Correlation of preoperative inferior vena cava diameter and inferior vena cava collapsibility index with preoperative fasting status, patient demography and general anaesthesia associated hypotension: A prospective, observational study

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ABSTRACT

Background and Aims: A definitive cutoff of inferior venacava (IVC) diameter in expiration (dIVCmax) and inferior vena cava collapsibility index (IVCCI) for predicting general anaesthesia associated hypotension (GAAH) is not yet determined. Primary objective of this study was to determine the correlation of dIVCmax and IVCCI, with GAAH. Other objectives were to determine the correlation of these IVC parameters with preoperative fasting duration, temperature and humidity. The correlation of dIVCmax with patient demography was also studied.

Methods: A total of 110 adult patients undergoing elective surgery under general anaesthesia were included in the study. IVC ultrasonography was done in the preoperative room, 20 to 30 minutes before shifting the patient to the operating room. Hypotension at (hypo@) 2 minutes and 10 minutes after administering vecuronium was recorded.

Results: Hundred and seven patients were analysed. A significant positive correlation was present between patient height and dIVCmax ($\rho = 0.25$, $P = 0.009$). Area under receiver operating characteristics curve was 0.595 (95% confidence interval (CI) 0.485–0.705) and 0.568 (95% CI 0.458–0.679) for dIVCmax and IVCCI for predicting hypo@2 min, with a diagnostic accuracy of 54% and 53%, respectively. dIVCmax $\leq 1.14$ cm had a sensitivity of 31% and specificity of 87% in predicting GAAH. IVCCI $\geq 63.3\%$ could predict GAAH with 31% sensitivity and 84% specificity. No significant correlation was found between preoperative IVC parameters and preoperative fasting or environmental factors.

Conclusion: Both dIVCmax and IVCCI have poor diagnostic accuracy, with good specificity and low sensitivity in predicting GAAH. A steady formula for calculating baseline IVC diameter adjusted for patient demography is needed.

Key words: Anaesthesia, demography, echocardiography, fasting, general, hypotension, inferior, temperature, vena cava

INTRODUCTION

Intraoperative hypotension adversely impacts the postoperative outcomes. Hypovolaemia is an important risk factor for intraoperative hypotension.[1] Preoperative inferior venacava diameter (dIVC) and collapsibility index (IVCCI) are now increasingly used to measure intravascular volume status and predicting anaesthesia associated hypotension (AAH).[1,2] A definitive cutoff of dIVC and IVCCI which consistently predicts AAH is yet to be determined.[1,3] Moreover,
baseline dIVC and IVCCI can vary with patient demographic parameters such as age, gender, weight, height, body mass index (BMI), and body surface area.\[4\]

Preoperative fasting status, environmental temperature and humidity can alter patients’ preoperative volume status.\[1\] Studies have often shown that preoperative fasting does not result in significant hypovolaemia; however, a positive association between preoperative fasting duration and AAH has been reported.\[5,6\] None of the studies have correlated environmental temperature and humidity with preoperative volume status and AAH.

This study was undertaken with the primary objective of determining the correlation of preoperative inferior vena cava (IVC) diameter during expiration in spontaneous respiration (dIVCmax) and IVCCI with general anaesthesia associated hypotension (GAAH). Other objectives were to determine the correlation of dIVCmax with patient demography; correlation of preoperative IVC parameters (dIVCmax and IVCCI) with preoperative fasting duration, environmental temperature and humidity.

**METHODS**

After approval from institutional ethics committee (HIMSR/IEC/005/2020), this single-centre, prospective, observational study was conducted from October 2020 to December 2021. The study was conducted in a tertiary care medical college hospital. The study protocol was registered at the Clinical Trials Registry of India (CTRI/2020/10/028332 dated 09/10/2020). Written informed consent was obtained from all patients and the study was conducted in accordance with the principles of the Declaration of Helsinki.

All American Society of Anesthesiologists (ASA) physical class I and II patients above 18 years of age, planned for elective non-cardiac, non-obstetric surgery under general anaesthesia with tracheal intubation were eligible for the study. All consecutive patients meeting the eligibility criteria were included in the study. The non-inclusion criteria were: patients having preoperative hypotension (systolic blood pressure <90 mmHg or mean arterial pressure <65 mmHg), intraabdominal mass, acute haemorrhage, history of underlying cardiovascular disease, pregnant patients and patients on positive pressure ventilation.

In the preoperative room, the nurse recorded the preoperative vitals and environmental temperature and humidity. IVC ultrasonography (USG) was done 20 to 30 minutes before shifting the patient to the operating room. All USGs were performed by one of the three designated anaesthesiologists who had received institutional training for USG in anaesthesia and had work experience of more than one year in this field.

USG was performed on patients in the dorsal recumbent position. USG machine (Mindray DC-N2, Shenzhen Mindray Bio-Medical Electronics Company Limited, Shenzhen, China) with convex array transducer (frequency 2–6 Megahertz, Mindray 35C50EA) was used. IVC was visualised in the longitudinal paramedian sub-xyphoid view using the B-mode. M-mode was applied on the vein 2–3 cm from the right atrium. The diameter of the vein was measured in expiration (dIVC max) and inspiration (dIVC min) in a single respiratory cycle [Figure 1] and IVCCI was calculated using the formula:

$$\text{IVCCI} = \frac{\text{dIVCmax} - \text{dIVCmin}}{\text{dIVCmax}} \times 100$$

The patient was then shifted to the operating room and general anaesthesia was administered. Anaesthesia was induced with injection fentanyl (1–2 µg/kg) and propofol (1.5–2.5 mg/kg) titrated to loss of verbal responsiveness. It was followed by injection vecuronium (0.08–0.1 mg/kg) and tracheal intubation. Mechanical ventilation was instituted and maintenance of anaesthesia was done with isoflurane at 1–1.2 minimum alveolar concentration. Balanced

![Figure 1: Inferior vena cava ultrasound](image-url)
salt solution was started at 10 ml/kg/h and further individualised as per case basis. Standard monitoring including electrocardiography (ECG), capnography and pulse oximetry was done. Non-invasive blood pressure (NIBP) was measured continuously at 5-minute intervals. Two additional NIBP readings were taken at ‘2 minutes’ after administering vecuronium (this reading was obtained before tracheal intubation) and ‘10 minutes’ after administering vecuronium. In all cases, surgical incision was made after the ‘10 minutes’ NIBP reading was obtained. The perioperative management was done by anaesthesiologists not involved in preoperative IVC USG. Patient demographics, preoperative fasting duration and intraoperative vitals were recorded from anaesthesia records.

GAAH was taken as drop in systolic blood pressure (SBP) below 90 mmHg, or ≥25% fall in SBP from preoperative value or mean arterial pressure (MAP) reading <65 mmHg.\(^1\)

Hypotension noted at 2 minutes after giving vecuronium was labelled as ‘hypo@ 2 minutes’, and hypotension occurring at 10 minutes after administering vecuronium was labelled as ‘hypo@10 min’. The management of hypotension was left to the discretion of the attending anaesthesiologist.

The sample size was calculated considering 15 mmHg change in SBP as clinically important and a standard deviation of 25 mmHg, taken from the reference study.\(^1\) With a type one error of 0.05, power of 0.8, a sample size of 88 patients was calculated. Considering 25% attrition, 110 patients were included in the study. Statistical Package for the Social Sciences (SPSS) statistics for Windows, version 23 (International Business Machines Corp., Armonk, N.Y., USA) was used for data analysis. Group comparisons for continuously distributed data were made using independent sample ‘t’ test when comparing two groups. Linear correlation between two continuous variables was explored using Pearson’s correlation (if the data were normally distributed) and Spearman’s correlation (for non-normally distributed data). Statistical significance was kept at \(P < 0.05\). The area under the receiver operating characteristic (AUROC) curve was compared using DeLong’s method.

## RESULTS

During the study period, 132 patients were screened and out of these, 107 patients were analysed [Figure 2]. The patients’ baseline characteristics and surgical operations were recorded [Table 1].

There was a positive correlation between height (cm) and dIVCmax (cm) (\(\rho = 0.25, P = 0.009\)) [Table 2, Figure 3]. No significant correlation was found between dIVCmax and patient age, gender, weight or BMI [Table 2].

The mean SBP at 2 minutes post-induction was 96.93 ± 16.32 mmHg and the percent change in SBP (from preoperative value) at the same time was: \(−21.56 ± 16.51\) [median (interquartile range): \(−23.20 (−31.84–9.13)\)]. Sixty-two (57.9%) participants had hypo@2 min and 22 (20.6%) participants had hypo@10 min. The relative risk (95% confidence interval [CI]) of patients developing hypo@10 min in patients who had hypo@2 min was 2.47 (1.04–6.13). Only five patients had hypo@10 min, who did not experience hypo@2 min. All these five patients had fall in SBP ≥25% but the SBP and MAP were within normal limits (SBP ≥90 mmHg and MAP ≥65 mmHg) at 10 minutes post induction. No significant association was found between preoperative IVC parameters (dIVCmax and IVCCI) and hypo@2 min or hypo@10 min [Table 2].

dIVCmax and IVCCI did not correlate with fasting duration [Tables 1 and 2]. No significant correlation was found between environmental factors (temperature, humidity) with IVC measurements and intraoperative haemodynamics [Tables 2 and 3].

The parameters that were analysed for prediction of hypo@2 min included preoperative fasting, preoperative dIVCmax, preoperative IVCCI, environmental temperature and humidity. None of these parameters significantly predicted hypo@2 min [Table 3].

## DISCUSSION

In the present study, a significant correlation was observed between patient height and dIVCmax (\(\rho = 0.25, P = 0.009\)) [Table 2, Figure 3]. Similar positive correlation between height and dIVCmax diameters has been observed in previous studies.\(^{[4,8]}\) Gui J et al.\(^{[4]}\) in their study, found patient height to be the sole significant predictor of dIVCmax.

Literature indicates that the average maximum and minimum height across the world population varies between 184 cm and 151 cm.\(^{[9]}\) According to the
present study, for every 1 cm increase in height of the patient, the dIVCmax increases by 0.01 cm. This being the case, height variation of the world population should lead to a difference of 3.3 mm in the baseline dIVCmax diameter across the world population. On similar lines, even within India, a variation of 1.8 mm in baseline dIVCmax diameter may be present (height range 149.2–169 cm). Baseline variations of 2–3 mm in dIVCmax appear small but are clinically significant, given the fact that mean IVC max diameter is only 16–17 mm. A mere 3 mm increase in dIVCmax increases the risk prediction of congestion from low risk to intermediate risk in patients with heart failure.

Baseline IVC diameter has also been shown to vary with age, gender, weight, BMI and body surface area.
in various studies. These demographic factors together can lead to significant variation in baseline IVC diameter across populations. A reliable formula predicting baseline IVC diameter adjusted for patient demographic parameters is yet to be developed.

No significant correlation was found between fasting duration and preoperative IVC parameters (dIVCmax, IVCCI) [Table 2]. Fasting duration also had poor diagnostic performance in predicting GAAH [measured at 2 minutes after induction of anaesthesia] [Table 3]. All patients were instructed to remain nil per oral preoperatively as per the practice guidelines of the Indian Society of Anaesthesiologists. None of the patients received intravenous fluids preoperatively. Patients experiencing longer than recommended fasting duration were either admitted on the day of surgery or were operated during the latter half of the day. No variation in fasting duration was observed with environmental temperature and humidity.

Prolonged fasting periods, similar to the present study, have also been reported from other centres. It has been shown that preoperative fasting does not result in significant hypovolaemia; however, a positive association between preoperative fasting duration and post-induction fall in blood pressure has been frequently observed. Also, preoperative functional intravascular deficit was observed in...
majority of anaesthetised patients, in the study by Bundgaard-Nielsen M et al.\(^{[18]}\)

Yeniay O et al.\(^{[6]}\) reported earlier hypotension and greater number of ischaemic ECG signs under spinal anaesthesia in patients having longer fasting durations (mean fasting durations were 15.5 ± 3.4 and 12.7 ± 4.4 hours versus 12 ± 2.8 hours and 9.5 ± 2.1 hours for foods and liquids in the two groups, respectively). The median age of patients was 72 years, belonging to ASA physical status II and III. The authors suggested hypovolaemia resulting from extended fasting to be an attributing factor for the observed cardiovascular derangements.

In a study by Tsukamoto M et al.\(^{[9]}\) vasopressors were required to treat temporary hypotension at the induction of anaesthesia, in the group of patients with mean fasting duration of 13.87 hours for solids and 216.5 minutes for liquids. The authors suggested that additional 150 minutes of solid fasting and 22 minutes of liquid fasting might have contributed to the lower intravascular volume status in the group requiring vasopressors.

It is possible that prolonged preoperative fasting induces a latent fluid deficit, which is not readily detected in young and healthy individuals. This deficit, however, can become clinically relevant in elderly patients, patients with co-morbidities and in high-risk surgeries.

In the present study, preoperative dIVCmax and IVCCI (%) did not correlate with hypo@2 min or hypo@10 min. Szabó M et al.\(^{[1]}\) in their study found that preoperative IVCCI ≥50% has a high specificity (90%) and low sensitivity (45.5%) in predicting post-induction hypotension. The median age of patients was more than 60 years and they belonged to ASA physical status I to III. This made the study participants more susceptible to profound volume disturbances and hypotension.

Zhang J et al.\(^{[7]}\) found preoperative IVCCI measurement to be a reliable predictor of post induction hypotension up to 10 minutes after tracheal intubation, with IVCCI >43% as the threshold. Preoperative dIVCmax also had diagnostic value for the same, with a cutoff of 1.8 cm. Patients were in ASA physical status I–III and also included patients undergoing cardiac surgeries. In the present study, the AUROC curve for IVCCI and dIVCmax predicting hypo@2 min were 0.568 (95% CI: 0.458–0.679), and 0.595 (95% CI: 0.485–0.705) with a diagnostic accuracy of 54% and 53%, respectively, thus demonstrating poor diagnostic performance. dIVCmax ≤1.14 cm had a sensitivity of 31% and specificity of 87% in predicting GAAH. IVCCI ≥63.3% could predict GAAH with 31% sensitivity and 84% specificity [Table 3]. Louro J et al.\(^{[3]}\) did not find preoperative IVCCI to be a reliable marker of intraoperative fluid requirements and hypotension. The findings of the present study are similar to the study by Louro J et al.\(^{[3]}\). Both the studies are also similar in analysing relatively younger patients, belonging to ASA physical status 1 and 2, undergoing elective surgeries.

Apparently, the correlation between preoperative IVC parameters and intraoperative hypotension is more evident in patients at higher risk of intraoperative volume disturbances and hypotension such as advanced age, high risk surgery and advanced ASA grade. As a clinical endpoint, it will also be prudent to analyse whether fluid administration based on these IVC parameters can prevent intraoperative hypotension. Further studies are required on these lines.

An interesting observation during the study was the correlation of ‘visible IVC collapse on ultrasonography’ (taken as walls collapsing, almost touching each other in inspiration) with GAAH. During the study, visible collapsibility of IVC was recorded in few patients randomly. Out of 31 patients, in whom visible IVC collapse was recorded,
20 patients developed hypo@2 min. Although this finding cannot be accounted statistically in the present study, it can be explored in future studies. It might offer an easier and quicker way of predicting anaesthesia associated hypotension even by technical staff or anaesthesiologists who are not adept in ultrasonographic calculations.

Studies have shown that changes in environmental temperature are associated with blood pressure variations and higher temperatures can lead to increased number of hospital visits due to hypotension. Nevertheless, the temperature range in these studies was wider (−14 degrees to 33 degrees) as compared to the present study. Moreover, the change in blood pressure was observed more frequently in patients with underlying cardiac disease.\(^{[20,21]}\)

In the present study, the changes in environmental temperature and humidity did not lead to any changes in baseline preoperative haemodynamics and intravascular volume status of the study patients. Predictably so, no variation was reflected in GAAH with respect to changes in environmental temperature and humidity [Tables 2 and 3].

The present study is novel in several aspects. It evaluated the correlation of preoperative IVC parameters with prolonged fasting states and environmental temperature and humidity. The promising role of ‘Visible IVC collapse’ in predicting GAAH is also highlighted. One limitation of the present study is the inclusion of only ASA physical status I and II patients, posted for elective non-cardiac surgeries. The median age of the patients was 34.00 (27.00–46.00) years. The patients were well-compensated. This might have led to insignificant preoperative or intra-operative haemodynamic variability in the study patients. Moreover, a wider dose range of fentanyl (1 to 2 µg/kg) was used which might have affected the incidence of GAAH.

CONCLUSION

Preoperative ultrasound guided measurement of dIVCmax and IVCCI did not show any significant correlation with preoperative fasting. GAAH, environmental temperature and humidity. Both dIVCmax and IVCCI had poor diagnostic accuracy, with good specificity and low sensitivity in predicting GAAH. A steady formula for prediction of IVC diameter adjusted for patient demography needs to be developed.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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