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Original Article

Anaesthesia Section

Evaluation of Inferior Vena Cava Collapsibility Index as a Predictor of Hypotension Following General Anaesthesia with Thiopentone Induction: An Observational Study

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ABSTRACT

Introduction: Hypotension during surgery can significantly increase morbidity and mortality. Volume depletion poses a major risk for intraoperative hypotension. The role of the Inferior Vena Cava Collapsibility Index (IVCCI) in assessing volume status is crucial, but its utility in predicting hypotension after the induction of general anaesthesia has been less evaluated.

Aim: To evaluate the usefulness of IVCCI in predicting post-induction hypotension after general anaesthesia, with the primary objective being to assess the correlation between IVCCI and hypotension.

Materials and Methods: An observational study was conducted in the Department of Anaesthesiology and Critical Care, Pt. B.D. Sharma, PGIMS, Rohtak, Haryana, India. Total 100 patients scheduled for elective surgery under general anaesthesia with thiopentone induction. IVCCI was measured preoperatively in spontaneously breathing patients. The patients were grouped into CI+ (Collapsible) and CI- (Non collapsible) groups based on IVCCI values of ≥ 50% and ≤ 50%, respectively. Haemodynamic parameters were recorded for up to one hour after anaesthesia 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. Receiver Operating Characteristic (ROC) curve was used to evaluate the performance of IVCCI, and multivariate logistic regression was employed to identify predictors of hypotension. 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.

Results: The mean age of the patients in the study was 42.11±12.6 years. Out of 100, total 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/m^2, but hypotension was more common in underweight patients with a BMI <18.5 kg/m^2 (p-value=0.0007). The results showed a significant correlation between IVCCI and hypotension (p-value <0.05). The mean value of IVCCI (%) was 47.34±6.96 in hypotensive patients, which was significantly higher than non hypotensive patients with a mean of 28.45±7.05 (%) (p-value <0.0001). The ROC curve demonstrated an excellent representation of IVCCI (%) (Area Under the ROC Curve (AUC) 0.944; 95% CI: 0.879 to 0.980) in predicting hypotension, with a sensitivity of 95.5% and specificity of 94.6% for hypotension. IVCCI (%) was a significant independent risk predictor of hypotension with a cut-off point of >38, as determined by performing multivariate logistic regression.

Conclusion: Preoperative assessment of IVCCI is highly sensitive and specific for prediction hypotension induced by general anaesthesia. It is recommended as a screening tool for high-risk patients.

Keywords: Dynamic indices, Intravascular volume, Ultrasound

INTRODUCTION

Induction of anaesthesia is associated with a risk of hypotension, and the patient's susceptibility to hypotension depends on the preoperative volume status, which may vary depending on co-morbidities, physical status, medications, and preoperative fasting [1]. Hypovolemia is probably the most common factor provoking post-induction hypotension [2]. Ultrasonography (USG) has evolved as an important tool in perioperative care. Its easy availability, shorter learning curve, and non-invasiveness make it a valuable gadget for assessing volume status. Measurement of Inferior Vena Cava (IVC) diameters and IVCCI are reliable indicators of both intravascular volume status and the clinical response to volume resuscitation [3]. The IVC collapsibility index is calculated using the following formula: IVC collapsibility index=maximum diameter on expiration-(minimum diameter on inspiration/maximum diameter on expiration) [4]. It has been found that when the collapsibility is high (i.e., >50%-70%), the patient is more likely to be hypovolemic. When it is low (i.e., <20%), the patient is likely to be either euvolemic or hypervolemic [3].

There is sufficient literature regarding the use of IVCCI to predict hypotension under spinal anaesthesia [5-11], and a few studies have also been conducted to determine its utility in predicting hypotension after general anaesthesia induction [12-17]. However, these studies have mostly used propofol as the induction agent, which is well known to cause severe hypotension [18,19], thus contributing as a significant confounding factor. Conversely, in the present study, thiopentone has been used to eliminate this confounding factor, as it causes lesser haemodynamic alterations and hypotension [20]. Since there is a paucity of literature regarding the use of IVCCI to determine hypotension in patients induced using thiopentone as the induction agent, present study was undertaken.

The present study was aimed was to evaluate the usefulness of the IVCCI in predicting post-induction hypotension after general anaesthesia.

MATERIALS AND METHODS

This observational study was conducted in the Department of Anaesthesiology and Critical Care, Pt. B.D. Sharma, PGIMS, Rohtak,

Haryana, India to evaluate the efficacy of IVCCI in predicting the incidence of hypotension after general anaesthesia from April 2021 to March 2023. All procedures were performed in accordance with the standards of Pt BDS PGIMS Rohtak's Institutional Biomedical Research Ethics Committee on human experimentation, and formal approval was obtained via letter no BREC/Th/20/Anaesth/35 dated 02/04/2021.

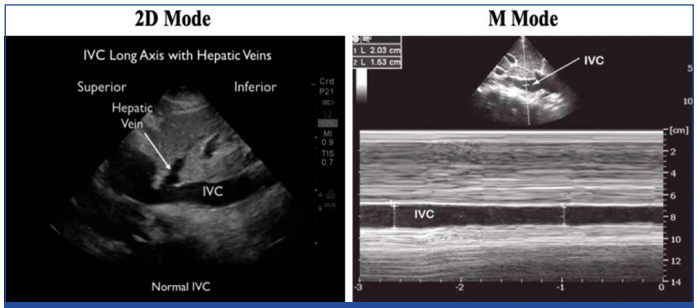
Inclusion criteria: Total 100 patients between the ages of 18 and 65 years, of either sex, belonging to American Society of Anaesthesiologists (ASA) physical status I or II, scheduled for elective surgery under general anaesthesia in the supine position, were included after obtaining written informed 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 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 [12].

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. [Table/Fig-1] IVCCI was calculated using the formula: IVCCI=(dIVCmax-dIVCmin)/dIVCmax×100 and expressed as a percentage [6,7,21].



[Table/Fig-1]: Measurement of IVC max and IVC min to derive IVCCI.

After the assessment, based on the value of IVCCI, patients were grouped into the Collapsible (CI+) group and Non-Collapsible (CI-) group, using a predecided 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 [12].

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. Haemodynamic parameters such as Non Invasive Blood Pressure (NIBP), Heart Rate (HR) and Oxygen Saturation (SPO_2) were recorded every minute for the initial five minutes, and then every five minutes for the next 60 minutes post-induction.

Hypotension after general anaesthesia 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.

STATISTICAL ANALYSIS

Quantitative variables were analysed using an independent t-test, while qualitative variables were analysed using the Chi-Square test and Fisher's-exact test. The ROC curve was utilised 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, Chicago, USA.

RESULTS

Total 100 patients participated in present study. The demographic variables are shown in [Table/Fig-2].

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 (<18.5 kg/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)

[Table/Fig-2]: Demographic parameters of patients.
BMI: Basal metabolic index

Out of the 100 patients who participated in 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/Fig-3].

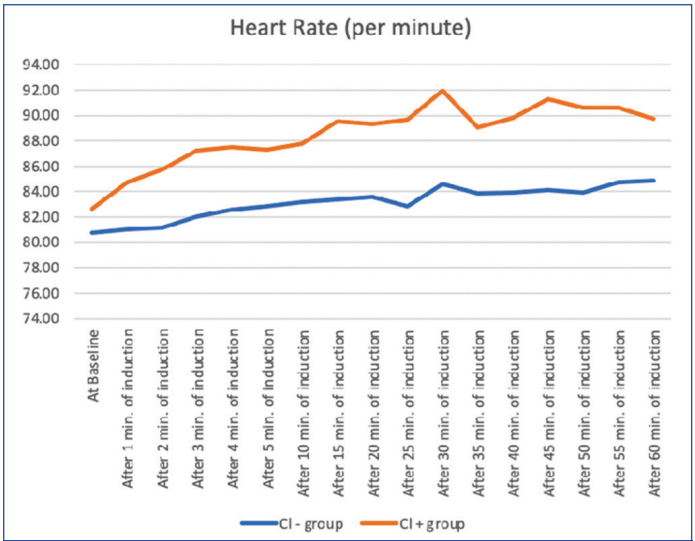
Variables	With hypotension (n=44)	Without hypotension (n=56)	p-value
Age (Mean±SD)	43±11.54 years	41.18±13.36 years	0.406‡
Female	38 (50.67%)	37 (49.33%)	0.02†
Male	6 (24%)	19 (76%)	
ASA grade-1	36 (45%)	44 (55%)	0.687†
ASA grade 2	8 (40%)	12 (60%)	
BMI<18.5 kg/m^2	12 (70.59%)	5 (29.41%)	0.0007*
BMI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

[Table/Fig-3]: Distribution of age, gender, BMI, ASA grading among hypotensive and non hypotensive patients.
‡Independent t-test †Chi-square test *Fisher's-exact test

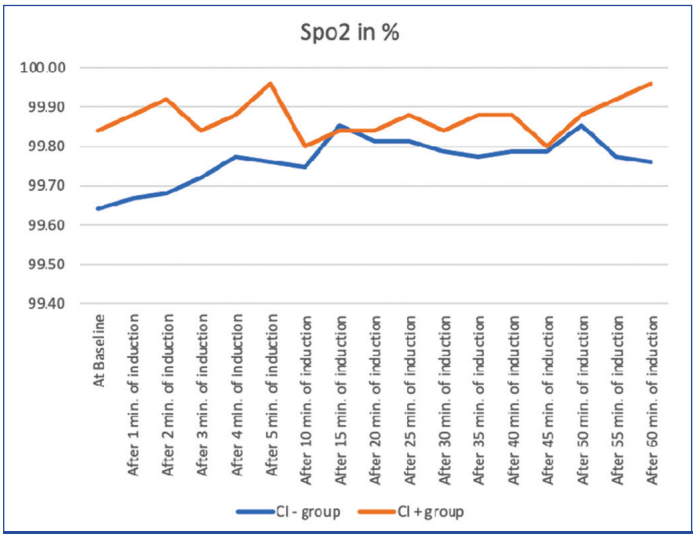
The majority of patients, n=75 (75.00%), were in the non-collapsible (CI-) group, while the collapsible (CI+) group had only n=25 (25.00%) patients. The number of patients with hypotension was significantly lower in the CI-group compared to the CI+ group (26.67% vs. 96%, respectively) (p-value <0.0001) [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 are shown in [Table/Fig-5-7].

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%)	

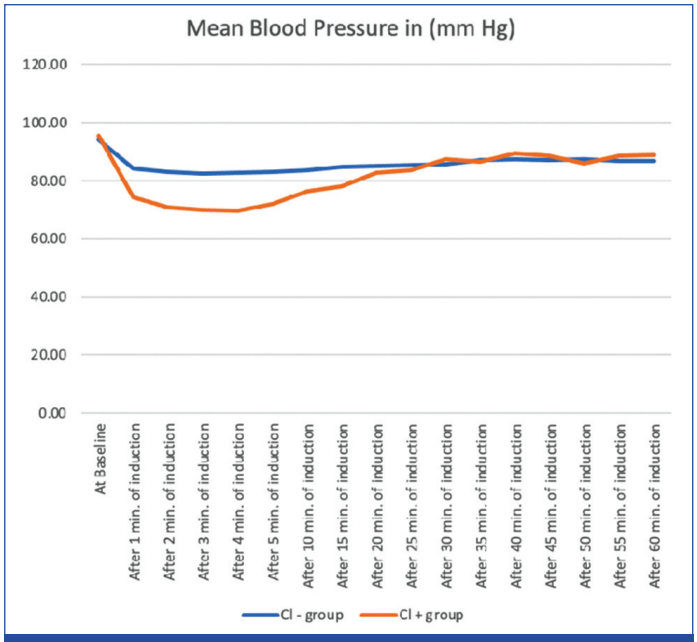
[Table/Fig-4]: Association of hypotension with Non collapsible (CI-) and Collapsible (CI+).
*Fisher's-exact test



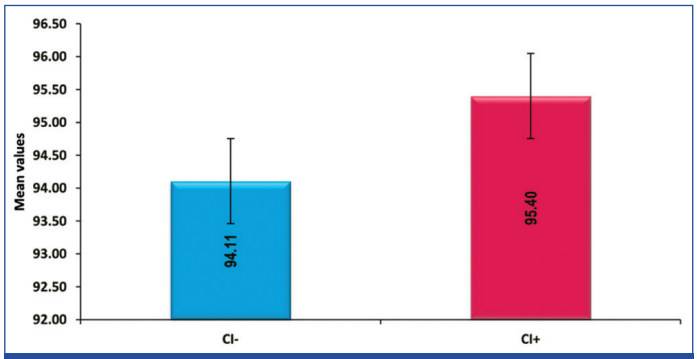
[Table/Fig-5]: Comparison of mean Heart Rate (per minute) at different time intervals among non-collapsible (CI-) and Collapsible (CI+) groups.



[Table/Fig-6]: Comparison of mean SpO_2 (in%) at different time intervals among non-collapsible (CI-) and Collapsible (CI+) groups.



[Table/Fig-7]: Comparison of mean blood pressure (mm Hg) at different time intervals among non-collapsible (CI-) and Collapsible (CI+) groups.



[Table/Fig-8]: Mean blood pressure (mmHg) at one minute after induction with non-collapsible (CI-) and Collapsible (CI+) groups.

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 (25^{th}-75^{th} percentile)	50 (43.75-51)	26.5 (23-32)	36 (25.75-49.25)	
Range	23-56	13-54	13-56	

[Table/Fig-9]: Mean, median and range of IVCCI % compared with and without hypotension patients.
‡Independent t-test

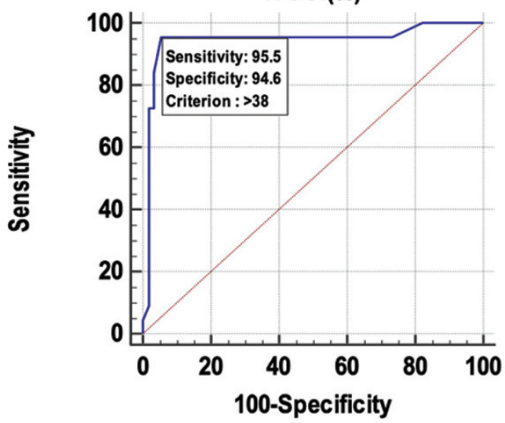
A significant association was seen in the absolute decrease in SBP (mmHg), DBP (mmHg), and mean blood pressure (mmHg) at one minute after induction with the non-collapsible (CI-) and collapsible (CI+) groups (p-value <0.05) [Table/Fig-8]. A significant association was seen between IVCCI (%) and hypotension (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)} [Table/Fig-9].

The interpretation of the area under the Receiver Operating Characteristic (ROC) curve showed that the performance of IVCCI (%) (AUC 0.944; 95% CI: 0.879 to 0.980) was outstanding. IVCCI (%) was a significant predictor of hypotension at a cut-off point of >38, with an area under the curve of 0.944 for correctly predicting hypotension, a sensitivity of 95.5%, and a specificity of 94.6% with a PPV of 93.3%, NPV of 96.4%, and diagnostic accuracy of 95% [Table/Fig-10]. On performing multivariate regression, IVCCI (%): >38 was a significant independent risk factor for hypotension after adjusting for confounding factors. Patients with IVCCI (%): >38 had a significantly higher risk of hypotension, with an adjusted odds ratio of 387.455 (43.802 to 3427.235) and a p-value of <0.0001.

DISCUSSION

General anaesthesia causes arterial and venous dilation, leading to reduced systemic vascular resistance and lower myocardial contractility, which can result in hypotension [22]. The incidence of hypotension in the present study was found to be 44%. Hypotension was more commonly observed in patients with low BMI, as underweight patients tend to have lower nutritional stores and cardiovascular reserves, making them more susceptible to hypotension after general anaesthesia [23]. The prevalence of hypotension after general anaesthesia has been reported to vary in previous studies. This variation may be attributed to the use of different induction agents, variations in sample sizes, and different definitions of hypotension [Table/Fig-11] [1,4,12-17,24,25].

In the current study, IVCCI demonstrated excellent diagnostic accuracy of 95% in predicting hypotension induced by general anaesthesia, with an AUC of 0.944 at a cut-off value of ≥38%.



Variables	Values
The area under the ROC curve (AUC)	0.944
Standard Error	0.0293
95% Confidence interval	0.879 to 0.980
P value	<0.0001
Cut off	>38
Sensitivity (95% CI)	95.45% (84.5 - 99.4%)
Specificity (95% CI)	94.64% (85.1 - 98.9%)
PPV (95% CI)	93.3% (81.7 - 98.6%)
NPV (95% CI)	96.4% (87.5 - 99.6%)
Diagnostic accuracy	95.00%

[Table/Fig-10]: Receiver operating characteristic (ROC curve) of performance of IVCCI (%).

Authors	Findings
Present study Sample size 100 patients Study place- India	Hypotension=44%, Cut-off value of IVCCI- 38%, Sensitivity of IVCCI- 95.5%, Specificity of IVCCI- 94.6%, PPV of IVCCI- 93.3%, NPV of IVCCI- 96.4%, Diagnostic accuracy of 95%
Omar H et al., [17] (2023) Sample size=102 patients Study place- Egypt	Hypotension=78.43%, Cut-off value of IVCCI- 28.3%, Sensitivity of IVCCI- 92.5%, Specificity of IVCCI- 18.2%, PPV of IVCCI- 80.4%, NPV of IVCCI- 40.0%
Rose N et al., [13] (2022) Sample size=120 patients Study place- India	Hypotension=41.6%, Cut-off value of IVCCI- 37%, Sensitivity of IVCCI- 94%, Specificity of IVCCI- 84%
Shakya S et al., [14] (2022) Sample size=100 patients Study place- Nepal	Hypotension=65%, Cut-off value of IVCCI:AO index-1
Aissaoui Y et al., [4] (2022) Sample size=64 patients Study place- Morocco	AUROC of 0.68 (95% CI: 0.54–0.80) and a threshold value of 42%
Mohammed S et al., [16] (2021) Sample size=88 patients Study place- India	Hypotension=30%, Cut-off value of IVCCI- 46%, Sensitivity of IVCCI- 47-59%, Specificity of IVCCI- 48-50%
Purushothaman SS et al., [15] (2020) Sample size=50 patients Study place- India	Hypotension=30%, Cut-off value of IVCCI- 43%, Sensitivity of IVCCI- 86.7%, Specificity of IVCCI- 94.29%, PPV of IVCCI- 84%
Arican S et al., [25] (2019) Sample Size=70 patients Study place- Turkey	Hypotension=25.7%, Cut-off value of IVCCI- 45%, Sensitivity of IVCCI- 83.3%, Specificity of IVCCI- 82.7%, PPV of IVCCI- 62.5%, NPV of IVCCI- 93.5%
Szabó M et al., [12] (2019) Sample size=102 patients Study place- Hungary	Hypotension=25.7%, Predetermined cut-off value of IVCCI- 50%, Sensitivity of IVCCI- 45.5%, Specificity of IVCCI- 90.0%, PPV of IVCCI- 75%, NPV of IVCCI- 71.4%
Zhang J and Critchley LA [1] (2016) Sample size=90 patients Study place- China	Hypotension=47%, Cut-off value of IVCCI- 43%, Sensitivity of IVCCI- 78.6%, Specificity of IVCCI- 91.7%, Odds ratio- 1.17
Au AK et al., [24] (2016) Sample size=40 patients Study place- USA	Hypotension=76% of patients with IVCCI ≥50% had significant hypotension compared to 39% with IVCCI <50%, Predetermined cut-off value of IVCCI- 50%, Sensitivity of IVCCI- 66.67%, Specificity of IVCCI- 77.27%, Odds ratio- 6.9

[Table/Fig-11]: Comparative analysis of various previous studies on IVCCI to predict hypotension after general anaesthesia [1,4,12-17,24,25].
IVCCI: Inferior vena cava collapsibility index; IVC:AO: Inferior vena cava: Aorta; PPV: Positive predictive value; NPV; Negative predictive value; AUROC: Area under the receiver operating characteristic

This cut-off value showed a sensitivity of 95.5% and specificity of 94.6%. Previous studies have also used IVCCI as a predictive tool for hypotension after both spinal anaesthesia [5-11] and general anaesthesia [1,4,12-17,24].

A review of similar studies conducted previously has concluded that IVCCI is a reliable predictor of hypotension after general anaesthesia, with good sensitivity and specificity. These findings are consistent with the observations of the present study [1,13,15,25]. However, a study conducted by Szabó M et al., reported a poor sensitivity of 45.5% and good specificity of 90.0%, which may be attributed to the use of a predetermined cut-off value of IVCCI ≥50% [12]. Omar H et al., also found a poor specificity of 18.2% and good sensitivity of 92.5% for IVCCI. They compared IVCCI with IVCDmax/Ao in predicting hypotension after general anaesthesia, which may have introduced bias inherent to the trial design [17]. Another study conducted by Mohammed S et al., did not find any correlation between hypotension and IVCCI, with low sensitivity ranging from 47-59% and specificity of IVCCI ranging from 48-50%, potentially due to the inability to visualise the IVC in many patients [Table/Fig-11] [16].

In present study, patients were divided into two groups based on IVCCI. Patients with IVCCI ≥50% were grouped as CI+, while those with IVCCI <50% were grouped as the CI-group. The proportion 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). These results are consistent with a study by Au AK et al., where 76% of patients with IVCCI ≥50% had significant hypotension compared to 39% with IVCCI <50%, showing similar findings [24].

A significant association was observed between IVCCI (%) and hypotension (p-value <0.05). The derived cut-off for IVCCI was found to be ≥38% with high sensitivity and specificity. Similar cut-off values close to the present study's cut-off have been derived by previous investigators [1,5,7,8,10,12]. However, Omar H et al., derived a cut-off value of 28.3%, which was lower than the present study's cut-off, as they compared IVCCI with the IVCDmax/Ao index [17]. IVCCI of ≥50% is generally accepted as a cut-off point to predict hypotension in critical care units, but the same may not hold true for relatively healthy surgical patients, as the derived cut-off in these cases is much lower.

Hypotension is common after general anaesthesia, and various risk factors such as poor nutrition, low cardiopulmonary reserve, preexisting co-morbidities, and the choice of anaesthetic agents contribute to its occurrence [26,27]. Previous investigators have used propofol as an induction agent [13-17,24], which itself can cause significant hypotension after general anaesthesia. To limit this confounding effect, a more cardio stable induction agent, thiopentone, was used in the present study.

The IVCCI of ≥50% is generally accepted as a cut-off point to predict hypotension in critically ill patients [28], but the same may not hold true for relatively healthy surgical patients, as the derived cut-off in these cases is much lower. In the present study, an IVCCI cut-off of ≥38% has shown excellent sensitivity and specificity, with outstanding diagnostic accuracy.

Limitation(s)

The present study was conducted at a single centre, and it did not include high-risk patients with ASA 3 or 4, pregnant females, or obese patients. It is important to note that the respiratory cyclic movements of the diaphragm can lead to an underestimation of IVCCI. This limitation could potentially be overcome by assessing the caval-aorta index. Further multicentre research is needed to explore the use of the caval-aorta index in predicting hypotension after general anaesthesia.

CONCLUSION(S)

The present study in spontaneously breathing patients demonstrated that preoperative ultrasonographic assessment of IVCCI is a reliable tool for predicting hypotension after general anaesthesia. 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 anaesthesia induction in suspected hypovolemic patients.

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