes for the rest of the study period (30 minutes). An anesthesiologist noted all the hemodynamic parameters inside the operation theater (not a part of the study). The fall of MBP by 20% from baseline or below 65 mm Hg was considered PSH. Hypotension was treated with 3 mg of mephenteramine intravenously and 200 ml of Ringer's lactate bolus. Bradycardia (HR < 55/minute) was managed intravenously with 0.6 mg of atropine. Any other complications such as nausea, vomiting, and shivering were managed according to the institutional protocol.

The prevalence of PSH in lower-segment cesarean section (LSCS) varies up to 80%. For this study, a prevalence of 60% was taken. Considering the IVCCI and PI as under evaluation modality, the sample size was calculated using an imperfect diagnostic tool strategy with sensitivity and specificity of 80% for both tools. Using a population threshold for infinite probability and applicable to a large population (1e + 06), a sample of 20 was required. Considering the nonrandom design, a design effect of 1.25 was applied, and 20% dropout was added, which gave a final sample of 30 participants to achieve a power of 80% with an alpha error of 0.05.

Outcomes

The primary outcome was the diagnostic accuracy of both IVCCI and PI presented with the area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) in predicting postspinal hypotension in patients posted for cesarean section.

Statistical analysis

All the data were entered into a Microsoft Excel spreadsheet. Participants were grouped into two groups based on the occurrence of PSH. Qualitative data are presented as proportions or groups. Quantitative data are presented as mean +_standard deviation (SD). Baseline continuous data are analyzed using an unpaired *t*-test or Mann–Whitney U-test. Diagnostic ability was evaluated regarding the AUC, sensitivity, specificity, PPV, and NPV, along with their 95% CI values for both IVCCI and PI. The predicting ability of IVCCI and PI is compared using Fisher's exact test. All statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS) version 26, Chicago, IL, USA, and a two-tailed *P* value of less than 0.05 was considered significant. Sensitivity, specificity, and receiver operating characteristic (ROC) curves were used to find IVCCI and PI cutoff values. IVCCI and PI were dichotomized to 0 and 1 based on their values falling into non-PSH and PSH. The association of IVCCI and PI with hypotension was analyzed with binary logistic regression, and a Chi-square test was used to detect statistical significance.

Results

Characteristics of study subjects

A total of 34 patients satisfying inclusion criteria were studied, of which four patients were excluded because of non-visualization of IVC with ultrasound (n = 3) and patient refusal (n = 1). The algorithm is shown in Figure 1. The mean (standard deviation) age of patients was 28.4 (3.9) years, the mean (SD) weight was 67.3 (7.3) kg, the mean (SD) height was 160.9 (4.8) cm, and the mean (SD) body mass index (BMI) was 25.9 (2.7).

Fifteen patients of thirty (50%) had at least one episode of hypotension (defined as a reduction of MBP <65 mm Hg within the first 30 minutes of spinal anesthesia). However, 25 patients had developed hypotension if the PSH was a

20% reduction from baseline MBP. There was no statistical difference concerning age, weight, height, MBP, and HR between the patients who developed PSH and who did not. The mean (SD) of IVCCI among the participants who experienced hypotension (MBP <65 mm Hg) was 36.63 (10.02), and the mean (SD) of PI was 5.61 (2.17). It did not show any statistical difference when comparing the PI between the PSH and non-PSH groups in both the PSH definition groups. IVCCI was significantly higher when PSH was considered an MBP <65 mm Hg) ($P = 0.01$). However, IVCCI was found to be statistically insignificant if PSH was considered a 20% reduction in baseline MBP [Table 1].

A ROC curve analysis was done in both definition groups. Postspinal hypotension with MBP <65 mm Hg definition group had shown that IVCCI had a sensitivity of 93.75% and specificity of 92.86%. It had a PPV of 93.75% and a NPV of 92.86% at a cutoff point of more than 29. The AUC was 0.78 [Figure 2]. PI had a sensitivity and specificity of 61.11% and 58.33%, respectively. It had a PPV and NPV of 68.75% and 50% at a cutoff point of 4.6. AUC for PI was 0.647 [Figure 3] with the same definition of PSH. However, in PSH with a 20% reduction from the baseline MBP definition group, sensitivity, specificity, PPV, and NPV were 89.29%, 66.67%, 96.15%, and 40.00%, respectively, for IVCCI at a cutoff point of more than 32.5. The AUC was 0.452 [Figure 2]. PI had a sensitivity and PPV of 83.33% and 100% in the above group. The ROC curves for the baseline PI showed an AUC of 0.472 and gave a cutoff value of 5.50 while considering the criterion for PSH as a 20% reduction in mean arterial pressure [Figure 3]. The correlation matrix between IVCCI and PI showed Pearson's r-value of 0.525, indicating a substantial relationship between the two that was statistically significant ($P = 0.003$) [Figure 4].

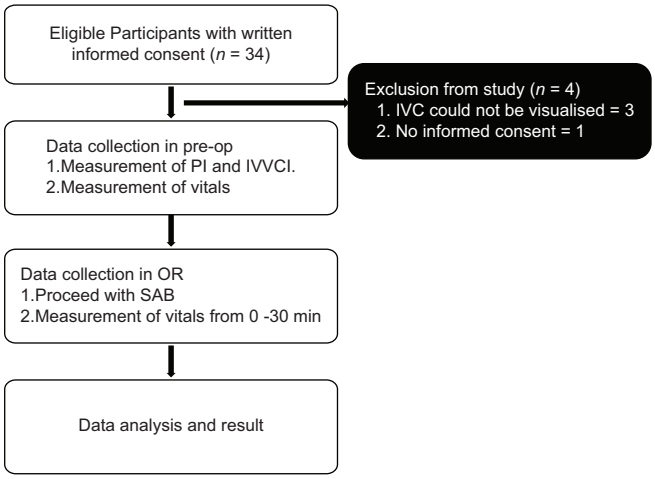

Figure 1: Study enrolment algorithm

Multivariate logistic regression analysis showed that neither IVCCI nor PI was a good predictor of PSH in parturients for definition groups for PSH [Table 2]. However, MBP was a good predictor of PSH in the MBP <65 mm Hg definition group but not in the other group. Univariate regression analysis showed that IVCCI was a significant predictor of PSH in the MBP <65 mm Hg definition group (95% CI: 0.002-0.04, $P = 0.03$) [Figure 5].

Discussion

In this study, we found that neither IVCCI nor PI was a good predictor of PSH in patients undergoing cesarean section. However, IVCCI had a better sensitivity and specificity than

Table 1: Comparison of baseline demographic and hemodynamic parameters in hypotensive and non-hypotensive patients

	All patients ($n=30$)	MBP <65 mm Hg				20% reduction of baseline MBP			
		Patients who developed PSH, $n=15$	Patients who did not develop PSH, $n=15$	*P*	95% CI	Patients who developed PSH, $n=25$	Patients who did not develop PSH, $n=5$	*P*	95% CI
Age (years)	28.43 (3.98)	28.33 (3.88)	28.53 (4.22)	0.89	-2.82 to 3.22	28.64 (3.99)	27.4 (4.21)	0.53	-5.27 to 2.79
Weight (kg)	67.3 (7.29)	65.86 (7.90)	68.73 (6.58)	0.28	-2.57 to 8.31	67.84 (7.57)	64.6 (5.55)	0.37	-10.58 to 4.10
Height (cm)	160.96 (4.82)	159.8 (4.54)	162.13 (4.97)	0.19	-1.22 to 5.9	161.16 (4.71)	160 (5.83)	0.63	-6.06 to 3.74
BMI (kg/mt^2)	25.91 (2.68)	25.76 (2.72)	26.06 (2.72)	0.76	-1.7 to 2.3	26.028 (2.66)	25.32 (3)	0.6	-3.43 to 2.01
Baseline SBP (mmHg)	124.96 (10.91)	123.46 (10.36)	126.46 (11.59)	0.46	-5.22 to 11.22	124.84 (10.62)	117.8 (12.1)	0.19	-17.93 to 3.85
Baseline DBP (mmHg)	75.066 (9.93)	74.66 (9.22)	75.46 (10.90)	0.82	-6.75 to 8.35	76 (8.76)	72.4 (5.9)	0.38	-12.04 to 4.84
Baseline MBP (mmHg)	90.96 (10.9)	88.8 (11.86)	93.13 (9.97)	0.28	-3.87 to 12.53	90 (9.72)	85 (8.42)	0.29	-14.58 to 4.58
Baseline HR (bpm)	98.46 (16.48)	98.46 (13.93)	98.46 (19.20)	1.00	-12.55 to 12.55	92.36 (12.64)	86.8 (16.76)	0.4	-18.92 to 7.8
IVCCI	32.4 (9.96)	36.63 (10.02)	27.57 (7.64)	0.01	-15.7 to -2.4	32.16 (10.2)	33.63 (9.6)	0.77	-8.69 to 11.63
PI	5.09 (2.15)	5.61 (2.17)	4.50 (2.02)	0.16	-2.7 to 0.4	5.07 (2.21)	5.2 (2)	0.9	-2.06 to 2.32

BMI: body mass index, CI: confidence interval, DBP: diastolic blood pressure, IVCCI: inferior vena cava collapsibility index, MBP: mean blood pressure, PI: perfusion index, PSH: post-spinal hypotension, SBP: systolic blood pressure

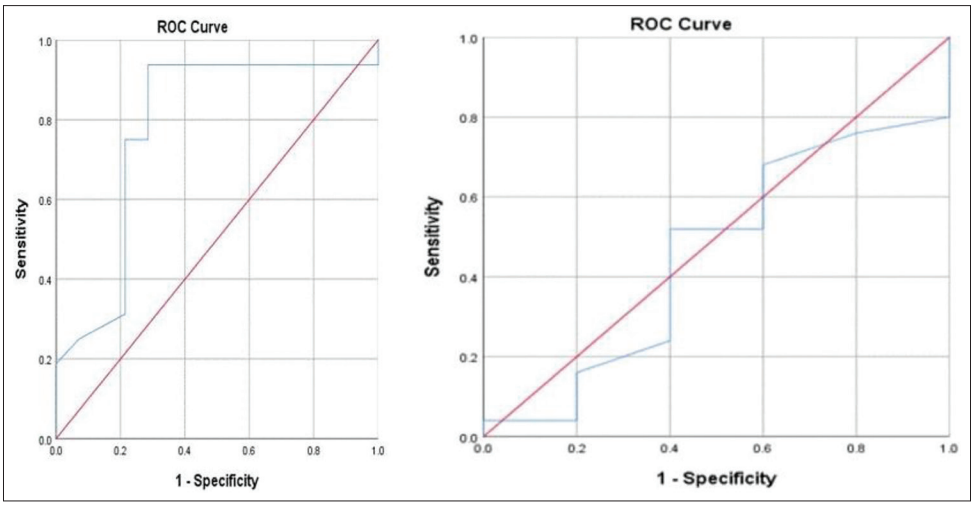

Figure 2: Receiver operating characteristic (ROC) curves for the baseline IVCCI during spinal anesthesia for cesarean delivery in the PSH <65 mm Hg group (left) and 20% reduction in the baseline MBP (right) group

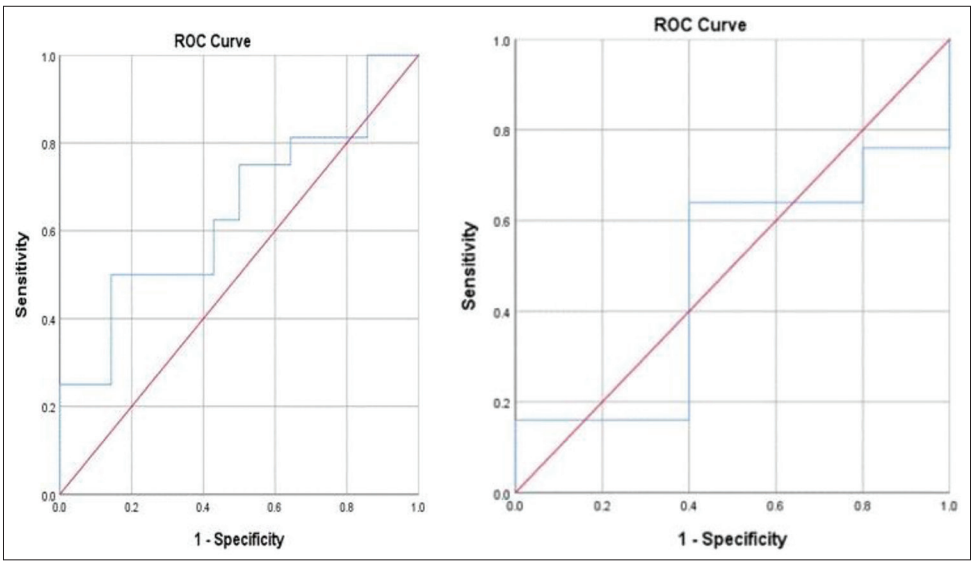

Figure 3: Receiver operating characteristic (ROC) curves for the baseline PI during spinal anesthesia for cesarean delivery in the PSH <65 mm Hg group (left) and 20% reduction in the baseline MBP (right) group

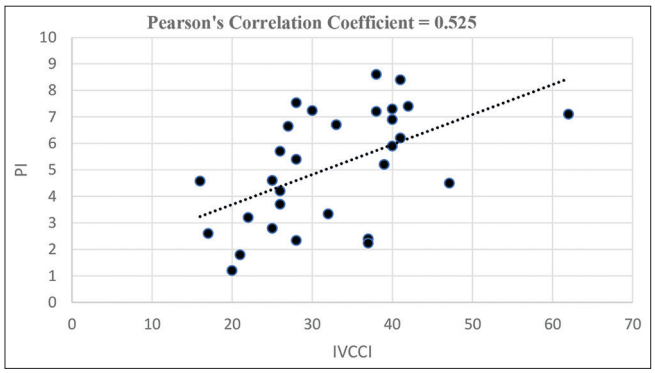

Figure 4: Graph showing the correlation of PI values and IVCCI values

PI. When PSH was taken as MBP <65 mm Hg, MBP was a good predictor of PSH.

Postspinal hypotension is a well-debated topic with a diversity of information. Nonuniformity in the definition of PSH led to many varied results in the literature related to postspinal hypotension prediction. Klöhr *et al*.[15] reported 15 different definitions in 63 studies, where the incidence of PSH was anywhere between 7.4 and 74.1%. Maternal hypotension effects after spinal anesthesia range from nausea and vomiting to severe cerebral hypoxia and increased risk of perinatal mortality in preterm infants.[5,16] A fall in systemic vascular resistance and a partial compensatory increase in cardiac output by increased HR are the significant consequences of spinal anesthesia leading to PSH.[16] Certain preoperative factors such as caval compression, advanced age (>35 years), increased BMI (>25 kg/mt2), dehydration, anxiety, and technique of spinal anesthesia predispose an

Table 2: Multivariate logistic regression of patients for hypotension after spinal anesthesia (*n*=30)

	MBP <65 mm Hg					20% reduction of baseline MBP				
	Standard error	t Stat	*P*	Lower 95%	Upper 95%	Standard error	t Stat	*P*	Lower 95%	Upper 95%
Intercept	3.585	0.804	0.43	-4.533	10.301	3.194	0.71	0.48	-4.338	8.877
Age	0.023	-0.234	0.81	-0.053	0.043	0.020	-0.54	0.59	-0.054	0.032
Height	0.021	-0.096	0.92	-0.045	0.04	0.018	-0.277	0.78	-0.043	0.033
BMI	0.032	-0.403	0.69	-0.08	0.054	0.028	-0.571	0.57	-0.076	0.043
MBP	0.01	-2.215	0.03	-0.044	-0.001	0.009	-0.678	0.5	-0.025	0.013
IVCCI	0.01	1.696	0.1	-0.004	0.039	0.009	0.207	0.83	-0.017	0.021
PI	0.047	-0.469	0.64	-0.12	0.075	0.042	-0.184	0.85	-0.095	0.079

BMI: body mass index, IVCCI: inferior vena cava collapsibility index, MBP: mean blood pressure, PI: perfusion index

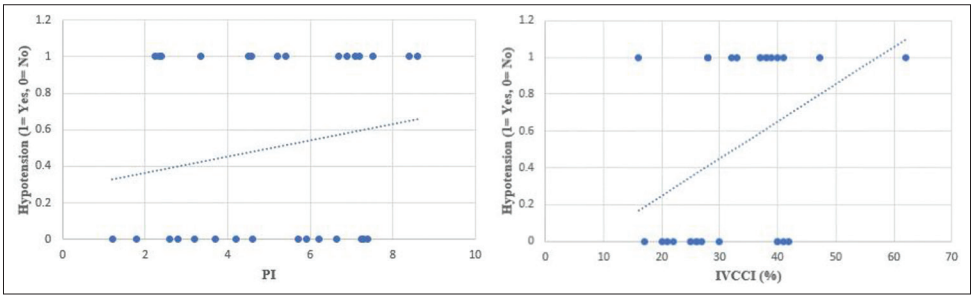

Figure 5: Association of PI (left) and IVCCI (right) with the PSH <65 mm Hg group

otherwise healthy individual to PSH.[17-20] Earlier prediction of PSH, especially in a patient with risk factors, may prevent the undesired adverse effects. Pleth variability index (PVI) and IVCCI were the most studied parameters with inconsistent findings for PSH prediction.[9] PI was another noninvasive modality that gained popularity in the last decade after a study published by Toyama *et al*.[21] They found a fair correlation of PI in predicting PSH in parturients.

PI is the ratio of the pulsatile component (arterial) to a nonpulsatile component of emitted light reaching the detector. The pulsatile component in a healthy pregnancy is expected to increase due to a decrease in systemic vascular resistance,[22] hence a higher PI value. Patients with higher baseline PI are expected to precipitate PSH because of a further decrease in vascular tone. A recent study by Duggappa DR *et al*.[14] showed that a baseline PI >3.5 and the probability of PSH significantly correlated in parturient. Because of its simplicity, this also helps predict PSH by non-anesthesia personnel. However, errors in interpretation might occur due to patient movement, peripheral vascular disease, anxiety, uterotonics, preoperative fluid administration, etc. Although our study had shown the association of higher baseline PI with PSH, it was statistically insignificant in both definition groups of PSH. This finding was consistent with the study published by Yokose M *et al*.[23] The AUC of the ROC curve in our study (0.647) was also found to be lower as compared to the previous two studies conducted by Toyama *et al*.[21] (0.87) and Duggappa *et al*. (0.848).[14]

Ultrasonography, used to predict fluid responsiveness, has gained popularity over the past few decades. The IVCCI is one of those parameters that is simple to calculate in mechanically ventilated and spontaneously breathing patients.[4,24] Our study found that IVCCI had excellent sensitivity (93.75%), specificity (92.86%.), PPV (93.75%), and NPV (92.86%) for predicting PSH (MBP <65 mm Hg definition group), which was consistent with previous studies.[24,25] Moreover, PSH prediction was statistically significant only with MBP <65 mmhg definition group ($P < 0.01$). With a 20% reduction from the baseline MBP definition group, PSH had poor specificity and NPV for IVCCI. Non-visualization of IVC in late pregnancy led to a failure rate of 10% in our study, which was similar to the result published by Singh Y *et al*.[26] Anxiety as a preoperative confounder may influence the patient's baseline MBP and PI. Though we counseled the patients before the procedure, the exact questionnaire pertinent to preoperative anxiety had not been examined. It also raises a question about the definition of PSH. We observed that the number of patients diagnosed with PSH was less in the MBP <65 mm Hg definition group than in the other group (15 vs 25). While there was no history of hypertension and PIH in the present cohort, baseline MBP was found to be elevated in both definition groups presuming preoperative anxiety as an inciting factor. Considering PSH as a 20% reduction from baseline MBP in such a scenario may falsely increase the incidence of PSH. This finding again questions the very definition of PSH.

While analyzing the correlation between IVCCI and PI with MBP in our study, a negative r-value was obtained at different time intervals. It indicates that pre-op baseline IVCCI and PI increase was associated with a decrease in MBP. However, these were not statistically significant at any time point except at 12 minutes for IVVCI ($r = -0.373$; $P < 0.05$). Furthermore, Pearson's correlation analysis showed a substantial correlation ($r = 0.525$) between the IVCCI and PI among the participants and was found to be statistically significant ($P = 0.003$). Despite a fair correlation between IVCCI and PI, we may not use PI as a replacement for IVCCI. Multivariate regression analysis of our data had not shown a statistically significant correlation between IVCCI and PI with PSH prediction. Further studies with a greater sample size may be needed.

Limitation

There were several limitations in our study. First, the study was limited to a homogenous population with no comorbidities, aged between 20 and 35 years, and height between 152 and 170 cm. The results may not be applied to any other group of patients. Second, this is a single-center tertiary care institute. The multicenter study may give a different result. Third, using a different monitor than ours may give different readings for PI due to different algorithms. Fourth, preoperative anxiety had not been addressed in our study. Fifth, we have not assessed the intraobserver variability, though a single experienced anesthesiologist took the measurements.

Conclusion

Although there is a modest correlation between PI and IVCCI, both cannot be used to predict postspinal hypotension in parturients undergoing elective LSCS.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Eltzschig HK, Lieberman ES, Camann WR. Regional anesthesia and analgesia for labor and delivery. N Engl J Med 2003;348:319-32.
2. Kinsella SM, Carvalho B, Dyer RA, Fernando R, McDonnell N, Mercier FJ, *et al*. International consensus statement on the management of hypotension with vasopressors during caesarean section under spinal anaesthesia. Anaesthesia 2018;73:71-92.
3. Carpenter RL, Caplan RA, Brown DL, Stephenson C, Wu R. Incidence and risk factors for side effects of spinal anesthesia. Anesthesiology 1992;76:906-16.
4. Zhang J, Critchley LA. Inferior vena cava ultrasonography before general anesthesia can predict hypotension after induction. Anesthesiology 2016;124:580-9.
5. Borgeat A, Ekatodramis G, Schenker CA. Postoperative nausea and vomiting in regional anesthesia. Anesthesiology 2003;98:530–47.
6. Okudaira S, Suzuki S. Influence of spinal hypotension on fetal oxidative status during elective cesarean section in uncomplicated pregnancies. Arch Gynecol Obstet 2005;271:292–5.
7. Zieleskiewicz L, Noel A, Duclos G, Haddam M, Delmas A, Bechis C, *et al*. Can point-of-care ultrasound predict spinal hypotension during caesarean section? A prospective observational study. Anaesthesia 2018;73:15-22.
8. Hasanin A, Amin S, Refaat S, Habib S, Zayed M, Abdelwahab Y, *et al*. Norepinephrine versus phenylephrine infusion for prophylaxis against post-spinal anaesthesia hypotension during elective caesarean delivery: A randomised controlled trial. Anaesth Crit Care Pain Med 2019;38:601-7.
9. Yu C, Gu J, Liao Z, Feng S. Prediction of spinal anesthesia-induced hypotension during elective cesarean section: A systematic review of prospective observational studies. Int J Obstet Anesth 2021;47:103175.
10. Langesæter E, Gibbs M, Dyer RA. The role of cardiac output monitoring in obstetric anesthesia. Curr Opin Anaesthesiol 2015;28:247-53.
11. Pourmand A, Pyle M, Yamane D, Sumon K, Frasure SE. The utility of point-of-care ultrasound in the assessment of volume status in acute and critically ill patients. World J Emerg Med 2019;10:232-8.
12. Nagi AI, Shafik AM, Fatah AMA, Selima WZ, Hefny AF. Inferior vena cava collapsibility index as a predictor of fluid responsiveness in sepsis-related acute circulatory failure. Ain-Shams J Anesthesiol 2021;13:75.
13. Salama ER, Elkashlan M. Pre-operative 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. Eur J Anaesthesiol 2019;36:297–302.
14. Duggappa DR, Lokesh MPS, Dixit A, Paul R, Raghavendra Rao RS, Prabha P. Perfusion index as a predictor of hypotension following spinal anaesthesia in lower segment caesarean section. Indian J Anaesth 2017;61:649–54.
15. Klöhr S, Roth R, Hofmann T, Rossaint R, Heesen M. Definitions of hypotension after spinal anaesthesia for Caesarean section: Literature search and application to parturients. Acta Anaesthesiol Scand 2010;54:909-21.
16. Laudenbach V, Mercier FJ, Rozé JC, Larroque B, Ancel PY, Kaminski M, *et al*. Anaesthesia mode for caesarean section and mortality in very preterm infants: An epidemiologic study in the EPIPAGE cohort. Int J Obstet Anesth 2009;18:142-9.
17. Kinsella SM, Norris MC. Advance prediction of hypotension at cesarean delivery under spinal anesthesia. Int J Obstet Anesth 1996;5:3-7.
18. Roofthooft E, Van de Velde M. Low-dose spinal anaesthesia for Caesarean section to prevent spinal-induced hypotension. Curr Opin Anaesthesiol 2008;21:259-62.
19. Brenck F, Hartmann B, Katzer C, Obaid R, Brüggmann D, Benson M, *et al*. Hypotension after spinal anesthesia for caesarean section: Identification of risk factors using an anesthesia information management system. J Clin Monit Comput 2009;23:85-92.
20. Orbach-Zinger S, Ginosar Y, Elliston J, Fadon C, Abu-Lil M, Raz A, *et al*. Influence of preoperative anxiety on hypotension after spinal anaesthesia in women undergoing Caesarean delivery. Br J Anaesth 2012;109:943-9.
21. Toyama S, Kakumoto M, Morioka M, Matsuoka K, Omatsu H, Tagaito Y, *et al*. Perfusion index derived from a pulse oximeter can predict the incidence of hypotension during spinal anaesthesia for Caesarean delivery. Br J Anaesth 2013;111:235-41.
22. Ajne G, Ahlborg G, Wolff K, Nisell H. Contribution of endogenous endothelin-1 to basal vascular tone during normal pregnancy and preeclampsia. Am J Obstet Gynecol 2005;193:234-40.
23. Yokose M, Mihara T, Sugawara Y, Goto T. The predictive ability of non-invasive haemodynamic parameters for hypotension during

caesarean section: A prospective observational study. Anaesthesia 2015;70:555-62.
24. Airapetian N, Maizel J, Alyamani O, Mahjoub Y, Lorne E, Levrard M, *et al*. Does inferior vena cava respiratory variability predict fluid responsiveness in spontaneously breathing patients? Crit Care 2015;19:400.
25. Elbadry AA, El Dabe A, Abu Sabaa MA. Pre-operative ultrasonographic evaluation of the internal jugular vein collapsibility index and inferior vena cava collapsibility index to predict post spinal hypotension in pregnant women undergoing caesarean section. Anesth Pain Med 2022;12:e121648.
26. Singh Y, Anand RK, Gupta S, Chowdhury SR, Maitra S, Baidya DK, *et al*. Role of IVC collapsibility index to predict post spinal hypotension in pregnant women undergoing caesarean section. An observational trial. Saudi J Anaesth 2019;13:312-7.