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Research Article

PREOPERATIVE ULTRASOUND-GUIDED INFERIOR VENA CAVA COLLAPSIBILITY INDEX AS A GUIDE TO PREDICT HYPOTENSION FOLLOWING SPINAL ANESTHESIA

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ABSTRACT

Objective: Post-spinal hypotension is a commonly encountered complication following spinal anesthesia. However, there is a dearth of a concrete tool to predict spinal-induced hypotension (SIH) and differentiate the cohort of patients requiring fluid boluses versus vasopressors to correct it. Thus, we aimed to determine the prognostic efficacy of ultrasonographic assessment of inferior vena caval collapsibility index (IVC-CI) to predict hypotension following spinal anesthesia and compare the requirements of crystalloids and Mephentermine among patients with IVC-Collapsibility Index >50% and <50%.

Methods: This observational study was conducted in the Department of Anesthesiology, Government Medical College, Kottayam. Preoperative IVC Ultrasonography was performed in 74 patients of ASA Grade 1–2 scheduled for elective surgery under spinal anesthesia and their IVC-CI was determined. Spinal anesthesia procedure protocol was standardized. Mean arterial pressure, intravenous fluids, and mephentermine requirements were documented in both IVC-CI groups.

Results: There was no significant difference in the demographics or pre-operative vital signs between the two groups. Significant hypotension was seen in 51.4% of patients. 97% of patients with IVC-CI>50% had significant hypotension, p=0.000. IVCCI>50% is 97.2% specific and 84.2% sensitive in predicting SIH with a positive predictive value of 96.97% and negative predictive value of 85.37%. Significantly, high requirement of intravenous fluids and mephentermine was noted among IVC-CI>50% group, p=0.000 and 0.026, respectively.

Conclusion: USG-guided IVC-CI is an easy to perform, non-invasive, time-efficient, and readily available technique to assess fluid responsiveness. Patients with IVC-CI>50% are more likely to develop SIH. Furthermore, the requirement of vasopressors and IV fluids increases with IVC-CI>50%. USG-guided IVC-CI is a reliable predictor of SIH.

Keywords: Inferior vena cava collapsibility index, Spinal anesthesia, Spinal induced hypotension.

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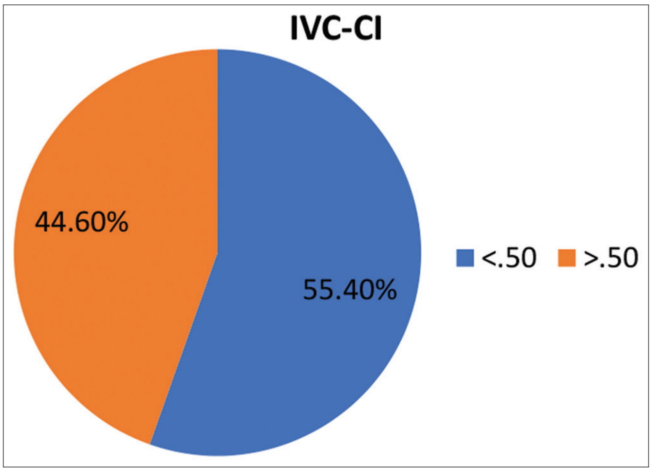
INTRODUCTION

Spinal anesthesia is a commonly employed regional anesthetic technique for infraumbilical surgeries. The most common side effects of spinal anesthesia are hypotension, bradycardia, nausea, and vomiting [1]. Spinal-induced hypotension is a common side effect that may result in several adverse effects such as coronary ischemia, acute kidney injury, heart failure, stroke, delirium, and prolonged hospital stay [2-4]. Spinal-induced hypotenion (SIH) can be attributed to the vasodilatation with subsequent reduction in systemic vascular resistance and reduced venous return, leading to decreased cardiac output. Patient's susceptibility to intraoperative hypotension can also be influenced by their preoperative volume status, which in turn depends on their comorbidities, physical status, pre-operative medications, bowel preparation, and fasting [5]. Monk *et al*. [6] in his retrospective analysis showed that intraoperative hypotension was associated with 30-day postoperative mortality in non-cardiac surgery. In spite of this evidence, fluids and vasopressors are often not administered to prevent SIH on a patient-adapted and monitoring-based concept [7]. In obstetric anesthesia, preventive empiric volume loading is commonly performed to minimize hemodynamic impairment, before giving spinal anesthesia [8]. However, several studies have yielded inconsistent results regarding prophylactic volume loading to prevent SIH. Therefore, the practice of routine volume preloading before spinal anesthesia in non-obstetric patients is not performed nowadays. Many static and dynamic indices of fluid responsiveness are being used with variable performance in different settings [9]. The efficiency of traditional methods of predicting volume status as predictors of SIH remains a controversy. Hence, there has been a continuous search for an easy, non-invasive, and reliable predictor of SIH. Various non-invasive modalities, such as, transthoracic echocardiography (TTE), transthoracic bioimpedance, and passive leg raising test, have been used to predict SIH in different subgroups including the obstetric patients, revealing varied results [10]. However, TTE is time-consuming and needs expertise and bioimpedance derived CO measurement is not readily available.

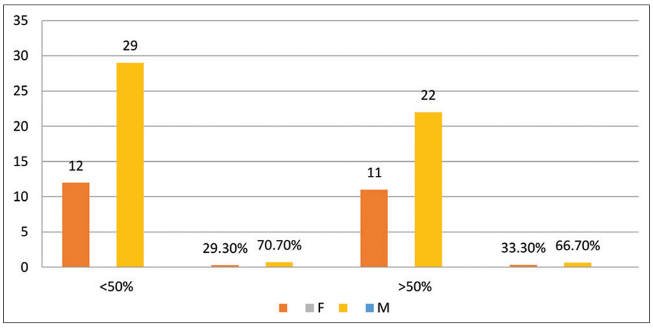
In contrast, ultrasonographic assessment of the inferior vena cava collapsibility index (IVC-CI) is easy to perform, non-invasive, time-efficient, and readily available as well. The ultrasonographic measurement of IVC-CI as a predictor of fluid responsiveness has been extensively studied in different patient populations, predominantly in patients with sepsis. Preau *et al*. [11] found out that IVC-CI can be used as a good predictor of volume responsiveness in sepsis-related acute circulatory failure patients. Recent guidelines from the American Society of Echocardiography support the general use of IVC-CI in assessing intravascular volume [12]. Moreover, operators with little experience in echocardiography can practice this method [5,13]. Pre-operative IVC-CI can predict hypotension after the induction of general anesthesia with high specificity [5]. In a randomized trial, IVC parameters guided fluid therapy before spinal anesthesia was found to produce a significant reduction of SIH [14]. To date, the predictive value of ultrasound-guided IVC examination remains inconclusive [15,16]. Thus, we hypothesized that patients with increased respiratory variations in IVC diameter would have more chances of developing SIH.

METHODS

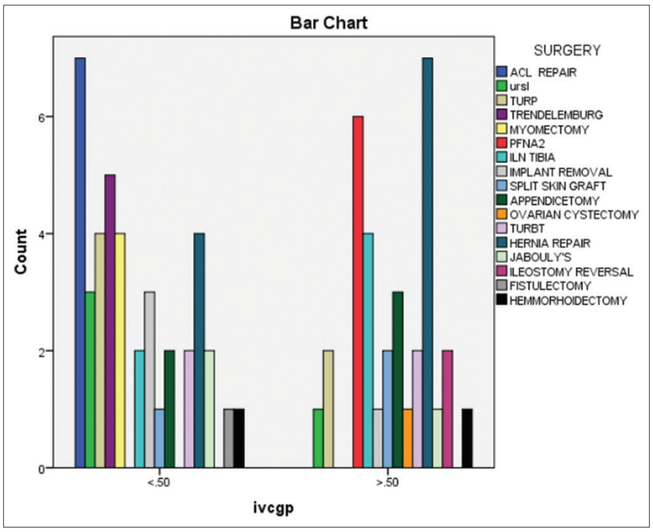
This prospective observational study was conducted in the Department of Anesthesiology, Government Medical College, Kottayam from



Graph 1: Distribution of patients among both the inferior vena caval groups



Graph 2: Gender distribution among both inferior vena caval groups



Graph 3: Surgical distribution of patients among inferior vena caval groups

November 2021 to November 2022. After ethical committee approval (IRB No: 87/2021) and informed written consent, 74 patients of ASA grade 1 and 2 scheduled for elective surgery under spinal anesthesia were selected by simple random sampling method. Adequate premedication and NPO status were ensured the day before surgery. On the day of surgery 45 min before the administration of spinal anesthesia, the patient was shifted to Anesthesia procedure room, positioned supine, and standard ASA monitors connected (5-lead echocardiogram, non-invasive blood pressure, and pulse oximetry). Baseline readings were noted and intravenous access secured. Ultrasonography was performed before spinal anesthesia with the aim to assess the volume status of the patient through assessment of size and extend of collapse of IVC during normal tidal breathing. The anteroposterior diameter of inferior vena cava was measured using images frozen at the end of inspiration (iIVCD) and end of expiration (eIVCD) on a subxiphoid view in the longitudinal axis 3 cm distal to IVC – right atrium junction where the anterior and posterior wall of the IVC are easily visualized and lie parallel to each other. Inferior vena cava collapsibility index was determined as the percentage of the difference between eIVCD and iIVCD divided by eIVCD as expressed by: IVC-CI= eIVCD - iIVCD/ eIVCD×100.

The observation of hypotension following spinal anesthesia was observed by a different anesthesiologist in operating room to prevent bias. On arrival to operating room, routine monitoring was done (non-invasive blood pressure, ECG, heart rate, and oxy-hemoglobin saturation). Spinal anesthesia technique was standardized for every patient: Patients were positioned in lateral decubitus, L3-L4 space identified, and spinal anesthesia administered through 25 G spinal needle (Quinke's). A standard dose of bupivacaine Heavy 0.5% 15 mg was injected intrathecally with needle oriented cranially without barbotage. After injection, patients were immediately positioned supine and the level of blockade was assessed. NIBP was measured every 5 min and documented in data collecting form for 30 min following spinal anesthesia. If the patient developed any sign or symptom of hypotension, they were treated according to standard internal protocol with crystalloid bolus initially followed by mephentermine bolus of 6 mg IV. In the study, hypotension is taken as a fall in mean arterial pressure (MAP) >20% of the patient's baseline. A comparison was made to determine the incidence of hypotension and the requirement of crystalloids and mephentermine following spinal anesthesia among patients with IVC-CI>50% and patients with IVC-CI<50% (Graph 1).

RESULTS

Our population comprised 74 patients, out of which 44.6% of patients had an IVCCI of >50% and 55.40% had IVCCI <50%.

Out of the 74 patients included in the study, 68.9% are males and 31.1% are females (Graph 2). There is no significant difference between the two groups (p=0.707).

We observed that there is no significant difference in the age, height, and weight between the IVC groups as the p-values are more than 0.05. (Table 1)

Around 51.4% of all patients had significant hypotension post-spinal anesthesia. 97% of the patients with an IVC-CI >50% had significant hypotension as compared to 14.6% with an IVC-CI <50%, p=0.000 (Table 2). IVCCI >50% has a specificity of 97.2% and sensitivity of 84.2 in predicting post spinal hypotension PPV of 96.97% and NPV of 85.37%.

16 patients had IVC-CI <30% and there was no significant hypotension (7.7%) in this group. 9 patients had IVC-CI between 30% and 40%, of which 11% had significant spinal-induced hypotension. 16 patients had an IVC-CI between 40% and 50%, out of whom 25% had significant post spinal hypotension. Out of the 33 patients who had an IVC-CI >50%, 97% had significant spinal induced hypotension with a p=0.000 (Table 3).

We observed that there is a significant difference in the mean mephentermine requirements between both the IVC groups with a p=0.026. The amount of mephentermine used to treat hypotension was significantly higher in patients with IVC-CI >50% (Table 4).

We observed that there is a significant difference in mean requirement of Mephentermine between the IVC groups with a p=0.000 (Table 5).

We observed that there is a significant difference in the mean IV fluid requirements between both the IVC groups with a p=0.000.

The amount of IV fluids used to treat spinal-induced hypotension was significantly higher in patients with IVC-CI >50% (Table 6).

We observed that there is a significant difference in the requirement of iv fluids as the IVC-CI increases (Table 7).

DISCUSSION

Spinal anesthesia is frequently associated with hypotension. In the present study, 51.4% patients had significant hypotension post-spinal anesthesia.

During spinal anesthesia, cardiovascular response is individualized and depends on the height of sympathetic block. The hemodynamic changes are minimal if the block is below T10. In our study, the sensory block reached T6-T10 and does not differ between groups.

Although preoperative HR, MAP, clinical methods of determining hydration status can predict intraoperative hypotension, they are not definitive. Kalantari *et al*. [17] studied various static and dynamic parameters for the assessment of intravascular volume status and concluded that static pressure measurements such as the CVP and PCWP have little utility due to their invasiveness and should not be routinely used to assess volume status. New dynamic measurements such as IVC ultrasonography offer great promise for the determination of intravascular fluid status [18]. We observed that the vasodilatation-induced hypotension seen in spinal anesthesia is manifested as an increased IVC collapsibility.

This study investigated the association of preprocedural IVC-CI as measured by bedside ultrasonography with the incidence of intraoperative post-spinal hypotension. A study conducted by Nagdev *et al*. [19] concluded that a 50% collapsibility of the IVC diameter during respiratory cycle is associated with a low CVP. We also observed that a pre-operative IVC-CI ≥50% was associated with a higher incidence of post spinal hypotension.

A total number of 74 patients were enrolled in our study. IVC ultrasound measurements were performed by the same anesthetist. All 74 patients met the inclusion criteria. Demographics of the population and a comparison of the participants in the IVC-CI <50% and IVC-CI >50% are given in Table 1. In our study population, mean age was 42 years (95% CI, 38.73–44.46) with 31.1% females. There was no significant difference in the age, sex, weight, height, or pre-operative vital signs between the two IVC groups.

As the type of surgery could alter the outcome of our study, we chose to conduct the study on patients scheduled for minor and intermediate surgeries of duration <2 h (Graph 3). Operative procedures included 23 orthopedic, 14 urology, 5 gynecology, 3 plastic, and 29 general surgeries. None of these procedures resulted in significant blood loss and no other reasons attributable to hypotension were observed. The endpoint of our study was 30 min following spinal anesthesia to avoid the influence of possible major fluid shifts.

In the study done by Zhang and Critchley [5], a systematic review where a total of eight studies involving 235 patients was analyzed. The sensitivity and specificity in the overall population were 0.76 (95% CI: 0.61–0.86) and 0.86 (95% CI: 0.69–0.95), respectively, in predicting SIH which is similar to our study. 51.4% of all patients had significant hypotension post-spinal anesthesia. 38 of these patients were given vasopressor (Mephentermine) during their surgery. The amount of mephentermine used to treat hypotension was significantly higher in patients with IVC-CI >50% with a p=0.026. A study by Ayyanagouda *et al*. [14] demonstrated that the IVC-guided fluid optimization using USG before spinal anesthesia leads to a 40% reduction in the incidence of SIH as well as requirement of vasopressor during spinal anesthesia. Ceruti *et al*. [20] conducted a prospective cohort study on 160 patients posted for surgeries under spinal anesthesia for prevention of spinal induced arterial hypotension using vena caval ultrasound to guide fluid management. They showed 35% reduction in SIH and also significant reduction in the need for vasoactive drugs.

We also observed that there is a significant difference in the mean IV fluids requirements between both the IVC groups with a p=0.000 (Table

Table 1: Age, height, and weight distribution

Group statistics					
Demographics	**IVCGP (%)**	**n**	**Mean**	**SD**	**p**
Height	<50	41	165.51	8.741	0.259
	>50	33	158.18	27.640	
Weight	<50	41	66.27	6.697	0.185
	>50	33	62.48	7.835	
Age	<50	41	40.46	11.651	0.992
	>50	33	43.09	12.630	

SD: Standard deviation

Table 2: Percentage fall in MAP within 30 min from baseline among both the inferior vena cava groups

IVCGP	IVCGP*BP fall cross tabulation		
	BP fall		Total
	<20%	>20%	
<50%	35 (85.4)	6 (14.6)	41 (100.0)
>50%	1 (3.0)	32 (97.0)	33 (100.0)
Total	36 (48.6)	38 (51.4)	74 (100.0)

BP: Blood pressure

Table 3: Percentage fall in MAP among subgroups of inferior vena cava collapsibility index within 30 min from baseline

IVC multiple (%)	BP fall		Total
	<20%	>20%	
<20	3 (100.0)	0	3 (100.0)
20–30	12 (92.3)	1 (7.7)	13 (100.0)
30–40	8 (88.9)	1 (11.1)	9 (100.0)
40–50	12 (75.0)	4 (25.0)	16 (100.0)
>50	1 (3.0)	32 (97.0)	33 (100.0)
Total (%)	48.6	51.4	100.0

IVC: Inferior vena cava, BP: Blood pressure

Table 4: Requirement of mephentermine among both the inferior vena cava groups

Group statistics					
Drug requirement	**IVCGP1**	**n**	**Mean**	**SD**	**p**
Mephentermine	<50%	41	1.46	4.405	0.026
	>50%	33	17.27	6.834	

SD: Standard deviation

Table 5: Requirement of mephentermine among subgroups of inferior vena caval collapsibility index

Mephentermine requirement				
IVC multi (%)	**Mean**	**n**	**SD**	**p**
<20	0.00	3	0.000	0.000
20–30	0.46	13	1.664	
30–40	0.67	9	2.000	
30–40	3.00	16	6.573	
>50	17.27	33	6.834	
Total	8.51	74	9.680	

SD: Standard deviation, IVC: Inferior vena cava

Table 6: Requirement of intravenous fluids among both the inferior vena cava groups

Group statistics					
Fluid requirement	**IVCGP (%)**	**n**	**Mean**	**SD**	**p**
Fluids	<50	41	2.39	0.919	0.000
	>50	33	5.03	1.045	

SD: Standard deviation

Table 7: Requirement of intravenous fluids among subgroups of inferior vena cava collapsibility index

IV fluids				
IVC multi (%)	**Mean**	**n**	**SD**	**p**
<20	1.33	3	0.577	0.000
20–30	1.85	13	0.555	
30–40	2.78	9	0.667	
30–40	2.81	16	0.981	
>50	5.03	33	1.045	
Total	3.18	74	1.639	

SD: Standard deviation, IVC: Inferior vena cava, IV: Intravenous

6). The amount of IV fluids used to treat spinal-induced hypotension was significantly higher in patients with IVC-CI >50%. Ni *et al.* [21] in their study also concluded that the requirement of iv fluids to restore volume status was higher in patients with IVC-CI >50%.

CONCLUSION

Ultrasound scanning of IVC and measuring the collapsibility index preoperatively is a reliable predictor of hypotension following spinal anesthesia, wherein clinically relevant hypotension is defined as a decrease in MBP from baseline more than 20%.

The threshold for predicting hypotension was a CI >50%. CI was also positively associated with a significant decrease in MAP post-spinal anesthesia. We conclude that IVC-CI>50% predicts post spinal hypotension. Furthermore, the requirement of vasopressors and IV fluids increases with IVC-CI >50%.

Clinically, IVC-CI technique is a simple, easy to learn method to assess the fluid status and it can be repeated as and when needed. Employing preoperative IVC-CI may help to identify the patients who are likely to become hypotensive and could be a useful adjunct in assisting provider with the decision on the usage of vasopressors and prophylactic intravenous fluids. This might be particularly useful in patients with an unclear preprocedural volume status. In this scenario, the provider could preload the patient with fluids without the concern of overloading or causing acute pulmonary edema. Future studies must be done to evaluate the effectiveness of volume-loading patients with IVC-CI >50%, to see if this significantly reduces spinal induced hypotension in these patients. Furthermore, additional research is needed to determine the reproducibility of these results, as well as their applicability in clinical setting.

AUTHORS CONTRIBUTION

First author is the primary investigator, study conducted, and data collected all the authors, publication work was done by the third author.

CONFLICTS OF INTERESTS

Nil.

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