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Research Article

Comparison of Sensory Block Levels with Crystalloid and Colloid Preloading in Spinal Anesthesia for Cesarean Delivery: A Randomized Controlled Study

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ABSTRACT

Background: Spinal anesthesia is widely used for cesarean deliveries due to its effectiveness and safety. However, it often causes post-anesthesia hypotension, which poses risks to both the mother and baby. Fluid preloading is a common method to prevent hypotension, yet the ideal type and volume of fluid remain uncertain. This research investigates how crystalloid and colloid preloading influence sensory block levels and hemodynamic stability during spinal anesthesia for cesarean sections.
Methods: Conducted as a randomized, double-blind, controlled trial at Imam Hossein Hospital in Tehran, Iran, from January to June 2022, this study involved 141 women undergoing elective cesarean sections under spinal anesthesia. Participants were randomly divided into three groups: normal saline, Ringer's lactate, or 6% hydroxyethyl starch (130/0.4). Sensory block levels were assessed every 5 minutes for the first 30 minutes and then at 60 and 90 minutes post-anesthesia. Continuous monitoring of hemodynamic parameters, such as systolic blood pressure and heart rate, was performed throughout the procedure.
Results: The findings revealed that normal saline achieved the highest maximum sensory block level. Hydroxyethyl starch (HES) showed a slightly longer duration of the block and a reduced incidence of hypotension. Despite these trends, the observed differences among the groups were not statistically significant.
Conclusion: This study demonstrates that the choice of preload fluid influences sensory block characteristics and hemodynamic stability during spinal anesthesia for cesarean sections. Additional research with larger sample sizes is necessary to refine fluid management strategies in this context.

Introduction

Spinal anesthesia is widely chosen for cesarean deliveries due to its rapid onset, effectiveness, and lower risks compared to general anesthesia. However, post-spinal hypotension occurs in up to 80-90% of cases, potentially causing nausea, vomiting, dizziness, or fetal acidosis if not managed properly [1–3]. Fluid preloading is often performed, but the optimal fluid type and volume remain debated. [1].

Hypotension following spinal anesthesia primarily results from sympathetic blockade, leading to peripheral vasodilation and venous pooling, which reduces venous return and cardiac output [4]. Pregnant women are particularly vulnerable due to the high block level (T4) required for cesarean sections, along with pregnancy-related physiological changes and increased sensitivity to sympathectomy.

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One approach to mitigate hypotension involves fluid preloading, though the ideal fluid choice remains unclear. The effects of local anesthetic drugs depend on their distribution in cerebrospinal fluid (CSF), and the most important factor influencing the level of spinal anesthesia is CSF volume. It has been suggested that the type of solution administered before spinal anesthesia may alter CSF volume, potentially affecting sensory levels. [5-6]. However, more research is needed to explore how these fluids influence sensory block characteristics.

This randomized controlled trial aims to investigate the impact of crystalloid and colloid preloading on sensory block levels during spinal anesthesia for cesarean deliveries by comparing normal saline, Ringer's lactate, and 6% hydroxyethyl starch (HES). The findings could provide valuable insights into optimizing fluid management strategies for cesarean section anesthesia.

Methods

After receiving ethical approval (IR.SBMU.RETECH.REC.1401.643, IRCT20120910010800N10), this randomized, double-blind, controlled trial was conducted at a teaching hospital from January to June 2022. It included 141 patients aged 18–40 years with singleton term pregnancies scheduled for elective cesarean sections under spinal anesthesia. Participants were randomly assigned to one of three groups using a computer-generated sequence: normal saline, Ringer's lactate, or HES (1:1:1 allocation ratio). Exclusion criteria included BMI ≥ 40 kg/m², preeclampsia, pregnancy-induced hypertension, allergy or contraindication to hydroxyethyl starch, fetal distress, or ASA physical status ≥ III (Figure 1).

Exclusion criteria included patients with a body mass index (BMI) ≥ 40 kg/m², preeclampsia or pre-existing pregnancy-induced hypertension, known allergy or contraindication to hydroxyethyl starch, fetal distress, or American Society of Anesthesiologists (ASA) physical status ≥ III.

All patients received standard monitoring, including non-invasive arterial pressure measurement, electrocardiography, and pulse oximetry. Preloading was administered 10 minutes before spinal anesthesia: 10 mL/kg for the normal saline and Ringer's lactate groups and 5 mL/kg for the HES group. Spinal anesthesia was performed with the patient seated at the L3-4 or L4-5 interspace using a 25-gauge needle, injecting 12.5 mg hyperbaric bupivacaine into the intrathecal space. Patients were placed supine with left lateral tilt, and surgery commenced once the sensory block exceeded the T6 dermatome.

The primary outcome was the maximum sensory block level, while secondary outcomes included block duration, hypotension incidence, and nausea/vomiting frequency. Sensory block levels were recorded every 5 minutes for the first 30 minutes and then at 60 and 90 minutes. Hemodynamic parameters, including systolic blood pressure (SBP) and heart rate (HR), were continuously monitored.

Statistical analysis was performed using SPSS version 22.0. Normally distributed variables were analyzed via unpaired t-tests, non-normally distributed variables via Mann-Whitney U tests, and categorical variables via chi-square tests. A p-value < 0.05 indicated statistical significance.

The sample size was calculated based on the study by Dehghani et al., focusing on individuals with a sensory level above the T6 dermatome. Using a type I error rate of 5% and a study power of 0.8, the sample size was determined through a sample size calculation web page, resulting in a group size of 36 individuals for each group [7-8]. All participants were included in the study, and none of them dropped out or were excluded after enrollment.

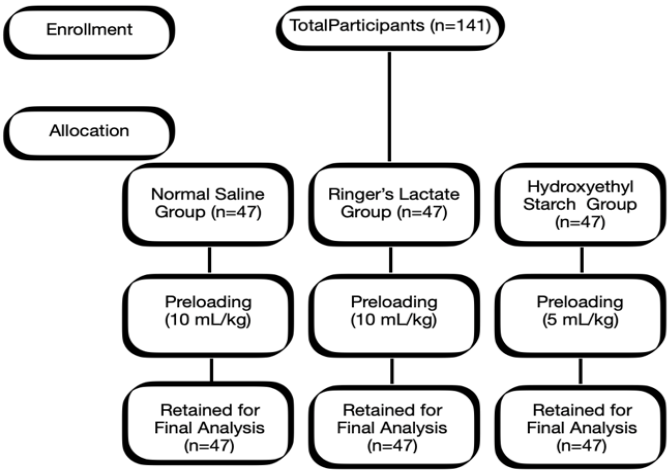

Figure 1- CONSORT Flow Diagram

Results

The study compared the effects of crystalloid (normal saline and Ringer's lactate) and colloid (HES) preloading on sensory block levels and hemodynamic stability during spinal anesthesia for cesarean sections. The study involved 141 women with a mean age of 29.8 years (SD ± 5.6), a mean BMI of 28.8 kg/m² (SD ± 3.1), and a baseline SBP of 116.7 mmHg (SD ± 8.9). No significant differences existed among the groups regarding age, BMI, surgery duration, or baseline hemodynamics ($p > 0.05$) (Table 1).

As depicted in (Figure 2), the normal saline group exhibited the highest sensory block level from the start until 60 minutes post-anesthesia, reaching statistical significance between 20 and 60 minutes. By 90–120 minutes, however, this group showed the lowest sensory block levels, though differences were not statistically significant.

Sensory block duration did not differ significantly among the groups, despite the HES group having the longest average duration (120 minutes) compared to normal saline and Ringer's lactate (both 90 minutes; $p = 0.362$).

Hypotension occurred in 35.5% of cases overall, varying across groups (normal saline: 34%, Ringer's lactate: 44.7%, HES: 27.7%), though these differences were not statistically significant ($p = 0.219$). Ephedrine requirements were similar across all groups ($p = 0.540$) (Table 2).

Nausea and vomiting affected 29.1% of participants, with the lowest incidence observed in the Ringer's lactate group (14.9%) versus 40.4% in the normal saline group and 31.9% in the HES group ($p = 0.075$) (Table 2).

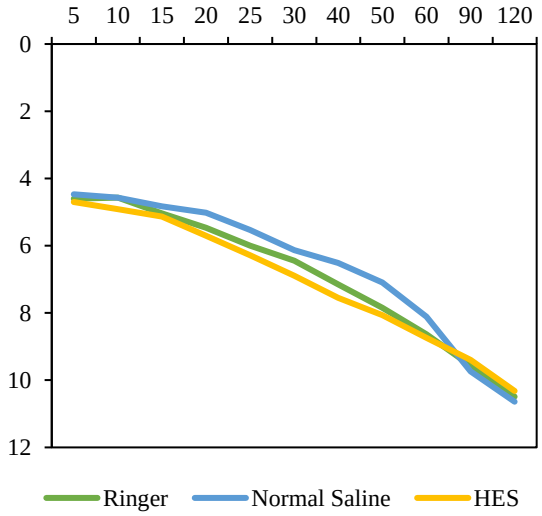

Figure 2- Sensory Level Trends Over 120 Minutes

Table 1- Demographics and Baseline Characteristics

Characteristic	Normal Saline Group Median (IQR)	Ringer's Lactate Group Median (IQR)	HES Group Median (IQR)	P value
Age (years)	29 (8)	30 (6)	32 (8)	0.89
BMI (kg/m²)	29.64 (4.31)	29.37 (2.90)	28.30 (3.92)	0.97
Baseline SBP (mmHg)	116.00 (14.00)	122.00 (12.00)	115.00 (10.00)	0.07
Baseline HR (bpm)	85.00 (17.00)	88.00 (13.00)	85.00 (11.00)	0.81
Duration of Surgery (minutes)	70.00 (20)	70.00 (30)	70 (22)	0.78

Table 2- Hemodynamic Parameters/Nausea and Vomiting

Parameter	Normal Saline Group	Ringer's Lactate Group	HES Group	P value
Incidence of Hypotension number (%)	16 (34%)	21 (44.7%)	13 (27.7%)	0.219
Total Ephedrine Requirements (mg) Median (IQR)	0.00 (5)	0.00 (10)	0.00 (5)	0.540
Nausea and Vomiting number (%)	19 (40.4%)	7 (14.9%)	15 (31.9%)	0.075

Discussion

This study highlights that preload fluid type influences sensory block characteristics and hemodynamic stability during spinal anesthesia for cesarean sections. Normal saline achieved the highest maximum sensory block level. For instance, Khosravi et al. found that Voluven resulted in higher sensory block levels compared to Ringer's lactate during cesarean delivery [9]. In contrast, Dehghani et al. observed no significant difference in sensory block levels between Voluven and normal saline [7]. Memari et al., focusing on surgeries other than cesarean sections, reported higher sensory block levels with normal saline compared to Voluven and Ringer's lactate [10].

The median interquartile range (IQR) for block duration within the normal saline cohort was documented at 90 (30) minutes, which is comparable to the Ringer's lactate cohort, also recorded at 90 (60) minutes. In contrast, the hydroxyethyl starch (HES) group demonstrated a marginally extended median block duration of 120 (30) minutes. Notwithstanding these discrepancies, no statistically significant difference in sensory block duration was observed among the three preload fluid types employed, as indicated by a P value of 0.362. Nevertheless, in the investigation conducted by Memari et al., normal saline exhibited a significantly prolonged sensory block duration in comparison to both Ringer's lactate and hydroxyethyl starch, with mean ± standard deviation (SD) values of 117.3 ± 8.6, 98.4 ± 9.3, and 92.4 ± 10.2 minutes, respectively [10]; conversely, Dehghani et al. reported no significant differences between normal saline and HES regarding the duration required for the sensory block to revert to the T10 dermatome level [7].

No substantial discrepancies were noted in the prevalence of hypotension among the various cohorts. However, the group receiving hydroxyethyl starch (HES) demonstrated a propensity for a diminished occurrence of hypotension, suggesting that colloid preloading may facilitate improved hemodynamic stability during spinal anesthesia administered for cesarean delivery. These observations align with previous research that has indicated no significant variations in blood pressure between crystalloid and colloid groups throughout the entirety of the study duration [9–11]. Conversely, the CAESAR trial, in conjunction with other investigations, revealed that preloading utilizing a mixture of HES and Ringer's lactate proved to be more efficacious in mitigating maternal hypotension compared to the administration of Ringer's lactate in isolation [12–14]. The most recent Cochrane meta-analysis further substantiated that colloids surpass crystalloids in their effectiveness at diminishing the incidence of maternal hypotension; nevertheless, the quality of the evidence presented was categorized as very low [15].

Sixteen mothers (11.3%) necessitated the administration of fentanyl during surgical procedures to augment the efficacy of spinal anesthesia. Seven individuals (14.9%) from the normal saline cohort, four (8.5%) from the Ringer's lactate cohort, and five (10.6%) from the Voluven cohort required supplementary analgesia. The variation among groups concerning the necessity for fentanyl to attain the desired anesthetic effect did not achieve statistical significance ($p = 0.610$). None of the patients experienced pain or discomfort of a severity that warranted a transition to general anesthesia. To date, there exists a paucity of studies that have investigated the variations in the type of intravenous fluid and its implications on the requirement for additional analgesics during spinal anesthesia.

In the investigation conducted by Madi-Jebara et al., no significant variation was detected in neonatal Apgar scores at both 1 and 5 minutes when comparing the groups receiving 10% hydroxyethyl starch and Ringer's lactate [13]. This observation is congruent with the outcomes presented by Alimian [16] and corroborated by additional studies [11, 14]. In a similar vein, our research indicated an absence of notable differences in Apgar scores at 1 and 5 minutes among all three groups ($p= 0.452$, $p= 0.732$, respectively), which is consistent with the conclusions of earlier investigations.

The research acknowledges a number of limitations. The calculated sample size, although based on prior studies, may not have been sufficiently large to identify subtle variations in outcomes such as the duration of sensory block or the prevalence of nausea and vomiting. Furthermore, the study exclusively involved women with singleton term pregnancies and ASA physical status I or II, which restricts the applicability of the findings to other patient demographics. Challenges related to blinding may have influenced the results, as achieving complete blinding was problematic due to variations in fluid administration protocols. The study employed a fixed dosage of hyperbaric bupivacaine, which might not adequately accommodate individual differences in reactions to local anesthetics. Moreover, while hemodynamic parameters and sensory block levels were observed for a duration of up to 90 minutes, the investigation did not evaluate long-term effects. The study also refrained from examining neonatal outcomes beyond Apgar scores or exploring the underlying reasons for the necessity of fentanyl supplementation in certain patients. Lastly, the quality of evidence concerning the efficacy of colloids in mitigating hypotension is deemed low, highlighting the imperative for further high-quality research to substantiate these findings.

Conclusion

The nature of preload fluid may impact both the extent and duration of sensory blocks during spinal anesthesia for cesarean deliveries; however, the disparities noted in this study lacked statistical significance. Normal saline produced the highest maximum sensory block level, whereas HES illustrated a slightly prolonged duration of the block. The HES group also exhibited a tendency towards a reduced incidence of hypotension, indicating potential advantages of colloid preloading for hemodynamic stability. Additional studies with more substantial sample sizes are warranted to elucidate these effects and refine fluid management strategies during spinal anesthesia for cesarean sections protocols. The study used a fixed dose of hyperbaric bupivacaine, which may not account for individual variability in responses to local anesthetics. Furthermore, hemodynamic parameters and sensory block levels were monitored for up to 90 minutes, but longer-term effects were not assessed. The study also did not explore neonatal outcomes beyond Apgar scores or investigate the reasons behind the need for fentanyl supplementation in some patients. Finally, the evidence regarding the effectiveness of colloids in reducing hypotension is of low quality, underscoring the need for further high-quality research to validate these findings.

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