IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 7 Ser.6 (July 2025), PP 82-89
www.iosrjournals.org

Perfusion Index-Guided Fluid and Vasopressor Management Protocol for Prevention of Spinal Anesthesia-Induced Hypotension in High-Risk Obstetric Patients

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Abstract
Background: *Spinal anesthesia-induced hypotension remains a significant complication in cesarean delivery, particularly in high-risk obstetric patients. While perfusion index has shown potential as a predictor of hypotension, its utility in guiding proactive management protocols remains unexplored. This study evaluated the effectiveness of a perfusion index-guided fluid and vasopressor management protocol in preventing spinal anesthesia-induced hypotension in high-risk obstetric patients.*
Methods: *A prospective observational study was conducted involving 120 high-risk parturients undergoing elective cesarean section under spinal anesthesia. Patients were managed using a standardized perfusion index-guided protocol that incorporated baseline perfusion index measurements, targeted fluid therapy, and prophylactic vasopressor administration. The primary outcome was the incidence of clinically significant hypotension, defined as mean arterial pressure below 65 mmHg. Secondary outcomes included maternal hemodynamic stability, neonatal outcomes, and protocol adherence rates.*
Results: *The perfusion index-guided protocol demonstrated a significant reduction in hypotension incidence compared to historical controls (25.8% vs 78.3%, $p<0.001$). Mean arterial pressure remained more stable throughout the procedure in protocol-managed patients. The protocol showed particular effectiveness in patients with baseline perfusion index values >3.5, with hypotension rates of 31.2% compared to 76.9% in historical controls ($p<0.001$). Neonatal outcomes, as measured by APGAR scores, showed improvement with protocol implementation.*
Conclusion: *Implementation of a perfusion index-guided fluid and vasopressor management protocol significantly reduced the incidence of spinal anesthesia-induced hypotension in high-risk obstetric patients. This approach represents a promising advancement in perioperative hemodynamic management for cesarean delivery.*
Keywords: *perfusion index, spinal anesthesia, hypotension, cesarean section, obstetric anesthesia, hemodynamic monitoring*

I. Introduction

Spinal anesthesia has become the preferred anesthetic technique for cesarean delivery due to its rapid onset, predictable block characteristics, and excellent maternal and fetal safety profile when properly administered (1). However, spinal anesthesia-induced hypotension remains one of the most common and potentially serious complications encountered during cesarean section, with reported incidence rates ranging from 70% to 90% in various studies (2). This complication poses significant risks to both maternal and fetal wellbeing, including maternal nausea, vomiting, altered consciousness, and potentially severe consequences such as cardiac arrest, while fetal complications may include acidosis, neurological injury, and compromised placental perfusion (3).

The pathophysiology of spinal anesthesia-induced hypotension involves complex hemodynamic alterations resulting from sympathetic blockade. The administration of local anesthetic agents into the subarachnoid space blocks sympathetic nerve fibers, leading to peripheral vasodilation, reduced venous return, decreased cardiac preload, and subsequent hypotension (4). In obstetric patients, these effects are further compounded by pregnancy-related physiological changes, including increased blood volume, reduced systemic vascular resistance, and aortocaval compression by the gravid uterus. High-risk obstetric patients, including those with preeclampsia, gestational diabetes, multiple pregnancies, or significant comorbidities, may exhibit

even greater susceptibility to hemodynamic instability following spinal anesthesia due to altered cardiovascular physiology and reduced compensatory mechanisms.

Traditional approaches to managing spinal anesthesia-induced hypotension have relied primarily on reactive strategies, including fluid resuscitation and vasopressor administration after hypotension has already occurred. While these interventions are generally effective in treating established hypotension, the reactive approach may not prevent the initial hemodynamic compromise and its associated maternal and fetal consequences. Recent research has focused on developing predictive tools and proactive management strategies to prevent hypotension before it occurs, thereby potentially improving outcomes for both mother and baby.

Perfusion index, a non-invasive parameter derived from pulse oximetry, has emerged as a promising tool for predicting spinal anesthesia-induced hypotension. Perfusion index represents the ratio of pulsatile blood flow to non-pulsatile blood flow in the peripheral tissue and reflects peripheral vascular tone and perfusion status (5). The physiological basis for using perfusion index as a predictor lies in its ability to detect changes in peripheral vascular resistance and sympathetic tone. During pregnancy, decreased systemic vascular resistance corresponds to higher perfusion index values due to increased pulsatile blood flow component resulting from vasodilation. Following spinal anesthesia, further sympathetic blockade leads to additional decreases in vascular resistance and increased peripheral blood pooling, which can be reflected in perfusion index changes.

Several studies have investigated the predictive value of baseline perfusion index for identifying patients at risk of developing hypotension following spinal anesthesia. Toyama and colleagues demonstrated that parturients with higher baseline perfusion index values were more likely to develop significant hypotension after spinal anesthesia for cesarean delivery (6). Similarly, other investigators have reported varying degrees of success in using perfusion index as a predictive tool, though optimal cutoff values and clinical implementation strategies remain subjects of ongoing research and debate (7).

Despite the growing evidence supporting perfusion index as a predictor of spinal anesthesia-induced hypotension, most previous studies have focused primarily on prediction rather than intervention. The translation of predictive information into actionable clinical protocols that can effectively prevent hypotension represents a critical gap in current obstetric anesthesia practice. The development of evidence-based, perfusion index-guided management protocols could potentially transform the approach to hemodynamic management during cesarean delivery, shifting from reactive treatment to proactive prevention.

High-risk obstetric patients represent a particularly important population for implementing such protocols, as these patients may have limited physiological reserves and greater vulnerability to hemodynamic perturbations. Conditions such as preeclampsia, gestational diabetes mellitus, multiple pregnancies, and maternal cardiac disease can significantly alter cardiovascular physiology and response to spinal anesthesia. These patients may benefit disproportionately from proactive hemodynamic management strategies that prevent rather than simply treat hypotension.

The concept of personalized medicine in anesthesia has gained increasing recognition, with growing emphasis on tailoring anesthetic management to individual patient characteristics and risk factors. Perfusion index-guided protocols represent an example of this personalized approach, utilizing patient-specific physiological parameters to guide clinical decision-making. Such protocols could potentially optimize fluid administration, vasopressor timing and dosing, and other interventions based on individual patient physiology rather than standardized approaches applied uniformly to all patients.

Current evidence suggests that proactive management strategies, including prophylactic vasopressor administration and optimized fluid therapy, can effectively reduce the incidence of spinal anesthesia-induced hypotension. However, the optimal implementation of these strategies remains unclear, particularly regarding patient selection, timing of interventions, and dosing protocols. Perfusion index-guided approaches could provide the individualized guidance needed to optimize these interventions for each patient.

The development and validation of perfusion index-guided management protocols also addresses important clinical workflow considerations. Modern pulse oximeters routinely display perfusion index values, making this parameter readily available in most clinical settings without requiring additional equipment or significant workflow modifications. This accessibility makes perfusion index-guided protocols potentially feasible for widespread clinical implementation, provided that their effectiveness can be demonstrated through rigorous clinical evaluation.

The present study was designed to address the critical gap between perfusion index prediction research and clinical implementation by developing and evaluating a comprehensive perfusion index-guided fluid and vasopressor management protocol specifically designed for high-risk obstetric patients undergoing cesarean delivery under spinal anesthesia. This research represents an important step toward translating predictive capabilities into improved patient outcomes through evidence-based protocol implementation.

II. Aims And Objectives

The primary aim of this study was to evaluate the effectiveness of a perfusion index-guided fluid and vasopressor management protocol in preventing spinal anesthesia-induced hypotension in high-risk obstetric patients undergoing elective cesarean section. The study sought to determine whether implementation of this structured protocol could significantly reduce the incidence of clinically significant hypotension compared to historical controls managed with conventional reactive approaches.

The secondary objectives included assessment of the protocol's impact on maternal hemodynamic stability throughout the perioperative period, evaluation of neonatal outcomes as measured by APGAR scores and umbilical cord blood gas analysis, determination of protocol adherence rates among healthcare providers, and identification of patient subgroups that demonstrated greatest benefit from the perfusion index-guided approach. Additional objectives encompassed analysis of fluid and vasopressor requirements, assessment of maternal satisfaction scores, and evaluation of any adverse events associated with protocol implementation.

III. Materials And Methods

Study Design and Setting

A prospective observational study was conducted at a tertiary care centre over a one-year period. The study protocol received approval from the institutional ethics committee, and written informed consent was obtained from all participating patients. The study was designed to evaluate the implementation of a perfusion index-guided management protocol in clinical practice rather than as a controlled trial, reflecting real-world clinical effectiveness.

Study Population and Sample Size

The study included 120 high-risk obstetric patients scheduled for elective cesarean section under spinal anesthesia. Sample size calculation was based on an expected reduction in hypotension incidence from 75% (historical baseline) to 35% with protocol implementation, requiring 56 patients per group to achieve 80% power at $\alpha=0.05$. Historical control data were derived from a retrospective analysis of 120 comparable patients managed during the preceding year using conventional approaches.

Inclusion Criteria

Patients were included if they met the following criteria: age between 18-40 years, singleton or multiple pregnancy at term (≥37 weeks gestation), scheduled for elective cesarean section, classified as high-risk based on presence of at least one of the following conditions: preeclampsia or gestational hypertension, gestational diabetes mellitus, multiple pregnancy, maternal age >35 years, BMI >30 kg/m², previous cesarean section with complications, or significant maternal comorbidities. Additional inclusion criteria required ASA physical status classification of II or III and ability to provide informed consent.

Exclusion Criteria

Patients were excluded for emergency cesarean section, contraindications to spinal anesthesia, severe cardiac disease requiring specialized management, active bleeding or coagulopathy, refusal to participate in the study, or inability to obtain reliable perfusion index measurements. Patients requiring general anesthesia or conversion from spinal to general anesthesia were also excluded from analysis.

Perfusion Index-Guided Protocol Development

The management protocol was developed based on existing literature and expert consensus, incorporating baseline perfusion index measurements to guide fluid and vasopressor administration. The protocol stratified patients into three risk categories based on baseline perfusion index values: low risk (PI ≤2.5), moderate risk (PI 2.6-4.0), and high risk (PI >4.0). Each risk category had specific fluid and vasopressor recommendations designed to prevent hypotension proactively.

Procedural Protocol

All patients underwent standardized preoperative preparation including establishment of intravenous access with 18-gauge cannula and attachment of standard monitoring equipment. Baseline perfusion index was measured using Masimo SET pulse oximetry technology applied to the index finger after a 10-minute stabilization period. Spinal anesthesia was performed using 25-gauge Quincke needle at L3-L4 or L2-L3 interspace with 2.0-2.5 mL of 0.5% hyperbaric bupivacaine, with dosing adjusted based on patient height and risk factors.

Fluid and Vasopressor Management

Low-risk patients (PI ≤2.5) received standard preloading with 500 mL crystalloid and prophylactic phenylephrine 0.5 mcg/kg/min infusion. Moderate-risk patients (PI 2.6-4.0) received enhanced preloading with 750 mL crystalloid plus prophylactic phenylephrine 1.0 mcg/kg/min infusion initiated before spinal anesthesia. High-risk patients (PI >4.0) received aggressive preloading with 1000 mL crystalloid, prophylactic phenylephrine 1.5 mcg/kg/min infusion, and additional norepinephrine 0.05 mcg/kg/min infusion if baseline systolic blood pressure exceeded 140 mmHg.

Monitoring and Data Collection

Hemodynamic parameters including heart rate, blood pressure, and oxygen saturation were recorded at baseline, immediately after spinal anesthesia, and at 2-minute intervals for the first 20 minutes, then every 5 minutes until delivery. Perfusion index values were monitored continuously and recorded at the same time points. Sensory block level was assessed using cold testing at 5-minute intervals until maximum block was achieved.

Primary and Secondary Outcomes

The primary outcome was incidence of clinically significant hypotension, defined as mean arterial pressure <65 mmHg or systolic blood pressure <90 mmHg sustained for >2 minutes. Secondary outcomes included severity of hypotension, time to hypotension onset, total fluid and vasopressor requirements, maternal side effects, neonatal APGAR scores at 1 and 5 minutes, umbilical arterial and venous blood gas parameters, and maternal satisfaction scores using a 10-point visual analog scale.

Statistical Analysis

Statistical analysis was performed using SPSS version 28.0. Continuous variables were presented as mean ± standard deviation or median (interquartile range) depending on distribution normality assessed by Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages. Comparison between protocol-managed patients and historical controls used independent t-tests for normally distributed continuous variables, Mann-Whitney U tests for non-normally distributed continuous variables, and chi-square or Fisher's exact tests for categorical variables. Subgroup analysis based on perfusion index categories used one-way ANOVA with post-hoc Tukey testing. Statistical significance was defined as $p<0.05$ for all analyses.

IV. Results

Patient Demographics and Baseline Characteristics

A total of 120 high-risk obstetric patients were enrolled in the perfusion index-guided protocol group, with complete data available for all participants. The historical control group comprised 120 patients with similar demographic and clinical characteristics managed during the preceding year. Mean maternal age was 31.2 ± 4.8 years in the protocol group versus 30.8 ± 5.1 years in controls (p=0.52). Mean gestational age at delivery was 38.1 ± 1.2 weeks versus 37.9 ± 1.4 weeks respectively (p=0.23). BMI was comparable between groups at 28.9 ± 4.2 kg/m² versus 29.3 ± 4.6 kg/m² (p=0.45). The distribution of high-risk conditions was similar between groups, with preeclampsia present in 32.5% versus 35.0% (p=0.68), gestational diabetes in 28.3% versus 25.8% (p=0.67), and multiple pregnancy in 15.8% versus 18.3% (p=0.61) for protocol and control groups respectively.

Perfusion Index Distribution and Risk Stratification

Baseline perfusion index values in the protocol group ranged from 1.2 to 8.9, with a mean of 3.8 ± 2.1. Risk stratification resulted in 35 patients (29.2%) classified as low risk (PI ≤2.5), 53 patients (44.2%) as moderate risk (PI 2.6-4.0), and 32 patients (26.7%) as high risk (PI >4.0). The distribution of perfusion index values was similar to that reported in previous studies of obstetric populations.

Primary Outcome: Hypotension Incidence

The primary outcome demonstrated significant improvement with protocol implementation. Clinically significant hypotension occurred in 31 patients (25.8%) in the protocol group compared to 94 patients (78.3%) in the historical control group, representing a 67% relative risk reduction ($p<0.001$, 95% CI: 0.21-0.41). The number needed to treat was 1.9, indicating that for every two patients managed with the protocol, one case of hypotension was prevented.

Subgroup Analysis by Risk Categories

Analysis by perfusion index risk categories revealed differential treatment effects. In low-risk patients (PI ≤2.5), hypotension occurred in 5 of 35 patients (14.3%) with protocol management versus an estimated 75%

in historical controls of similar risk profile (p<0.001). Moderate-risk patients (PI 2.6-4.0) experienced hypotension in 16 of 53 patients (30.2%) versus approximately 78% in comparable historical controls (p<0.001). High-risk patients (PI >4.0) had the highest hypotension rate at 10 of 32 patients (31.2%), but this still represented significant improvement compared to 76.9% in historical high-risk controls (p<0.001).

Hemodynamic Parameters and Stability

Mean arterial pressure remained significantly more stable in the protocol group throughout the observation period. Baseline mean arterial pressure was 89.2 ± 12.4 mmHg in the protocol group versus 88.7 ± 11.8 mmHg in controls (p=0.74). At 10 minutes post-spinal anesthesia, mean arterial pressure was 76.8 ± 9.2 mmHg versus 68.4 ± 14.6 mmHg respectively (p<0.001). The maximum decrease in mean arterial pressure was 18.2 ± 8.9% in the protocol group versus 28.7 ± 12.4% in controls (p<0.001). Time to maximum hypotension was significantly longer in protocol patients at 8.4 ± 3.2 minutes versus 5.1 ± 2.8 minutes in controls (p<0.001).

Fluid and Vasopressor Requirements

Total intraoperative fluid administration was higher in the protocol group at 1247 ± 384 mL versus 943 ± 312 mL in controls (p<0.001), reflecting the proactive fluid management strategy. Despite increased fluid administration, the protocol group required significantly less rescue vasopressor therapy. Phenylephrine bolus doses were administered to 23 patients (19.2%) in the protocol group versus 78 patients (65.0%) in controls (p<0.001). Mean total phenylephrine dose for patients requiring rescue therapy was 127 ± 45 mcg versus 218 ± 89 mcg respectively (p<0.001).

Maternal and Neonatal Outcomes

Maternal side effects were significantly reduced in the protocol group. Nausea and vomiting occurred in 18 patients (15.0%) versus 67 patients (55.8%) in controls (p<0.001). No patients in either group experienced severe hypotension requiring emergency interventions or cardiac arrest. Neonatal outcomes showed improvement with protocol implementation. Mean APGAR scores at 1 minute were 8.2 ± 0.9 versus 7.8 ± 1.2 (p=0.003), and at 5 minutes were 9.1 ± 0.7 versus 8.9 ± 0.8 (p=0.04) for protocol versus control groups respectively. Umbilical arterial pH was significantly higher in the protocol group at 7.28 ± 0.06 versus 7.25 ± 0.08 (p=0.001). The incidence of neonatal acidosis (pH <7.20) was reduced from 18.3% in controls to 6.7% in the protocol group (p=0.008).

Table 1: Patient Demographics and Baseline Characteristics

Variable	Protocol Group (n=120)	Historical Controls (n=120)	P-value
Age (years)	31.2 ± 4.8	30.8 ± 5.1	0.52
Weight (kg)	74.6 ± 12.3	76.1 ± 13.8	0.34
Height (cm)	162.4 ± 6.2	161.9 ± 6.8	0.52
BMI (kg/m²)	28.9 ± 4.2	29.3 ± 4.6	0.45
Gestational age (weeks)	38.1 ± 1.2	37.9 ± 1.4	0.23
Preeclampsia, n (%)	39 (32.5)	42 (35.0)	0.68
Gestational diabetes, n (%)	34 (28.3)	31 (25.8)	0.67
Multiple pregnancy, n (%)	19 (15.8)	22 (18.3)	0.61

Table 2: Perfusion Index Distribution and Risk Stratification

Risk Category	PI Range	Protocol Group n (%)	Mean PI ± SD	Historical Estimated n (%)
Low Risk	≤2.5	35 (29.2)	1.9 ± 0.4	36 (30.0)
Moderate Risk	2.6-4.0	53 (44.2)	3.2 ± 0.4	51 (42.5)
High Risk	>4.0	32 (26.7)	5.8 ± 1.4	33 (27.5)
Overall	1.2-8.9	120 (100)	3.8 ± 2.1	120 (100)

Table 3: Primary and Secondary Outcomes

Outcome	Protocol Group (n=120)	Historical Controls (n=120)	P-value
Primary hypotension, n (%)	31 (25.8)	94 (78.3)	<0.001
Severe hypotension, n (%)	8 (6.7)	34 (28.3)	<0.001
Time to hypotension (min)	8.4 ± 3.2	5.1 ± 2.8	<0.001
Maximum MAP decrease (%)	18.2 ± 8.9	28.7 ± 12.4	<0.001
Nausea/vomiting, n (%)	18 (15.0)	67 (55.8)	<0.001

Outcome	Protocol Group (n=120)	Historical Controls (n=120)	P-value
APGAR 1 min	8.2 ± 0.9	7.8 ± 1.2	0.003
APGAR 5 min	9.1 ± 0.7	8.9 ± 0.8	0.04

Table 4: Hypotension Incidence by Risk Categories

Risk Category	Protocol Group	Historical Controls	Relative Risk Reduction	P-value
Low Risk (PI ≤2.5)	5/35 (14.3%)	27/36 (75.0%)	81%	<0.001
Moderate Risk (PI 2.6-4.0)	16/53 (30.2%)	40/51 (78.4%)	61%	<0.001
High Risk (PI >4.0)	10/32 (31.2%)	27/33 (81.8%)	62%	<0.001
Overall	31/120 (25.8%)	94/120 (78.3%)	67%	<0.001

Table 5: Fluid and Vasopressor Management

Parameter	Protocol Group (n=120)	Historical Controls (n=120)	P-value
Total IV fluids (mL)	1247 ± 384	943 ± 312	<0.001
Prophylactic vasopressor, n (%)	120 (100)	0 (0)	<0.001
Rescue phenylephrine, n (%)	23 (19.2)	78 (65.0)	<0.001
Total phenylephrine dose (mcg)*	127 ± 45	218 ± 89	<0.001
Norepinephrine requirement, n (%)	8 (6.7)	12 (10.0)	0.37
Protocol adherence, n (%)	114 (95.0)	N/A	N/A

*Among patients requiring rescue therapy

Table 6: Neonatal Outcomes and Maternal Satisfaction

Parameter	Protocol Group (n=120)	Historical Controls (n=120)	P-value
Umbilical arterial pH	7.28 ± 0.06	7.25 ± 0.08	0.001
Umbilical venous pH	7.34 ± 0.05	7.32 ± 0.07	0.008
Neonatal acidosis, n (%)	8 (6.7)	22 (18.3)	0.008
Birth weight (grams)	3127 ± 456	3094 ± 478	0.58
NICU admission, n (%)	6 (5.0)	14 (11.7)	0.07
Maternal satisfaction score	8.7 ± 1.2	7.9 ± 1.8	<0.001

V. Discussion

The present study demonstrated that implementation of a perfusion index-guided fluid and vasopressor management protocol significantly reduced the incidence of spinal anesthesia-induced hypotension in high-risk obstetric patients undergoing cesarean delivery. The 67% relative risk reduction in hypotension incidence, from 78.3% in historical controls to 25.8% with protocol implementation, represents a clinically meaningful improvement that translates into better outcomes for both mothers and neonates. These findings support the concept that perfusion index can be effectively utilized not merely as a predictor, but as a guide for proactive hemodynamic management in obstetric anesthesia (11).

The results of this study align with and extend previous research demonstrating the predictive value of perfusion index for spinal anesthesia-induced hypotension. Toyama and colleagues initially showed that baseline perfusion index could predict hypotension development, while subsequent studies by Duggappa and others confirmed these findings in various populations (12, 13). However, most previous investigations focused primarily on prediction rather than intervention. The current study addresses this gap by demonstrating that perfusion index-guided protocols can translate predictive information into improved clinical outcomes through systematic implementation of risk-stratified management strategies.

The differential effectiveness observed across perfusion index risk categories provides important insights into the physiological basis of the protocol's success. Low-risk patients (PI ≤2.5) achieved the greatest relative benefit, with hypotension rates reduced from an estimated 75% to 14.3%. This finding suggests that patients with lower baseline perfusion index values, indicating higher peripheral vascular tone, respond particularly well to standardized preloading and low-dose prophylactic vasopressor therapy. Conversely, high-risk patients (PI >4.0) still experienced meaningful benefit but had higher absolute hypotension rates, indicating that patients with elevated baseline perfusion index require more aggressive management strategies (14).

The hemodynamic stability achieved with protocol implementation had important implications for maternal comfort and safety. The significant reduction in nausea and vomiting from 55.8% to 15.0% represents a substantial improvement in maternal experience during cesarean delivery. These symptoms, while not life-

threatening, significantly impact patient satisfaction and can interfere with important early bonding experiences between mother and newborn. The protocol's ability to maintain more stable blood pressure throughout the procedure likely contributed to this improvement in maternal comfort (15).

Neonatal outcomes showed statistically significant improvements with protocol implementation, though the clinical significance of these differences requires careful interpretation. The improvement in umbilical arterial pH from 7.25 ± 0.08 to 7.28 ± 0.06, while statistically significant, represents a relatively modest change. However, the reduction in neonatal acidosis incidence from 18.3% to 6.7% is more clinically meaningful and suggests that maintaining maternal hemodynamic stability can have measurable benefits for fetal wellbeing. These findings are consistent with established understanding that maternal hypotension can compromise uteroplacental perfusion and lead to fetal acidosis (16).

The increased fluid administration in the protocol group (1247 ± 384 mL versus 943 ± 312 mL) reflects the proactive approach to volume optimization based on perfusion index risk stratification. This increased fluid use did not result in adverse effects such as pulmonary edema or prolonged recovery, suggesting that the risk-stratified approach successfully identified patients who could benefit from enhanced preloading. The concurrent reduction in rescue vasopressor requirements indicates that the combination of optimized preloading and prophylactic vasopressor infusions provided more effective hemodynamic support than reactive management approaches (17).

Protocol adherence was excellent at 95.0%, indicating that the perfusion index-guided approach was feasible to implement in routine clinical practice. The high adherence rate likely contributed to the protocol's effectiveness and suggests that healthcare providers found the risk stratification system intuitive and practical. The availability of perfusion index measurements on standard pulse oximetry equipment eliminated the need for additional monitoring devices, which may have facilitated protocol adoption (18).

Several limitations of this study warrant consideration. The observational design using historical controls rather than concurrent randomization may have introduced temporal bias and confounding variables that could have influenced the observed outcomes. Changes in clinical practice, staff experience, or equipment over time might have contributed to the differences observed between groups. However, the magnitude of improvement and consistency across multiple outcome measures suggest that the protocol implementation was the primary factor responsible for the observed benefits.

The single-center design may limit generalizability to other institutions with different patient populations, equipment, or clinical practices. The high-risk obstetric population studied may not be representative of lower-risk patients, and the protocol's effectiveness in routine cesarean deliveries remains to be established. Additionally, the study did not include a cost-effectiveness analysis, which would be valuable for healthcare systems considering protocol implementation.

The perfusion index cutoff values used for risk stratification were based on previous literature but may require optimization for different populations or clinical settings. The protocol's effectiveness might be further enhanced through refinement of these thresholds based on larger datasets or through incorporation of additional predictive variables alongside perfusion index measurements (19).

Despite these limitations, the study provides compelling evidence that perfusion index-guided protocols represent a significant advancement in obstetric anesthesia practice. The combination of improved maternal outcomes, enhanced neonatal wellbeing, and high protocol adherence suggests that this approach should be considered for broader clinical implementation. Future research should focus on validating these findings in multicenter studies, optimizing protocol parameters for different patient populations, and developing cost-effectiveness analyses to support healthcare policy decisions (20).

The implications of this study extend beyond immediate clinical outcomes to broader considerations of perioperative care optimization. The successful implementation of a perfusion index-guided protocol demonstrates the potential for incorporating readily available physiological parameters into systematic management approaches that improve patient outcomes. This concept could be extended to other clinical scenarios where predictive monitoring might guide proactive interventions rather than reactive treatments.

VI. Conclusion

Implementation of a perfusion index-guided fluid and vasopressor management protocol resulted in a significant 67% reduction in spinal anesthesia-induced hypotension among high-risk obstetric patients undergoing cesarean delivery. The protocol demonstrated effectiveness across all perfusion index risk categories, with particular benefit observed in patients with lower baseline perfusion index values. Maternal outcomes were improved through enhanced hemodynamic stability and reduced side effects, while neonatal outcomes showed measurable benefits including reduced acidosis incidence and improved APGAR scores.

The high protocol adherence rate of 95% indicates that perfusion index-guided management is feasible for routine clinical implementation using standard monitoring equipment. The proactive approach of risk-

stratified fluid and vasopressor administration proved superior to traditional reactive management strategies, supporting a paradigm shift toward predictive and preventive approaches in obstetric anesthesia.

These findings have important implications for clinical practice, suggesting that perfusion index-guided protocols should be considered for implementation in obstetric anesthesia services caring for high-risk patients. The demonstrated improvements in both maternal and neonatal outcomes, combined with the feasibility of implementation using existing monitoring technology, support the adoption of this evidence-based approach to hemodynamic management during cesarean delivery.

Future research should focus on multicenter validation studies, protocol optimization for different patient populations, and economic evaluations to further establish the role of perfusion index-guided management in obstetric anesthesia practice. The success of this protocol represents an important step toward personalized anesthetic management based on individual patient physiology rather than standardized approaches applied universally.

References

[1]. Bingham AE, Fu R, Horn JL, Abrahams MS. Continuous peripheral nerve block compared with single-injection peripheral nerve block: a systematic review and meta-analysis of randomized controlled trials. Reg Anesth Pain Med. 2012;37(6):583-594.

[2]. Klohr 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(8):909-921.

[3]. Reynolds F, Seed PT. Anaesthesia for Caesarean section and neonatal acid-base status: a meta-analysis. Anaesthesia. 2005;60(7):636-653.

[4]. Carpenter RL, Caplan RA, Brown DL, Stephenson C, Wu R. Incidence and risk factors for side effects of spinal anesthesia. Anesthesiology. 1992;76(6):906-916.

[5]. Lima AP, Beelen P, Bakker J. Use of a peripheral perfusion index derived from the pulse oximetry signal as a noninvasive indicator of perfusion. Crit Care Med. 2002;30(6):1210-1213.

[6]. Toyama S, Kakumoto M, Morioka M, 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(2):235-241.

[7]. Duggappa DR, Lokesh M, 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(8):649-654.

[8]. Ginosar Y, Weiniger CF, Meroz Y, et al. Pulse oximeter perfusion index as an early indicator of sympathectomy after epidural anesthesia. Acta Anaesthesiol Scand. 2009;53(8):1018-1026.

[9]. Bishop DG, Cairns C, Grobbelaar M, Rodseth RN. Heart rate variability as a predictor of hypotension following spinal anaesthesia for elective caesarean delivery: a prospective observational study. Anaesthesia. 2017;72(5):603-608.

[10]. Hasanin A, Amin S, Agiza N, et al. Norepinephrine infusion for preventing post-spinal anesthesia hypotension during cesarean delivery: a randomized dose-finding trial. Anesthesiology. 2019;130(1):55-62.

[11]. Mercier FJ, Bonnet MP, De la Dorie A, et al. Spinal anaesthesia for caesarean section: fluid loading, vasopressors and hypotension. Ann Fr Anesth Reanim. 2007;26(7-8):688-693.

[12]. Varghese RV, Kumar CM, Krishnan S. Perfusion index assessed from a pulse oximeter as a predictor of hypotension during spinal anaesthesia for cesarean section. J Med Sci Clin Res. 2018;6(4):427-431.

[13]. George J, Valiaveedan SS, Thomas MK. Role of perfusion index as a predictor of hypotension during spinal anesthesia for cesarean section: a prospective study. J Med Sci Clin Res. 2019;7(5):1208-1216.

[14]. Yokose M, Mihara T, Sugawara Y, Goto T. The predictive ability of non-invasive haemodynamic parameters for hypotension during cesarean section: a prospective observational study. Anaesthesia. 2015;70(5):555-562.

[15]. Singh PM, Singh NP, Reschke M, Ngan Kee WD. Vasopressor drugs for the prevention and treatment of hypotension during neuraxial anaesthesia for Caesarean delivery: a Bayesian network meta-analysis of fetal and maternal outcomes. Br J Anaesth. 2020;124(3):e95-e107.

[16]. Ngan Kee WD, Lee SW, Ng FF, Tan PE, Khaw KS. Randomized double-blinded comparison of norepinephrine and phenylephrine for maintenance of blood pressure during spinal anesthesia for cesarean delivery. Anesthesiology. 2015;122(4):736-745.

[17]. Doherty A, Ohashi Y, Downey K, Carvalho JC. Phenylephrine infusion versus bolus regimens during cesarean delivery under spinal anesthesia: a double-blind randomized clinical trial to assess hemodynamic changes. Anesth Analg. 2012;115(6):1343-1350.

[18]. Mowafi HA, Ismail SA, Shafi MA, Al-Ghamdi AA. The efficacy of perfusion index as an indicator for intravascular injection of epinephrine-containing epidural test dose in propofol-anesthetized adults. Anesth Analg. 2009;108(2):549-553.

[19]. Cesur M, Alici HA, Erdem AF, Silbir F, Celik M. Administration of crystalloid fluid with a forced-air warming device prevents hypothermia during spinal anesthesia. J Clin Anesth. 2009;21(1):24-29.

[20]. Banerjee A, Stocche RM, Angle P, Halpern SH. Preload or coload for spinal anesthesia for elective Cesarean delivery: a meta-analysis. Can J Anaesth. 2010;57(1):24-31.