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Comparison of Phenylephrine and Ephedrine in Managing Spinal-Induced Hypotension in Lower Segment Caesarean Section (LSCS)

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ABSTRACT

Spinal-induced hypotension is a frequent complication of spinal anesthesia during lower-segment caesarean section and may adversely affect maternal comfort and uteroplacental perfusion. Phenylephrine and ephedrine are commonly used vasopressors, but they differ in their cardiovascular effects. **Objectives:** To compare systolic blood pressure stabilization, heart rate changes, vasopressor dose requirements, and maternal outcomes between phenylephrine and ephedrine. **Methods:** This prospective observational comparative cohort study was conducted at the Department of Anesthesiology, Hazrat Bari Imam Sarkar Medical and Dental College, and Hazrat Bari Imam Sarkar Teaching Hospital, Islamabad. Two hundred parturient who developed spinal-induced hypotension were enrolled (100 received phenylephrine and 100 ephedrine). Hemodynamic parameters were recorded at baseline and at 3 and 6 minutes after vasopressor administration. Data were analyzed using an independent-samples t-test, a Mann–Whitney U test, and a Chi-square test. **Results:** Phenylephrine maintained significantly higher systolic blood pressure at 3 minutes (p=0.008). Ephedrine was associated with significantly higher pulse and heart rate (p=0.003 and p=0.004). Bradycardia was more frequent with phenylephrine (p=0.001), while tachycardia and higher repeat-dose requirements were more common with ephedrine (p=0.025 and p=0.017). Duration of hypotension was significantly shorter with phenylephrine (p=0.003). **Conclusions:** Both vasopressors effectively managed spinal-induced hypotension; however, phenylephrine provided more stable systolic control and faster recovery, whereas ephedrine caused greater heart rate variability.

INTRODUCTION

Spinal anesthesia is the preferred technique for lower-segment caesarean section because it provides a rapid onset of dense sensory and motor block, excellent postoperative analgesia, and a more favorable safety profile compared with general anesthesia [1]. Despite these advantages, spinal-induced hypotension remains a frequent and clinically significant complication, with reported incidence ranging from 60% to 80% in untreated patients [2]. The sudden reduction in systemic vascular resistance following sympathetic blockade may lead to maternal nausea, vomiting, dizziness, and, in severe cases, compromised uteroplacental perfusion and fetal well-being [3, 4]. To prevent and treat spinal-induced hypotension, vasopressors are routinely administered during caesarean delivery. Phenylephrine and ephedrine are the two most commonly used agents worldwide [5]. Phenylephrine is a selective α-adrenergic agonist that increases vascular tone and arterial pressure primarily

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through vasoconstriction, whereas ephedrine has mixed α- and β-adrenergic activity, resulting in increases in both blood pressure and heart rate [6, 7]. Ephedrine, by contrast, is both an alpha and beta agonist, thereby increasing both heart rate and blood pressure [8]. These pharmacological differences produce distinct hemodynamic profiles that may influence maternal cardiovascular stability and fetal outcomes. Previous studies comparing phenylephrine and ephedrine have reported variable findings. Some investigations suggest that phenylephrine provides more consistent systolic blood pressure control with fewer fetal metabolic effects, while others favor ephedrine for reducing the incidence of reflex bradycardia [9, 10].

However, discrepancies in study design, dosing regimens, and patient populations have resulted in continued variation in clinical practice, particularly in resource-limited settings. This study aimed to compare the hemodynamic responses and maternal outcomes associated with phenylephrine and ephedrine in parturient who developed spinal-induced hypotension during elective caesarean section, with specific emphasis on blood pressure trends, heart rate changes, vasopressor dose requirements, duration of hypotension, and maternal recovery outcomes.

METHODS

This study was conducted as a prospective observational comparative cohort study to evaluate the hemodynamic effects of phenylephrine and ephedrine in parturient developing spinal-induced hypotension during lower-segment caesarean section (LSCS). The study was carried out at the Department of Anesthesiology, Hazrat Bari Imam Sarkar Medical and Dental College, and Hazrat Bari Imam Sarkar (HBS) Teaching Hospital, Islamabad, Pakistan. Ethical approval was obtained from the Institutional Review Board of Hazrat Bari Imam Sarkar Medical and Dental College, Islamabad (Approval No. Appl #HBS/IRB/25/25). The study was conducted over a period of three months from July to October 2025. The required sample size was calculated before study initiation to ensure adequate statistical power. A difference in systolic blood pressure between the two vasopressor groups was taken as the primary outcome variable. The following formula for comparison of two independent means was used: $n = 2(Z_{\alpha/2} + Z_{\beta})^2 \times \sigma^2 / d^2$. Where: $Z_{\alpha/2} = 1.96$ (for 95% confidence), $Z_{\beta} = 0.84$ (for 80% power), $\sigma = 6.5$ mmHg (standard deviation of systolic blood pressure obtained from the study by Ngan *et al.* Anesthesiology [11],], d= minimum clinically significant difference. Based on this calculation, the minimum required sample size was 172 participants. To account for possible incomplete data, a final sample size of 200 parturient (100 per group) was enrolled. A purposive sampling technique was employed. All eligible women who developed spinal-induced hypotension during LSCS and required vasopressor therapy were consecutively included. Written informed consent was taken. This technique was selected because the study targeted a specific clinical subgroup, and randomization was not ethically feasible as vasopressor selection followed routine anaesthetic practice. Purposive sampling ensured that only clinically relevant cases were included while maintaining the observational nature of the study. The inclusion criteria comprised women aged 18–45 years with singleton pregnancies undergoing elective lower-segment caesarean section under spinal anesthesia and classified as ASA physical status I or II. Spinal-induced hypotension was defined as a systolic blood pressure of <90 mmHg or a ≥20% reduction from baseline values. Patients with chronic hypertension, pre-eclampsia, underlying cardiac disease, arrhythmias, or multiple gestations were excluded. Baseline variables, including age, weight, height, body mass index, parity, and ASA status, were recorded. Blood pressure and heart rate were measured before spinal anesthesia, at the onset of hypotension, and at 3- and 6-minutes following vasopressor administration. Dose requirements, the incidence of bradycardia and tachycardia, and the duration of hypotension were documented. To ensure measurement reliability, all patients were monitored using calibrated automated blood pressure devices, and heart rate was cross-checked using electrocardiographic monitoring. Data collectors received standardized training and supervision, and all entries were verified prior to data entry into SPSS. Data were analyzed using SPSS version 22.0. Normality of continuous variables was assessed using the Shapiro–Wilk test. Age, weight, and height demonstrated normal distribution and were summarized as mean ± standard deviation and compared using an independent-samples t-test. All baseline hemodynamic variables and maternal outcome variables showed non-normal distribution and were analyzed using Mann–Whitney U test. Categorical variables were analyzed using the chi-square test. A p-value≤0.05 was considered statistically significant. Normality testing was performed using the SPSS Explore procedure. Shapiro–Wilk test results demonstrated that age, weight, and height were normally distributed ($p>0.05$), while baseline hemodynamic and maternal outcome variables were non-normally distributed ($p<0.05$).

RESULTS

Baseline demographic and clinical variables were statistically comparable between the two groups. Normality of continuous variables was assessed using the Shapiro–Wilk test before inferential analysis. Shapiro–Wilk

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normality testing showed that age, weight, and height were normally distributed (p>0.05), whereas maternal outcome variables and baseline hemodynamic parameters demonstrated non-normal distribution (p<0.05). An independent-samples t-test demonstrated no significant differences in age, weight, and height. Mann-Whitney U test revealed no significant differences in BMI and all baseline hemodynamic parameters (SBP, DBP, MAP, pulse rate, and heart rate). Parity and ASA classification were similarly distributed between the groups (p>0.05 for all), confirming baseline equivalence before vasopressor administration (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Variables	Phenylephrine (n=100)	Ephedrine (n=100)	p-value	Test
Age (Years)	26.01 ± 5.28	25.94 ± 4.58	0.920[a]	t-test[a]
Weight (kg)	67.78 ± 6.22	67.49 ± 8.73	0.790[a]	t-test[a]
Height (cm)	163.04 ± 8.43	165.01 ± 10.81	0.153[a]	t-test[a]
BMI	25.53 ± 1.89	25.09 ± 4.60	0.087[b]	Mann-Whitney[b]
Baseline SBP (mmHg)	119.81 ± 7.34	119.30 ± 7.88	0.522	Mann-Whitney[b]
Baseline DBP (mmHg)	78.00 ± 6.85	77.77 ± 7.22	0.929	Mann-Whitney[b]
Baseline MAP (mmHg)	91.94 ± 6.39	91.61 ± 6.94	0.799	Mann-Whitney[b]
Baseline Pulse (bpm)	95.66 ± 12.38	95.03 ± 14.26	0.793	Mann-Whitney[b]
Baseline Heart Rate (bpm)	97.19 ± 12.34	96.53 ± 14.24	0.786	Mann-Whitney[b]
Primiparous	49 (49%)	57 (57%)	0.257	χ^{2c}
ASA I	57 (57%)	59 (59%)	0.774	χ^{2c}

[a]Independent samples t-test, [b]Mann-Whitney U test, [c]Chi-square test, Significance set at p≤0.05

At the onset of hypotension and at 6 minutes, there were no significant differences in systolic, diastolic, or mean arterial pressure between groups (p>0.017). At 3 minutes, systolic blood pressure was significantly higher in the phenylephrine group (U=3922, p=0.008). Pulse rate and heart rate were significantly higher in the ephedrine group at 3 minutes (p=0.003 and p=0.004, respectively). No significant between-group differences were observed at 6 minutes (Table 2).

Table 2: Comparison of Hemodynamic Parameters Between Phenylephrine and Ephedrine Groups at Different Time Intervals After Spinal Anesthesia

Variables	Time	Phenylephrine	Ephedrine	U	p-value
Systolic BP (mmHg)	After Spinal	92.85 ± 6.45	92.38 ± 6.71	4738	0.522
	3 Min	88.88 ± 5.41	86.85 ± 4.51	3922	0.008*
	6 Min	92.30 ± 4.09	90.97 ± 5.17	4325	0.098
Diastolic BP (mmHg)	After Spinal	68.07 ± 6.29	68.02 ± 6.61	4945	0.893
	3 Min	65.63 ± 6.52	65.41 ± 6.67	4992	0.984
	6 Min	67.12 ± 6.44	66.78 ± 6.93	4945	0.893
MAP (mmHg)	After Spinal	76.33 ± 5.70	76.14 ± 6.17	4906	0.818
	3 Min	73.40 ± 4.82	72.54 ± 4.81	4547	0.267
	6 Min	75.54 ± 4.61	74.85 ± 4.99	4565	0.287
Pulse (bpm)	After Spinal	79.70 ± 13.37	81.40 ± 14.45	4553	0.275
	3 Min	74.81 ± 25.52	85.22 ± 27.71	3792	0.003*
	6 Min	77.20 ± 14.42	80.44 ± 17.08	4465	0.191
Heart Rate (bpm)	After Spinal	80.90 ± 13.39	82.53 ± 14.51	4574	0.298
	3 Min	76.35 ± 25.31	86.66 ± 27.78	3813	0.004*
	6 Min	78.32 ± 14.43	81.43 ± 17.05	4495	0.217

Mann-Whitney U test. *Significant at Bonferroni-adjusted p ≤ 0.017.

The incidence of bradycardia was significantly higher in the phenylephrine group compared with the ephedrine group (χ^2 = 10.602, p=0.001). Conversely, tachycardia occurred more frequently among women receiving ephedrine (χ^2 = 5.007, p=0.025). The distribution of total repeat-dose requirements also differed significantly between groups, with a greater proportion of women in the ephedrine group requiring additional doses for hemodynamic stabilization (χ^2 = 5.704, p=0.017) (Table 3).

Table 3: Comparison of Maternal Bradycardia, Tachycardia and Vasopressor Dose Requirements

Variables	Category	Phenylephrine (n=100)	Ephedrine (n=100)	χ^2	p-value	Cramer's V
Bradycardia	Yes	40 (40%)	19 (19%)	10.602	0.001*	0.230
	No	60 (60%)	81 (81%)			
Tachycardia	Yes	15 (15%)	28 (28%)	5.007	0.025*	0.158
	No	85 (85%)	72 (72%)			
Total Doses Required	1 dose	42 (42%)	26 (26%)	5.704	0.017*	0.169
	2-3 Doses	58 (58%)	74 (74%)			

Chi-square test. *p ≤ 0.05 indicates statistical significance.

The duration of hypotension was significantly shorter in the phenylephrine group compared with the ephedrine group (U=3861.5, p=0.003). Delivery duration and total length of hospital stay did not differ significantly between groups (p>0.05) (Table 4).

Table 4: Comparison of Maternal Outcomes Between Phenylephrine and Ephedrine Groups

Outcomes	Phenylephrine (n=100)	Ephedrine (n=100)	U	p-value
Duration of Hypotension (min)	4.89 ± 2.12	5.79 ± 2.14	3861.5	0.003*
Delivery Duration (min)	65.35 ± 19.58	68.05 ± 21.31	4578.0	0.302
Total Hospital Stay (Days)	2.85 ± 1.45	3.05 ± 1.46	4613.5	0.335

Mann-Whitney U test. *p ≤ 0.05 indicates statistical significance.

Phenylephrine maintained significantly higher systolic blood pressure at 3 minutes (p = 0.008), while no significant differences were observed at baseline and at 6 minutes (Figure 1).

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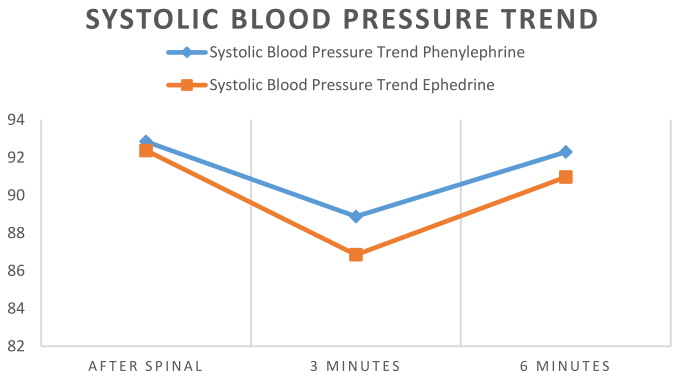

Figure 1: Trend of Systolic Blood Pressure After Spinal Anesthesia and Vasopressor Administration in Phenylephrine and Ephedrine Groups

DISCUSSION

This study compared the hemodynamic effects of phenylephrine and ephedrine in women who developed spinal-induced hypotension during lower-segment caesarean section. Baseline demographic and clinical comparability between the two groups allowed for an unbiased assessment of treatment effects. There were no statistically significant differences in age, body mass index, obstetric history, or ASA physical status. Both cohorts entered surgery with comparable systolic and diastolic blood pressure values and similar baseline heart rates, strengthening the validity of the comparative analysis. A distinct difference emerged following vasopressor administration. Phenylephrine more effectively maintained systolic blood pressure at the 3- and 6-minute intervals and exhibited a more stable hemodynamic profile than ephedrine. These findings are consistent with previous randomized and observational studies reporting superior systolic blood pressure stability with phenylephrine during caesarean delivery under spinal anesthesia [12, 13]. Similar results have been reported in tertiary centers across Asia, where phenylephrine was associated with more rapid recovery of blood pressure and minimal fluctuation in systolic values [14, 15]. Furthermore, a network meta-analysis ranked phenylephrine among the safest vasopressors for managing spinal-induced hypotension in parturient without cardiac comorbidities [16]. Ephedrine demonstrated a more pronounced chronotropic effect. Women receiving ephedrine showed significantly higher pulse and heart rates at three minutes, consistent with its mixed α- and β-adrenergic agonist activity. These findings align with recent randomized controlled trials that reported increased maternal heart rates following ephedrine administration [17, 18]. Consequently, ephedrine may be less suitable for patients who are tachycardic or have limited cardiac reserve. Bradycardia occurred more frequently in the phenylephrine group, whereas tachycardia was more prevalent in the ephedrine group. This distribution mirrors recent systematic reviews indicating that pure α-agonists enhance vagal tone, while ephedrine produces stronger cardiac stimulation [19]. Although both adverse effects were clinically manageable, these findings provide useful guidance for tailoring vasopressor selection according to individual hemodynamic profiles. Patients receiving phenylephrine required fewer repeat doses, while a higher proportion of women in the ephedrine group required three doses to achieve hemodynamic stability. Previous comparative studies have shown that ephedrine has a slower onset and shorter duration of action, necessitating more frequent dosing [20]. The significant chi-square results in this study support this observation and suggest a clinically relevant difference in drug utilization and workload. There were no significant differences in delivery duration or length of hospital stay between the two groups. However, the significantly shorter duration of hypotension observed in the phenylephrine group is clinically meaningful. Rapid correction of hypotension has been associated with reduced intraoperative discomfort and a lower incidence of nausea and dizziness [21]. Although fetal outcomes were not evaluated in this study, emerging international evidence supports phenylephrine for improved fetal acid–base balance, particularly during prolonged hypotension. Overall, these findings support the growing body of evidence recommending phenylephrine as the first-line vasopressor for treating spinal-induced hypotension during caesarean delivery. The consistency of results across multiple regions further strengthens the generalizability of these findings.

This was a single-center study with a relatively small sample size, which may limit the generalizability of the findings. In addition, neonatal outcomes and fetal acid–base status were not assessed, restricting evaluation of fetal effects. Future multicentre randomized studies incorporating neonatal outcomes are recommended to further define the optimal vasopressor for spinal-induced hypotension during caesarean delivery.

CONCLUSIONS

Both phenylephrine and ephedrine are effective for managing spinal-induced hypotension during caesarean delivery. However, phenylephrine provides superior systolic blood pressure stability, requires fewer repeat doses, and is associated with a shorter duration of hypotension. Ephedrine, while effective, produces greater heart rate responses and necessitates more frequent dosing. These findings, supported by contemporary international literature, suggest that phenylephrine offers a more predictable hemodynamic profile for routine obstetric anesthesia. Nevertheless, vasopressor selection should be individualized, particularly in patients with susceptibility to bradycardia or tachycardia.

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Authors' Contribution

Conceptualization: SKJ
Methodology: UJ, AS
Formal analysis: WA[1], WA[2]
Writing and drafting: MS, SKJ, UJ, AS, WA[1], WA[2], ZR
Review and editing: MS, SKJ, UJ, AS, WA[1], WA[2], ZR

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

All the authors declare no conflict of interest.

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