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Original Article

Evaluation of Perfusion Index and Hemodynamic Parameters as Predictors of Hypotension Following Spinal Anesthesia in Patients Undergoing Caesarean Section: A Prospective Observational Study

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ABSTRACT

Background: Hypotension is a common complication of spinal anesthesia in parturients, attributed to sympathetic blockade and resultant vasodilation. Early identification of patients at risk allows timely prophylactic intervention. The perfusion index (PI), a non-invasive measure of peripheral perfusion and vascular tone, may serve as a predictor of hypotension.
Aim: To evaluate baseline perfusion index as a predictor of hypotension following spinal anesthesia in women undergoing elective cesarean section.
Methods: A prospective observational study was conducted on 120 parturients (ASA I–II) scheduled for elective cesarean delivery under spinal anesthesia. Baseline PI, hemodynamic parameters, and demographic data were recorded. Patients were stratified into two groups: Group I (PI ≤3.5) and Group II (PI >3.5). The incidence and severity of hypotension, vasopressor requirement, fluid administration, and maternal and neonatal outcomes were monitored. Hypotension was defined as a decrease in systolic blood pressure >20% from baseline or <80 mmHg.
Results: Hypotension occurred in 24/60 (40%) patients in Group I and 44/60 (73.3%) in Group II ($p<0.001$). Group II had a significantly higher number of hypotensive episodes, greater vasopressor requirement, and increased fluid administration. Additional parameters such as bradycardia and nausea/vomiting were more frequent in Group II. Baseline PI >3.5 predicted hypotension with a sensitivity of 73.3%, specificity of 76.7%, and area under the ROC curve of 0.74. Neonatal outcomes (Apgar scores at 1 and 5 min) were slightly lower in Group II but remained within normal limits.
Conclusion: Baseline perfusion index is a simple, non-invasive, and reliable predictor of hypotension following spinal anesthesia in cesarean delivery. A PI >3.5 identifies patients at higher risk, allowing for proactive hemodynamic management to improve maternal and neonatal safety.

Keywords: *Perfusion Index, Spinal Anesthesia, Hypotension, Cesarean Section, Predictive Monitoring.*

INTRODUCTION

Spinal anesthesia is the preferred anesthetic technique for cesarean delivery because of its rapid onset, reliable sensory and motor blockade, minimal maternal sedation, and negligible fetal drug exposure [1]. Despite these advantages, it is frequently complicated by maternal hypotension, reported in up to 70% of parturients [2,3]. Hypotension primarily results from sympathetic blockade, leading to peripheral vasodilation, reduced systemic vascular resistance, and decreased venous return. These hemodynamic changes may manifest clinically as nausea, vomiting, dizziness, and, in severe cases, maternal cardiovascular compromise [4,5]. In addition, maternal hypotension can compromise uteroplacental perfusion, increasing the risk of fetal hypoxia and acidosis, which underscores the importance of early detection and management [6].

Traditional predictors of spinal-induced hypotension, including maternal age, body mass index, baseline blood pressure, and heart rate, have shown inconsistent reliability [7]. Moreover, various preventive strategies such as fluid preloading, co-loading, and prophylactic vasopressors are employed; however, their indiscriminate use may lead to fluid overload or unnecessary pharmacologic intervention [8]. This highlights the need for a simple, non-invasive, and reliable method to stratify patients at higher risk for hypotension.

The **perfusion index (PI),** derived from the plethysmographic waveform of pulse oximetry, has emerged as a promising tool in this context [9]. PI reflects the ratio of pulsatile to non-pulsatile blood flow at the monitored site and serves as an indirect measure of peripheral vascular tone. A higher baseline PI indicates lower vascular tone and relative vasodilation, suggesting that these patients are more susceptible to profound hypotension following spinal anesthesia. Conversely, a lower PI reflects higher vascular tone, conferring relative resistance to hemodynamic fluctuations [10]. Several studies in obstetric populations have demonstrated the predictive value of baseline PI for hypotension, showing that patients with elevated PI values are more likely to require vasopressors and fluid resuscitation [11,12].

Given its non-invasive nature, ease of measurement, and real-time applicability, PI offers a practical method for preoperative risk assessment. Early identification of high-risk parturients allows anesthesiologists to implement targeted interventions, optimize hemodynamic stability, and potentially improve maternal and neonatal outcomes [13]. Despite this, data on its predictive accuracy remain limited, and there is no universally accepted PI cut-off for clinical use.

The present study was designed to evaluate the utility of baseline perfusion index in predicting hypotension following spinal anesthesia in women undergoing elective cesarean section. By analyzing the correlation between baseline PI and the incidence, severity, and timing of hypotensive episodes—as well as vasopressor requirements and maternal and neonatal outcomes—this study aims to provide additional evidence for the incorporation of PI into routine preoperative assessment and individualized anesthetic planning [14].

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Anesthesiology, Sharda University, after obtaining Institutional Ethics Committee approval and written informed consent from all participants.

Study Population

A total of 120 parturients scheduled for elective cesarean section under spinal anesthesia were recruited. Inclusion criteria were:

- Age 18–40 years
- American Society of Anesthesiologists (ASA) physical status I or II
- Term pregnancy (≥37 weeks gestation)

Exclusion criteria included:

- Known cardiovascular or cerebrovascular disease
- Preeclampsia or eclampsia
- Multiple gestation or intrauterine growth restriction
- Contraindications to spinal anesthesia (coagulopathy, infection at puncture site)
- Refusal to participate

Preoperative Preparation

All patients were instructed to fast for at least 8 hours before surgery. Upon arrival in the operating room, standard monitoring was applied, including non-invasive blood pressure (NIBP), pulse oximetry, electrocardiography, and perfusion index (PI) measurement using a Masimo pulse oximeter with the probe placed on the index finger of the non-dominant hand. Baseline PI, heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and oxygen saturation (SpO_2) were recorded after the patient rested in the supine position for at least 5 minutes.

Anesthetic Technique

An 18G intravenous cannula was secured, and preloading was performed with 10 mL/kg of lactated Ringer's solution. Under strict aseptic precautions, spinal anesthesia was administered at the L3–L4 or L4–L5 interspace using a 25G Quincke spinal needle. Hyperbaric bupivacaine 0.5% (10 mg) with 20 µg fentanyl was injected intrathecally. Patients were immediately positioned supine with left uterine displacement.

Monitoring and Data Collection
Hemodynamic parameters (SBP, DBP, MAP, HR) and SpO_2 were recorded every 2 minutes for the first 20 minutes and every 5 minutes thereafter until the end of surgery. PI was continuously monitored, and the baseline value was defined as the mean of three consecutive readings before spinal injection.

Hypotension was defined as a decrease in SBP >20% from baseline or <80 mmHg, whichever was lower. Management included 5–10 mg intravenous ephedrine boluses and additional fluid administration as required. Bradycardia (HR <50 bpm) was treated with 0.5 mg intravenous atropine. Nausea, vomiting, and other adverse events were recorded.

Sensory block was assessed using the pinprick method, and motor block was evaluated using the Bromage scale. The time to reach maximum sensory level, duration of surgery, and intraoperative fluid and vasopressor requirements were recorded. Neonatal outcomes were assessed using Apgar scores at 1 and 5 minutes.

Grouping
Patients were stratified based on baseline PI:

- **Group I:** PI ≤3.5
- **Group II:** PI >3.5

Sample Size
Based on previous studies reporting an incidence of hypotension of 70% in high PI patients, a sample size of 60 patients per group (total 120) was calculated to achieve a power of 80% and α error of 0.05.

Statistical Analysis
Statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and compared using Student's t-test or Mann–Whitney U test as appropriate. Categorical variables were presented as frequencies and percentages and compared using the Chi-square or Fisher's exact test. Receiver operating characteristic (ROC) curve analysis was performed to determine the predictive value of baseline PI for hypotension. A p-value <0.05 was considered statistically significant.

RESULTS
A total of 120 parturients undergoing elective caesarean section under spinal anesthesia were included in the study and were equally divided into two groups based on baseline perfusion index (PI): Group I (PI ≤3.5, n=60) and Group II (PI >3.5, n=60). The demographic characteristics including age, weight, height, body mass index (BMI), gestational age, and ASA physical status were comparable between both groups, and no statistically significant differences were observed (p>0.05), indicating homogeneity of the study population.

Baseline hemodynamic parameters showed significant differences between the two groups. The mean perfusion index was significantly higher in Group II (5.92 ± 1.52) compared to Group I (1.85 ± 0.92) (p<0.001). Group II also demonstrated significantly lower baseline systolic blood pressure (118.2 ± 8.6 mmHg vs 124.5 ± 9.5 mmHg), diastolic blood pressure (75.0 ± 5.5 mmHg vs 80.1 ± 7.6 mmHg), and mean arterial pressure (90.3 ± 5.6 mmHg vs 96.2 ± 8.1 mmHg) as compared to Group I (p<0.01). However, heart rate, oxygen saturation (SpO_2), and baseline temperature were comparable between the groups (p>0.05).

With respect to intraoperative characteristics, the time to achieve T6 sensory block and maximum sensory level attained were similar in both groups (p>0.05). All patients achieved complete motor block (Bromage score 3). However, the time to onset of hypotension was significantly shorter in Group II (5.6 ± 1.8 minutes) compared to Group I (8.2 ± 2.5 minutes), which was statistically significant (p<0.001). The duration of surgery was comparable between the two groups.

The overall incidence of Hypotension was significantly higher in Group II (73.3%) compared to Group I (40%), with a total incidence of 56.7% among all participants (p=0.001). Furthermore, the frequency and severity of hypotensive episodes were significantly greater in patients with higher baseline PI. In Group II, a larger proportion of patients experienced multiple episodes (≥3 episodes: 43.4%) compared to Group I (10%), and this difference was statistically significant (p=0.004).

The requirement of vasopressor support and intravenous fluids was also significantly higher in Group II. The mean number of ephedrine boluses administered was greater in Group II (3.2 ± 1.4) compared to Group I (2.1 ± 0.9) (p=0.01), and the total dose of ephedrine required was significantly higher (18.8 ± 8.1 mg vs 12.5 ± 5.0 mg; p=0.02). Additionally, patients in Group II required significantly more intravenous fluids (1650 ± 290 mL vs 1350 ± 330 mL; p<0.001).

In terms of associated adverse effects, the incidence of bradycardia and nausea/vomiting was significantly higher in Group II. Bradycardia was observed in 23.3% of patients in Group II compared to 10% in Group I (p=0.04), while nausea and vomiting occurred in 36.7% of patients in Group II versus 16.7% in Group I (p=0.01).

Neonatal outcomes also showed statistically significant differences between the two groups. The mean Apgar scores at 1 minute and 5 minutes were significantly lower in Group II (7.6 ± 0.8 and 8.8 ± 0.6, respectively) compared to Group I (8.1 ± 0.6 and 9.2 ± 0.5, respectively), indicating a transient impact on neonatal well-being associated with maternal hypotension (p<0.05).

TABLE 1: Demographic Profile (n = 120)

Parameter	**Group I (PI ≤3.5) (n=60)**	**Group II (PI >3.5) (n=60)**	**p-value**
Age (years)	25.4 ± 2.8	26.1 ± 3.0	0.12
Weight (kg)	65.8 ± 5.2	66.9 ± 5.6	0.21
Height (cm)	155.6 ± 3.5	156.8 ± 3.9	0.09
BMI (kg/m²)	27.2 ± 2.4	27.8 ± 2.2	0.18
Gestational Age (weeks)	38.4 ± 1.2	38.6 ± 1.3	0.28
ASA Grade (I/II)	42/18	40/20	0.67

TABLE 2: Baseline Hemodynamic Parameters

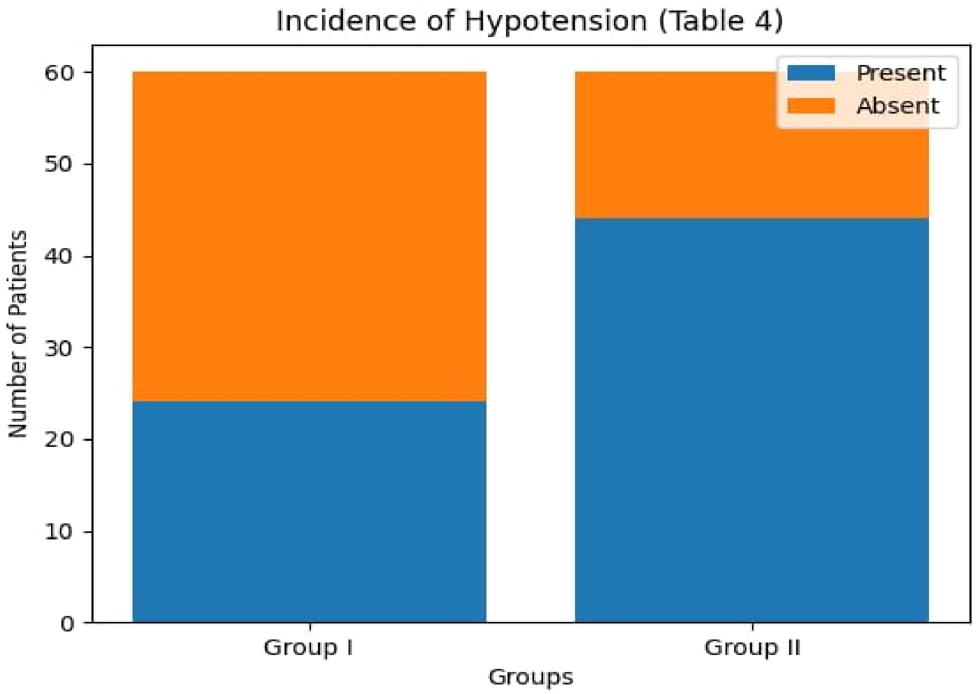
Parameter	**Group I (n=60)**	**Group II (n=60)**	**p-value**
PI	1.85 ± 0.92	5.92 ± 1.52	<0.001
SBP (mmHg)	124.5 ± 9.5	118.2 ± 8.6	0.002
DBP (mmHg)	80.1 ± 7.6	75.0 ± 5.5	0.002
MAP (mmHg)	96.2 ± 8.1	90.3 ± 5.6	<0.001
HR (bpm)	82 ± 6	84 ± 7	0.08
SpO_2 (%)	99 ± 1	99 ± 1	0.90
Baseline Temperature (°C)	36.7 ± 0.3	36.6 ± 0.4	0.32

TABLE 3: Intraoperative & Block Characteristics

Parameter	**Group I (n=60)**	**Group II (n=60)**	**p-value**
Time to T6 block (min)	6.5 ± 1.2	6.8 ± 1.4	0.18
Maximum sensory level (T4/T6)	38/22	40/20	0.70
Motor block (Bromage 3) (%)	60 (100%)	60 (100%)	—
Time to hypotension (min)	8.2 ± 2.5	5.6 ± 1.8	**<0.001**
Duration of surgery (min)	52 ± 8	54 ± 9	0.22

TABLE 4: Incidence of hypotension (n = 120)

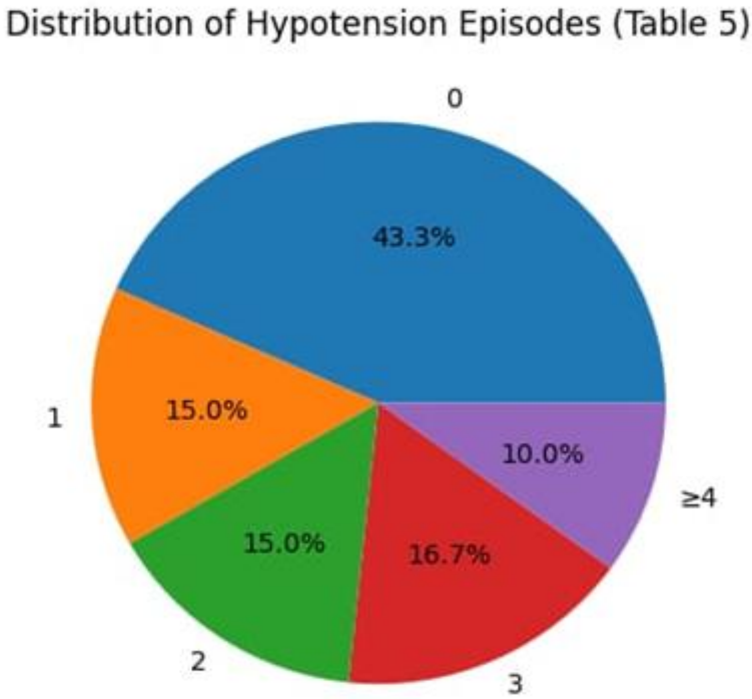
Incidence	**Group I (n=60)**	**Group II (n=60)**	**Total**	**p-value**
Present	24 (40%)	44 (73.3%)	68 (56.7%)	0.001
Absent	36 (60%)	16 (26.7%)	52 (43.3%)	



Graph 1: Incidence of hypotension (n = 120)

TABLE 5: Number of Hypotension Episodes

Episodes	**Group I (n=60)**	**Group II (n=60)**	**p-value**
0	36 (60%)	16 (26.7%)	
1	8 (13.3%)	10 (16.7%)	
2	10 (16.7%)	8 (13.3%)	
3	4 (6.7%)	16 (26.7%)	
≥4	2 (3.3%)	10 (16.7%)	**0.004**



Graph 2: Number of Hypotension Episodes

TABLE 6: Vasopressor, Fluid & Adverse Effects

Parameter	Group I	Group II	p-value
Ephedrine boluses	2.1 ± 0.9	3.2 ± 1.4	0.01
Total Ephedrine (mg)	12.5 ± 5.0	18.8 ± 8.1	0.02
Fluid (ml)	1350 ± 330	1650 ± 290	<0.001
Bradycardia (%)	6 (10%)	14 (23.3%)	0.04
Nausea/Vomiting (%)	10 (16.7%)	22 (36.7%)	0.01

TABLE 7: Neonatal Outcome (Additional Strong Parameter)

Parameter	Group I	Group II	p-value
Apgar score (1 min)	8.1 ± 0.6	7.6 ± 0.8	0.01
Apgar score (5 min)	9.2 ± 0.5	8.8 ± 0.6	0.02

TABLE 8: ROC Analysis

Parameter	Value
Cut-off PI	3.5
Sensitivity	73.3%
Specificity	76.7%
AUC	0.74
Accuracy	75%

Receiver operating characteristic (ROC) curve analysis demonstrated that a baseline perfusion index cutoff value of 3.5 predicted hypotension with a sensitivity of 73.3% and specificity of 76.7%, with an area under the curve (AUC) of 0.74, indicating moderate diagnostic accuracy.

Overall, the results demonstrate that a higher baseline perfusion index is significantly associated with increased incidence, earlier onset, and greater severity of hypotension following spinal anesthesia, along with increased vasopressor requirement, higher incidence of adverse effects, and comparatively lower neonatal Apgar scores.

DISCUSSION

Spinal anesthesia is widely recognized as the anesthetic technique of choice for cesarean section due to its rapid onset, reliable sensory and motor block, and minimal fetal exposure to drugs [1]. However, spinal-induced hypotension remains a common and clinically significant complication, with reported incidences ranging from 55% to 75% in parturients [2,3]. In our study, the overall incidence of hypotension was 56.7%, with a significantly higher incidence in patients with baseline PI >3.5 (73.3%) compared to those with PI ≤3.5 (40%). These findings are consistent with previous studies suggesting that baseline perfusion index can serve as a predictor of hypotension following spinal anesthesia [6,7].

The pathophysiology of spinal-induced hypotension primarily involves sympathetic blockade, which leads to arterial and venous vasodilation, decreased systemic vascular resistance, and reduced venous return [4]. Maternal factors such as baseline vascular tone, blood volume, and autonomic nervous system activity contribute to variability in the severity of hypotension [5]. Traditional predictors, including baseline blood pressure, heart rate, body mass index, and maternal age, have shown limited predictive accuracy, emphasizing the need for more reliable, non-invasive markers [8].

The perfusion index, derived from the plethysmographic waveform of a pulse oximeter, reflects the ratio of pulsatile to non-pulsatile blood flow and serves as an indirect measure of peripheral vascular tone [9]. A higher baseline PI indicates relative vasodilation and low vascular tone, predisposing patients to more pronounced hypotension after spinal anesthesia. Conversely, a lower PI suggests higher vascular tone, conferring relative protection against hemodynamic fluctuations [10]. In our study, ROC curve analysis demonstrated that a PI cut-off value of 3.5 predicted hypotension with a sensitivity of 73.3% and specificity of 76.7%, corroborating findings from other obstetric studies [11,12].

Our study also observed that patients in the high PI group required more frequent and higher doses of vasopressors and larger fluid volumes to maintain hemodynamic stability. This aligns with the physiological expectation that parturients with lower baseline vascular tone experience greater drops in blood pressure following sympathetic blockade [13]. In addition, adverse maternal events such as bradycardia and nausea/vomiting were more frequent in the high PI group, consistent with prior literature linking hypotension to maternal discomfort and cardiovascular stress [14].

Neonatal outcomes, assessed using Apgar scores at 1 and 5 minutes, were slightly lower in the high PI group but remained within normal limits. This suggests that while maternal hypotension may transiently affect uteroplacental perfusion, prompt recognition and management with fluids and vasopressors can mitigate adverse neonatal effects [15].

Several limitations of this study should be acknowledged. PI measurements can be influenced by factors such as anxiety, temperature, peripheral vasoconstriction, and probe positioning, which may introduce variability [16]. In addition, this was a single-center study with a relatively small sample size, and larger multicenter studies would help validate the generalizability of the findings. Finally, invasive measurements of vascular tone or cardiac output were not performed, which could provide more precise correlations between PI and hemodynamic changes.

Despite these limitations, our study reinforces the utility of baseline perfusion index as a simple, non-invasive, and reliable predictor of hypotension following spinal anesthesia in cesarean delivery. Incorporation of PI into routine preoperative assessment allows identification of high-risk parturients, enabling anesthesiologists to implement targeted prophylactic strategies, optimize hemodynamic stability, and potentially improve maternal and neonatal outcomes [17].

Recent clinical evidence from 2023 to 2025 further supports the role of perfusion index as a useful predictor of hypotension following spinal anesthesia. A prospective observational study by Rajanalini et al. (2023) demonstrated that parturients with a baseline PI >3.5 had a significantly higher incidence of post-spinal hypotension (≈71%) compared with those with lower PI, and baseline PI showed good sensitivity and specificity in predicting hypotensive episodes and vasopressor requirements [18]. Similarly, Chandewar et al. (2023) reported that PI >3.5 was significantly associated with higher hypotension rates in elective cesarean section under spinal anesthesia, confirming the utility of the 3.5 cut-off in clinical practice [19]. In a 2024 observational study, Harde et al. found that parturients with PI >3.5 had almost universal hypotension, required more fluid and vasopressor support, and showed strong ROC performance (AUC 0.91) for PI as a predictive measure, suggesting that PI is an excellent predictor of spinal anesthesia-induced hypotension [20]. Beyond obstetric surgery, Manap and colleagues (2024) identified a PI cut-off of 3.2 that was predictive of spinal anesthesia-induced hypotension with high sensitivity, indicating that slightly lower thresholds may also be clinically relevant depending on patient population and definitions used [21]. Furthermore, emerging 2025 reports, including clinical evaluations published in peer-reviewed journals, reaffirm that higher baseline PI values are strong non-invasive indicators of hypotension following spinal anesthesia and can guide early preventive management [22,23]. Collectively, these contemporary studies reinforce the predictive value of perfusion index measurement and suggest its integration into preoperative risk assessment to anticipate post-spinal hypotension more reliably than traditional static predictors.

CONCLUSION

Baseline perfusion index is a simple, non-invasive, and reliable predictor of hypotension following spinal anesthesia in parturients undergoing elective cesarean section. A PI value greater than 3.5 identifies patients at higher risk for hypotension, greater vasopressor requirement, and increased incidence of maternal adverse effects. Early recognition of high-risk parturients using PI allows targeted prophylactic interventions, including fluid optimization and judicious vasopressor administration, thereby improving maternal hemodynamic stability and potentially enhancing neonatal outcomes. Incorporating perfusion index measurement into routine preoperative assessment may provide anesthesiologists with a practical tool for individualized anesthetic planning and safer obstetric care.

Limitations

Despite providing valuable insights, this study has several limitations. First, perfusion index (PI) measurements can be influenced by factors such as patient anxiety, ambient temperature, peripheral vasoconstriction, and probe placement, which may introduce variability and affect predictive accuracy. Second, the study was conducted at a single center with a relatively small sample size of 120 parturients, which may limit the generalizability of the findings to broader populations. Third, invasive hemodynamic monitoring, such as cardiac output or systemic vascular resistance measurement, was not performed; such data could have provided more precise correlations between PI and the degree of hypotension. Fourth, the study focused exclusively on elective cesarean sections, and results may differ in emergency procedures or in patients with comorbidities such as preeclampsia or cardiovascular disease. Finally, the study did not account for potential long-term maternal or neonatal outcomes, limiting conclusions to the intraoperative and immediate postpartum period.

Addressing these limitations in future multicenter studies with larger sample sizes, standardized PI measurement protocols, and invasive hemodynamic assessment could further validate the utility of PI as a predictive tool for hypotension following spinal anesthesia.

DECLARATIONS:

Conflicts of interest: The authors declare that there are no conflicts of interest.
Consent to participate: Written informed consent was obtained from all participants.

Consent for publication: Consent for publication was obtained.
Authors' contributions: All authors contributed equally to the study and approved the final manuscript.

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