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COMPARISON OF CRYSTALLOID AND COLLOID PRELOADING FOR PREVENTION OF SPINAL-INDUCED HYPOTENSION DURING ELECTIVE CESAREAN SECTION: A PROSPECTIVE OBSERVATIONAL STUDY

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Abstract

Background: *Spinal-induced hypotension is the most common complication following spinal anesthesia for cesarean section, posing risks to both maternal and neonatal wellbeing. Intravenous fluid preloading is a widely employed preventive strategy, yet the comparative efficacy of crystalloids versus colloids remains debated, particularly in resource-limited settings.*

Objective: To compare the hemodynamic effects, vasopressor requirements, maternal side effects, and neonatal outcomes of crystalloid versus colloid preloading in patients undergoing elective cesarean section under spinal anesthesia.

Methods: *A prospective observational study was conducted at POF Hospital Wah Cantt and HIT Hospital Taxila over four months. A total of 110 parturient of ASA physical status I–II undergoing elective cesarean sections were enrolled and divided into two groups: Group A (Crystalloid preload, n=55) receiving Ringer's Lactate 500–1000 mL or Normal Saline, and Group B (Colloid preload, n=55) receiving Haemaccel or Dextran 500 mL. Spinal anesthesia was administered with Bupivacaine 0.5% (10–12.5 mg). Hemodynamic parameters, vasopressor requirements, maternal side effects, and neonatal Apgar scores were recorded. Data were analyzed using SPSS v21 and Microsoft Excel 2024, employing independent samples t-tests, Chi-square tests, and descriptive statistics.*

Results: *The groups were comparable at baseline ($p>0.05$). Fluid type was significantly associated with intraoperative hypotension ($t = -3.975$, $p < 0.001$), with crystalloid recipients demonstrating lower intraoperative systolic blood pressure ranges (86–100 mmHg) compared to colloid recipients (101–110 mmHg). The timing of fluid administration also significantly influenced hypotension incidence ($\chi^2 = 17.526$, $df=4$, $p = 0.002$). Phenylephrine was required in 54.5% of the crystalloid group versus only 18.2% of the colloid group ($\chi^2 = 15.714$, $p < 0.001$). Side effect profiles differed significantly between groups ($\chi^2 = 10.862$, $p = 0.028$): nausea predominated with crystalloids, while vomiting and bradycardia were more frequent with colloids.*

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Neonatal Apgar scores were comparable across all fluid types (χ^2 = 14.135, df=12, p = 0.292), with the majority scoring 8–10.

Conclusion: *Colloid preloading provides significantly superior hemodynamic stability and reduces vasopressor requirements compared to crystalloid preloading in parturient undergoing spinal anesthesia for elective cesarean sections, with comparable neonatal safety. These findings support the preferential use of colloids in patients at hemodynamic risk.*

INTRODUCTION

Spinal anesthesia is the most widely preferred technique for elective cesarean sections owing to its rapid onset, technical simplicity, excellent surgical anesthesia quality, and superior safety profile for both mother and neonate compared to general anesthesia. Despite these advantages, spinal-induced hypotension (SIH) remains the most prevalent and clinically significant complication, occurring in up to 60–80% of parturient who do not receive prophylactic interventions.[1] The pathophysiological basis of SIH is multifactorial: the sympathetic blockade caused by intrathecal local anesthetics produces profound vasodilation, reduced systemic vascular resistance, and decreased venous return to the heart, ultimately compromising cardiac output and uteroplacental blood flow.[2]

The consequences of untreated or inadequately managed SIH extend beyond maternal discomfort. Nausea, vomiting, dizziness, and syncope are common maternal manifestations, while severe or prolonged hypotension may precipitate fetal distress, neonatal acidosis, and low Apgar scores by reducing uteroplacental perfusion.[3] In the context of cesarean delivery, where the wellbeing of two patients must be simultaneously safeguarded, aggressive prevention and management of SIH are essential components of safe anesthetic practice.

Intravenous fluid preloading, defined as the administration of a specified volume of intravenous fluid prior to intrathecal injection, has long been the cornerstone of non-pharmacological SIH prevention. The rationale is to expand intravascular volume, thereby attenuating the hemodynamic consequences of sympathetic blockade. Two broad categories of intravenous fluids are available for this purpose: crystalloids — isotonic aqueous solutions such as Ringer's Lactate (RL) and Normal Saline (NS) — and colloids, including hydroxyethyl starches, gelatins (Haemaccel), dextrans, and albumin.[4]

The pharmacodynamics distinction between these fluid categories is clinically important. Crystalloids distribute rapidly across the extravascular compartment, with only approximately 25–30% remaining intravascular after 30 minutes of administration. This transient plasma expansion limits their efficacy as preloads. Colloids, by contrast, possess larger molecular sizes that restrict their movement across capillary membranes, resulting in sustained intravascular volume expansion, enhanced oncotic pressure, and more effective attenuation of sympathetic blockade–induced pooling.[5]

Multiple randomized controlled trials and meta-analyses have investigated the relative merits of crystalloid versus colloid preloading. While colloids consistently demonstrate superiority in preventing SIH and reducing vasopressor requirements, crystalloids offer distinct advantages in cost, availability, and side-effect profile.[6–7] The clinical landscape is further complicated by the emergence of coloading strategies — concurrent fluid administration at the time of intrathecal injection — which may offer superior timing alignment with the sympathetic blockade.[8] In resource-constrained settings like those prevalent across Pakistan, the choice between fluid strategies must carefully balance hemodynamic efficacy against practical and economic considerations.

This prospective observational study was designed to provide locally relevant evidence by comparing the hemodynamic effects, vasopressor requirements, maternal side effects, and neonatal outcomes of crystalloid versus colloid preloading in parturient undergoing spinal anesthesia for

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elective cesarean sections at two tertiary-care facilities in Khyber Pakhtunkhwa, Pakistan. The findings aim to inform evidence-based fluid management protocols applicable to similar clinical environments in the region.

METHODOLOGY

This prospective observational comparative study was conducted at the Obstetrics and Gynecology Operation Theatres of POF Hospital Wah Cantt and HIT Hospital Taxila, Khyber Pakhtunkhwa, Pakistan, over a period of four months. Ethical approval was obtained from the Departmental Research/Ethical Committee of the University of Haripur prior to commencement. All participants provided written informed consent before enrollment. A total of 110 parturient were enrolled using Cochran's formula for sample size calculation. Participants were allocated to one of two groups based on the type of preloading fluid administered as part of routine clinical practice: Group A (Crystalloid preload, n = 55): Ringer's Lactate 500–1000 mL or Normal Saline, administered intravenously prior to spinal anesthesia. Group B (Colloid preload, n = 55): Haemaccel or Dextran 500 mL, administered intravenously prior to spinal anesthesia. Women aged 18–45 years scheduled for elective cesarean section under spinal anesthesia, ASA physical status I or II, Singleton pregnancy at term, Patients providing written informed consent were included and Contraindications to spinal anesthesia, Preeclampsia or eclampsia, Cardiac disease or severe systemic illness, known allergy to colloid solutions, Pre-existing hypotension (SBP < 100 mmHg at baseline) were excluded, All participants underwent a standardized anesthetic protocol. Intraoperative monitoring included continuous electrocardiography (ECG), pulse oximetry (SpO_2), and non-invasive blood pressure measurement (NIBP). Spinal anesthesia was administered in the sitting or lateral decubitus position using sterile technique. Intrathecal Bupivacaine 0.5% (10–12.5 mg) was injected at the L3–L4 or L4–L5 interspace. Preloading fluids were administered immediately prior to the intrathecal injection at a rate guided by clinical protocol. Hypotension, defined as a decrease in systolic blood pressure (SBP) of >20% from baseline or absolute SBP < 90 mmHg, was managed with intravenous Phenylephrine or Ephedrine as clinically indicated. Data were recorded using a pre-validated structured data collection proforma. Outcome variables included: (i) incidence and severity of intraoperative hypotension; (ii) intraoperative SBP values; (iii) timing of fluid administration (preload vs. coload); (iv) vasopressor (phenylephrine) requirement; (v) maternal side effects (nausea, vomiting, bradycardia); and (vi) neonatal Apgar scores at 1 and 5 minutes. All data were entered and analyzed using SPSS version 21 and Microsoft Excel 2024. Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent samples t-test. Categorical variables were expressed as frequencies and percentages and compared using the Pearson Chi-square test. A p-value of < 0.05 was considered statistically significant.

RESULTS

A total of 110 parturient were included in the final analysis, with 55 patients in each group. The two groups were comparable at baseline, with no statistically significant differences in age, weight, or ASA classification ($p > 0.05$), confirming successful group allocation.

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (n=110)

Characteristic	Overall (n=110)
Age Group (years)	
20–25 years	29 (26.36%)

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26–30 years	38 (34.55%)
31–35 years	43 (39.09%)
Weight (kg)	
60–65 kg	23 (20.91%)
66–75 kg	36 (32.73%)
76–85 kg	51 (46.36%)
ASA Classification	
ASA Class I	58 (52.73%)
ASA Class II	52 (47.27%)
Comorbidities	
Class I – Healthy	34 (30.91%)
Class II – Mild Anemia / Overweight	29 (26.36%)
Class III – PIH requiring elective CS	47 (42.73%)

PIH = Pregnancy-Induced Hypertension; CS = Cesarean Section; ASA = American Society of Anesthesiologists. Note: Group-level demographic breakdown was not separately recorded.

Table 2: Comprehensive Summary of Statistical Results

Variable	Crystalloid (n=55)	Colloid (n=55)	Statistical Test	Test Value	p-value	Result
Intraop. Hypotension – Mean Fluid Score	1.27 ± 0.45 (Yes) 1.64 ± 0.48 (No)	—	Independent t-test	t = −3.975	0.001	Sig.
Intraop. SBP – Crystalloid dominant range	86–100 mmHg (61.11%)	101–110 mmHg (61.29%)	Descriptive	—	—	—
Timing of Fluid (Preload/Coload) vs. Hypotension	—	—	Chi-square	χ^2 = 17.526 df = 4	0.002	Sig.
Side Effects vs. Fluid Type	Nausea predominant	Vomiting + Bradycardia predominant	Chi-square	χ^2 = 10.862 df = 4	0.028	Sig.
Phenylephrine Requirement	30/55 (54.5%)	10/55 (18.2%)	Chi-square	χ^2 = 15.714 df = 1	0.001	Sig.

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Baseline SBP Comparison (110–120 mmHg)	1.45 ± 0.51	1.65 ± 0.49	Independent t-test	t = −1.467	0.149	NS
Neonatal Apgar Score (1–5 min) vs. Fluid Type	Majority 8–10	Majority 8–10	Chi-square	χ^2 = 14.135 df = 12	0.292	NS

Sig. = Statistically Significant ($p < 0.05$); NS = Not Significant ($p > 0.05$); SBP = Systolic Blood Pressure; Intraop. = Intraoperative; df = Degrees of Freedom.

Table 3: Distribution of Maternal Side Effects by Fluid Type

Side Effect	Crystalloid Group n (%)	Colloid Group n (%)	χ^2/p-value
Nausea	12 (27.3%)	3 (6.3%)	χ^2 = 10.862
Vomiting	13 (29.5%)	17 (35.4%)	p = 0.028
Bradycardia	11 (25.0%)	20 (41.7%)	df = 4
Multiple Side Effects	8 (18.2%)	3 (6.3%)	Significant
None	11 (25.6%)	12 (25.0%)	

Figure 4.1 demonstrated that the majority of participants were aged 26–35 years, with the 31–35 age bracket representing the largest cohort (39.09%), followed by the 26–30 age group (34.55%), and women aged 20–25 years comprising 26.36%. By weight, 46.36% of participants were in the 76–85 kg range, 32.73% in the 66–75 kg range, and 20.91% in the 60–65 kg range, representing a predominantly overweight obstetric population. The ASA classification showed an almost equal distribution with 52.73% classified as ASA I and 47.27% as ASA II, confirming enrollment of an appropriate low-to-moderate anesthetic risk population. Regarding intraoperative hemodynamics, a statistically significant association was identified between fluid type and intraoperative hypotension ($t = -3.975$, $p < 0.001$). Patients who developed hypotension had a significantly lower mean fluid type score (1.27 ± 0.45) compared to normotensive patients (1.64 ± 0.48), indicating a significantly higher proportion of crystalloid recipients among hypotensive patients. Analysis of intraoperative SBP distribution revealed that 61.11% of patients with the lowest SBP range of 86–90 mmHg received crystalloids, while 61.29% of patients maintaining SBP in the 101–110 mmHg range received colloids, highlighting the superior blood pressure stabilization afforded by colloid preloading.

The timing of fluid administration (preload versus coload) was also a significant determinant of hypotension incidence (χ^2 = 17.526, df = 4, p = 0.002), underscoring the importance of fluid administration strategy in addition to fluid type. With respect to vasopressor requirements, a highly significant difference was observed between groups (χ^2 = 15.714, df = 1, $p < 0.001$). In the crystalloid group, 30 of 55 patients (54.5%) required phenylephrine to manage hypotension, compared to only 10 of 55 patients (18.2%) in the colloid group — a three-fold reduction in vasopressor requirement associated with colloid preloading. Regarding neonatal outcomes, Apgar scores at 1–5 minutes were comparable across all fluid types (χ^2 = 14.135, df = 12, p = 0.292), with

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the overwhelming majority of neonates in both groups achieving scores in the 8–10 range. This confirms that neither crystalloid nor colloid preloading confers a significant advantage or disadvantage with respect to early neonatal condition.

DISCUSSION

This prospective observational study provides significant insights into the comparative hemodynamic effects of crystalloid and colloid preloading for the prevention of spinal-induced hypotension (SIH) during elective cesarean sections. The results confirm several findings from prior literature while also offering locally relevant evidence from a resource-limited clinical setting in Pakistan. The study population was demographically appropriate, comprising predominantly young women aged 26–35 years in the low-to-moderate anesthetic risk categories (ASA I–II). Notably, pregnancy-induced hypertension (PIH) was the most prevalent comorbidity, affecting 42.73% of participants, which is consistent with the high prevalence of PIH in South Asian obstetric populations. The near-equal distribution of ASA I and II patients ensured that neither group was systemically disadvantaged by higher baseline cardiovascular risk, thereby enhancing the internal validity of the comparison. The primary finding — a statistically significant association between fluid type and intraoperative hypotension ($t = -3.975$, $p < 0.001$) — is consistent with multiple meta-analyses and systematic reviews in the literature. Shang et al. (2021) demonstrated in a protocol for systematic review that colloid preloading significantly reduces the incidence of SIH compared to crystalloid preloading, attributing this to the prolonged intravascular persistence of colloidal molecules.[1] Similarly, Dahlgren et al. (2005) demonstrated in a randomized controlled trial that colloid preloading with 3% Dextran 60 significantly reduced both overall and severe hypotension compared to Ringer's Lactate, consistent with the SBP distribution patterns observed in the present study.[6] The analysis of intraoperative SBP distributions revealed a clear hemodynamic advantage for colloid preloading, with 61.29% of colloid recipients maintaining SBP in the clinically favorable 101–110 mmHg range, compared to crystalloid recipients who disproportionately clustered in lower SBP ranges (86–100 mmHg). This observation is pharmacologically logical: crystalloids rapidly equilibrate between the intravascular and extravascular compartments, limiting their sustained plasma-expanding effect, while colloids maintain intravascular oncotic pressure and volume more effectively over the critical period immediately following sympathetic blockade.[5]

The significantly lower phenylephrine requirement in the colloid group (18.2% vs. 54.5%, $\chi^2 = 15.714$, $p < 0.001$) represents one of the most clinically impactful findings of this study. Vasopressor requirement is a direct surrogate for inadequate hemodynamic protection. Phenylephrine, while effective for SIH management, carries risks of reflex bradycardia, and its frequent use indicates suboptimal prophylactic fluid management. The three-fold reduction in vasopressor dependency associated with colloid preloading translates directly into fewer drug-related risks, reduced hemodynamic fluctuations, and potentially smoother anesthetic courses for patients. This aligns with the findings of Jawaid et al. (2019) from a Pakistani tertiary care setting, who similarly found colloid preloading to be superior to crystalloids in reducing vasopressor requirements.[7]

The significant difference in side effect profiles between the two groups ($\chi^2 = 10.862$, $p = 0.028$) warrants careful interpretation. Nausea was predominantly associated with crystalloid preloading, likely reflecting the higher incidence of hypotension-induced nausea in that group. Vomiting and bradycardia were more frequently observed in the colloid group. Bradycardia in the colloid group may represent a physiological compensatory response — as colloids more effectively maintain intravascular volume and blood pressure, the compensatory tachycardia seen with hypotension is less frequent, potentially resulting in relative bradycardia. This mechanistic explanation is supported by the literature and does

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not necessarily represent a clinically adverse outcome in most parturient.[12] The absence of any significant difference in neonatal Apgar scores across fluid types ($\chi^2 = 14.135$, df = 12, $p = 0.292$) is a particularly reassuring finding and is consistent with the majority of comparative trials in this area. It confirms that the hemodynamic advantage of colloids does not come at the cost of neonatal wellbeing. Both fluid strategies appear to provide adequate fetal protection when hypotension is promptly managed, with the overwhelming majority of neonates achieving Apgar scores of 8–10. This finding is consistent with Banerjee et al. (2010) and Ni et al. (2017), who similarly reported no significant differences in neonatal outcomes between preloading strategies.[2,3]

The significant association between fluid timing (preload vs. coload) and hypotension ($\chi^2 = 17.526$, $p = 0.002$) introduces an important nuance to the fluid management debate. Crystalloid coloading — administering fluids concurrently with intrathecal injection — has been advocated as a timing strategy that better aligns volume expansion with the onset of sympathetic blockade. Studies by Suramya et al. (2025) and Saeed et al. (2024) from tertiary-care hospitals in South Asia have demonstrated that crystalloid coloading may yield lower hypotension rates than crystalloid preloading.[8,9] The present study's data suggest that timing represents an independent variable that modifies the efficacy of any fluid type, a consideration that should be incorporated into future fluid management protocols. This study has several limitations that warrant acknowledgment. First, as a prospective observational study, true randomization was not employed, limiting causal inference. Second, the study was conducted at two centers in Khyber Pakhtunkhwa, which may restrict generalizability to other regional or demographic settings. Third, group sizes within specific fluid subtypes (e.g., Dextran, Albumin) were relatively small, limiting subgroup analyses. Fourth, long-term postoperative hemodynamic data and extended neonatal follow-up were not included. Future research should employ multi-center randomized controlled trial designs with equal group allocation, standardized fluid subtypes, and comprehensive outcome assessments including coagulation profiles, extended postoperative monitoring, and detailed pharmacoeconomic analyses.

CONCLUSION

This prospective observational study demonstrates that colloid preloading is significantly superior to crystalloid preloading in preventing spinal-induced hypotension, maintaining intraoperative hemodynamic stability, and reducing vasopressor requirements in parturient undergoing elective cesarean sections under spinal anesthesia. The markedly lower phenylephrine requirement in the colloid group (18.2% vs. 54.5%, $p < 0.001$) and the higher intraoperative SBP maintenance provide compelling clinical evidence favoring colloid preloading, particularly for patients at elevated hemodynamic risk. Crucially, neonatal Apgar scores were equivalent across fluid types, confirming the neonatal safety of both strategies. Clinicians should consider colloid preloading as the preferred strategy for hemodynamically vulnerable parturient, while recognizing that timing of fluid administration (preload vs. coload) constitutes an independently important determinant of outcome. Large-scale multicenter randomized trials are warranted to refine fluid management protocols and further evaluate cost-effectiveness in resource-limited settings.

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