ORIGINAL ARTICLE ASIAN JOURNAL OF MEDICAL SCIENCES

Pulse oximeter perfusion index as a new predictor of hypotension following subarachnoid block in lower segment Cesarean section: A prospective randomized study

Ashish Mohan M[1], Suman Gupta[2], Kavya Kanjikkal[3], Vankudoth Bhaskar[4]

[1,3,4]Postgraduate Resident, [2]Professor, Department of Anaesthesiology, Gajra Raja Medical College, Gwalior, Madhya Pradesh, India

Submission: 07-11-2024 Revision: 31-12-2024 Publication: 01-02-2025

ABSTRACT

Background: Hypotension is a common adverse effect of spinal anesthesia, especially during pregnancy, due to the blockade of pre-ganglionic sympathetic fibers, resulting in reduced peripheral vascular resistance. This study explores the perfusion index (PI) as a potential predictor for hypotension during spinal anesthesia in lower segment Cesarean sections (LSCS). **Aims and Objectives:** The aim of the study was to study the correlation between baseline PI and the incidence of hypotension following subarachnoid block in LSCS. **Materials and Methods:** This prospective observational study included 90 parturients, divided into two groups based on baseline PI: Group 1 (PI≤3.5) and Group 2 (PI>3.5). Spinal anesthesia was administered with 10 mg of 0.5% hyperbaric bupivacaine at the L3-L4 interspace. The study evaluated the correlation between baseline PI and the degree of hypotension, as well as PI's predictive capacity for hypotension during Cesarean delivery. **Results:** Hypotension occurred in 35.55% of Group 1 and 75.55% of Group 2 (P<0.001). A significant correlation was found between baseline PI>3.5 and both the incidence of hypotension and the total mephentermine dose required (P<0.001). The sensitivity and specificity of PI>3.5 for predicting hypotension were 68% and 72.5%, respectively. The area under the receiver operating characteristic curve for PI as a predictor of hypotension was 0.914. **Conclusion:** A higher baseline PI is associated with a higher incidence and severity of hypotension following spinal anesthesia. Baseline PI is a reliable predictor of spinal anesthesia-induced hypotension during Cesarean delivery and could be used for early identification and management of at-risk patients.

Key words: Pregnancy; Spinal anesthesia; Subarachnoid; Hyperbaric; Hypotension; Perfusion index

Access this article online

Website: https://ajmsjournal.info/index.php/AJMS/index

DOI: 10.71152/ajms.v16i2.4395

E-ISSN: 2091-0576

P-ISSN: 2467-9100

INTRODUCTION

Cesarean delivery, the most common obstetric surgery, aims to improve maternal and fetal outcomes or prevent complications from spontaneous labor. Anesthesia-related morbidity and mortality in cesarean deliveries have decreased to 1.7 per million.[1] Due to higher maternal risk with general anesthesia, the use of subarachnoid block (SAB) and epidural anesthesia has increased for both elective and emergency cesarean sections.

Hypotension following spinal anesthesia affects 15–33% of the general population[2] but rises to 60–80% in parturients.[3] This is influenced by pre-operative vascular tone, compensatory sympathetic activity, and hydration status. SAB is preferred for elective Cesarean delivery due

Address for Correspondence:
Dr. Vankudoth Bhaskar, Postgraduate Resident, Department of Anaesthesiology, Gajra Raja Medical College, Gwalior, Madhya Pradesh, India. **Mobile:** +91-9000133382. **E-mail:** bhaskar863@gmail.com

to its ease of administration, rapid onset, adequate surgical anesthesia, post-operative analgesia, and safety for both mother and fetus.

The primary adverse effect of spinal anesthesia is hypotension, resulting from decreased peripheral vascular resistance due to the blockade of pre-ganglionic sympathetic fibers, exacerbated by pregnancy.[4] Intrathecal anesthesia causes pharmacological sympathectomy, leading to peripheral vasodilation and venous pooling, and the gravid uterus compresses the aorta and vena cava, further lowering mean arterial pressure (MAP).[5]

To address hypotension, strategies include co-loading with crystalloids and colloids,[6] and prophylactic vasopressors like phenylephrine or norepinephrine.[4,7] However, these interventions can cause side effects such as reactive hypertension and volume overload.[8,9] Non-invasive methods such as heart rate (HR) variability, point-of-care ultrasound, cerebral near-infrared spectroscopy, perfusion index (PI), and pleth variability index have been used to predict hypotension, though not all are widely available.[10-12]

The PI, measured with a pulse oximeter, shows good sensitivity and specificity in predicting post-spinal hypotension in mothers.[12] PI estimates blood pulsatility in the extremities, ranging from 0.02% to 20%.[13] It is inversely related to vascular tone; lower PI indicates higher peripheral vascular tone.[14,15] The study aims to establish a correlation between pre-operative PI and intraoperative hypotension following spinal anesthesia in lower-segment Cesarean sections.

Aims and objectives

To measure Perfusion Index (PI) in parturients for Elective Lower Segment Caesarean Section and investigate the correlation between perfusion index and incidence of hypotension following Subarachnoid block.

MATERIALS AND METHODS

After obtaining approval from the Institutional Ethics Committee, Gajra Raja Medical College (No: 125/IEC-GRMC/2022) and registering in Clinical trials registry-India (CTRI)-trial registration number CTRI/2023/09/058147, A prospective randomized observational double-blinded study was conducted on 90 patients of American society of anesthesiologists (ASA) Grade II in the age group of 20 years–35 years undergoing Lower Segment Cesarean Section under SAB at Gajra Raja Medical College and J.A. Group of Hospitals from September 2022 to September 2024.

Reference study

Peripheral PI: A Predictor of Post Spinal Hypotension in Cesarean Section (DOI: 10.7759/cureus.25699).

According to the study, the incidence of hypotension was significantly higher in PI≥3.5 (79.16%).

Taking P=79.16%=0.7916

1.96=z value for 95% significance level

e=Allowable error=0.10

Cochran formula for an observational study

Minimum Sample Size =

$$N=\frac{1.96^2\times P\times(1\text{-}P)}{e^2}=\frac{1.96^2\times 0.7916\times(1-0.7916)}{(0.10)^2}$$

=64 patients.

The minimum sample size is 64 patients. To increase the reliability and power of the study, 90 samples were taken and divided into two groups, each containing 45 patients each.

Inclusion criteria

The patients, aged 20–35 years with ASA II status and a height of 145–165 cm, scheduled for an elective cesarean section and has provided consent were included in the study.

Exclusion criteria

Patients who refused to give consent, ASA III and IV status, placenta previa, pre-eclampsia, cardiovascular or cerebrovascular disease, gestational diabetes, body mass index over 40, overdistended uterus, twin pregnancy, and patients requiring additional oxytocin or surgical intervention were excluded from the study.

Patients were categorized into two groups based on a PI cutoff of 3.5, each comprising 45 patients. Group 1 included those with a baseline PI≤3.5, while Group 2 included those with a baseline PI>3.5. Baseline hemodynamic values, including PI, were recorded in the supine position by an anesthesiologist not involved in subsequent intraoperative monitoring. The study compared the incidence of hypotension episodes, vasopressor requirements, other hemodynamic parameters, and complications between the two groups.

Patient's age, body weight, and baseline vital parameters were recorded. A history of previous anesthesia, surgeries,

significant comorbid illnesses, medications, and allergies was recorded. A complete physical examination and airway assessment were conducted. During the pre-operative visit, patients were informed about the purpose of the study and potential complications, and written informed consent was obtained.

All patients were kept nil by mouth for 8 h before surgery. Premedication with IV Metoclopramide and IV Ondansetron 0.1 mg/kg was administered 30 min before surgery. Two wide-bore IV lines were secured. Each parturient was pre-loaded with 500 mL of Ringer's lactate. Routine monitors, including electrocardiogram, automated non-invasive blood pressure (NIBP), and pulse oximetry (SpO_2), were connected to obtain baseline values and for intraoperative monitoring. The PI was measured in the supine position using a pulse oximeter probe attached to the left index finger of all parturients to ensure uniformity in measured PI values.

Patients were divided into two groups based on a cutoff point of 3.5 (Group 1: PI≤3.5 and Group 2: PI>3.5). Spinal anesthesia was performed using a Quincke 23-gauge BD spinal needle in the left lateral decubitus position with 10 mg of 0.5% hyperbaric bupivacaine at the L3-L4 interspace. The parturient was then returned to the supine position with a 15° left lateral tilt to facilitate left uterine displacement. Oxygen was administered through a face mask at 4 L/min.

The level of sensory block was checked after the spinal injection. If a T6 sensory block level was not achieved, the parturients were excluded from the study. Maximum cephalad spread was checked 20 min after SAB. NIBP, HR, respiratory rate, SpO_2, and PI were recorded at 2-min intervals after SAB for up to 20 min and then at 5-min intervals until the end of surgery. Following the delivery of the baby, APGAR scores were recorded at the 1st and 5th min. To promote uterine contraction, 10 units of oxytocin were administered at a rate of 200 mU/min as a separate infusion. Patients requiring additional oxytocin and/or additional surgical interventions were excluded from the study.

The following parameters were studied for statistical analysis.

- Demographic data-age, weight, height
- Pre-operative baseline values-PI, systolic blood pressure (SBP), diastolic blood pressure (DBP), MAP, HR, SpO_2
- Time of SAB performed
- Level of blockade
- Incidence of hypotension
- Vasopressor needed
- APGAR scores
- Episode of bradycardia.

RESULTS

Statistical analysis was performed using the SPSS program for Windows, version 20.0. Continuous variables were presented as mean±SD, and categorical variables were presented as absolute numbers and percentages. Data were checked for normality before statistical analysis. Normally distributed continuous variables were compared using the t-test, whereas the Mann–Whitney U test was used for those variables that were not normally distributed. Categorical variables were analyzed using either the Chi-square test or Fisher's exact test. The data were entered into an MS Excel spreadsheet, and analysis was conducted using the Statistical Package for the Social Sciences version 20.0.

Demographic profile of patients in both the groups was comparable with respect to distribution of age, height, and weight and it was evident that there was no statistically significant difference (P>0.05) among the groups (Table 1).

A parametric unpaired t-test has been used to test the significance difference in mean.

In Figure 1, the SBP of both groups was compared from baseline, with readings taken at 2-min intervals up to 20 min, and then at 5-min intervals from 20 to 60 min. Between the 14th and 20th min, the mean differences between the two groups were found to be statistically significant (P<0.05). However, for all other time points, the differences were not statistically significant (P>0.05).

Figure 2 shows the comparison of DBP between the two groups starting from baseline. Significant differences were found at induction and at the 2nd min (P<0.05), but no significant differences were observed at other time points (P>0.05).

Table 1: Comparison of demographic characteristics (Mean±SD) between two groups

Demographic parameter	Group 1 (PI≤3.5)	Group 2 (PI>3.5)	P-value
Age (years)	26.61±3.19	26.3±2.94	0.53
Height (cm)	153.28±1.76	152.83±1.81	0.23
Weight (kg)	76.22±11.73	77.88±12.08	0.52

PI: Perfusion index, SD: Standard deviation

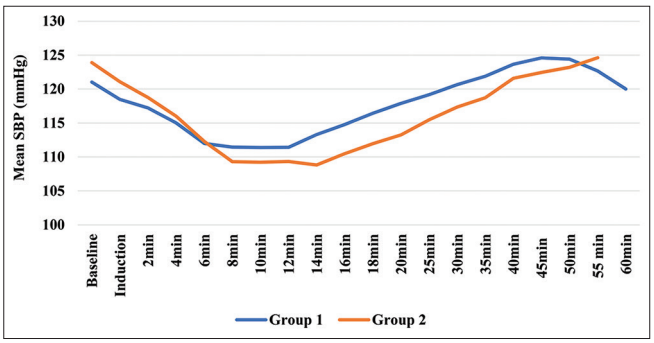

Figure 1: Comparison of mean systolic blood pressure between the two groups intraoperatively with values presented as mean±standard deviation

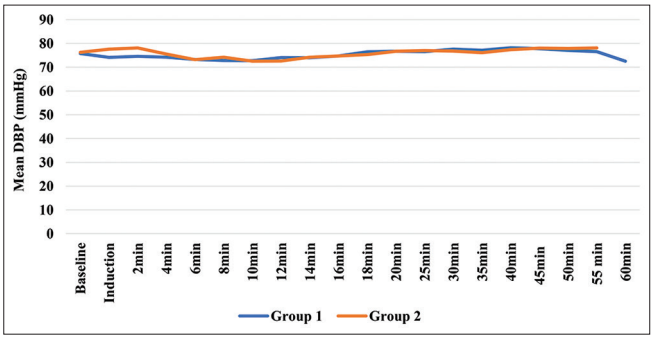

Figure 2: Comparison of mean diastolic blood pressure between the two groups intraoperatively with values presented as mean±standard deviation

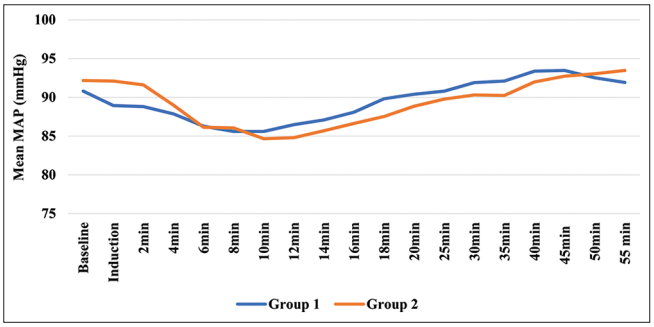

Figure 3: Comparison of mean arterial pressure between the two groups intraoperatively with values presented as mean±standard deviation

The comparison of MAP between the two groups showed statistically significant differences at induction (P<0.05). However, at all other recorded time points, the differences were not statistically significant (P>0.05) as shown in Figure 3.

In the PI≤3.5 group, the hypotension episodes were 35.55% (16/45), whereas in the group with PI>3.5, it was 75.55% (34/45). This disparity was both clinically and statistically highly significant (P<0.001), indicating a doubling in hypotension episodes in the PI>3.5 group compared to the PI≤3.5 group (Table 2). In the PI≤3.5 group, 29 patients experienced no hypotensive episodes, 11 had one episode, and 5 had two episodes. Conversely, in the PI>3.5 group, 11 patients had no episodes, 17 had one episode, 13 had two episodes, two had three episodes, and two had four episodes of hypotension.

Table 2: Comparison of requirement of mephentermine and number of episodes of hypotension (Mean±SD) between the groups

Parameter	Group 1 (PI≤3.5)	Group 2 (PI>3.5)	P-value
Mean episodes of hypotension	0.47±0.70	1.27±0.53	<0.001
Mean mephentermine usage (mg)	2.8±4.16	7.6±6.19	<0.001

PI: Perfusion index, SD: Standard deviation

The receiver operating characteristic (ROC) analysis revealed that baseline PI was suitable for detecting parturients at risk for hypotension (area under the curve [AUC] -0.914, P<0.001; Figure 4). The baseline PI cut-off point that predicted hypotension as determined by the ROC analysis was 3.5 with a sensitivity of 68% and a specificity of 72.5%.

Area under the curve				
Test result variable (s): Baseline PI				
Area	Standard error	P-value	Asymptotic 95% confidence interval	
			Lower bound	Upper bound
0.914	0.034	<0.001	0.848	0.981

PI: Perfusion index

Mephentermine usage was higher in the group with PI>3.5 compared to the group with PI≤3.5. The mean mephentermine usage for the PI≤3.5 group was 2.8±4.16, whereas for the PI>3.5 group, it was 7.6±6.19. This disparity between the two groups was statistically highly significant (P<0.001) (Table 2).

The comparison of APGAR scores between the two groups, as shown in Table 3, revealed no statistically significant differences at 1 min and 5 min (P>0.05).

There were no statistically significant differences in complications between the two groups. Specifically, 5 patients (11.11%) in group PI≤3.5 and 8 patients (17.78%) in group PI>3.5 experienced nausea and vomiting (Table 4).

DISCUSSION

Hypotension commonly occurs after administering a SAB for cesarean delivery. Spinal anesthesia-induced

Table 3: Comparison of APGAR scores between the two groups

APGAR	Group 1 (PI≤3.5)	Group 2 (PI>3.5)	P-value
APGAR 1 min	9.23±0.77	9.23±0.68	0.89
APGAR 5 min	9.18±0.72	9.39±0.62	0.16

PI: Perfusion index

Table 4: Side effects/complications

Complications	Group 1 (PI≤3.5)		Group 2 (PI>3.5)	
	Yes (%)	No (%)	Yes (%)	No (%)
Nausea and vomiting	5 (11.11)	40 (88.89)	8 (17.78)	24 (82.22)
Bradycardia	0 (0)	45 (100)	0 (0)	45 (100)
Allergy	0 (0)	45 (100)	0 (0)	45 (100)

PI: Perfusion index

hypotension is mainly a result of decreased systemic vascular resistance due to blockade of preganglionic sympathetic fibers.[16] Presently, there is no definitive monitoring system to reliably predict hypotension, necessitating additional precautions. Studies have explored the potential of PI in predicting hypotension after SABs for cesarean sections. Fluctuations in the PI stem from pulsatile alterations in arterial blood volume as well as shifts in venous and non-pulsatile arterial blood volume, which arise from changes in the tone of the arterial and venous muscle walls across different conditions.[15] Parturients with an elevated baseline PI, caused by an increase in the pulsatile component due to vasodilation, are expected to exhibit lower peripheral vascular tone. Consequently, they are at a higher risk of experiencing hypotension following spinal anesthesia.

In the present study, demographic profiles of patients in both groups were comparable with respect to the distribution of age, height, and weight and it was evident that there was no statistically significant difference among the groups (Table 1).

Comparing SBP, DBP, and MAP between the groups showed significant differences (P<0.05), (Figures 1-3) aligning with the study[14] finding that a baseline PI>3.5 was associated with hypotension after spinal anesthesia, significant differences were observed in the first 25 min. Study[17] found that PI increased and MAP decreased significantly after epidural anesthesia, while study[12] showed that a high baseline PI predicted greater decreases in SBP after spinal injection for cesarean delivery.

Contrary to our findings, study[18] found that a PI<1.05 predicted higher hypotension risk after propofol induction, indicating hypovolemia and vasoconstriction. Our study

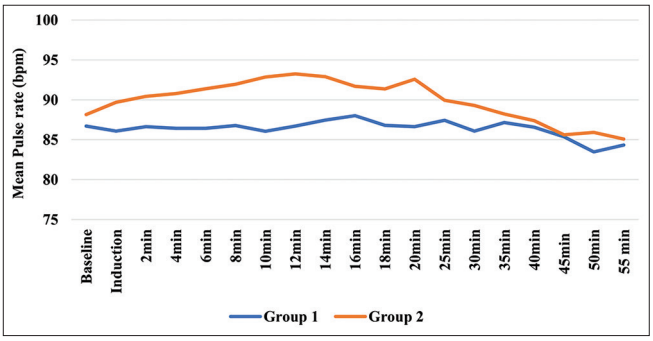

Figure 4: Comparison of mean pulse rate between the two groups intraoperatively with values presented as mean±standard deviation

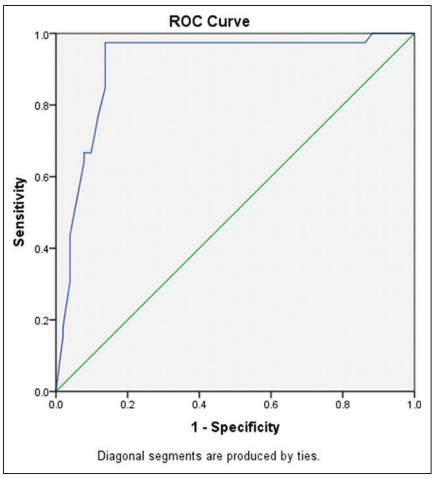

Figure 5: Receiver operator characteristic curve depicting baseline perfusion index against incidence of hypotension

showed that a baseline PI>3.5 predicted hypotension after spinal anesthesia, reflecting reduced sympathetic tone.

Pulse rate comparisons (Figure 5) showed significant differences between groups from induction to the 20th min, with higher rates in group 2 (PI>3.5) linked to greater episodes of hypotension. Study[19] found that pre-anesthetic HR, rather than PI, was a better predictor of hypotension during spinal anesthesia. This discrepancy may be due to differences in methodology, including definitions of hypotension, co-loading with colloids and baseline PI calculation.

Hypotension episodes were significantly more frequent in the PI>3.5 group (75.55%, 34/45) compared to the PI≤3.5 group (35.55%, 16/45), with a significant difference (P<0.001). The mean±SD of hypotension episodes was (0.47±0.70) in the PI≤3.5 group and (1.27±0.53) in the PI>3.5 group, indicating a doubling in episodes. Mephentermine usage was also higher in the PI>3.5 group (7.6±6.19) compared to the PI≤3.5 group (2.8±4.16), due to increased hypotensive episodes (P<0.001) (Table 2). These results align with study,[14] who found higher hypotension and vasopressor needs with a baseline PI>3.5; study,[12]

which linked higher baseline PI to greater arterial pressure decreases and phenylephrine doses; study,[20] which showed that a decrease in PI following an epidural test dose indicated vasoconstriction; study,[21] which found increased PI reflected effective brachial plexus blocks and vasodilation; and study,[22] which confirmed that increased PI after a caudal block indicated vasodilation and blood volume redistribution.

In this study, the ROC curve analysis (Figure 4) yielded an AUC of approximately 0.914, indicating a fair ability to discriminate between patients with and without hypotension using a PI cutoff of 3.5, with sensitivity of 68% and specificity of 72.5%. These results are consistent with studies,[14] which reported a sensitivity of 69.84% and specificity of 89.29% for the same PI cutoff, and study,[12] which found a sensitivity of 81% and specificity of 86% for predicting hypotension during spinal anesthesia.

The APGAR scores of the two groups, as shown in Table 3 were not statistically significant at 1 min and 5 min ($P>0.05$). This aligns with findings from study,[14] which observed no significant differences in APGAR scores at 1 and 5 min, and study,[12] which reported similar results. Study[19] also found no differences in neonatal APGAR scores or umbilical artery pH between groups. In addition, study[23] found no significant differences in fetal APGAR scores between groups receiving colloid versus crystalloid co-loading during spinal anesthesia.

Table 4 compares complications between the two groups, showing that 11.11% (5/45) of the PI≤3.5 group and 17.78% (8/45) of the PI>3.5 group experienced nausea and vomiting, a difference that was statistically insignificant. These findings are consistent with studies,[12,14] both of which found no significant difference in nausea and vomiting incidence between groups.

Limitations of the study

This study has several limitations. Patient movement or stimuli like anxiety could alter PI values. To mitigate this, we recorded baseline PI values without patient movement and counseled all parturients to reduce anxiety. Systemic vascular resistance was not measured, as it was invasive and unnecessary for uncomplicated cesarean sections. Fetal pH was not assessed, which could have helped rule out hypoxia from hypoperfusion. Additionally, the operating theatre temperature may have affected PI values.

CONCLUSION

The present study established that PI can be used as a tool for predicting hypotension in healthy parturients undergoing elective cesarean section under SAB.

The baseline PI measured preoperatively at the upper limb was found to correlate with the degree of arterial pressure decrease during SAB for cesarean delivery. A baseline PI cutoff point of 3.5 can be used to identify parturients at risk for hypotension. The incidence of hypotension was twice as high in the group with PI>3.5 compared to the group with PI≤3.5. Therefore, we conclude that parturients with a baseline PI>3.5 are at a higher risk of developing hypotension following SAB compared to those with a baseline PI≤3.5.

ACKNOWLEDGMENT

We are grateful to the patients and their family undergoing the surgery for their cooperation in the study and to the entire team of Department of Anaesthesiology, Gajra Raja Medical College.

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Authors' Contribution:
AMM- Definition of intellectual content, literature survey, prepared the first draft of manuscript, implementation of study protocol, data collection, data analysis, manuscript preparation and submission of article; **SG-** Concept, design, clinical protocol, manuscript preparation, editing, and manuscript revision; **KK-** Review manuscript; **VB-** Coordination and manuscript revision.

Work attributed to:
Gajra Raja Medical College, Gwalior, Madhya Pradesh, India.

Orcid ID:
Dr. Ashish Mohan M - https://orcid.org/0009-0004-7660-1141
Dr. Suman Gupta - https://orcid.org/0000-0003-2205-8353
Dr. Kavya Kanjikkal - https://orcid.org/0009-0002-8582-5476
Dr. Vankudoth Bhaskar - https://orcid.org/0009-0006-8387-9998

Source of Support: Nil, **Conflicts of Interest:** None declared.