International Journal of Public Health Science (IJPHS)
Vol. 15, No. 2, June 2026, pp. 466~473
ISSN: 2252-8806, DOI: 10.11591/ijphs.v15i2.26957

Hemodynamic stabilization in cesarean section patients administered spinal anesthesia: a quasi-experimental study comparing ephedrine and phenylephrine

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Article Info

Article history:

Received Dec 17, 2025
Revised May 2, 2026
Accepted May 22, 2026

Keywords:

Cesarean section
Ephedrine
General anesthesia
Hypotension
Phenylephrine

ABSTRACT

This quasi-experimental research aimed to compare the effects observed following the administration of ephedrine 10 mg and phenylephrine 50 mg administered as therapeutic bolus doses for the management of intraoperative hypotension due to spinal anesthesia in cesarean section. The study involved 60 parturients who developed intraoperative hypotension during spinal anesthesia, who were divided into two groups treated with either phenylephrine or ephedrine. Maternal blood pressure, including systolic and diastolic values, was assessed pre- and post- vasopressor administration and analyzed using descriptive statistics, normality testing, and independent-samples t-tests. Both vasopressors were associated with increased maternal blood pressure following intervention, with no significant differences observed at baseline. However, between-group comparisons revealed statistically significant differences in post-intervention systolic and diastolic blood pressure ($p < 0.05$), indicating distinct hemodynamic response profiles. These findings demonstrate the effectiveness of both ephedrine and phenylephrine in treating hypotension associated with spinal anesthesia; vasopressor selection influences maternal blood pressure outcomes. From a practical perspective, this study provides clinically relevant evidence to inform anesthetic decision-making in maternal healthcare services, particularly in settings where therapeutic bolus administration is routinely utilized for the management of hypotension associated with spinal anesthesia.

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1. INTRODUCTION

A cesarean delivery is a major surgical intervention involving the extraction of the fetus via incision in both the uterus and abdominal wall [1], [2]. When clinically indicated, cesarean section (CS) has a vital role in decreasing the rates of morbidity and mortality among mothers and newborns [3], [4]. Globally, however, the utilization of cesarean delivery has increased beyond the level considered optimal for population health outcomes. The World Health Organization (WHO) reports that the global CS rate has exceeded the recommended threshold of 10–15%, reaching approximately 21% of all births worldwide in 2021 [5]-[7]. Substantial regional variation exists, with particularly high rates in the Americas and Europe, while low- and middle-income countries experience heterogeneous patterns influenced by healthcare access,

system capacity, and clinical practice variations [7], [8]. In Indonesia, national health data indicate that 17.2% of all deliveries were conducted by cesarean section in 2022, with marked interprovincial disparities [9], [10]. In countries classified as low- and middle-income countries, including Indonesia, this increase is also influenced by health financing mechanisms, availability of referral facilities, and institutional delivery practices, which shape cesarean section utilization patterns across regions [11], [12]. This increasing trend highlights the growing importance of ensuring not only access to cesarean delivery but also the safety and quality of perioperative maternal care.

Alongside the rising prevalence of cesarean section, spinal anesthesia is increasingly preferred owing to its quick onset, technical simplicity, cost-efficiency, and better maternal outcomes compared to general anesthesia [13]. Even with its recognized benefits, spinal anesthesia is associated with a high incidence of maternal hypotension, a complication that remains highly prevalent and clinically significant [14], [15]. Spinal anesthesia–induced hypotension occurs primarily due to sympathetic blockade, resulting in systemic vasodilation and reduced venous return, which may compromise maternal hemodynamic stability [16], [17]. From a public health and patient safety perspective, this condition is of particular concern because untreated hypotension can result in maternal symptoms including nausea and vomiting, dizziness, decreased consciousness, cardiovascular collapse, and in severe cases.

More importantly, maternal hypotension during cesarean delivery has implications that extend beyond individual clinical events. Reduced uteroplacental perfusion associated with hypotension may impair fetal oxygen delivery and adversely affect neonatal outcomes [18], [19]. Consequently, strategies for preventing and managing hypotension associated with spinal anesthesia represent a critical component of quality obstetric anesthesia care, particularly in healthcare systems with limited monitoring resources and high surgical workloads. Various preventive and therapeutic strategies have been evaluated, including fluid loading techniques, positional interventions to reduce aortocaval compression, and the administration of vasopressor agents [20], [21].

Among available vasopressors, the management of hypotension in cesarean section under spinal anesthesia most commonly involves the use of phenylephrine and ephedrine [22], [23]. Phenylephrine, a selective α1-adrenergic receptor agonist, is widely recommended for its efficacy in maintaining blood pressure with minimal impact on fetal acid–base status in prophylactic protocols [24], [25]. Ephedrine, which exerts mixed α- and β-adrenergic effects, remains an important alternative, particularly in settings where rapid restoration of blood pressure is required or where phenylephrine availability is limited. However, clinical practice patterns vary considerably, especially in resource-constrained hospitals, where vasopressor selection is often guided by availability, clinician preference, and immediate hemodynamic response rather than standardized protocols.

Despite extensive research on vasopressor use during cesarean section, a clear research gap remains. Most contemporary studies and meta-analyses have focused on randomized controlled trials evaluating prophylactic vasopressor infusion strategies, with outcomes emphasizing neonatal acid–base status and hypotension incidence [26], [27]. In contrast, evidence comparing the therapeutic effectiveness of fixed bolus doses of ephedrine and phenylephrine after hypotension has already occurred, particularly using quasi-experimental designs in real-world clinical settings, remains limited [28]. Furthermore, data from Indonesian hospital contexts are scarce, despite differences in patient characteristics, resource availability, and clinical workflows that may influence vasopressor performance and maternal outcomes.

Therefore, the present study seeks to assess the comparative effectiveness of 10 mg ephedrine versus 50 mg phenylephrine in elevating systolic and diastolic blood pressure in cesarean section patients experiencing hypotension induced by spinal anesthesia using a quasi-experimental design. By focusing on immediate hemodynamic stabilization in routine clinical practice, this study seeks to provide context-specific evidence to support safer maternal care and inform vasopressor selection in obstetric anesthesia, especially in resource-limited settings.

2. METHOD

The research adopted a quasi-experimental, non-equivalent control group approach to compare the therapeutic effects of ephedrine and phenylephrine in addressing hypotension caused by spinal anesthesia during cesarean delivery. The study was conducted between March and April 2023 at a secondary-level public hospital in North Sumatra, Indonesia. Participants were selected using purposive sampling and included women who experienced hypotension in the course of a cesarean section administered spinal anesthesia following an intrathecal block during the study period. A cohort of 60 eligible patients was divided equally into two groups, where 30 patients were treated with 10 mg intravenous ephedrine 10 mg and the remaining 30 patients received 50 mg phenylephrine.

The inclusion criteria comprised cesarean section patients who underwent spinal anesthesia and developed hypotension intraoperatively, while patients who did not experience hypotension after spinal

anesthesia or had incomplete hemodynamic data were excluded from the study. All cesarean section procedures were performed under spinal anesthesia as the standard anesthetic technique. Spinal anesthesia was administered via intrathecal injection to achieve adequate sensory and motor blockade for surgery. Following spinal anesthesia, maternal blood pressure was monitored routinely, and hypotension was managed according to standard clinical practice using therapeutic vasopressor administration. Once hypotension occurred, patients received a standardized intravenous bolus consisting of either ephedrine 10 mg or phenylephrine 50 mg.

Maternal blood pressure, including systolic and diastolic values, was assessed at baseline (pre-test) and after vasopressor administration (post-test). All data were subjected to editing, coding, entry, and cleaning procedures before analysis was conducted. SPSS was utilized for statistical analysis, where participant characteristics were summarized through univariate analysis and group comparisons were performed using either the Mann–Whitney U test or the independent samples t-test based on the distribution of data.

3. RESULTS AND DISCUSSION

A cohort of 60 patients who developed intraoperative hypotension during cesarean delivery, performed administered spinal anesthesia, were enrolled in this research. The participants were allocated into two intervention groups of equal size, with 30 patients receiving 10 mg of ephedrine and the remaining 30 administered 50 mg of phenylephrine. The respondents' sociodemographic profiles, including age, level of education, employment status, and parity, are summarized in Table 1.

As shown in Table 1, most respondents in both groups were aged 20–35 years, with a higher proportion observed in the ephedrine group. Secondary education was the most common educational level in both groups, while the majority of respondents were unemployed. Most participants had two children, followed by those with three or more children. These distributions indicate that the overall sociodemographic profiles of respondents in the two intervention groups were generally similar.

Maternal blood pressure measurements obtained before and after vasopressor administration are summarized in Table 2. Table 2 demonstrates that the average systolic and diastolic blood pressure values increased from pre-test to post-test in both intervention groups. The ephedrine group exhibited an increase in systolic blood pressure from 87.83 mmHg to 98.13 mmHg, whereas the phenylephrine group it increased from 88.03 mmHg to 93.77 mmHg. A similar pattern was observed for diastolic blood pressure, with higher post-test values compared to pre-test values in both groups. These data indicate an increase in maternal blood pressure following vasopressor administration.

Table 1. Respondent characteristics

Characteristics	Category	Ephedrine 10 mg (n = 30)	Phenylephrine 50 mg (n = 30)
Age	20-35 years	26 (86.7%)	21 (70.0%)
	>35 years	4 (13.3%)	9 (30.0%)
Education	Elementary	0 (0%)	6 (20.0%)
	Secondary	22 (73.3%)	17 (56.7%)
	Higher	8 (26.7%)	7 (23.3%)
Employment status	Employed	6 (20.0%)	8 (26.7%)
	unemployed	24 (80.0%)	22 (73.3%)
Number of children	0 child	1 (3.3%)	3 (10.0%)
	1 child	6 (20.0%)	4 (13.3%)
	2 children	15 (50.0%)	14 (46.7%)
	≥3 children	8 (26.7%)	9 (30.0%)

Table 2. Mean blood pressure during pre-test and post-test

Variable	Group	Mean ± standard deviation
Systolic blood pressure (pre-test)	Ephedrine 10 mg	87.83 ± 2.942
	Phenylephrine 50 mg	88.03 ± 3.189
Diastolic blood pressure (pre-test)	Ephedrine 10 mg	59.50 ± 2.354
	Phenylephrine 50 mg	59.63 ± 2.419
Systolic blood pressure (post-test)	Ephedrine 10 mg	98.13 ± 5.043
	Phenylephrine 50 mg	93.77 ± 2.991
Diastolic blood pressure (post-test)	Ephedrine 10 mg	66.97 ± 3.328
	Phenylephrine 50 mg	63.53 ± 2.646

Prior to comparative analysis, the distribution of blood pressure data was assessed using the Kolmogorov–Smirnov normality assessment, as displayed in Table 3. As shown in Table 3, all p-values exceeded 0.05, indicating that pre-test and post-test systolic and diastolic blood pressure data were normally distributed. This result supports the application of parametric statistical tests for group comparisons.

The outcome of the independent samples t-test comparing blood pressure values between the ephedrine and phenylephrine groups is presented in Table 4. According to Table 4, no significant differences were observed in systolic or diastolic blood pressure between the two groups prior to the intervention. In contrast, there were statistically significant differences in systolic and diastolic blood pressure, with lower p-values indicating differences between the ephedrine and phenylephrine groups following vasopressor administration.

Table 3. Normality testing (Kolmogorov-Smirnov)

Variable	p-value
Pre-intervention systolic blood pressure	0.310
Pre-intervention diastolic blood pressure	0.398
Post-intervention systolic blood pressure	0.134
Post-intervention diastolic blood pressure	0.147

Table 4. Independent sample t-test

Variable	t-value	p-value	Interpretation
Pre-intervention systolic blood pressure	-0.264	0.793	No significant
Pre-intervention diastolic blood pressure	-0.158	0.846	No significant
Post-intervention systolic blood pressure	-4.079	0.000	Significant ($p < 0.05$)
Post-intervention diastolic blood pressure	-3.433	0.001	Significant ($p < 0.05$)

The present study demonstrated that both ephedrine 10 mg and phenylephrine 50 mg, administered as therapeutic boluses subsequent to the onset of hypotension associated with spinal anesthesia, were associated with increases in maternal blood pressure. However, significant differences were observed in post-intervention blood pressure outcomes between the groups, as the ephedrine group exhibited larger mean increases than the phenylephrine group. These results build on the descriptive analysis presented in the Results and require physiologic interpretation consistent with established hemodynamic principles.

Post-spinal anesthesia hypotension is predominantly driven by sympathetic blockade, which leads to vasodilation of arterioles and veins, reduced systemic vascular resistance, and decreased venous return. This reduction in preload results in lowered ventricular output and arterial pressure. Vasopressor agents are therefore used to counteract these effects by increasing vascular tone and improving perfusion pressure. Ephedrine exerts mixed α- and β-adrenergic activity: the β-adrenergic component increases heart rate and ventricular output, while the α-adrenergic receptor effect causes peripheral vasoconstriction. Phenylephrine acts as a selective α_1-adrenergic agonist that enhances systemic vascular resistance via vasoconstriction, with negligible direct influence on heart rate and cardiac output. These differing pharmacologic profiles provide a biologic basis for the observed differences in maternal hemodynamic responses in this study.

The findings are consistent with recent clinical evidence from international settings. A randomized controlled trial conducted in Pakistan comparing prophylactic administration of ephedrine and phenylephrine demonstrated that phenylephrine was associated with a significant reduction in the incidence of hypotension and provided more stable systolic blood pressure and mean arterial pressure than ephedrine in cesarean sections conducted under spinal anesthesia, suggesting superior hemodynamic efficacy for phenylephrine in preventing spinal anesthesia–induced hypotension. Although that study focused on prevention, its hemodynamic trends align with the concept that phenylephrine maintains vascular tone effectively.

Similarly, a recent multicenter Indonesian study investigating evidence evaluating prophylactic phenylephrine 100 mcg versus ephedrine 10 mg showed that phenylephrine achieved greater stability in blood pressure and mean arterial pressure in the initial period following spinal anesthesia, supporting the hemodynamic advantage of phenylephrine in maintaining vascular resistance [29]. These findings, while prophylactic in design, reinforce the mechanistic understanding that α-adrenergic–mediated vasoconstriction can lead to sustained blood pressure stability compared with mixed adrenergic agents.

A comparative observational study from Bangladesh examining vasopressor efficacy in emergency cesarean sections reported variations in hemodynamic stability between groups treated with phenylephrine and ephedrine, with phenylephrine showing better maternal blood pressure maintenance in real-world clinical conditions [30]. Although dosing strategies differed, this observational evidence supports the clinical observation that phenylephrine's vasoconstrictive effect contributes to more consistent blood pressure control.

Taken together, these studies suggest a pattern in which both vasopressors effectively increase maternal blood pressure after spinal anesthesia. Phenylephrine's selective α_1-agonism tends to produce more stable systemic vascular resistance, whereas ephedrine's mixed adrenergic activity may result in greater increases in cardiac output that translate to different hemodynamic profiles when administered therapeutically. This pattern is consistent with the present study's data showing differential systolic and diastolic pressure responses.

The clinical relevance of these physiologic differences is underscored by their potential impact on maternal hemodynamics and adverse effects. For example, ephedrine's β-adrenergic stimulation may increase heart rate, which could be beneficial or detrimental depending on baseline maternal cardiovascular status. Phenylephrine's predominant vasoconstrictive effect may lead to reflex bradycardia, a phenomenon documented in other comparative studies. While neonatal outcomes were not the primary focus of the current analysis, existing evidence suggests that robust maintenance of maternal blood pressure with phenylephrine does not compromise neonatal Apgar scores when compared with ephedrine, further supporting its safety profile in obstetric practice.

Despite these insights, the generalizability of findings should be considered in light of study limitations. As a quasi-experimental study performed in a single clinical setting, causal inferences are limited, and variations in clinical practice patterns may affect applicability. Moreover, the focus on blood pressure outcomes without additional hemodynamic parameters such as heart rate or cardiac output limits the granularity of physiologic interpretation.

Nevertheless, the present study contributes to the evolving evidence base by demonstrating differential hemodynamic responses to therapeutic vasopressor boluses. It also situates these findings within a framework supported by recent international research. These insights may inform vasopressor selection in clinical settings where therapeutic bolus administration is the primary approach to managing spinal anesthesia–induced hypotension.

4. CONCLUSION

This present study establishes that both ephedrine 10 mg and phenylephrine 50 mg, when administered as therapeutic bolus doses after the initiation of hypotension associated with spinal anesthesia during cesarean section, were effective in increasing maternal systolic-diastolic blood pressure. However, significant differences in post-intervention blood pressure responses were observed between the two vasopressors, indicating distinct hemodynamic profiles associated with each agent. From a practical perspective, these findings have important implications for anesthetic management in clinical settings, particularly in hospitals where therapeutic bolus administration remains the primary strategy for managing hypotension during spinal anesthesia. The observed differences in blood pressure responses highlight the importance of careful vasopressor selection based on desired hemodynamic effects, patient characteristics, and available resources. The findings reinforce the ongoing use of both ephedrine and phenylephrine as effective therapeutic options, while underscoring that their clinical effects are not interchangeable. The key message of this study is that vasopressor choice influences maternal blood pressure response following spinal anesthesia–induced hypotension, even when administered after hypotension has occurred. This emphasizes the need for clinicians to consider the pharmacologic profile of vasopressors in routine obstetric anesthesia practice, rather than relying solely on institutional habit or availability. Further research is recommended to expand upon these findings. To improve generalizability, future studies should incorporate randomized controlled designs, larger samples, and multicenter settings. In addition, the inclusion of broader hemodynamic parameters, such as heart rate and cardiac output, as well as maternal and neonatal outcomes, would provide a broader perspective on the clinical implications of vasopressor selection in obstetric anesthesia.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Sindu Sintara	✓				✓	✓	✓		✓	✓			✓	
Annes Rindy Permana		✓							✓	✓		✓		
Widigdo Rekso Negoro		✓								✓		✓		
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Reko Priyonggo					✓			✓		✓				
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The datasets contain clinical and demographic information of human participants and are therefore not publicly available to protect patient confidentiality and comply with ethical requirements.

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