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A Prospective Study On The Use Of Ultrasonographic Inferior Vena Cava Collapsibility Index And Caval Aorta Index In Predicting Hypotension Following Spinal Anaesthesia.

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ABSTRACT

Spinal anesthesia-induced hypotension (SAIH) is a frequent side effect of spinal anesthesia (SA). It occurs due to the combined effect of the sympathetic block and paradoxical activation of cardioinhibitory receptors. SAIH is more common in patients with hypovolemia. Pre-loading or co-loading with crystalloid or colloid to optimize the intravascular volume has shown variable results. To evaluate the usefulness of IVCCI in predicting post-induction hypotension after general anesthesia, with the primary objective being to assess the correlation between IVCCI and hypotension. This observational study was conducted in the Department Of Anesthesiology And Critical Care, Karpagam Faculty Of Medical Science And Research, Coimbatore, Tamil Nadu, India in the years 2023-2024. A total of 100 patients were scheduled for elective surgery under general anesthesia with thiopentone induction. IVCCI was measured preoperatively in spontaneously breathing patients. Hemodynamic parameters were recorded for up to one hour after anesthesia induction. Hypotension was defined as a fall of more than 20% in Systolic Blood Pressure (SBP) or SBP <90 mmHg or a mean blood pressure of <60 mm Hg. Independent t-test was used for quantitative associations, while Chi-square and Fisher's-exact test were used for qualitative associations, with a p-value <0.05 considered significant. The mean age of the patients in the study was 42.11±12.6 years. Out of 100, a total of 44 patients experienced post-induction hypotension, which was significantly higher in females compared to males (p-value=0.02). The mean Basal Metabolic Index (BMI) of the study population was 21.2±3.06 kg/m2, but hypotension was more common in underweight patients with a BMI <18.5 kg/m2 (p-value=0.0007). The results showed a significant correlation between IVCCI and hypotension (p-value <0.05). Preoperative assessment of IVCCI is highly sensitive and specific for the prediction of hypotension induced by general anesthesia. It is recommended as a screening tool for high risk.

Keywords: Aorta, collapsibility index, hypotension, hypovolemia, inferior vena cava, ultrasonography, vena cava, spinal anesthesia-induced hypotension

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INTRODUCTION

Intraoperative hypotension has been the most frequent side effect after spinal anesthesia, with an incidence of 15.3% to 33% [1]. Hypotension can be severe (incidence 5.4%) and may cause systemic hypoperfusion and ischemic events. The magnitude of hypotension is determined by the preoperative volume status, which varies depending on ASA physical status, preoperative comorbidities, preoperative medications, and fasting. To prevent hypotension, neither crystalloid nor colloid (preloading or co-loading) was found to be superior [2]. Studies have shown the use of vasopressors like mephentermine, phenylephrine, or ephedrine to prevent or treat hypotension. Still, there is no accurate predictive tool to correctly evaluate the incidence of hypotension following spinal anesthesia in high-risk patients (old age/cardiac diseases/autonomic neuropathy) to avoid preemptive volume loading [2]. Hypotension occurs because of vasodilation due to preganglionic sympathetic fiber blockade resulting in peripheral vasodilatation. When spinal anesthesia reaches up to T4–T6 level, Systemic Vascular Resistance (SVR) decreases by 23–26%, Left Ventricular End-Diastolic Volume (LVEDV) by 20%, and Central Venous Pressure (CVP) by 2–3 mmHg [3]. In patients with pre-existing intravascular fluid deficit, the effects of hypotension are more pronounced, leading to many unwanted side effects like nausea, vomiting, aspiration, dizziness, syncope, cardiac arrhythmias. However, we cannot preload every patient prophylactically because there are side effects of volume overload like pulmonary edema, congestive cardiac failure, and renal dysfunction. That's why many new guidelines and recommendations are coming up that advocate only maintenance fluid administration in fasting patients preoperatively [4, 5], the goal should be to discover a new suitable predictive tool for hypotension to find at-risk patients in an easy, feasible, cost-effective, and non-invasive way [6]. Recently, ultrasound has come up as a new modality to predict the intravascular volume status of patients undergoing surgery. There are many methods for assessing intravascular volume preoperatively (CVP measurements, esophageal Doppler Ultrasound, pulmonary arterial catheterization, and transesophageal echocardiography). Still, most of them are invasive, time-consuming, or may require complex calculations [7, 8]. The ultrasound-guided measurement of the diameter of the Inferior Vena Cava (IVC) can indirectly assess the intravascular volume. In this study, we hypothesized that preoperative Inferior Vena Cava Collapsibility Index (IVCCI) assessment is a good predictor of intraoperative hypotension within thirty minutes of giving spinal anesthesia in patients undergoing elective surgery.

MATERIALS AND METHODS

This observational study was conducted in the Department Of Anesthesiology And Critical Care, Karpagam Faculty Of Medical Science And Research, Coimbatore, Tamil Nadu, India in the years 2023-2024. A total of 100 patients were scheduled for elective surgery under general anesthesia. Inclusion criteria: A total of 100 patients between the ages of 18 and 65 years, of either sex, belonging to (ASA) Physical status I or II, scheduled for elective surgery under general anesthesia in the supine position, were included after obtaining written informed consent. Exclusion criteria: Pregnant females, patients with intra-abdominal pathology causing an increase in intra-abdominal pressure, cardiac disease, BMI >30 kg/m^2, and those who were uncooperative or unwilling to participate were excluded. Sample size calculation: The sample size calculation was based on a study by Szabó M et al., which observed a sensitivity of 45.5% and specificity of 90%. Taking these values as a reference, the minimum required sample size with a desired precision of 15%, 80% power of the study, and a 5% level of significance was 86. However, to reduce the margin of error, a total sample size of 100 was chosen Hypotension after general anesthesia was defined as any one of the following: 1) a fall of <20% in SBP from the baseline; 2) SBP<90 mm Hg; 3) mean blood pressure <60 mmHg.

Study Procedure

Patients were kept fasting for six hours for solids and two hours for clear fluids before surgery. On the day of surgery, in the preoperative holding area, patients were assessed for Ultrasound Sonography (USG)-guided Inferior Vena Cava (IVC) measurement by an anaesthesiologist with at least five years of experience in preoperative USG, who was not involved in further patient care. The diameter of the IVC was measured during expiration (IVC max) and inspiration (IVC min) in a single respiratory cycle using a Sonosite Edge II ultrasound machine IVCCI was calculated using the formula: IVCCI=(dIVCmax-dIVCmin)/dIVCmax×100 and expressed as a percentage [6,7,8]. After the assessment, based on the value of IVCCI, patients were grouped into the Collapsible (CI+) group and Non-Collapsible (CI-) group, using a pre-decided cut-off of IVCCI at 50%. Patients with IVCCI 50% were grouped into CI+, and patients with

IVCCI < 50% were grouped under the CI- group [9]. Patients were then shifted to the operating theater where they were premedicated with 0.02 mg/kg of midazolam, 0.005 mg/kg of glycopyrrolate, and 2 μg/kg of fentanyl, and induction was carried out with 5 mg/kg of thiopentone sodium. For muscle relaxation,0.1 mg/kg of vecuronium was administered after confirming bag and mask ventilation. The patient was ventilated with 100% O2 for three minutes, after which the airway was secured. An infusion of Ringer's lactate solution was administered at a rate of 10 mL/kg/hr to all patients intraoperatively. Hemodynamic parameters such as Non-Invasive Blood Pressure (NIBP), Heart Rate (HR), and Oxygen Saturation (SPO2) were recorded every minute for the initial five minutes, and then every five minutes for the next 60 minutes post-induction.

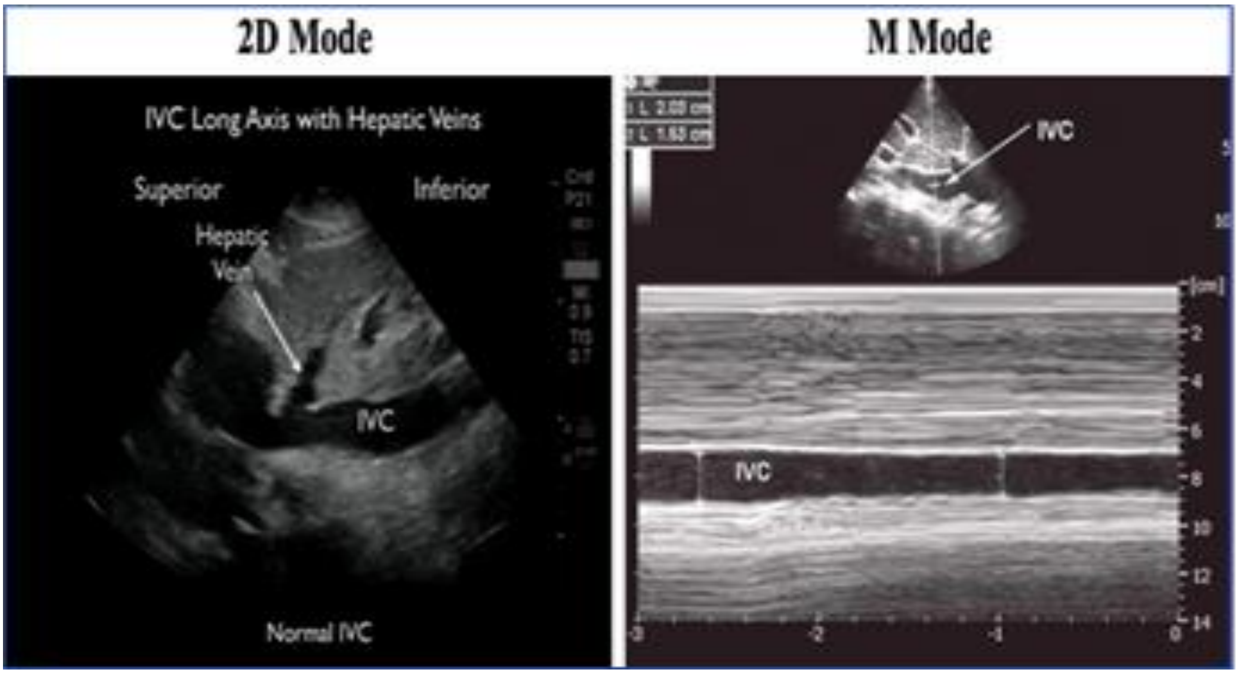

Figure 1: Measurement of IVC max and IVC min to derive IVCCI.

Statistical Analysis

Quantitative variables were analyzed using an independent t-test, while qualitative variables were analyzed using the Chi-Square test and Fisher's-exact test. The ROC curve was utilized to determine the cut-off point, sensitivity, specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV). Multivariate logistic regression was employed to identify significant predictors of hypotension. A p-value<0.05 was considered statistically significant. The final analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software, version 25.0, manufactured by IBM, India.

RESULTS

Table 1: Demographic Variables.

Age (years)	**Median age=42.11±12.6 years**		**Median age=42 (32.75-52) years**
Gender	75% females (n=75)		25% males (n=25)
BMI (kg/m^2)	**Mean BMI- 21.2±3.06 kg/m^2**		
	Low BMI (<18.5kg/m^2)-17%(n=17)	Normal BMI (18.5 to 24.99 kg/m^2)-73% (n=73)	High BMI (25 to 29.99 kg/m^2)-10% (n=10)
ASA physical status grading	80% ASA Grade-1 (n=80)		20% ASA Grade-2 (n=20)

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Table 2: Distribution Of Age, Gender, BMI, Asa Grading Among Hypotensive And Non Hypotensive Patients.

Variables	With hypotension (n=44)	Without hypotension (n=56)	p-value
Age (Mean ± SD)	43±11.54 years	41.18±13.36 years	0.406
Female	38 (50.67%)	37 (49.33%)	0.02
Male	6 (24%)	19 (76%)	
ASA grade-1	36 (45%)	44 (55%)	0.687
ASA grade 2	8 (40%)	12 (60%)	
BMI<18.5 kg/m^2	12 (70.59%)	5 (29.41%)	0.0007*
BMI 18.5-24.99 kg/m^2	32 (43.84%)	41 (56.16%)	
Total	44 (44%)	56 (56%)	

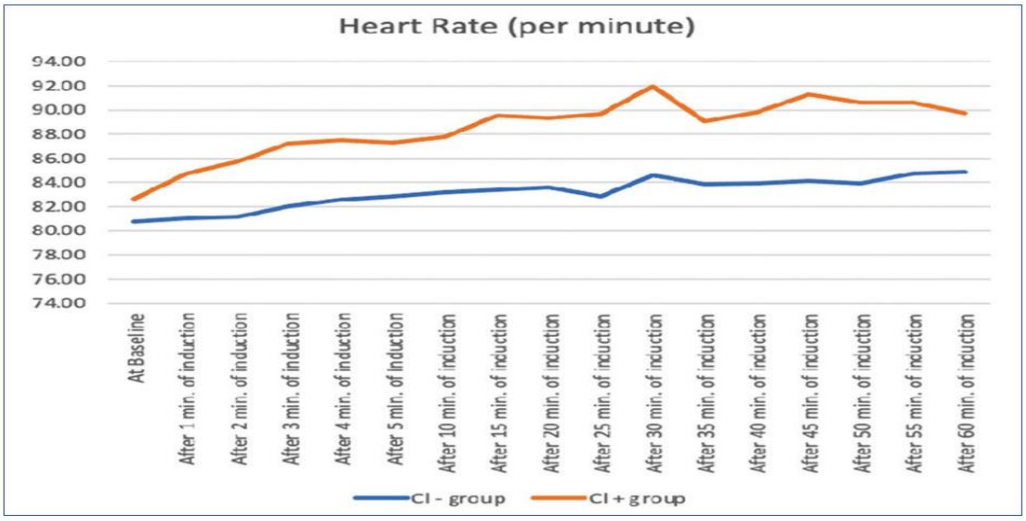
Out of the 100 patients who participated in the present study, the incidence of post-induction hypotension was recorded in 44 (44%) patients, while the remaining 56 (56%) remained normotensive. The distribution of age (p-value=0.406) and ASA physical status (p-value=0.687) was comparable among hypotensive and non-hypotensive patients. Hypotension was significantly higher in females (50.67%) compared to males (24%) (p-value=0.02). The incidence of hypotension was significantly higher among patients with lower BMI (70.59%) compared to those with normal and high BMI (p-value=0.0007)

Table 3: Association Of Hypotension With Non-Collapsible (Ci-) And Collapsible (Ci+).*Fisher's-Exact Test.

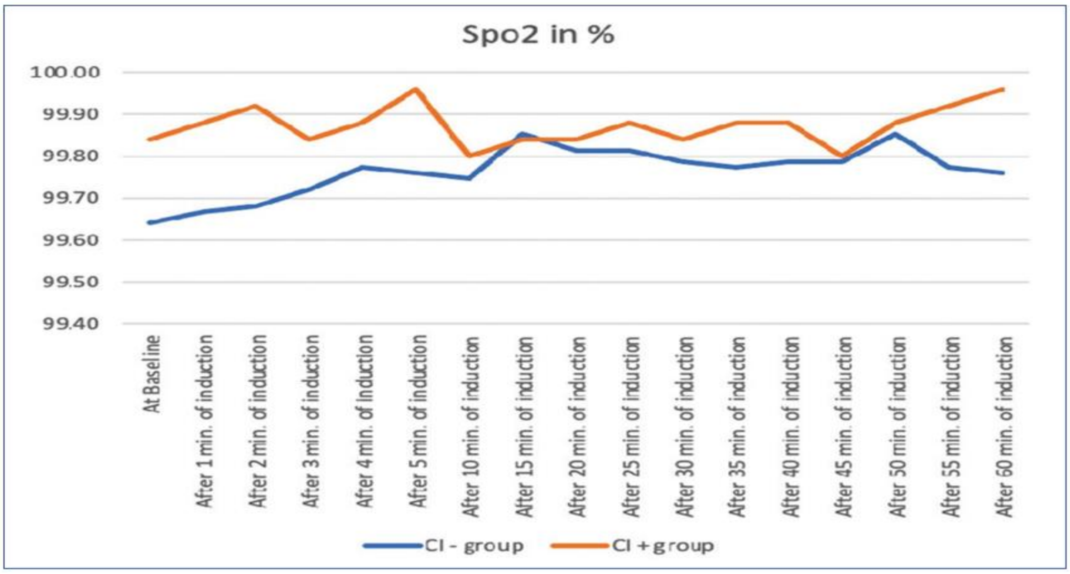
Hypotension	CI-(n=75)	CI+(n=25)	Total	p-value
No	55 (73.33%)	1 (4%)	56 (56%)	<0.0001*
Yes	20 (26.67%)	24 (96%)	44 (44%)	
Total	75 (100%)	25 (100%)	100 (100%)	

The majority of patients, n=75 (75.00%), were in the non-collapsible (CI-) group, while the collapsible (CI+) group had only n=25 (25.00%) patients. The number of patients with hypotension was significantly lower in the CI group compared to the CI+ group (26.67% vs. 96%, respectively) (p-value <0.0001) [Table/Fig-4]. There was no significant association seen between heart rate, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and mean blood pressure with hypotension (p-value >0.05) and also with the non-collapsible (CI-) and collapsible (CI+) groups (p-value >0.05). The mean values of heart rate, SpO_2, and mean blood pressure among the non-collapsible (CI-) and collapsible (CI+) groups.

Graph 1: Comparison Of Mean Heart Rate (Per Minute) At Different Time Intervals Among Non-Collapsible (Cl-) And Collapsible (Cl+) Groups.



Graph 2: Comparison Of Mean Spo$_2$ (In%) At Different Time Intervals Among Non-Collapsible (Cl-) And Collapsible (Cl+) Groups. On Of Mean Spo$_2$ (In%) At Different Time Intervals Among Non-Collapsible (Cl-) And Collapsible (Cl+) Groups.



Graph 3: Comparison Of Mean Blood Pressure (Mm Hg) At Different Time Intervals Among Non-Collapsible (Cl-) And Collapsible (Cl+) Groups.

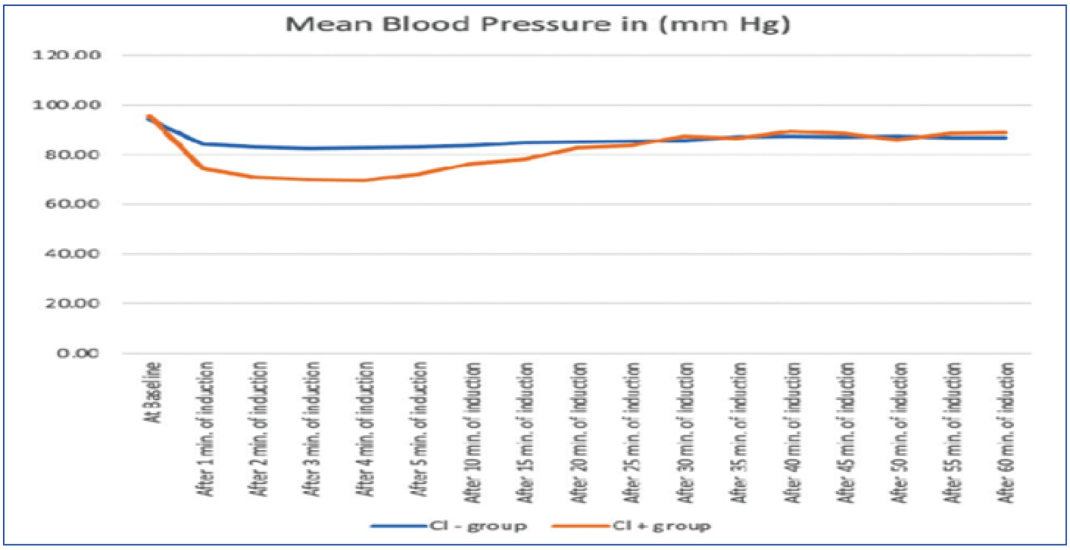


Table Mean, Median, And Range Of Ivcci % Compared With And Without Hypotension Patients.

Inferior Vena Cava Collapsibility Index (IVCCI) (%)	With hypotension (n=44)	Without hypotension (n=56)	Total	p-value
Mean ± SD	47.34±6.96	28.45±7.05	36.76±11.73	<0.0001
Median (25th - 75th percentile)	50 (43.75-51)	26.5 (23-32)	36 (25.75-49.25)	
Range	23-56	13-54	13-56	

A significant association was seen in the absolute decrease in SBP (mmHg), DBP (mmHg), and mean blood pressure (mmHg) at one minute after induction with the non-collapsible (CI-) and collapsible (CI+) groups (p-value <0.05) [Table/Fig-8]. A significant association was seen between IVCCI (%) and hypotension

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(p-value <0.05). The mean ± SD of IVCCI (%) in patients with hypotension was 47.34±6.96, which was significantly higher compared to patients without hypotension {28.45±7.05 (p-value <0.0001).

DISCUSSION

Intraoperative hypotension is a frequent complication after intrathecal local anesthetic administration. In this study, a fall in mean BP ≥ 30% from the baseline was taken as the cut-off for significant hypotension because this definition is included in most of these studies [9] and because mean BP is a better indicator for tissue perfusion than SBP or DBP. As only one cut-off of hypotension was taken, the incidence of clinically significant hypotension found in our study (19.37%) was much lower than what was found in other studies [10]. The study period was from intrathecal drug administration to 30 minutes after spinal anesthesia [11], during which no significant hemodynamic changes were expected due to external factors. Female patients developed hypotension more often (33.3%) than males (16.19%) (*p*-value = 0.05). Many studies have tried to demonstrate the IVCCI as a fluid-responsiveness-predicting tool for guiding fluid therapy in resuscitation and intensive care settings [12]. In anesthesia, volume status optimization is the primary concern. Fluid responsiveness is a 10% to 15% increment in the cardiac output after a fluid bolus [10]. But very few anesthesiologists use cardiac output monitoring regularly [13], most anesthesiologists use basic monitoring like blood pressure and HR as their main hemodynamic monitoring tool, and that's why we can include bedside IVC ultrasound to identify volume-depleted patients who need fluid optimization. As a part of POCUS (point of care ultrasound), IVC ultrasound examination before spinal anesthesia to screen high-risk patients, the elderly, and suspected hypovolemic patients, is desirable. A significantly large IVCCI denotes truncated volume status, increasing the predicting value when the IVC diameter is smaller [14]. IVCCI was influenced by the sampling location and that's why the measurement point was limited to 3 cm inferior to the right atrium [15]. In this study, 2.5 to 3 mL of local anesthetic was used for spinal block, depending on the type of surgery and patient constitution, to achieve spinal block height to the level of T9 to T10. There was no correlation between the amount of drug used and post-spinal hypotension though there was a 20% difference in local anesthetic mass. Our findings can be explained by the fact that IVC is a high-capacity vessel and its diameter varies significantly from person to person. It also depends on age, body surface area, and BMI [16]. Intrathoracic and intra-abdominal pressures alter its diameter, and it is modified by various diseases like pneumonia or chronic obstructive diseases. The Inferior Vena Cava (IVC) diameter changes during the respiratory cycles because of the intrathoracic pressure changes. Most of the previous data were from ICU settings, where IVC diameter changes were used to find volume-responsive patients in circulatory shock. Some studies claim that it is controversial to use IVCCI after spinal anesthesia because it causes sympathetic denervation and reveals insufficient fluid reserve. One study could not detect the predictive role of the IVCCI in patients undergoing knee surgery [17], while another found it as a useful tool to decrease the magnitude of hypotension by giving ultrasound-guided fluid therapy [18]. There were many limitations in the present study. USG observer experience was variable in some measurements. We included ASA I and II patients because ASA III and IV patients might have more chances of hemodynamic instability in the post-spinal period. It could be either due to the depleted intravascular status or due to the poor optimization of the actual disease process. It was a single-center study. Furthermore, a multicenter study is recommended to assess the ideal prognostic value of IVCCI. Respiration caused diaphragmatic movement, which resulted in two distinct sites of measurement of the IVC in the respiratory cycle. This might have led to an underestimation of IVCCI (because IVC is less collapsible when the measurement is taken near the diaphragm during inspiration) [19, 20]. To overcome limitations caused by the varying respiratory parameters in spontaneously breathing patients, we can simultaneously take IVC and Aorta measurements to get the Caval-Aorta index. Further research should be directed to this index to assess intravascular volume status to predict intraoperative hypotension.

CONCLUSION

The present study in spontaneously breathing patients demonstrated that preoperative ultrasonographic assessment of IVCCI is a reliable tool for predicting hypotension after general anesthesia. It has a high sensitivity of 95.5%, specificity of 94.6%, and diagnostic accuracy of 95% at a cut-off value of >38%. Therefore, IVCCI can be used as an effective screening tool to predict the risk of subsequent hypotension following general anesthesia induction in suspected hypovolemic patients.

REFERENCES

[1] Hartmann B, Junger A, Klasen J, Benson M, Jost A, Banzhaf A, Hempelmann G. The incidence and risk factors for hypotension after spinal anesthesia induction: An analysis with automated data collection. Anesth Analg 2012; 94: 1521–1529.

[2] Shitemaw T, Jemal B, Mamo T, Akalu L. Incidence and associated factors for hypotension after spinal anesthesia during cesarean section at Gandhi Memorial Hospital Addis Ababa, Ethiopia. PLoS One 2020;15(8):e0236755.

[3] Massoth C, Töpel L, Wenk M. Hypotension after spinal anesthesia for cesarean section: How to approach the iatrogenic sympathectomy. Curr Opin Anaesthesiol 2020; 33: 291–298.

[4] Shen CL, Ho YY, Hung YC, Chen PL. Arrhythmias during spinal anesthesia for Cesarean section. Can J Anaesth 2021; 47: 393–397.

[5] Duan W, et al. A long duration of intraoperative hypotension is associated with postoperative delirium occurrence following thoracic and orthopedic surgery in the elderly. J Clin Anesth 2023; 88: 111125.

[6] Wachtendorf LJ, et al. Association Between Intraoperative Arterial Hypotension and Postoperative Delirium After Noncardiac Surgery: A Retrospective Multicenter Cohort Study. Obstet Anesth Dig 2021; 134: 822–833.

[7] Pressman Z, Henningsen J, Huff S, Merrill A, Froehle A, Prayson M. Increased risk of hip fracture mortality associated with intraoperative hypotension in elderly hip fracture patients is related to under resuscitation. J Clin Orthop Trauma 2022; 26: 101783.

[8] Beecham G, Cusack R, Vencken S, Crilly G, Buggy DJ. Hypotension during hip fracture surgery and postoperative morbidity. Ir J Med Sci 2020; 189: 1087–1096.

[9] Hallqvist L, Granath F, Ford M, Bell M. Intraoperative Hypotension and Myocardial Infarction Development Among High-Risk Patients Undergoing Noncardiac Surgery: A Nested Case-Control Study. Obstet Anesth Dig 2021; 133: 6–15.

[10] Christopherson R, et al. Perioperative morbidity in patients randomized to epidural or general anesthesia for lower extremity vascular surgery. Perioperative Ischemia Randomized Anesthesia Trial Study Group. Anesthesiology 1993; 79: 422–434.

[11] Chung HM, Kluge R, Schrier RW, Anderson RJ. Postoperative hyponatremia. A prospective study. Arch Intern Med 1986; 146: 333–336.

[12] Lundberg J, Lundberg D, Norgren L, Werner O. Dopamine counteracts hypertension during general anesthesia and hypotension during combined thoracic epidural anesthesia for abdominal aortic surgery. J Cardiothorac Anesth 1990; 4: 348–353.

[13] Holte K, Sharrock NE, Kehlet H. Pathophysiology and clinical implications of perioperative fluid excess. Br J Anaesth 2002; 89: 622–632.

[14] Theodoraki K, Hadzilia S, Valsamidis D, Stamatakis E. Prevention of hypotension during elective cesarean section with a fixed-rate norepinephrine infusion versus a fixed-rate phenylephrine infusion. A double-blinded randomized controlled trial. Int J Surg 2020; 84: 41–49.

[15] Feng S, Gu J, Yu C, Liu J, Ni J. Exploring the predictive value of combined ultrasound parameters for spinal anesthesia-induced hypotension in cesarean section: A prospective observational study. BMC Anesthesiol 2023; 23: 255.

[16] Kim HJ, Cho AR, Lee H, Kim H, Kwon JY, Lee HJ, Kang C, Jeon S, Kim N. Ultrasonographic Carotid Artery Flow Measurements as Predictors of Spinal Anesthesia-Induced Hypotension in Elderly Patients: A Prospective Observational Study. Med Sci Monit 2022; 28: e938714.

[17] Yılmaz, A, Demir, U, Taşkın, Ö, Soylu, V.G, Doğanay, Z. Can Ultrasound-Guided Femoral Vein Measurements Predict Spinal Anesthesia-Induced Hypotension in Non-Obstetric Surgery? A Prospective Observational Study. Medicina 2022, 58, 1615.

[18] Salama ER, Elkashlan M. Pre-operative ultrasonographic evaluation of inferior vena cava collapsibility index and caval aorta index as new predictors for hypotension after induction of spinal anesthesia: A prospective observational study. Eur J Anaesthesiol 2019; 36: 297–302.

[19] Bradley CA, Ma C, Hollon MM. Perioperative Point of Care Ultrasound for Hemodynamic Assessment: A Narrative Review. In Seminars in Cardiothoracic and Vascular Anesthesia; SAGE Publications: Los Angeles, CA, USA, 2023; 16-23.

[20] Kaptein MJ, Kaptein EM. Inferior Vena Cava Collapsibility Index: Clinical Validation and Application for Assessment of Relative Intravascular Volume. Adv. Chronic Kidney Dis 2021; 28: 218–226.