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Original Research Article

Role of Inferior Vena Cava Collapsibility Index in Preoperative Volume Assessment: A Prospective Observational Study

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Abstract

Background: Preoperative fasting may result in varying degrees of intravascular volume depletion, which can contribute to hemodynamic instability following induction of anaesthesia. Bedside ultrasonographic assessment of the Inferior Vena Cava Collapsibility Index (IVCCI) has emerged as a simple, non-invasive method for evaluating volume status and predicting fluid responsiveness.

Objectives: To assess the role of the Inferior Vena Cava Collapsibility Index in preoperative volume assessment among fasting patients undergoing elective surgery and to evaluate changes in IVCCI following intravenous fluid administration.

Materials and Methods: This prospective observational study included 120 adult patients with American Society of Anesthesiologists (ASA) physical status I or II who had fasted for at least 8 hours before elective surgery. Baseline inferior vena cava (IVC) diameters during inspiration and expiration were measured using M-mode ultrasonography with a 3-MHz phased-array probe. IVCCI was calculated before and after administration of a 500 mL intravenous bolus of 0.9% normal saline over 20 minutes. Hemodynamic parameters and ultrasonographic measurements were compared using appropriate statistical tests, with $p<0.05$ considered statistically significant.

Results: The mean baseline IVCCI was 46.2 ± 11.4%, which decreased significantly to 30.8 ± 8.6% following fluid administration ($p<0.001$). Both maximum and minimum IVC diameters increased significantly after the fluid bolus ($p<0.001$). Before fluid administration, 59.1% of patients had an IVCCI >40%, whereas this proportion decreased to 13.3% after volume expansion ($p<0.001$). Heart rate decreased significantly, while systolic, diastolic, and mean arterial pressures improved following fluid therapy. Oxygen saturation remained unchanged.

Conclusion: Inferior Vena Cava Collapsibility Index is a rapid, safe, and non-invasive bedside tool for assessing preoperative intravascular volume status in fasting elective surgical patients. Significant reduction in IVCCI after crystalloid administration demonstrates its usefulness in identifying relative hypovolemia and monitoring response to fluid therapy. Incorporation of IVCCI into routine preoperative assessment may facilitate individualized perioperative fluid optimization and improve hemodynamic stability.

Keywords: Inferior Vena Cava Collapsibility Index; IVCCI; Preoperative Fasting; Volume Assessment; Fluid Responsiveness; Ultrasonography; Elective Surgery; Perioperative Fluid Management.

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Introduction

Preoperative fasting is routinely advised before elective surgery to reduce the risk of pulmonary aspiration; however, prolonged fasting may contribute to intravascular volume depletion in some patients. Accurate assessment of preoperative volume status is therefore important because unrecognized hypovolemia may predispose patients to hypotension after induction of anaesthesia, impaired tissue perfusion, and perioperative complications. Conventional clinical parameters such as heart rate, blood pressure, capillary refill time, and urine output may not reliably identify early or compensated hypovolemia. [1] Bedside ultrasonographic assessment of the inferior vena cava (IVC) has emerged as a rapid, non-invasive method for evaluating intravascular volume status. Respiratory changes in IVC diameter reflect variations in venous return and right atrial pressure. The inferior vena cava collapsibility index (IVCCI), calculated from the maximum and minimum IVC diameters during respiration, has been investigated as a potential marker of preload and fluid responsiveness. Early studies demonstrated that respiratory variations in IVC diameter could help predict fluid responsiveness in mechanically ventilated patients with circulatory failure. [2]

Subsequent studies extended the application of IVC ultrasonography to spontaneously breathing patients. Muller et al. reported that marked respiratory variation in IVC diameter may identify patients likely to respond to fluid administration, although intermediate values require cautious interpretation.[3] Similarly, Airapetian et al. observed that IVC respiratory variability alone had limited predictive reliability in spontaneously breathing critically ill patients, highlighting the influence of respiratory effort and clinical condition on IVC measurements.[4]

Systematic reviews and meta-analyses have shown that respiratory variation in IVC diameter has moderate diagnostic value for predicting fluid responsiveness, but considerable heterogeneity exists among studies due to differences in patient populations, ventilation status, measurement techniques, and threshold values. [5-7] Despite these limitations, IVCCI remains attractive in the preoperative setting because it is simple, repeatable, non-invasive, and can be performed rapidly at the bedside. The present prospective observational study was therefore undertaken to evaluate the role of the inferior vena cava collapsibility index in assessing preoperative volume status among fasting patients scheduled for elective surgery.

Materials and Methods

Study Design: This prospective observational study was conducted to evaluate the role of the Inferior Vena Cava Collapsibility Index (IVCCI) in preoperative volume assessment among fasting patients undergoing elective surgery.

Study Setting and Duration: The study was carried out in the preoperative waiting area of the operation theatre at Military Hospital, Bareilly, UP, India, between November 2025 to May 2026, after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment.

Sample Size: A total of 120 patients were included in the study using consecutive sampling.

Study Population: Adult patients scheduled for elective surgery under anaesthesia were screened for eligibility.

Inclusion Criteria

- Patients aged 18 years or older.
- American Society of Anesthesiologists (ASA) Physical Status I or II.
- Fasting duration of 8 hours or more.
- Patients posted for elective surgical procedures.

Exclusion Criteria

- ASA Physical Status III, IV, or V.
- Pregnant women.
- Patients with abdominal masses or ascites.
- Fasting duration of less than 8 hours.
- Patients undergoing emergency surgery.
- Patients with known conditions affecting accurate IVC assessment or significant cardiac dysfunction.

Study Procedure: Baseline demographic details, including age, sex, body mass index (BMI), ASA physical status, fasting duration, and planned surgical procedure, were recorded. Hemodynamic parameters, including heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and peripheral oxygen saturation (SpO_2), were documented before ultrasonographic assessment. Ultrasonographic evaluation of the inferior vena cava was performed using a portable ultrasound machine equipped with a 3-MHz phased-array (echocardiography) probe. The examination was carried out with the patient in the supine position using the subxiphoid long-axis view. The inferior vena cava was identified approximately 2–3 cm distal to its junction with the right atrium, and M-mode imaging was used to measure the maximum IVC diameter during expiration (IVCmax) and the minimum diameter during inspiration (IVCmin).

The Inferior Vena Cava Collapsibility Index (IVCCI) was calculated using the following formula:

$$\text{IVCCI } (\%) = [(\text{IVCmax} - \text{IVCmin}) / \text{IVCmax}] \times 100$$

Following the baseline assessment, each patient received a 500 mL intravenous bolus of 0.9% normal saline administered over approximately 20 minutes. .After completion of fluid administration, ultrasonographic measurements of IVCmax and IVCmin were repeated, and IVCCI was recalculated. The pre- and post-fluid IVCCI values were compared to evaluate changes in intravascular volume status and assess fluid responsiveness.

Outcome Measures: The primary outcome was the baseline IVCCI in fasting preoperative patients. Secondary outcomes included the change in IVCCI following administration of a 500 mL crystalloid bolus and its usefulness in identifying patients with preoperative volume depletion.

Statistical Analysis: Data were entered into Microsoft Excel and analysed using SPSS version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Pre- and post-fluid IVCCI values were compared using the paired t-test. Associations between categorical variables were analysed using the Chi-square test or

Fisher's exact test, as appropriate. A p-value of <0.05 was considered statistically significant.

Results

A total of 120 fasting adult patients scheduled for elective surgery were included in the study. All patients underwent preoperative ultrasonographic assessment of the inferior vena cava (IVC) before and after administration of a 500 mL normal saline bolus. No patient was excluded after enrolment, and adequate ultrasonographic visualization of the IVC was achieved in all participants.

Table 1: Baseline demographic and clinical characteristics of the study population (n = 120)

Variable	Number (%)
Age group (years)	
18–30	32 (26.7)
31–45	46 (38.3)
46–60	28 (23.3)
>60	14 (11.7)
Gender	
Male	68 (56.7)
Female	52 (43.3)
ASA Physical Status	
ASA I	74 (61.7)
ASA II	46 (38.3)
Duration of fasting	
8–10 hours	71 (59.2)
>10 hours	49 (40.8)

The majority of patients belonged to the 31–45 years age group (38.3%), followed by 18–30 years (26.7%). Males constituted 56.7% of the study population. Most patients were classified as ASA I (61.7%), and approximately 59.2% had fasted for 8–10 hours before surgery.

Table 2: Inferior vena cava measurements before and after fluid bolus (n = 120)

Parameter	Before fluid bolus (Mean ± SD)	After fluid bolus (Mean ± SD)	p value
IVC maximum diameter (cm)	1.82 ± 0.29	2.01 ± 0.25	<0.001
IVC minimum diameter (cm)	0.98 ± 0.22	1.39 ± 0.21	<0.001
IVC Collapsibility Index (%)	46.2 ± 11.4	30.8 ± 8.6	<0.001

Administration of a 500 mL normal saline bolus resulted in a significant increase in both inspiratory and expiratory IVC diameters. The mean IVCCI decreased significantly from 46.2% to 30.8% (p<0.001), indicating improved intravascular volume status following fluid administration.

Table 3: Distribution of patients according to pre- and post-fluid IVCCI categories

IVCCI (%)	Before fluid bolus n (%)	After fluid bolus n (%)	p value
<20	8 (6.7)	32 (26.7)	<0.001
20–40	41 (34.2)	72 (60.0)	
>40	71 (59.1)	16 (13.3)	

Before fluid administration, 59.1% of patients demonstrated an IVCCI greater than 40%, suggesting relative preoperative volume depletion. Following fluid loading, the proportion of patients with IVCCI >40% decreased significantly to 13.3%, while most patients shifted to the 20–40% category (p<0.001).

Table 4: Comparison of hemodynamic parameters before and after fluid administration

Parameter	Before fluid bolus (Mean ± SD)	After fluid bolus (Mean ± SD)	p value
Heart rate (beats/min)	84.6 ± 11.8	79.8 ± 10.2	0.001
Systolic BP (mmHg)	118.5 ± 12.4	122.3 ± 11.6	0.012
Diastolic BP (mmHg)	74.8 ± 8.6	77.1 ± 7.9	0.028
Mean arterial pressure (mmHg)	89.4 ± 8.5	92.2 ± 7.8	0.009
SpO_2 (%)	98.4 ± 0.8	98.6 ± 0.7	0.186

Following fluid administration, there was a statistically significant reduction in heart rate and modest increases in systolic, diastolic, and mean arterial pressures. Oxygen saturation remained stable with no significant difference. These findings indicate improvement in preload without clinically significant hemodynamic instability.

Discussion

The present prospective observational study evaluated the utility of the Inferior Vena Cava Collapsibility Index (IVCCI) as a bedside ultrasonographic tool for preoperative volume assessment in fasting patients undergoing elective surgery. The findings demonstrated that a considerable proportion of patients exhibited elevated baseline IVCCI values suggestive of relative intravascular volume depletion despite being clinically stable.

Administration of a standardized 500 mL crystalloid bolus resulted in a significant reduction in IVCCI together with increased inspiratory and expiratory IVC diameters, indicating improved preload and intravascular volume status. These findings support the role of IVCCI as a simple, rapid, and non-invasive marker for identifying preoperative volume depletion.

Juhl-Olsen et al. investigated the usefulness of IVC ultrasonography in elective surgical patients and reported that although IVC measurements alone were not a perfect predictor of fluid responsiveness, they provided valuable information regarding preload status when interpreted in conjunction with clinical findings and other hemodynamic parameters.[8] The present study similarly demonstrated that fasting patients frequently showed elevated baseline IVCCI, which decreased significantly following intravenous fluid administration, indicating correction of relative hypovolemia.

Cherpanath et al. emphasized that fluid responsiveness depends on the interaction between cardiac function and venous return rather than static preload measurements alone. Their review highlighted that dynamic parameters, including respiratory variation in vena cava diameter, provide more clinically meaningful information than conventional static indices for guiding fluid therapy.[9] The significant reduction in IVCCI observed after crystalloid administration in the present study supports this concept and suggests that IVCCI reflects changes in preload more effectively than routine clinical examination alone.

Focused cardiac and vascular ultrasonography has become increasingly integrated into perioperative practice. Via et al. published international evidence-based recommendations supporting focused cardiac ultrasound as an important component of perioperative and critical care assessment, particularly for evaluating intravascular volume status and guiding fluid management.[10] The standardized ultrasound protocol employed in the present study, using M-mode measurements obtained in the subxiphoid view, demonstrated that bedside IVC assessment can be performed reliably in the preoperative holding area without causing delay in routine surgical workflow.

Monnet et al. reviewed current methods for predicting fluid responsiveness and concluded that dynamic ultrasound-derived indices provide superior physiological information compared with static filling pressures, although they should always be interpreted within the patient's overall clinical context.[11] The present findings agree with these recommendations, as significant improvement in IVCCI after fluid loading was accompanied by modest reductions in heart rate and improvements in arterial blood pressure, supporting the physiological relevance of the ultrasonographic observations.

Bentzer et al. systematically evaluated bedside methods for predicting fluid responsiveness and concluded that no single parameter should be used in isolation. Rather, fluid administration should be guided by integrating clinical examination with dynamic hemodynamic assessment whenever possible.[12] In the present study, IVCCI complemented routine hemodynamic monitoring by identifying patients with relative volume depletion despite stable baseline blood pressure. This suggests that ultrasonographic assessment may help optimize perioperative fluid management before induction of anaesthesia and potentially reduce the risk of post-induction hypotension.

Miller and Mandeville further highlighted the expanding role of echocardiography in evaluating preload and fluid responsiveness. They concluded that ultrasonographic assessment of the inferior vena cava is practical, reproducible, and particularly valuable because it is rapid, non-invasive, repeatable, and free from radiation exposure.[13] The observations of the present study are consistent with these conclusions. The significant reduction in IVCCI following fluid administration indicates that bedside IVC ultrasonography is capable of detecting clinically meaningful changes in intravascular volume status among fasting elective surgical patients.

The strengths of the present study include its prospective design, standardized ultrasound technique, and inclusion of a relatively large cohort of elective surgical patients. However, several limitations should be acknowledged. The study was conducted at a single center and included only ASA physical status I and II patients, which may limit generalizability to critically ill patients or those with significant cardiovascular disease.

Furthermore, IVCCI was evaluated after a single standardized crystalloid bolus without comparison with invasive hemodynamic monitoring or postoperative clinical outcomes. Future multicenter studies incorporating advanced cardiac output monitoring and perioperative outcome measures would further clarify the clinical utility of IVCCI-guided fluid optimization.

Conclusion

Inferior vena cava collapsibility index is a valuable, non-invasive bedside ultrasonographic parameter for assessing preoperative intravascular volume status in fasting patients undergoing elective surgery.

A significant reduction in IVCCI following administration of a 500 mL crystalloid bolus demonstrates its ability to identify relative preoperative volume depletion and monitor response to fluid therapy. Incorporation of IVCCI assessment into routine preoperative evaluation may facilitate individualized fluid optimization, improve perioperative hemodynamic stability, and reduce the risk of hypovolemia-related complications. Further large-scale multicenter studies are warranted to validate its role in guiding perioperative fluid management across diverse surgical populations.

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