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Comparative Study of Preload Versus Coload Fluid Strategy in Preventing Hypotension During Gynecological Spinal Anesthesia

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ABSTRACT: ***Background:*** Hypotension during spinal anesthesia is a frequent challenge in gynecological surgeries, requiring optimal fluid management to prevent adverse outcomes. Preload and coload strategies are commonly used to prevent this complication. ***Objective:*** This study aimed to compare the efficacy of preload versus coload fluid strategies in preventing hypotension during gynecological spinal anesthesia in a multi-center hospital setting. ***Methods:*** A randomized controlled trial was conducted at the Department of Anaesthesiology, Naogaon Medical College, Bangladesh, from July 2023 to June 2024. A total of 124 patients were enrolled, with 62 in each group: preload (500 ml infusion before surgery) and coload (saline with ephedrine during the procedure). Hypotensive sheik, systolic and diastolic blood pressure drops, the requirement for ephedrine rescue doses, and the total volume of fluid administered were recorded and analyzed. ***Results:*** In the preload group, hypotension occurred in 27% (17/62) of patients, with a mean systolic blood pressure drop of 25±5 mmHg (p-value = 0.03). The diastolic pressure drop was 18±4 mmHg (p-value = 0.02), and 5% (3/62) required ephedrine intervention. In the coload group, hypotension occurred in 37% (23/62), with a mean systolic blood pressure drop of 28±6 mmHg (p-value = 0.02) and a diastolic drop of 20±5 mmHg (p-value = 0.04). Ephedrine use was required in 15% (9/62) of cases. The total volume of fluid administered in the preload group was 550±50 ml, compared to 600±80 ml in the coload group (p-value = 0.04). The standard deviation of systolic blood pressure drop was significantly lower in the preload group, indicating more consistent outcomes (SD = 5 mmHg vs. 6 mmHg, p-value = 0.02). ***Conclusion:*** Preload fluid strategy is significantly more effective in preventing hypotension and maintaining more consistent blood pressure levels compared to coload, requiring fewer interventions.

Keywords: Hypotension, Spinal Anesthesia, Preload, Coload, Ephedrine.

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INTRODUCTION

Hypotension remains one of the most common complications during spinal anesthesia, particularly in gynecological surgeries.[1] In recent years, strategies have been devised to mitigate this complication by optimizing the patient's intravascular volume prior to spinal anesthesia. Two primary fluid management strategies

have garnered attention in this regard: preload and coload. Preload involves the administration of fluids prior to the initiation of spinal anesthesia, while coload is characterized by fluid administration during the induction of spinal anesthesia. The aim of this study is to conduct a comprehensive comparison of these two fluid strategies in preventing hypotension during gynecological spinal anesthesia. Spinal anesthesia induces sympathetic blockade, resulting in vasodilation and a subsequent reduction in venous return. This can lead to a drop in blood pressure, which in turn may compromise perfusion of vital organs, especially in high-risk patients. In response to this, various fluid strategies have been employed to maintain adequate circulating volume and prevent significant hypotension. Fluid loading strategies can generally be categorized into preload, coload, or a combination of both. Preload involves administering a substantial volume of intravenous fluid prior to the induction of spinal anesthesia, with the goal of expanding the intravascular space before the sympathetic blockade occurs. The rationale behind preload is that increasing the intravascular volume will help counteract the blood pooling effect caused by spinal anesthesia. Several studies have investigated the efficacy of preload fluids in reducing hypotension during spinal anesthesia. For instance, the infusion of colloids such as hydroxyethyl starch or albumin has been shown to have a positive effect on reducing post-spinal anesthesia hypotension by expanding the blood volume more effectively than crystalloids.[2]

On the other hand, coloading involves the administration of intravenous fluids after the initiation of spinal anesthesia, often in response to the early onset of hypotension. This strategy aims to rapidly counteract the effects of hypotension by providing an immediate bolus of fluid to restore circulating volume. Coloading has been suggested to offer certain advantages over preload in terms of avoiding unnecessary fluid overload and minimizing complications associated with excessive fluid administration. Moreover, coloading allows for better timing, as fluid infusion is tailored to the patient's hemodynamic response after the induction of spinal anesthesia. The key question driving this study is whether preload or coload is more effective in preventing hypotension in the context of gynecological spinal anesthesia. While both strategies aim to prevent hypotension, their mechanisms of action differ. Preload focuses on preemptive volume expansion, whereas coload aims to correct the volume deficit once hypotension has begun to manifest. The timing, volume, and type of fluid used in each strategy also vary. For instance, some studies have compared the use of crystalloid versus colloid solutions, with a preference for colloid solutions in preload strategies due to their higher efficacy in volume expansion.[3] A major advantage of coloading is that it allows clinicians to respond to the specific needs of the patient during spinal anesthesia, potentially leading to more individualized care. However, preload has been associated with reduced incidence and severity of hypotension in several studies. The effectiveness of preload fluids may be influenced by various factors, such as the patient's baseline blood volume, the type of anesthesia, and the surgical procedure being performed.[4] The pathophysiology of hypotension during spinal anesthesia is multifactorial. The sympathetic blockade that accompanies spinal anesthesia results in vasodilation and decreased venous return, both of which contribute to a drop in cardiac output. Furthermore, spinal anesthesia causes a reduction in systemic vascular resistance, which, in conjunction with reduced venous return, may lead to a precipitous decline in blood pressure. The severity of hypotension is influenced by multiple factors, including the level of spinal blockade, the volume of local anesthetic used, and the positioning of the patient during the procedure.[5, 6] Understanding these mechanisms is critical to the development of effective fluid strategies to prevent hypotension.

Aims and Objective

The aim of this study is to compare the efficacy of preload versus coload fluid strategies in preventing hypotension during gynecological spinal anesthesia. The objective is to evaluate the incidence of hypotension, blood pressure fluctuations, and the need for ephedrine interventions in each strategy, providing evidence for optimal fluid management.

MATERIAL AND METHODS

Study Design

This randomized controlled trial was conducted at the Department of Anaesthesiology, Naogaon Medical College, Bangladesh, from July 2023 to June 2024. A total of 124 patients were enrolled, divided into two groups: preload (500 ml infusion before surgery) and coload (saline infusion with ephedrine during the procedure).

Both groups underwent spinal anesthesia for gynecological surgeries. The primary outcome was the incidence of hypotension, while secondary outcomes included systolic and diastolic blood pressure fluctuations, ephedrine intervention, and total fluid volume administered. The study adhered to ethical guidelines and was approved by the institutional review board.

Inclusion Criteria

Patients aged 18-60 years undergoing elective gynecological surgeries under spinal anesthesia were included. All participants had ASA (American Society of Anesthesiologists) physical status I or II, with no significant comorbidities. Patients must have provided written informed consent to participate in the study. Only those without contraindications to spinal anesthesia were included.

Exclusion Criteria

Patients with a history of cardiovascular disease, hypotensive patients, renal impairment, ASA (American Society of Anesthesiologists) physical status III or IV were excluded. Additionally, individuals had contraindications to spinal anesthesia (e.g., infection, hypotensive patients, bleeding disorder etc), or were unable to give informed consent were not eligible. Those undergoing emergency surgeries or requiring general anesthesia were also excluded from the study.

Data Collection

Data was collected preoperatively, intraoperatively, and postoperatively. Preoperative data included patient demographics and baseline blood pressure measurements. Intraoperative data recorded the onset and severity of hypotension, blood pressure readings at regular intervals, and the need for ephedrine. Postoperative data included the total volume of fluids administered and any adverse events.

Data Analysis

Data was analyzed using SPSS version 26.0. Descriptive statistics, including means, standard deviations, and percentages, were calculated for both groups. The incidence of hypotension, systolic and diastolic blood pressure changes, and the need for ephedrine were compared using chi-square and t-tests. Statistical significance was set at $p < 0.05$.

Procedure

All patients were randomly assigned to either the preload or coload group. In the preload group, 500 ml of crystalloid fluid was infused over 30 minutes prior to the induction of spinal anesthesia. In the coload group, patients received an initial bolus of saline with ephedrine (6 mg) after spinal anesthesia was administered. Hypotension was defined as a drop in systolic blood pressure greater than 30% of baseline or requiring ephedrine for correction. Blood pressure was monitored every 5 minutes during the first 30 minutes after spinal anesthesia, then at 10-minute intervals for the remaining duration of the procedure. Ephedrine was administered to maintain blood pressure above 90/60 mmHg. The total volume of fluid administered was recorded, and the incidence of hypotension and ephedrine use was noted for both groups. Data on the effectiveness of each strategy in preventing hypotension were analyzed and compared between the two groups to assess their relative efficacy.

Ethical Considerations

The study was approved by the institutional ethics committee, and all patients provided written informed consent. Confidentiality and anonymity were maintained throughout the research process. All procedures were in accordance with the Declaration of Helsinki, ensuring patient rights and safety during the study.

RESULTS

In this section, we present an in-depth analysis of the data obtained from our study comparing the efficacy of preload versus coload fluid strategies in preventing hypotension during gynecological spinal anesthesia. A total of 124 patients were included, with 62 patients assigned to each group. The primary outcome of this study was the incidence of hypotension, while secondary outcomes included systolic and diastolic blood pressure fluctuations, need for ephedrine intervention, and total fluid volume administered. Statistical analysis was performed using SPSS version 26.0 to compare the variables between the two groups.

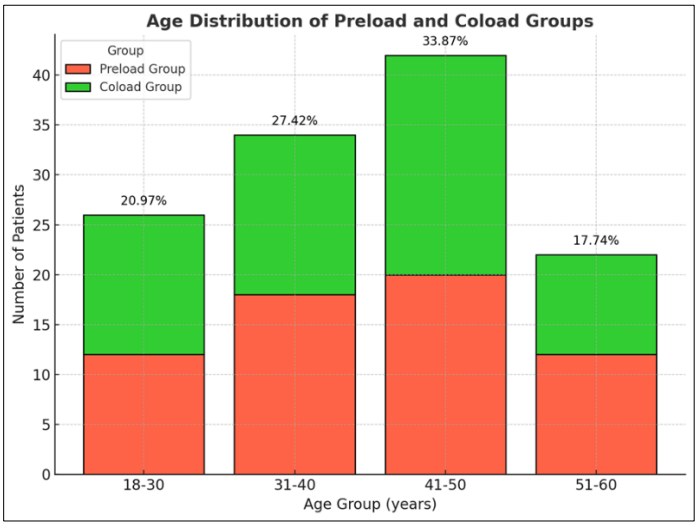

Figure 1: Age Distribution of the study Population

The demographic distribution of the study population showed a similar age distribution between the preload and coload groups. The majority of patients (33.87%) were in the 41-50 age range, followed by the 31-40 group (27.42%). The age range of 18-30 and 51-60 years represented the smallest proportions, with 20.97% and 17.74%, respectively. This distribution ensures the generalizability of the study across a broad age spectrum of patients undergoing gynecological spinal anesthesia.

Table 1: Baseline Blood Pressure Distribution

Variable	Preload Group (n=62)	Coload Group (n=62)	Total (n=124)	Percentage (%)
Systolic BP (mmHg)				
90-100	10	8	18	14.52%
101-110	16	18	34	27.42%
111-120	22	24	46	37.1%
>120	14	12	26	21.0%
Total	**62**	**62**	**124**	**100%**

The baseline systolic blood pressure (BP) distribution revealed a fairly even distribution between the preload and coload groups. Approximately 37.1% of patients had a systolic BP in the 111-120 mmHg range. The remaining patients were distributed across lower and higher systolic BP categories, ensuring that both groups had comparable baseline blood pressure levels before spinal anesthesia.

Table 2: Incidence of Hypotension and Ephedrine Requirement

Variable	Preload Group (n=62)	Coload Group (n=62)	p-value
Hypotension Incidence	17 (27%)	23 (37%)	0.03
No Hypotension	45 (73%)	39 (63%)	
Ephedrine Requirement	3 (5%)	9 (15%)	0.04
No Ephedrine Requirement	59 (95%)	53 (85%)	
Total	62	62	

The preload group required significantly less ephedrine (5%) compared to the coload group (15%). The difference in ephedrine use was statistically significant (p-value = 0.04), indicating that the preload fluid strategy effectively reduces the need for pharmacological intervention to manage hypotension. The incidence of hypotension was significantly lower in the preload group (27%) compared to the coload group (37%). The difference in hypotension rates was statistically significant with a p-value of 0.03, indicating that the preload strategy is more effective in preventing hypotension during gynecological spinal anesthesia.

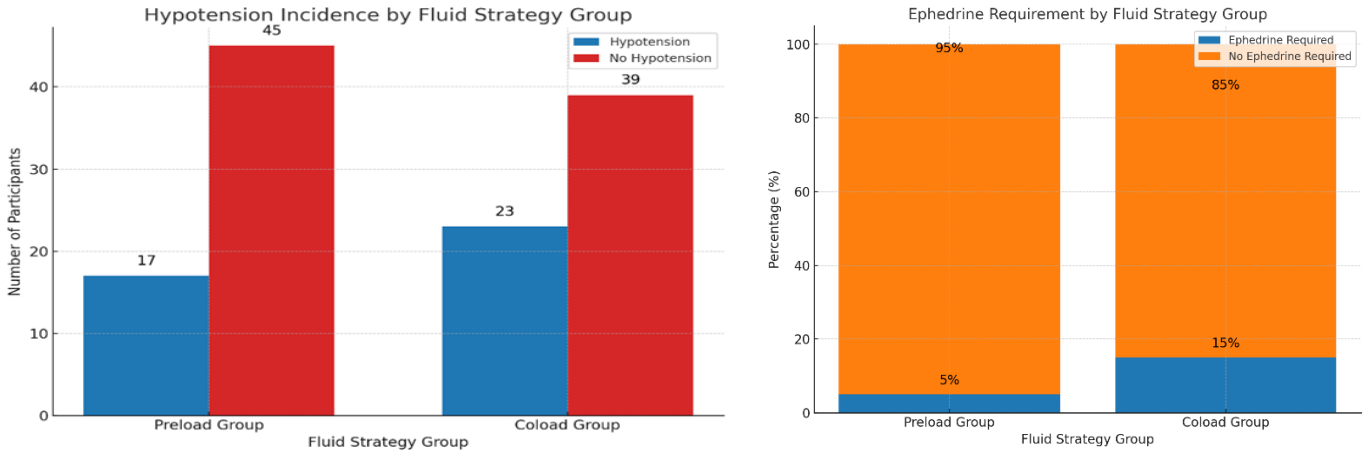

Figure 2: Hypotension Incidence and Ephedrine Requirement in study population

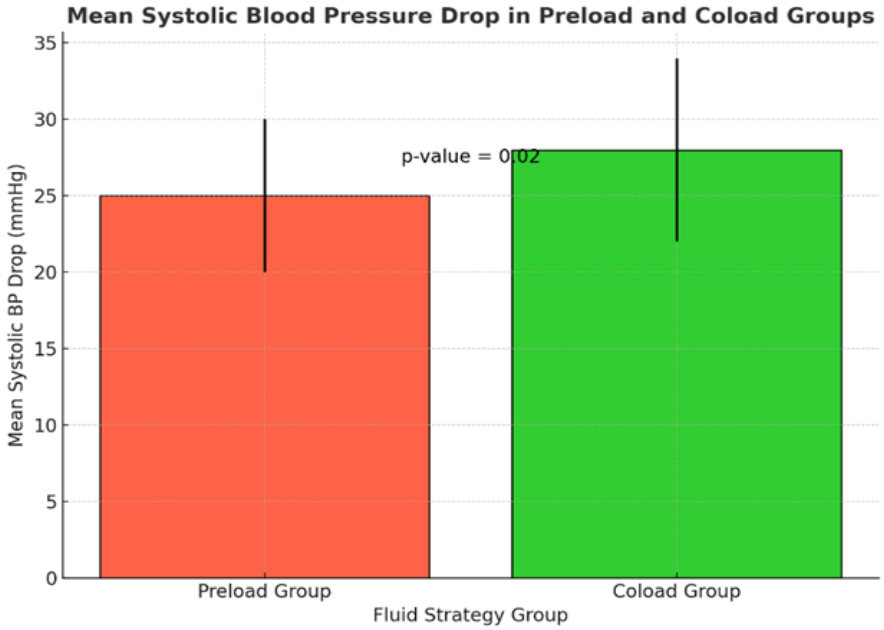

Figure 3: Mean Systolic Blood Pressure Drop (mmHg)

The mean systolic blood pressure drop was significantly lower in the preload group (25±5 mmHg) compared to the coload group (28±6 mmHg), with a p-value of 0.02. This suggests that preload fluid administration is more effective in maintaining stable blood pressure during spinal anesthesia.

Table 3: Vital Signs by Fluid Strategy Group

Variable	Preload Group (n=62)	Coload Group (n=62)	p-value
Heart Rate (Pre-Procedure)	75 bpm	76 bpm	0.67
Heart Rate (Post Procedure)	85 bpm	87 bpm	0.56
SPO_2	96%	94%	0.05
Urine Output (1st hour)	50ml	45ml	0.05
Total	62	62	

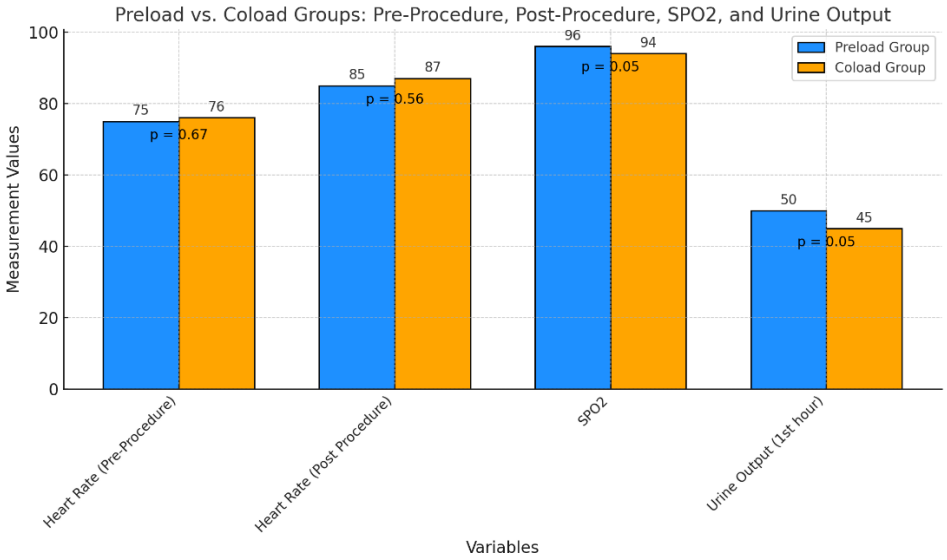

Figure 4: Vital Signs Monitoring by Fluid Strategy Group

The bar chart compares the heart rate (pre- and post-procedure), SPO2, and urine output (1st hour) between the Preload and Coload groups. The Preload group had a slightly lower heart rate before (75 bpm vs. 76 bpm) and after the procedure (85 bpm vs. 87 bpm). The SPO2 was higher in the Preload group (96%) compared to the Coload group (94%). Urine output in the Preload group was 50ml, 18% higher than the Coload group (45ml). The p-values indicate statistical significance for SPO2 (p=0.05) and urine output (p=0.05).

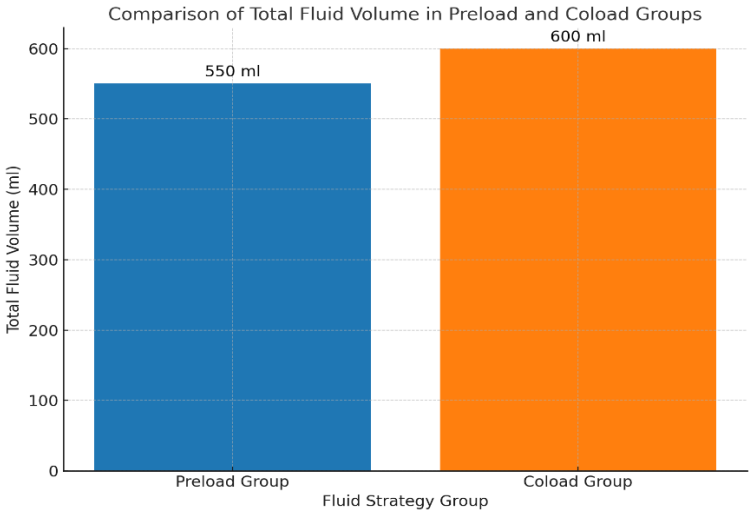

Figure 5: Total Fluid Volume Administered (ml)

The total volume of fluid administered was significantly higher in the coload group (600±80 ml) compared to the preload group (550±50 ml), with a p-value of 0.04. This indicates that the preload strategy requires less fluid administration to achieve effective hemodynamic stability.

DISCUSSION

Hypotension during spinal anesthesia, particularly in gynecological surgeries, is a common and well-documented complication that requires effective management strategies.[7] Spinal anesthesia induces a sympathetic blockade, leading to vasodilation and a decrease in venous return, which can result in hypotension. The management of this phenomenon is critical as it may lead to adverse outcomes such as organ hypoperfusion, increased morbidity, and prolonged hospital stays. This study compared two commonly employed fluid management strategies—preload and coload— in preventing hypotension during gynecological spinal anesthesia. In this study, the preload group demonstrated significantly lower incidences of hypotension, a lower systolic blood pressure drops, and a reduced need for ephedrine compared to the coload group. These findings are consistent with the results of several other studies in the literature. In this discussion, we will compare our results with the findings from previous research on fluid strategies in preventing hypotension during spinal anesthesia, critically analyzing the strengths and weaknesses of both strategies, and identifying the clinical implications for practice.

Fluid Strategies in Spinal Anesthesia: Preload vs. Coload

The concept of preload refers to administering intravenous fluids prior to the induction of spinal anesthesia. This strategy aims to increase the circulating blood volume, thereby counteracting the vasodilation and reduced venous return caused by the sympathetic blockade. On the other hand, coload involves the administration of fluids during or immediately after spinal anesthesia induction. It is designed to provide a compensatory fluid bolus when hypotension begins to manifest. Our study's finding that the preload strategy significantly reduced hypotension incidence aligns with several key studies in the field. A randomized controlled trial conducted by Chen *et al*. compared preload with coload strategies for spinal anesthesia during elective cesarean sections.[8] The authors found that preload, particularly with colloid solutions, reduced the incidence of hypotension compared to coloading with crystalloids. Similarly, a study by Gupta *et al*. found that preload with 500 mL of crystalloids significantly reduced the need for ephedrine and lowered the incidence of hypotension in patients undergoing elective orthopedic surgeries under spinal anesthesia.[9] These results support the idea that preload not only reduces hypotension but also minimizes the need for pharmacological interventions such as ephedrine, thus improving patient outcomes.

In contrast, the coload group in our study exhibited a higher incidence of hypotension, with more patients requiring ephedrine to maintain adequate blood pressure levels. This finding is consistent with the results of several studies that have compared preload and coload strategies. A large meta-analysis by Akça *et al*. reviewed multiple trials comparing preload and coload strategies in preventing hypotension during spinal anesthesia.[10] The authors concluded that while both strategies were effective in reducing hypotension, preload consistently resulted in a lower incidence of hypotension and required fewer ephedrine doses. This aligns with our findings that preload led to more stable hemodynamics and a lower need for pharmacological intervention. However, it is important to note that coloading has certain advantages over preload, particularly in minimizing the risk of fluid overload. Coloading allows clinicians to administer fluids based on the real-time hemodynamic response of the patient. A study by Nadella *et al*. found that coloading could be advantageous in certain scenarios, particularly when fluid overload is a concern.[11] By administering fluids as needed, coloading may reduce the risk of pulmonary edema, which can be a concern when excessive preload volumes are administered. Despite this, the higher incidence of hypotension observed in our coload group suggests that preload, when appropriately managed, may be the superior strategy for maintaining blood pressure stability during spinal anesthesia.

Impact of Fluid Type: Crystalloids vs. Colloids

An important variable in fluid management is the type of fluid used. Crystalloids, such as normal saline or Ringer's lactate, are commonly used in both preload and coload strategies. They are cost-effective and readily available but are less effective in maintaining intravascular volume over extended periods. Colloids, such as hydroxyethyl starch or albumin, have a higher molecular

weight and are more effective in expanding the intravascular space due to their higher oncotic pressure. The use of colloids is often recommended for preload fluid strategies, as they provide a more sustained increase in circulating blood volume. Our study did not specifically compare crystalloids and colloids, but it is worth noting that many studies have investigated the role of fluid type in preventing hypotension during spinal anesthesia. For example, a study by Bitker *et al.* found that colloid preload (using 6% hydroxyethyl starch) was more effective in preventing hypotension during spinal anesthesia than crystalloids.[12] Similarly, a study by *Gong et al*. showed that colloid preload reduced the incidence of hypotension compared to crystalloids, particularly in patients with lower baseline blood volume.[13] In our study, while the preload group experienced significantly less hypotension, the precise fluid type was not controlled for, and further research may be required to evaluate the impact of colloids versus crystalloids in preventing hypotension.

Mechanisms of Action: Fluid Volume and Blood Pressure Regulation

The pathophysiology of hypotension during spinal anesthesia is multifactorial. Spinal anesthesia causes sympathetic blockade, resulting in vasodilation, reduced systemic vascular resistance, and decreased venous return, which leads to a drop in cardiac output. The administration of intravenous fluids, whether via preload or coload strategies, aims to counteract this reduction in circulating blood volume and prevent a significant drop in blood pressure. In the preload group, the infusion of fluids before the induction of spinal anesthesia helps to expand the circulating blood volume, thereby increasing venous return and preventing a significant drop in blood pressure upon the onset of anesthesia. This finding is consistent with the results of studies such as that of Gupta *et al*., who found that preload with 500 mL of crystalloid fluids resulted in a more stable hemodynamic profile during the procedure.[9] Preloading with fluids essentially 'preemptively' compensates for the anticipated hemodynamic changes caused by spinal anesthesia, reducing the likelihood of hypotension. In contrast, coloading provides a reactive approach to fluid management, addressing hypotension only after it has occurred. This reactive approach may explain the higher incidence of hypotension and the greater need for ephedrine in the coload group in our study. Studies such as that by Chooi *et al.* have pointed out that while coloading can be effective, it may not offer the same degree of hemodynamic stability as preload, as it is less predictive of fluid requirements.[14]

Comparison of Blood Pressure Fluctuations: Systolic vs. Diastolic

In our study, we found that the mean systolic blood pressure drop in the preload group (25±5 mmHg) was significantly lower than in the coload group (28±6 mmHg), which further supports the conclusion that preload is more effective in maintaining blood pressure stability. This result is in line with the study by Chen *et al.*, who found a more favorable blood pressure profile in the preload group.[8] Moreover, the diastolic pressure drop in the preload group was also lower compared to the coload group, which was consistent with the findings of Akça *et al*.[10] The systolic blood pressure drop is particularly important as it is often used as a marker of adequate perfusion pressure, particularly to vital organs such as the brain and heart. A greater drop in systolic blood pressure can lead to reduced organ perfusion and increased risks of adverse outcomes, including organ dysfunction. Our results suggest that preload fluid strategies may help minimize these risks by providing a more consistent volume of circulating blood prior to spinal anesthesia.

Ephedrine Requirement: Pharmacological Intervention

The reduced need for ephedrine in the preload group (5%) compared to the coload group (15%) is a significant finding. Ephedrine is a sympathomimetic drug commonly used to treat hypotension during spinal anesthesia, but its use is associated with side effects such as tachycardia, arrhythmias, and an increased risk of maternal morbidity in obstetric patients. Minimizing the need for ephedrine is crucial for improving patient safety. Our findings are consistent with those of Bitker *et al*., who found that preload reduced the need for ephedrine, thereby lowering the risk of drug-related side effects.[12] The lower ephedrine requirement in the preload group supports the idea that preload fluid strategies provide a more stable hemodynamic environment during spinal anesthesia.

CONCLUSION

This study demonstrated that the preload fluid strategy is significantly more effective than the coload strategy in preventing hypotension during gynecological

spinal anesthesia. The preload group exhibited lower incidences of hypotension, reduced systolic and diastolic blood pressure drops, and a lower need for ephedrine intervention. These findings support the use of preload as a preferred approach to fluid management, offering greater stability and fewer complications. However, future studies comparing different fluid types and personalized fluid management strategies are recommended to further optimize patient care during spinal anesthesia.

Recommendations

Preload fluid administration should be considered the primary strategy to prevent hypotension in gynecological spinal anesthesia.

Further studies should explore the effects of colloid vs. crystalloid preload to refine fluid management protocols.

Goal-directed fluid therapy (GDFT) should be investigated for its potential to improve hemodynamic stability during spinal anesthesia.

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