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Ultrasound Assessment of Inferior Vena Cava Prior to Spinal Anesthesia: A Guide to IV Fluid and Durg Administration

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ABSTRACT

Background and Objectives: Sustained and significant hypotension resulting from spinal anesthesia increases the risk of inadequate organ perfusion, which can lead to perioperative complications and even death. Utilizing dynamic, non-invasive techniques such as assessing the Inferior Vena Cava (IVC) collapsibility index through abdominal ultrasonography provides insight into intravascular volume changes. This respiratory-induced variation in IVC diameter is recognized as a valuable indicator of volume responsiveness, applicable in cases of circulatory insufficiency, whether patients are mechanically ventilated or breathing spontaneously.

Material and Methods: This prospective randomized study involved 90 participants aged 18-60 years, with 45 in each group. Randomization was done using computer-generated techniques. Group A (control) received standard spinal anesthesia, while Group B (study) had pre-anesthetic ultrasonographic assessment of the IVC to guide fluid administration based on the IVC Collapsibility Index.

Results: Both groups of patients had similar demographic characteristics, such as age, gender, and weight. There was no notable statistical distinction between the two groups in terms of the administration of Ephedrine. Likewise, when evaluating the use of Phenylephrine between the two groups, no significant statistical difference was observed. However, there was a highly significant statistical difference between the two groups in terms of the amount of intraoperative fluid used .

Conclusion: Utilization of preoperative ultrasonographic assessment of the IVC and subsequent optimization of intravascular volume status guided by the IVC collapsibility index can indeed assist in the management of intraoperative IV crystalloids and vasopressors.

Key words: Ultrasonography, Hypotension, Spinal Anesthesia, Inferior Vena Cava, Collapsibility Index.

INTRODUCTION

Spinal anesthesia constitutes a widely employed, secure, and dependable anesthesia modality, distinguished by its favorable attributes including predictable outcomes, a minimal incidence of complications, accelerated recovery of gastrointestinal motility, and reduced reliance on systemic opioid analgesia. This technique entails the introduction of a local anesthetic agent into the subarachnoid space, housing cerebrospinal fluid (CSF), thereby facilitating the absorption and dispersion of the drug along nerve roots requiring inhibition to attain surgical anesthesia. Consequently, spinal anesthesia is a suitable choice for surgical procedures below the umbilicus, encompassing interventions such as hernia repair, hysterectomy, cesarean section, urological procedures like lithotripsy and prostate resection, cystoscopy, as well as orthopedic surgeries affecting the lower extremities (1-4).

The manifestation of hypotension induced by spinal anesthesia results from the blockade of lumbar sympathetic outflow, culminating in profound vasodilation within the systemic venous, arterial, and arteriolar vasculature. This vasodilatory cascade leads to a decline in cardiac output, primarily due to diminished preload. While diverse definitions exist, systolic arterial blood pressure falling below 80% of the baseline is a widely accepted criterion for defining spinal anesthesia-induced hypotension (5). Notably, sustained and pronounced hypotension secondary to spinal anesthesia imposes the risk of organ hypoperfusion, contributing to perioperative morbidity and mortality (6, 7).

Preventing spinal anesthesia-induced hypotension involves strategies like fluid co-loading, vasopressor use, and non-pharmacological interventions like compression stockings, splints, and the Trendelenburg position.

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Fluid responsiveness indicates a person's ability to increase cardiac output with increased preload, reflected in static parameters like blood pressure and heart rate. This informs proactive or symptomatic management in critical care, allowing for fluid administration instead of vasopressors when appropriate. It also aids in identifying those who won't benefit from fluids. Yet, static parameters are less sensitive in perioperative settings, driving the need for dynamic, non-invasive measures like the Inferior Vena Cava collapsibility index assessed via abdominal ultrasonography, reflecting intravascular volume changes. This respiratory-induced variation in IVC diameter is considered a valuable predictor of volume responsiveness in cases of circulatory insufficiency, both in mechanically ventilated patients and those breathing spontaneously, even in the presence of non-fatal cardiac arrhythmias (8-16).

Consequently, anesthesia providers may harness this technique to forestall spinal anesthesia-induced hypotension and its associated sequelae. The IVC collapsibility index presents as a non-invasive, cost-effective, uncomplicated, and reliable approach to ascertaining volume status in spontaneously breathing patients (6,17,18). Its incorporation into clinical practice holds the potential to elevate the standard of perioperative patient care in a discernible manner.

MATERIAL & METHODS

This prospective randomized study comprised a sample size of 90 participants, with 45 individuals allocated to each of the two groups. Eligible participants, belonging to ASA 1 or 2 categories, were scheduled for urological procedures and lower limb wound debridement surgeries under spinal anesthesia, falling within the age range of 18-60 years.

Randomization was performed using computer-generated randomization techniques, and the patients were then stratified into two groups. Group A, designated as the control group, received routine spinal anesthesia, while Group B, the study group, underwent ultrasonographic assessment of the Inferior Vena Cava (IVC) before spinal anesthesia. Fluid administration in Group B was guided by the IVC Collapsibility Index, as necessary.

Patients meeting criteria for ASA PS III or above, or those contraindicated for spinal anesthesia (e.g., injection site infection, increased intracranial pressure, coagulopathy, sepsis, fixed cardiac output states, ischemic heart disease, indeterminate neurological disease, hypersensitivity to local anesthetic drugs), as well as those requiring emergency, obstetric, or cardiovascular surgeries, were excluded from the study.

Baseline non-invasive blood pressure (NIBP), pulse oximetry, and electrocardiogram (ECG) monitoring were conducted for all participants. In Group B, individuals underwent ultrasound-guided measurement of the inferior vena cava (IVC) diameter while in a supine position prior to spinal anesthesia. Using a subcostal approach during spontaneous tidal breathing, M-mode transabdominal ultrasonography was employed to measure IVC variations, including maximum diameter (IVCmax) during inspiration and minimum diameter (IVCmin) during expiration. The IVC Collapsibility Index was calculated using the formula IVCCI = (IVCmax - IVCmin) / IVCmax, with individuals having an IVCCI >36% classified as fluid responders. These individuals received a crystalloid pre-load of 10 ml/kg (0.9% Normal Saline or Ringer's lactate solution). After 15 minutes, IVC diameter variations were reassessed under ultrasound guidance. If individuals still exhibited an IVCCI >36%, they received an additional 10 ml/kg crystalloid bolus. This process was repeated until the IVCCI fell below 36%, indicating a non-responder pattern. Individuals with an IVCCI <36% then underwent spinal anesthesia under strict aseptic conditions.

Group A (the control group) did not undergo ultrasound-guided inferior vena cava volume optimization and received spinal anesthesia directly. During spinal anesthesia, individuals were seated, and 0.5% Bupivacaine at an appropriate dosage was slowly infiltrated into the L3-L4 interspace in the subarachnoid space using a 27G needle. Continuous monitoring was maintained throughout the procedure, and intraoperative management was tailored based on the assigned group.

Significant intraoperative hypotension was defined as a systolic arterial blood pressure decrease of 20% from the initially measured baseline values. Individuals in Group B received the appropriate vasopressor drug (0.1-0.2mg/kg of Ephedrine or 20mcg of Phenylephrine) without additional bolus administration of IV Crystalloids in response to significant intraoperative hypotension. In contrast, individuals in Group A initially received a bolus administration of IV crystalloids at 10 ml/kg over 15 minutes. If the blood pressure continued to fall persistently 5 minutes after the fluid bolus, they were subsequently treated with the appropriate vasopressor drug (0.1-0.2mg/kg of Ephedrine or 20mcg of Phenylephrine). Both groups received maintenance fluid therapy based on the Holiday-Segar formula and were adequately replaced according to fluid loss during the procedures.

RESULTS

In this study, a total of 90 patients were included for statistical analysis, with 45 individuals in each of the two groups, A and B. The patients in both groups exhibited comparable demographic variables, including age, sex, and weight (Table 1).

Table 1: Demographic parameters in study groups

Demographic Parameters	Group A (n=45)	Group B (n=45)	P Value
Age (in years)	50.32 ± 12.48	48.95 ± 11.27	0.71
Females	13	14	0.45
Males	32	31	
Weight (in Kg)	69.8 ± 9.72	66.21 ± 9.36	0.21

Upon conducting statistical analysis, it was found that there was no statistically significant difference between the two groups when comparing the use of Ephedrine administration. Similarly, the comparison of Phenylephrine use between the two groups did not reveal any statistically significant difference (Table 2).

Table 2: Comparison of fluid and vasopressor administration in study groups

Parameters	Group A (n=45)	Group B (n=38)	P Value
Intraoperative IV fluids (ml)	460.75 ± 230.12	100.42 ± 5.10	<0.05
Total IV fluids (ml)	455.62 ± 228.29	303.78 ± 334.99	<0.05
Phenylephrine administration	8/45	5/45	0.43
Ephedrine administration	16/45	8/45	0.206

However, it is noteworthy that the amount of intraoperative fluid used exhibited a highly statistically significant difference between the two groups. The mean volume of intraoperative fluid was higher in group A. Additionally, the total amount of fluid administered during the entire procedure also showed a statistically significant difference. The mean total fluid volume was higher in group A. Interestingly, despite these differences in fluid administration, there was no positive correlation found between the fluid administration and the Inferior Vena Cava (IVC) collapsibility index (p-value=0.89, r-value=-0.018). This suggests that the amount of fluid administered did not correlate with the IVC collapsibility index in this study.

DISCUSSION

The primary objective of our study was to evaluate the effectiveness of preoperative USG guided IVC diameter optimization before spinal anesthesia. This assessment was carried out by establishing correlations between the preoperative assessment, the amount of intraoperative IV fluids and vasopressors administered.

Our study led to the conclusion that the assessment of IVC collapsibility before spinal anesthesia significantly influenced the management of spinal-induced hypotension by guiding the administration of intraoperative fluids and vasopressors. Our findings align with previous studies study which demonstrated significantly higher fluid administration in the control group compared to the study group (7, 19)

In contrast, a study by Chowdhary *et al*. (15) compared IVC collapsibility index (IVCCI) and variations in carotid artery peak systolic velocity (CAPV) among patients undergoing elective lower abdominal surgeries and concluded that IVCCI and CAPV were poor predictors of post-spinal hypotension. However, they suggested that a composite model including ultrasound parameters and baseline mean blood pressure (MBP) could be more efficient.

In our study, we employed a cutoff value of 36% for IVCCI, similar to the study by Ayyangouda *et al*., based on previous literature and meta-analysis. This choice was informed by a meta-analysis by Zhang *et al*. (20), who studied cut-off values of IVCCI ranging from 12% to 40% across studies to predict fluid responsiveness in critically ill patients. Additionally, abdominal ultrasonography has been used to assess parameters such as aortic peak flow velocity and aortic velocity time integral. Achar *et al*. (21) employed these measures in a study involving children under general anesthesia and found them to be reliable indices for fluid responsiveness in this population.

It's important to acknowledge the limitations of our study. We used randomization to allocate patients to their respective groups, but blinding was not possible due to the preoperative performance of ultrasonography. Furthermore, our study only included patients classified as ASA 1 or 2, and further research is warranted to assess the efficacy of this approach in critically ill patients belonging to ASA grade 3 and above. We also did not measure IVCCI during episodes of hypotension and after spinal anesthesia. Future studies may address these limitations with more comprehensive analyses.

CONCLUSION

Based on the findings of this study, it can be concluded that the utilization of preoperative ultrasonographic assessment of the Inferior Vena Cava (IVC) and subsequent optimization of intravascular volume status guided by the IVC collapsibility index can indeed assist in the management of intraoperative IV crystalloids and vasopressors.

Conflicts of interest: none

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