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Preloading versus Coloading with Crystalloids for Preventing Hypotension during Spinal Anesthesia for Cesarean Sections in Resource-limited Settings

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Abstract

Background: Maternal hypotension often occurs during spinal anesthesia for cesarean delivery and can be risky for both mother and fetus. Crystalloids are commonly used to prevent this, but it remains unclear whether giving them before anesthesia (preload) or during anesthesia (coload) is more effective. This study compares the effectiveness of preload versus coload crystalloid administration for preventing hypotension during spinal anesthesia for cesarean sections. **Methods:** This prospective, controlled clinical trial was conducted at Gazi Medical College, Khulna, Bangladesh, from July 2024 to December 2024. The study enrolled a total of 200 ASA Grade I-III parturients undergoing elective cesarean delivery under spinal anesthesia. Participants were randomly divided into two groups: preload (n=100) and coload (n=100) using an odd-even method based on the enrollment sequence. Intravenous crystalloids were administered before or immediately after spinal anesthesia, respectively. Standard monitoring and spinal anesthesia procedures were followed. Statistical analysis was performed using SPSS v26.0, and a p-value <0.05 was considered statistically significant. **Results:** Some baseline characteristics showed statistical differences but were not considered clinically meaningful. Hemodynamic parameters were monitored at several intervals post-spinal anesthesia. Heart rate initially increased, peaking at 5 minutes, then gradually declined. The maximum SBP drop at 5 minutes was significantly greater in the preload group (p <0.001). DBP also decreased notably at 10 minutes (p <0.001). MAP was significantly higher in the coload group at 10 minutes (p <0.001). Hypotension occurred less frequently in the coload group (57% vs. 86%, p <0.001), indicating greater coloading effectiveness in preventing hypotension during cesarean section under subarachnoid block (SAB). **Conclusion:** Coloading with crystalloids during spinal anesthesia (SAB) for cesarean sections is a more effective approach than preloading in preventing maternal hypotension, particularly in resource-limited settings. Due to its simplicity and practicality, coloading is a cost-effective strategy for managing anesthesia in obstetric care.

Keywords: Hypotension, Subarachnoid Block, Cesarean Sections, Preload, Coload, Crystalloids.

Introduction

Maternal hypotension, defined as a decrease in systolic blood pressure of more than 20% from baseline or below 100 mmHg, may be mild, moderate, or severe depending on its extent and clinical consequences.[1] Cesarean section is among the most commonly performed surgeries worldwide, with 80–90% conducted under spinal anesthesia.[2] Spinal anesthesia is preferred for elective cesarean deliveries because it is simple, rapid, cost-effective, provides dense neural blockade, minimizes fetal drug exposure, and allows early maternal mobilization. However, maternal hypotension remains its most frequent complication, affecting both mother and fetus[3], with reported incidences up to 60–70%.[4] Maternal hypotension can cause nausea, vomiting, dizziness, and syncope. In addition, fetal effects include hypoxia and acidosis due to reduced uteroplacental perfusion.[5] If prolonged, hypotension may result in cardiovascular collapse, unconsciousness, or organ ischemia.[1] Therefore, fluid management is crucial for prevention. Crystalloids are preferred for their low cost and minimal allergic or coagulation effects,

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while colloids offer superior volume expansion.[6]
The timing of fluid administration greatly influences its effectiveness. Preloading means giving fluids before spinal anesthesia to maintain blood volume and counteract the drop in blood pressure caused by the nerve block. However, its benefit has been questioned.[7,8] Preloaded crystalloids quickly leave the bloodstream. This triggers hormone release, widening of blood vessels, and increased urine output. As a result, their ability to prevent low blood pressure is reduced.[9,10] Coloading, in which fluids are administered concurrently with spinal anesthesia, has gained attention for its potential to maintain intravascular volume during the vasodilatory phase, thereby minimizing redistribution and excretion losses. The comparative rationale stems from skepticism about the efficacy of preloading, increasing interest in coloading as an alternative.[8,11] Comparative studies of preloading versus coloading with crystalloids have produced mixed outcomes; for example, earlier data reported hypotension rates of 68.4% in the preload group and 59.3% in the coload group.[12,13]

Coloading appears promising, especially in resource-limited settings. These settings are characterized by limited infrastructure (the absence of advanced monitors or automated infusion systems), restricted access to expensive drugs (colloids, vasopressors such as phenylephrine), shortages of trained personnel, financial constraints, and patient factors such as malnutrition, anemia, and inadequate antenatal care. Although preloading may be effective, it can be less economical due to fluid redistribution and wastage. In contrast, coloading maximizes fluid utility during sympathetic blockade, offering a potentially more cost-effective strategy to prevent maternal hypotension and improve outcomes.[14] Therefore, this study aims to compare the effectiveness of preload and coload crystalloid strategies in preventing hypotension during subarachnoid block (SAB) for lower uterine cesarean section (LUCS) in a resource-limited setting.

Materials and methods

This prospective, controlled clinical trial was conducted at Gazi Medical College, Khulna, Bangladesh, over six months (July–December 2024), following approval from the Institutional Ethical Review Board and obtaining informed consent from all participants. A total of 200 parturients with singleton pregnancies between 37–40 weeks of gestation and ASA physical status I–III scheduled for elective lower uterine cesarean section (LUCS) under spinal anesthesia were enrolled in this study. Exclusion criteria were preterm pregnancy, fetal distress, preeclampsia or eclampsia, cardiovascular disease, and uncontrolled diabetes mellitus. Cases were equally divided into two groups (n=100 each): Preload group, receiving 15 mL/kg of crystalloid solution 15 minutes before spinal anesthesia, and Coload group, receiving the same volume immediately after subarachnoid block (SAB). Randomization was done using an odd-even sequence method based on enrollment order due to resource limitations.

Standard monitoring (noninvasive blood pressure, pulse oximetry, temperature, respiratory rate, and urine output) was performed throughout the procedure. Spinal anesthesia was administered at the L3–L4 interspace using a 25G Quincke-Babcock needle after infiltration with 2–3 mL of 2% lidocaine. A total of 2.5 mL (12.5 mg) of 0.5% hyperbaric bupivacaine with 8% dextrose was injected intrathecally. Patients were then placed supine with a 15° right buttock wedge to prevent aortocaval compression. Sensory block was assessed using the pinprick method, and motor block was evaluated by the Bromage scale.

Hemodynamic parameters, including heart rate, systolic and diastolic blood pressure, mean arterial pressure (MAP), oxygen saturation (SpO_2), and temperature, were recorded using a “G3L Patient Monitor” (Shenzhen General Meditech Inc., China) at 5-minute intervals for the first three readings, then every 15 minutes for three additional readings, and finally at 90 minutes post-injection. Hypotension, defined as a ≥ 20% fall in systolic blood pressure from baseline, was treated with 5 mg intravenous ephedrine as required. Incidents of nausea, vomiting, and other intraoperative events were documented.

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± SD and compared using Student’s t-test, while categorical variables were analyzed using the Chi-square test. A p-value < 0.05 was considered statistically significant.

Results

A total of 200 patients were enrolled in the study, with 100 patients in each group using an odd-even method based on the sequence of enrollment. Although age and BMI were comparable between groups, statistically significant differences were observed in baseline characteristics, including gravida, gestational age, type of pregnancy, and pre-existing conditions; however, these differences were not clinically meaningful (Table 01).

Most patients in both groups were classified as ASA Grade II, accounting for 94% in the preload group and 87% in the coload group. A small proportion of patients were ASA Grade III (6% in preload, 12% in coload), while only 1% of patients in the coload group were ASA Grade I (Figure 01). The hemodynamic parameters, including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP), were recorded at the following time points: baseline, immediately after drug administration for spinal anesthesia, and subsequently at 5, 10, 15, 30, 45, 60, and 90 minutes post-intrathecal injection. However, the mean heart rate gradually increased in both groups, and the maximum increase was observed at 5 minutes, 105.42±14.28 vs 106.92±14.28 (p=0.463) beats per minute after induction of spinal anesthesia. The mean heart rate declined gradually at 30 min (89.9±11.78 vs 91.95±11.47, p=0.768).

Maximum drop in mean SBP from baseline occurred in preload and coload groups at 5 minutes, 96.57±13.03 vs. 94.94±3.58 mmHg (p<0.001), which showed a significant difference between the groups. After 10 minutes of SAB, the SBP rose gradually. The decrease in mean DBP after spinal anesthesia in preload and coload groups at 10 minutes was 63.38±4.40 vs 73.42±5.12 (p<0.001) (Table 02).

Table 03 presents MAP at different time points during cesarean sections using preload and coload techniques. The highest MAP was at resting (90.77±6.88 in coload vs. 88.21±6.58 in preload, p=0.603). After 5 minutes, the MAP was slightly lower in the preload group (76.13±8.04) than in coload (77.53±5.23, p=0.46). A significant difference occurred at 10 minutes, with higher MAP in coload (84.03±4.10) than in preload (75.87±3.74, p<0.001). At 15 minutes, values were similar in both groups (86.81±7.87 vs. 87.18±6.13, p=0.075). No significant differences were observed at 30 minutes (p=0.495), 45 minutes (p=0.385), 60 minutes (p=0.366), or 90 minutes (p=0.662). The incidence of hypotension was significantly lower in the coload group, while 86.0 percent of parturients in the preload group experienced hypotension compared to only 57.0 percent in the coload group, with a p-value of less than 0.001 (Figure 02).

Table 01: Baseline Characteristics of Patients in Preload and Coload Groups

Traits	Preload (N=100)		Coload (N=100)		p-value
	n	%	n	%	
	Mean±SD		Mean±SD		
Age (In years)	25.33±4.78		24.09±4.78		0.394
BMI (kg/m^2)	27.22±3.87		27.50±3.71		0.554
Gravida					
Primigravida	75	75.00	89	89.00	0.005
Second Gravida	25	25.00	9	9.00	
Third Gravida	0	0.00	2	2.00	
Gestational age (Weeks)					
37	14	14.00	32	32.00	0.007
38	86	86.00	66	66.00	
39	0	0.00	2	2.00	
Pregnancy with					
FTP	100	100.00	66	66.00	<0.001
Previous C/S	0	0.00	10	10.00	
PROM	0	0.00	16	16.00	
Elective C/S	0	0.00	5	5.00	
LFM	0	0.00	3	3.00	
Pre-existing Condition					
No interference	84	84.00	81	81.00	<0.001
Mild Anemia	11	11.00	9	9.00	
HTN	1	1.00	2	2.00	
Hypothyroidism	2	2.00	2	2.00	
Bronchial Asthma	0	0.00	3	3.00	
GDM	1	1.00	3	3.00	
PCOS	1	1.00	0	0.00	

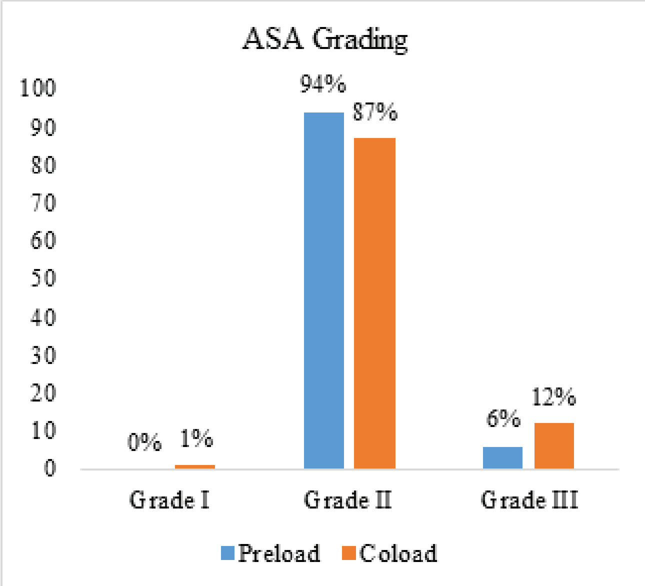

Figure 01: ASA grading among participants

Table 02: Hemodynamic and Physiological Parameters during Cesarean Sections with Preload and Coload Techniques

Traits	Groups	Resting	5 min	10 min	15 min	30 min	45 min	60 min	90 min	p-value
Heart Rate (b/min), (Mean ± SD)	Preload	76.54 ± 8.48	105.42 ± 14.28	105 ± 9.57	101.06 ± 11.68	89.9 ± 11.78	71.16 ± 11.86	69.74 ± 11.36	88.63 ± 11.53	<0.001 (10 min); 0.027 (15 min)
	Coload	74.69 ± 8.56	106.92 ± 14.28	79.42 ± 5.93	105.92 ± 15.39	91.95 ± 11.47	70.54 ± 12.90	69.91 ± 12.62	88.85 ± 12.13	
Systolic BP (mmHg), (Mean ± SD)	Preload	114.78 ± 8.74	96.57 ± 13.03	100.85 ± 6.88	114.47 ± 9.10	116.83 ± 8.67	106.09 ± 4.66	115.17 ± 9.77	115.72 ± 9.28	0.003 (rest); <0.001 (5 min); 0.002 (10 min)
	Coload	120.4 ± 10.23	94.94 ± 3.58	105.26 ± 6.87	114.13 ± 8.69	115.85 ± 8.54	105.54 ± 3.70	115.29 ± 9.11	115.5 ± 8.94	
Diastolic BP (mmHg), (Mean ± SD)	Preload	74.93 ± 9.30	65.91 ± 9.31	63.38 ± 4.40	73.54 ± 8.95	75.89 ± 8.85	64.55 ± 3.16	75.82 ± 8.88	75.7 ± 8.45	0.008 (5 min); <0.001 (10 min)
	Coload	75.95 ± 8.71	68.83 ± 7.66	73.42 ± 5.12	73.15 ± 10.86	75.53 ± 8.98	65.14 ± 3.77	76.35 ± 8.29	75.3 ± 8.04	
SpO_2 (%), (Mean ± SD)	Preload	97.9 ± 1.11	97.04 ± 9.03	98.01 ± 0.88	98.08 ± 0.82	98.09 ± 0.83	96.12 ± 0.81	98.21 ± 0.81	98.13 ± 0.81	NS
	Coload	98.03 ± 0.83	97.99 ± 0.80	98.04 ± 0.79	97.87 ± 0.81	97.96 ± 0.84	95.77 ± 2.82	98.08 ± 0.80	98.14 ± 0.88	
RR (breaths/min), (Mean ± SD)	Preload	13.89 ± 2.59	14.15 ± 2.57	13.77 ± 2.53	14.23 ± 2.56	13.67 ± 2.51	17.75 ± 2.52	14.02 ± 2.69	14.08 ± 2.53	NS
	Coload	14.68 ± 2.49	14.1 ± 2.69	14.14 ± 2.59	14.07 ± 2.59	14.28 ± 2.54	17.77 ± 2.58	13.82 ± 2.57	14.17 ± 2.69	
Urine Output (ml), (Mean ± SD)	Preload	–	–	–	–	–	–	123.5 ± 15.79	–	<0.001
	Coload	–	–	–	–	–	–	99.98 ± 0.20	–	
Infusion (ml), (Mean ± SD)	Preload	454.5 ± 49.80	653 ± 50.16	849 ± 50.24	1044 ± 106.72	1253 ± 50.53	1451 ± 50.24	1653 ± 50.16	1894 ± 83.87	<0.001 (up to 60 min)
	Coload	–	344 ± 49.89	544 ± 49.89	738 ± 48.78	958 ± 49.60	1200 ± 50	1347 ± 50.16	1884 ± 96.11	
Temperature (°F), (Mean ± SD)	Preload	97.93 ± 0.81	–	–	–	97.52 ± 0.50	–	97.52 ± 0.50	–	NS
	Coload	97.94 ± 0.79	–	–	–	97.48 ± 0.52		97.57 ± 0.50	–	
RBS (mmol/L), (Mean ± SD)	Preload	6.16 ± 1.2	–	–	–	–	–	–	–	NS
	Coload	6.07 ± 0.13	–	–	–	–	–	–	–	
Ephedrine (mg), (Mean ± SD)	Preload	–	5 ± 0	–	5 ± 0	5 ± 0	–	–	–	NS
	Coload	–	5 ± 0	–	–	5 ± 0	–	–	–	

Table 03: Mean Arterial Pressure (MAP) during Cesarean Sections with Preload and Coload Techniques

Traits	Preload (N=100)	Coload (N=100)	p-value
	Mean±SD	Mean±SD	
MAP			
At resting	88.21±6.58	90.77±6.88	0.603
At 5 min	76.13±8.04	77.53±5.23	0.46
At 10 min	75.87±3.74	84.03±4.10	<0.001
At 15 min	87.18±6.13	86.81±7.87	0.075
At 30 min	89.54±6.74	88.97±6.90	0.495
At 45 min	78.40±2.84	78.61±2.75	0.385
At 60 min	88.94±6.86	89.33±6.40	0.366
At 90 min	89.04±6.39	88.70±7.33	0.662

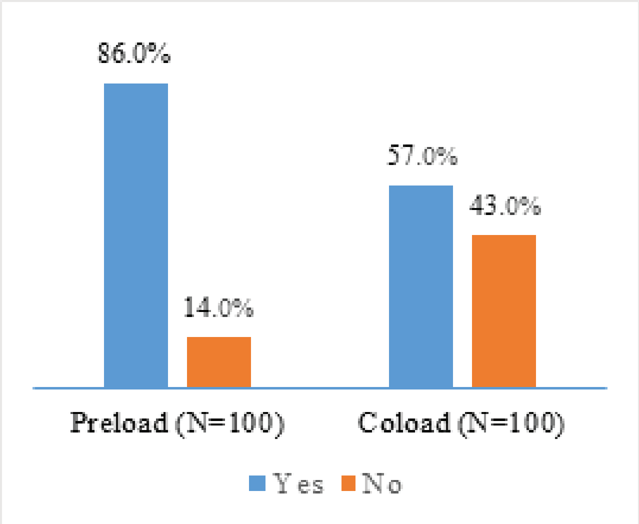

Figure 02: Incidence of Hypotension between Preload and Coload Groups

Discussion

Spinal-induced hypotension is a common physiological consequence of subarachnoid block (SAB), resulting from sympathetic blockade that leads to peripheral vasodilation, reduced venous return, and decreased cardiac output.[15,16] Vagal reflexes triggered by reduced preload further aggravate hemodynamic instability.[17] To prevent this, intravenous fluid administration either preloading (before SAB) or coloading (at SAB onset) is widely practiced.6 The optimal approach remains debated, particularly in resource-limited settings where vasopressors and advanced monitors are scarce. In this study, coloading significantly reduced the incidence of hypotension (57%) compared to preloading (86%) ($p<0.001$), consistent with previous findings showing coloading's superior hemodynamic stability during cesarean section under SAB.[5,17]

Systolic blood pressure at 5 and 10 minutes post-SAB was higher in the coload group ($p<0.05$), aligning with Dana et al., who found that rapid intra-induction fluid administration more effectively counteracts vasodilation-induced hypotension than preoperative loading.[18] Pregnancy-related aortocaval compression also limits the efficacy of preload in maintaining intravascular expansion until anesthesia induction.[19] Heart rate decreased significantly in the coload group (79.42 ± 5.93 bpm) compared to the preload group (105 ± 9.57 bpm) at 10 minutes ($p<0.001$), consistent with prior studies reporting more stable heart rates in coloaded patients.[6] This indicates better hemodynamic adaptation, as preload-related fluid shifts may cause transient tachycardia through compensatory mechanisms.[20] Diastolic blood pressure was significantly higher in the coload group (73.42 ± 5.12 mmHg) than in the preload group (63.38 ± 4.40 mmHg; $p<0.001$), corroborating Saeed et al., who observed similar findings favoring coloading.[21] Likewise, mean arterial pressure (MAP) was higher in the coload group at 10 minutes (84.03 ± 4.10 mmHg vs. 75.87 ± 3.74 mmHg, $p<0.001$), confirming its superior preservation of perfusion. Artawan et al. similarly found smaller reductions in systolic, diastolic, and mean pressures with coloading compared to preloading ($p<0.001$).[22] Interestingly, the preload group required more total fluids (1044.1 ± 106.72 mL) than the coload group (738 ± 48.78 mL, $p<0.001$), yet achieved inferior blood pressure control.

Coloading thus provided greater hemodynamic stability with less fluid, minimizing the risk of overload or pulmonary edema, a key concern in obstetric care. This supports prior evidence that preload fluids redistribute rapidly before SAB-induced vasodilation, reducing effectiveness.[23] Vasopressor requirements were also lower in the coload group, consistent with Rao et al. and Oh et al., who reported reduced hypotension and ephedrine use with coloading.[6,7] Ni et al. similarly found a decreased incidence of hypotension with coloading during cesarean delivery.[14] Urine output was higher in the preload group ($p<0.001$), likely reflecting larger fluid volumes rather than improved renal perfusion. No significant group differences were noted in SpO_2, respiratory rate, temperature, or glucose, underscoring that fluid timing primarily influences cardiovascular stability.

Limitations of the study

The outcome assessor was not blinded, and an odd-even allocation rather than computer-generated randomization may have introduced selection bias, although protocol adherence minimized this bias. Hydration alone did not fully prevent hypotension in the coload group, indicating the need for vasopressor use. Additionally, comprehensive neonatal outcomes were not assessed, limiting the evaluation of overall effectiveness.

Conclusion

Coloading with crystalloids during spinal anesthesia for cesarean sections is more effective than preloading in preventing maternal hypotension, improving hemodynamic stability, reducing vasopressor use, and minimizing fluid overload. Its simplicity and feasibility make it a practical, cost-effective strategy for resource-limited settings, with potential benefits for maternal and fetal safety. Further research is needed to optimize fluid volume and timing and to evaluate broader maternal and neonatal outcomes.

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