RESEAERCH PAPER

Comparative Evaluation Of Phenylephrine Infusion And Intravenous For Spinal-Induced Hypotension In Elective Caesarean Delivery

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ABSTRACT

Background & Aim: Spinal anaesthesia is the preferred technique for elective cesarean sections, though maternal hypotension remains a frequent cardiovascular challenge. While phenylephrine is the gold-standard vasopressor, the most effective delivery method is still debated. This study compared two commonly practiced prophylactic phenylephrine strategies continuous infusion and intermittent bolus administration for prevention of spinal-induced hypotension during elective caesarean delivery.

Methods: In this randomized, open-label trial, 70 ASA II parturients (aged 18-40) undergoing planned caesarean delivery were divided into two cohorts. Group A (n=35) received a prophylactic phenylephrine infusion at 0.15 µg/kg/min immediately post-subarachnoid block. Group B (n=35) received an initial 50 µg bolus. Supplemental rescue doses (30µg) were administered if Mean Arterial Pressure (MAP) fell >20% from baseline. Outcomes included hemodynamic stability, total vasopressor consumption, maternal side effects, and neonatal Apgar scores.

Results: Baseline demographics, surgical duration, and block characteristics were comparable across groups. Group A was associated with improved hemodynamic stability during the critical early post-spinal phase, maintaining higher blood pressure and more controlled heart rates. Notably, 100% of Group A required no rescue vasopressors, whereas most patients in Group B needed supplemental doses. Neonatal outcomes were uniform, though Group A exhibited higher incidences of reflex bradycardia and reactive hypertension. Conversely, Group B experienced more frequent maternal nausea.

Conclusion: Prophylactic phenylephrine infusion was associated with improved prevention of spinal-induced hypotension compared with intermittent bolus dosing in elective caesarean sections. However, this enhanced haemodynamic control is linked to a greater frequency of vasopressor-related physiological responses, such as reflex bradycardia.

Keywords: Anaesthesia Obstetrical; Anaesthesia spinal; Hypotension; Infusions; Intravenous; Phenylephrine

How to site this article : Sakshi, Anita Kumari, Arvinder Pal Singh, Ruchi Gupta, Suneetpal Kaur, "Comparative Evaluation Of Phenylephrine Infusion And Intravenous For Spinal-Induced Hypotension In Elective Caesarean Delivery"Int J Drug Deliv Technol. 2026;16(69s):824--832. DOI: 10.25258/ijddt.16.69s.83.

DOI : xxx

INTRODUCTION

Lower Segment Caesarean Section (LSCS) represents one of the most common surgical interventions in parturients of reproductive age. Spinal anaesthesia remains the preferred clinical protocol for elective caesarean delivery owing to its reliability, rapid onset, and the avoidance of risks inherent to general anaesthesia.[1] This neuraxial technique ensures superior postoperative analgesia, mitigates maternal airway-related morbidity, minimises transplacental fetal exposure to anaesthetic agents, and notable reduction in surgical blood volume loss.[1-2]

A significant complication of spinal anaesthesia is maternal hypotension, primarily resulting from pre-ganglionic sympathetic blockade and exacerbated by aortocaval compression from the gravid uterus. In the absence of timely prophylaxis or intervention, this haemodynamic instability can manifest in maternal

morbidity, including nausea, emesis, vertigo, and impaired consciousness. Furthermore, diminished uteroplacental perfusion may adversely affect fetal acid-base status and overall well-being. Consequently, the preservation of haemodynamic stability remains a fundamental objective in obstetric anaesthesia during caesarean delivery. [3-4]

Phenylephrine is currently established as the gold-standard vasopressor for the prophylaxis and management of spinal-induced hypotension, owing to its rapid onset, predictable alpha-adrenergic vasoconstrictive profile, and superior neonatal acid-base outcomes. Despite its clinical prevalence, the optimal prophylactic administration regimen remains a subject of investigation. Continuous intravenous infusion is hypothesised to ensure more consistent haemodynamic stability, whereas intermittent bolus dosing provides clinical flexibility and ease of titration in specific operative environments. Both modalities present distinct advantages and constraints; therefore, a superior strategy must prioritise maternal haemodynamic preservation while mitigating dose-dependent adverse effects, such as reflex bradycardia.[6-7]

Maintaining arterial pressure during elective caesarean section is vital for both maternal safety and fetal perfusion. Despite substantial evidence supporting phenylephrine prophylaxis, variability persists regarding the optimal administration strategy in routine clinical practice, particularly in resource-variable settings. The present study was undertaken to evaluate the haemodynamic performance and maternal adverse-effect profile of two commonly used prophylactic regimens in our institutional setting.

MATERIALS AND METHODS

The present prospective, randomised, open-label, comparative intervention was conducted in the Department of Anaesthesia at a tertiary Healthcare Institute between July 2024 and December 2025. Ethical approval was obtained from the Institutional Ethics Committee (SGRD/IEC/2024-312) prior to study initiation. The trial adhered strictly to the principles of the Declaration of Helsinki and was formally registered with the Clinical Trials Registry (CTRI/2025/01/079107). Following a comprehensive explanation of the clinical protocol, all participants provided voluntary, written informed consent in their primary vernacular language.

A total of 70 patients, aged 18 to 40, were enrolled in the current study by convenient sampling technique. All participants were categorized as ASA Physical Status II and were scheduled for elective lower segment caesarean sections (LSCS). The surgical procedures were performed under subarachnoid block to ensure standardized anaesthetic conditions. We established strict exclusion parameters to safeguard the study's results. Patients did not qualify for participation if they had spinal deformities that could interfere with the block or any medical contraindication to spinal anaesthesia. Additionally, those presenting in a state of clinical shock were disqualified to prevent interference with the assessment of phenylephrine efficacy. Additional exclusion parameters included localized infections at the injection site and pre-existing neurological deficits. Furthermore, to ensure the homogeneity of the hemodynamic data, we omitted patients diagnosed with chronic hypertensive disorders or pregnancy-induced hypertension (PIH), as these conditions could skew the vasopressor response. Additional exclusion parameters included known hypersensitivity to the study medications, coagulopathy, bleeding diathesis, pre-existing cardiovascular or cerebrovascular disease, and suspected fetal congenital abnormalities.

Randomisation and Allocation: Patients were allocated into two equal cohorts (n=35 per group) using a computer-generated randomisation sequence. To ensure concealment, allocation was managed via sealed, opaque envelopes. The assigned group was disclosed only to the attending anaesthesiologist responsible for drug preparation, thereby maintaining the integrity of the study design.

Interventions: Following a comprehensive pre-anaesthetic assessment and review of baseline laboratory investigations, all patients adhered to a mandatory 6-hour fasting period. A large-bore peripheral line (18G or 20G) was inserted for each participant to ensure reliable intravenous access throughout the surgical intervention. Haemodynamic optimization was achieved through fluid co-loading with Ringer's lactate or 0.9% normal saline, after which baseline, physiological parameters were documented.

Anaesthetic Technique: The subarachnoid block was performed with the patient situated in the left lateral position, ensuring appropriate spinal curvature for the anaesthetic procedure. Under aseptic conditions, we identified the L3-L4 lumbar interval and proceeded with the spinal puncture using a 26G Quincke-type needle. Following the confirmation of CSF backflow, a 2.4 mL dose of 0.5% hyperbaric bupivacaine was administered. Patients were immediately repositioned supine to facilitate the establishment of the spinal blockade.

Group A (Infusion Cohort): Post-spinal induction, a fixed-rate intravenous infusion of phenylephrine (0.15 µg/kg/min) was administered as a preventative measure against maternal hypotension.

Group B (Bolus Cohort): Immediately after the subarachnoid block was established, parturients were administered a single prophylactic intravenous bolus of 50µg phenylephrine.

The dosing regimens used in the present study were selected based on previously published obstetric anaesthesia studies employing prophylactic phenylephrine infusion rates between 0.1–0.25 µg/kg/min and intermittent bolus doses ranging from 30–100 µg for prevention of spinal-induced

hypotension during caesarean delivery.[4,9,12,15] The study was designed to compare two clinically practiced prophylactic approaches rather than dose-equivalent phenylephrine exposure protocols.

In both groups, a rescue intravenous of phenylephrine 30µg was given if mean arterial pressure decreased by more than 20% from baseline.

Primary and Secondary Outcomes: The primary goal was to compare the efficacy of this continuous infusion against intermittent bolus dosing in maintaining hemodynamic stability. Secondary outcomes included maternal bradycardia, hypotension, and neonatal Apgar scores at 1 and 5 minutes.

Monitoring and Block Assessment: Vital signs, including heart rate, arterial pressure, respiratory rate, and peripheral oxygen saturation, were recorded every 2 minutes for the first 10 minutes, then at 5-minute intervals until the end of surgery. We assessed the cranial spread of sensory anaesthesia using the pin-prick technique at 1-minute intervals until the maximum dermatomal height was reached. The degree of motor impairment was determined using the modified Bromage scale

Management of Adverse Events: Adverse clinical events were managed through targeted pharmacological and supportive interventions. Maternal emesis was treated with weight-adjusted doses of ondansetron, while respiratory compromise was mitigated using 5 L/min of oxygen therapy. Cardiovascular stability was maintained by administering atropine for bradycardia and promptly halting phenylephrine delivery should hypertensive spikes occur.

Postoperative Surveillance: Post-surgical surveillance began with high-frequency monitoring in the PACU, where patients were evaluated every 15 minutes for one hour. This was followed by a structured 24-hour observation period in the obstetric unit, with assessments occurring at 0, 2, 4, 8, 12, and 24 hours to track the patients' recovery trajectory and ensure sustained stability.

Statistical analysis: Data analysis was conducted by first tabulating results in Excel, followed by rigorous statistical testing. For continuous data, the mean and standard deviation were calculated, with inter-group differences assessed via Student's t-tests. Categorical trends were identified using percentages and the Pearson chi-square method. Results were considered statistically meaningful only when the p-value fell below the 0.05 benchmark.

RESULTS

As illustrated in the baseline data (Table 1), the two study groups exhibited high homogeneity,

Group A participants had a mean age of 28.86±4.19 years, weight of 70.11±7.17 kg, and height of 5.17±0.17 ft. In comparison, Group B showed similar metrics with an average age of 27.74±3.17, a mean weight of 71.57±6.42 kg, and a mean height of 5.21±0.16 ft. These figures indicate that the groups were well-balanced for the duration of the trial. Baseline hemodynamic and respiratory variables were also comparable, including pulse rate (82.66± 7.12 bpm vs 83.40±6.90 bpm), systolic blood pressure (110.46±7.61 mmHg vs 113.14 ± 9.60 mmHg), diastolic blood pressure (71.37±6.65 mmHg vs 71.60±7.60 mmHg), mean arterial pressure (84.40±6.14 mmHg vs 85.45±7.65 mmHg), respiratory rate (17.49± 1.95/min vs 18.17±1.82/min), and SpO_2 (99.43±0.98% vs 99.23±0.81%). These findings confirm strong baseline homogeneity between the two groups and support the validity of subsequent comparative analysis.

As detailed in Table 2, there were no clinically significant differences between the two study groups regarding surgical duration, sensory/motor block characteristics, or early neonatal metrics. These findings suggest that both administration regimens are equally effective concerning procedural efficiency and immediate newborn outcomes. The operating time for Group A was 92.86±12.56 minutes, compared to 89.29±12.67 minutes for Group B (p=0.240). Similarly, the initiation of the sensory block occurred at 2.80±0.87 minutes and 2.49±0.70 minutes, respectively (p=0.100). The time to attain the maximum sensory level was also similar, at 3.80 ± 0.87 minutes in Group A and 3.51 ± 0.74 minutes in Group B (p=0.143), with parallel findings for onset of motor block and achievement of Bromage grade 3 (3.80 ± 0.87 vs 3.51 ± 0.74 minutes and 4.80 ± 0.87 vs 4.51 ± 0.74 minutes, respectively; p=0.143 for both). Respiratory metrics, including breathing rate and oxygen saturation, stayed stable and virtually identical in both study arms. With SpO_2 levels consistently staying above 99%, the results demonstrate that respiratory integrity was well-preserved throughout the procedural period. The results suggest that the protocol used for Group A offered improved cardiovascular control in the early stages of the procedure. Crucially, this benefit did not come at the cost of maternal recovery or neonatal well-being, both of which remained optimal across the study. Neonatal outcomes remained reassuring and statistically comparable, with Apgar scores at 1 minute (7.69±0.72 vs 7.71±0.83, p=0.878) and 5 minutes (9.80±0.41 vs 9.69±0.47, p=0.281) showing no difference, as did neonatal heart rate (139.49±9.00 bpm vs 138.17±8.70 bpm, p=0.537). The evidence highlights a clinical equivalence between both phenylephrine protocols, each maintaining robust surgical stability and neonatal well-being with no statistically significant variance (Table 2).

Data from Figure 1 highlights that while postoperative recovery was uniform across both groups, Group A demonstrated improved maintenance of haemodynamic parameters during the early post-spinal period. Specifically, Group A maintained lower heart rates and significantly higher Mean Arterial Pressure (MAP) at the 15-minute mark, reflecting a

more controlled response to spinal anaesthesia. As time progressed, these physiological parameters converged, resulting in nearly identical hemodynamic profiles during the late postoperative phase.

The table 3 shows a clear difference in vasopressor requirement and side-effect profile between the two groups. All patients in Group A required no rescue dose, whereas only 8 patients in Group B remained free of rescue medication; the remaining patients in Group B needed one, two, or three additional rescue doses, indicating less stable hemodynamic control in that group.

Among adverse events, nausea occurred only in Group B, while vomiting and headache were infrequent and similar between groups. In contrast, reactive hypertension and reflex bradycardia were seen only in Group A, suggesting that continuous phenylephrine was associated with greater vasopressor-related side effects. While respiratory integrity was perfectly preserved across both groups, the protocols yielded contrasting clinical profiles. Group A excelled in preventing hypotension, though at the expense of increased bradycardia and hypertensive episodes. Conversely, Group B demonstrated a higher dependency on rescue support and was more frequently associated with maternal nausea, highlighting the differing clinical challenges of each strategy.

DISCUSSION

Spinal anaesthesia is the preferred technique for elective obstetric surgery, offering the dual benefits of dependable surgical conditions and improved recovery. By mitigating blood loss and avoiding general anaesthesia's respiratory risks, it ensures a safer perioperative environment for the parturient. The most significant constraint of spinal anaesthesia is acute hypotension, arising from sympathetic inhibition and uterine-induced aortocaval compression. Left unmanaged, this can impair maternal well-being and jeopardize vital uteroplacental blood flow. The present randomized study, phenylephrine infusion provided more stable early hemodynamics than a single intravenous, with fewer rescue doses and comparable neonatal outcomes, validating its efficacy as a more consistent strategy for proactive management.[8]

Baseline comparability between the cohorts validates the randomization protocol and ensures that potential confounding variables are minimized, strengthening the internal validity of the findings. Similarities in surgical duration and block profiles indicate that the hemodynamic differences were specifically driven by the vasopressor strategy rather than external procedural influences. This strengthens the internal validity of the study and aligns with earlier work by Kannan et al.[1], Choudhary and Bajaj,[4] and Singh et al.[9], who also reported balanced baseline characteristics across treatment arms.

The present findings suggest that prophylactic phenylephrine infusion was associated with more consistent haemodynamic control during the early post-spinal period compared with intermittent bolus administration. Maternal hemodynamics in Group A remained significantly more robust during the early post-spinal period, whereas Group B demonstrated a more severe reduction across all arterial pressure parameters. This pattern is consistent with the observations of Choudhary and Bajaj,[4]; Singh et al.[9]; Buthelezi et al.[10] all of whom reported better preservation of blood pressure with infusion-based prophylaxis than with intermittent intravenous dosing. The larger early variability in Group B likely reflects the transient nature of intravenous pharmacokinetics, whereas continuous infusion offers steadier α-adrenergic support during the period of maximal sympathectomy.

Heart rate findings also favoured infusion for hemodynamic control, although the pattern was expected from the pharmacology of phenylephrine. Group A showed a lower intraoperative heart rate than Group B, particularly during the early post-spinal phase (Figure 1). This is in keeping with the reflex bradycardia described by Habib,[11]; Ngan Kee et al.[12]; Buthelezi et al.[10] and Choudhary and Bajaj,[4] where phenylephrine infusion effectively prevented hypotension but increased baroreceptor-mediated slowing of the pulse. The mechanism is well established: α1-mediated vasoconstriction raises arterial pressure, triggering vagal activation and a reduction in heart rate. Despite these findings, maternal stability was maintained, and neonatal health remained uncompromised throughout the study period.

Ultimately, the minimal need for rescue support serves as a key indicator of the infusion strategy's more robust and predictable performance. All patients in Group A remained free of rescue intravenous es, whereas most patients in Group B required one or more rescue doses, demonstrating the limited durability of a single prophylactic intravenous (Table 3). These results align with the meta-analytic data previously reported by Garg et al.[13] and Sharkey et al.[14] and with the randomized studies of Doherty et al.[15] which showed that infusion reduces the incidence and severity of spinal Anaesthesia -induced hypotension more effectively than intravenous regimens. Although intravenous may be simpler to administer, it appears less dependable for maintaining blood pressure throughout the vulnerable predelivery interval. Unlike dose-equivalent pharmacodynamic investigations, the present study aimed to reflect pragmatic clinical practice patterns in which continuous infusion and intermittent bolus regimens are commonly administered using institutionally accepted protocols. Therefore, the findings primarily represent comparative clinical effectiveness rather than isolated pharmacological equivalence. Nevertheless, the possibility that improved

haemodynamic stability in the infusion group may partly reflect greater cumulative phenylephrine exposure should be acknowledged when interpreting the results.

Respiratory rate and oxygen saturation remained stable and comparable in both groups (Table 2), indicating that neither phenylephrine strategy adversely affected maternal ventilation or oxygenation. This is consistent with the findings of Garg et al.[13]; Doherty et al.[15]and Hasanin et al.[16] who similarly reported no clinically meaningful respiratory compromise with phenylephrine-based vasopressor prophylaxis. The preserved neonatal Apgar scores and neonatal heart rates in the present study are also reassuring and align with the work of Singh et al.[9] Sharkey et al.[14] and Garg et al.[13] supporting the fetal safety of phenylephrine when maternal blood pressure is adequately maintained.

The adverse-event profile reflected the expected trade-off between the two regimens. Group A had more reactive hypertension and reflex bradycardia, whereas Group B had more nausea, consistent with greater episodes of hypotension (Table 3). Similar patterns were described by Kannan et al.[1]; Doherty et al.[15] and Das Neves et al.[17] who noted that infusion improves hemodynamic stability but may increase vasopressor-related side effects if not titrated carefully. In the present study, these events were manageable and did not affect neonatal wellbeing, but they underscore the need for close monitoring when using continuous infusion.

The present study has certain limitations. First, cumulative phenylephrine exposure was not standardized between the infusion and bolus groups, which may have contributed to differences in haemodynamic outcomes. Therefore, the observed superiority of infusion-based prophylaxis should be interpreted within the context of greater overall vasopressor exposure rather than mode of administration alone. Second, the study was conducted at a single centre with a relatively modest sample size, potentially limiting broader generalizability. Future multicentric trials using dose-equivalent protocols are warranted to better isolate the independent effect of administration strategy. In addition, the open-label design may have introduced observer-related bias despite objective haemodynamic measurements.

CONCLUSION

Prophylactic phenylephrine infusion was associated with improved haemodynamic stability and reduced rescue vasopressor requirement compared with intermittent bolus administration during elective caesarean section under spinal anaesthesia. However, interpretation of these findings should consider the higher cumulative phenylephrine exposure in the infusion group. Further dose-equivalent randomized trials are required to determine whether the observed benefits are attributable primarily to the mode of administration or total vasopressor dose.

Conflicts of Interest: The authors declare that there are no competing interests, financial or otherwise, that could be perceived as influencing the results or interpretation of this study.

Acknowledgements: The authors wish to express their sincere gratitude to Dr. Prabhjot Kaur Gill, Professor of Biomedical Research, for her invaluable guidance and significant contributions to the preparation and formal submission of this manuscript.

Table 1. Baseline characteristics and preoperative variables

Variable	Group A (n=35)	Group B (n=35)
Age (years)	28.86 ± 4.19	27.74 ± 3.17
Weight (kg)	70.11 ± 7.17	71.57 ± 6.42
Height (ft)	5.17 ± 0.17	5.21 ± 0.16
Pulse (bpm)	82.66 ± 7.12	83.40 ± 6.90
SBP (mmHg)	110.46 ± 7.61	113.14 ± 9.60
DBP (mmHg)	71.37 ± 6.65	71.60 ± 7.60
MAP (mmHg)	84.40 ± 6.14	85.45 ± 7.65
RR (breaths/min)	17.49 ± 1.95	18.17 ± 1.82
SpO_2 (%)	99.43 ± 0.98	99.23 ± 0.81

Table 2. Comparison of Surgical, Block, Respiratory, and Neonatal Outcomes between Group A and Group B

Variable	Group A (n=35)	Group B (n=35)	Mean Difference (95% CI)	*p-value
Surgical & Block Characteristics				
Duration of surgery (min)	92.86 ± 12.56	89.29 ± 12.67	3.57 (-2.45 to 9.59)	0.240
Onset of sensory block (min)	2.80 ± 0.87	2.49 ± 0.70	0.31 (-0.06 to 0.68)	0.100
Time to maximum sensory level (min)	3.80 ± 0.87	3.51 ± 0.74	0.29 (-0.10 to 0.68)	0.143

Onset of motor block (min)	3.80 ± 0.87	3.51 ± 0.74	0.29 (-0.10 to 0.68)	0.143
Time to Bromage grade 3 (min)	4.80 ± 0.87	4.51 ± 0.74	0.29 (-0.10 to 0.68)	0.143
Respiratory & Oxygenation				
RR 30 min Intraoperative (bpm)	19.49 ± 2.34	20.37 ± 2.24	-0.88 (-1.97 to 0.21)	0.112
RR 24 h Postoperative (bpm)	19.06 ± 1.91	19.94 ± 1.85	-0.88 (-1.77 to 0.01)	0.051
SpO_2 30 min Intraoperative (%)	99.11 ± 0.99	99.43 ± 0.98	-0.32 (-0.79 to 0.15)	0.179
SpO_2 24 h Postoperative (%)	99.43 ± 0.98	99.23 ± 0.81	0.20 (-0.23 to 0.63)	0.355
Neonatal Outcomes				
Apgar score at 1 min	7.69 ± 0.72	7.71 ± 0.83	-0.02 (-0.39 to 0.35)	0.878
Apgar score at 5 min	9.80 ± 0.41	9.69 ± 0.47	0.11 (-0.10 to 0.32)	0.281
Neonatal heart rate (bpm)	139.49 ± 9.00	138.17 ± 8.70	1.32 (-2.89 to 5.53)	0.537

Data expressed as Mean ± SD. CI: Confidence Interval. Statistical analysis by Independent Samples t-test (df=68). $p<0.05$ considered statistically significant.

Table 3. Vasopressor requirement and adverse events

Variable	Group A (n=35)	Group B (n=35)	Statistics	p-value
No rescue dose	35 (100%)	8 (22.9%)	χ^2=43.953, df=3	<0.001
One rescue dose	0 (0%)	5 (14.3%)		
Two rescue doses	0 (0%)	13 (37.1%)		
Three rescue doses	0 (0%)	9 (25.7%)		
Adverse events			**Fisher's Exact test**	**p-value**
Nausea	0	5 (14.3%)	95% CI (-25.9, -2.7)	0.027*
Vomiting	1 (2.9%)	2 (5.7%)	95% CI (-12.4, 6.7)	0.555
Headache	0	1 (2.9%)	95% CI (-8.4, 2.7)	0.314
Reactive hypertension	7 (20.0%)	0	95% CI (6.8, 33.2)	0.011*
Reflex bradycardia	8 (22.9%)	0	95% CI (9.0, 36.7)	0.005*
Respiratory depression	0	0	-	—

Data presented as frequency (percentage). χ^2= Chi-square test; df = degrees of freedom; CI = Confidence Interval. p-values for adverse events calculated using Fisher's Exact Test. *Statistically significant at $p < 0.05$.

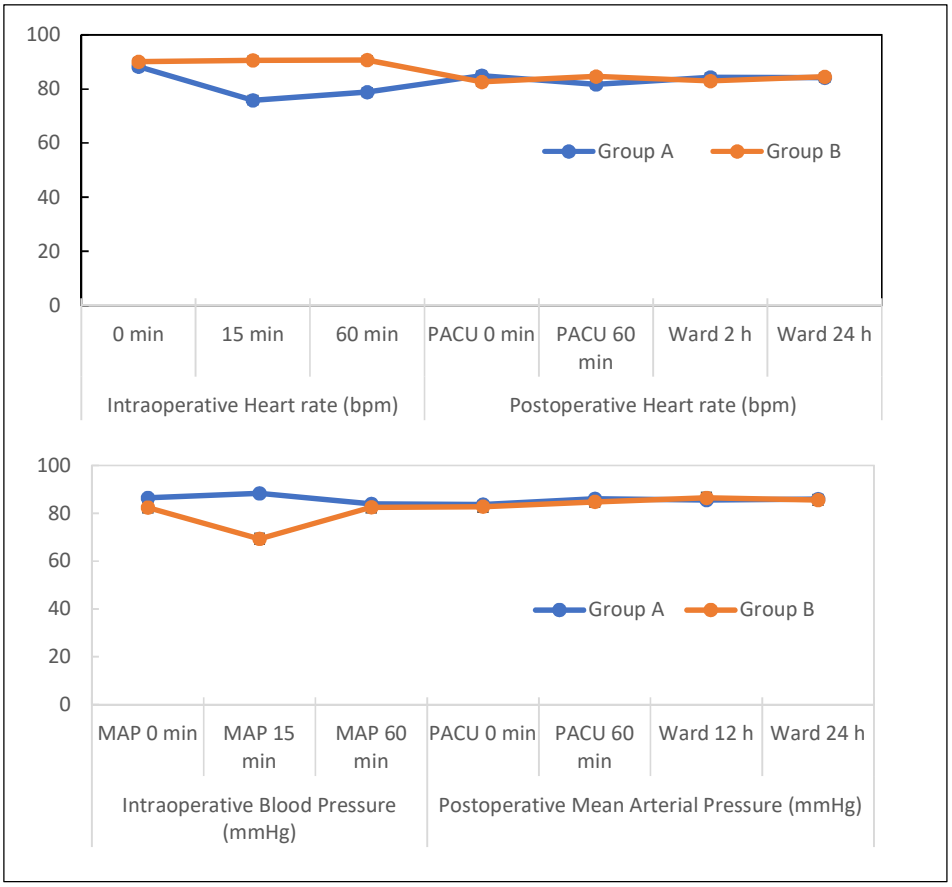

Figure 1: Perioperative Hemodynamic Trends in Group A and Group B.

Panel A: Intraoperative and postoperative heart rate (bpm) trends across various time points.
Panel B: Intraoperative and postoperative mean arterial pressure (mmHg) trends.

Note: Data are expressed as Mean ± Standard Deviation (SD). Statistical significance ($p < 0.05$) is observed at the 15-minute intraoperative mark for both heart rate and mean arterial pressure.

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