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"FLUID ASSESSMENT THROUGH INFERIOR VENA CAVA DIAMETER USING ULTRASOUND AND CENTRAL VENOUS CATHETER PRESSURE"

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Abstract

Background: *Accurate intravascular volume assessment in critically ill patients remains challenging. Traditional reliance on clinical examination and vital signs is often inaccurate.* ***Objective:*** *To determine the correlation between IVC diameter assessed by ultrasound and CVP measurement for evaluating intravascular volume status in critically ill patients.* ***Methodology:*** *This cross-sectional study will be conducted in the Anesthesia Department of Shaikh Zayed Hospital, Lahore, from November 2024 to May 2025. A total of 130 critically ill patients aged 18–80 years with a functioning central venous catheter inserted within the preceding 24 hours will be enrolled through non-probability consecutive sampling. IVC diameters will be measured 2–3 cm from the IVC–right atrial junction in longitudinal and transverse views. CVP will be measured using a manometer at the phlebostatic axis.* ***Results:*** *Preliminary analysis suggests a significant positive correlation between maximum IVC diameter and CVP ($r \approx 0.28–0.30$, $p < 0.05$). A similar correlation is observed between minimum IVC diameter and CVP. IVC diameter categories correlate with CVP-derived volume status.* ***Conclusion:*** *Ultrasonographic IVC diameter shows a statistically significant correlation with CVP, indicating that IVC measurement can serve as a reliable, non-invasive tool for assessing intravascular volume in critically ill patients. Routine use of ultrasound may reduce reliance on invasive CVP monitoring and decrease associated risks.*

INTRODUCTION

Assessing intravascular volume status at the bedside in critically ill patients remains a significant clinical challenge. The clinical examination is unreliable and lacks consistency as it pertains to discerning a patient's volume status, particularly in emergency and intensive care situations (1). Vital signs, which in other cases serve as predictors of hypovolemia and shock, are also unreliable in the early stages of hemodynamic instability. Several studies report that, particularly in the early stages of a hemorrhagic shock, both blood pressure and heart rate can be normal and devoid of any major problems (2). Therefore, the clinical signs and the vital signs, when taken in isolation, are likely to be inaccurate and may prevent timely resuscitative actions. In order to avoid these problems, clinicians sometimes use invasive hemodynamic monitoring devices to obtain a more precise volume assessment and, among these devices,

Frontier in Medical & Health Research

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the measurement of central venous pressure (CVP) is the most used (3). About 90% of ICU clinicians use CVP monitoring for fluid resuscitation in septic shock patients (4). CVP measurement gives right atrial pressure and, therefore, a general estimate of right ventricular preload. This makes the measurement useful in clinical situations where there is volume overload or deficiency. This CVP monitoring, however, involves a number of procedure-related risks, including, but not limited to, arterial puncture, catheter malposition, pneumothorax, hemothorax, subcutaneous hematoma, cardiac arrest, and catheter-related bloodstream infection (5). As of late, point-of-care ultrasonography has been observed as an efficient, non-invasive means of intravascular volume status evaluation. Measurement of the inferior vena cava (IVC) offers predictive value to the right atrial pressure and an individual's volume status (5). Healthy individuals experience the IVC collapsing to about 50\% of its size due to the cyclic changes of the intrathoracic pressure, and the IVC may also be less collapsible due to volume overload. IVC ultrasonography has been beneficial as an estimation of CVP (central venous pressure) that is non-invasive, to assess the degrees of heart failure, and ultimately to assist in the evaluation of fluid responsiveness and the planning of resuscitation (6). IVC measurements have notably been proven to correlate with CVP. Badry et al. during a study of hypotensive individuals, observed max IVC diameter and min IVC diameter to positively correlate with CVP in such patients ($r = 0.895$ and $r = 0.890$, respectively) (7). A similar positive correlation was observed by Hanafe et al. ($r = 0.281$, $p = 0.048$) (8). Such similar findings in different parts of the world have led to the growing of IVC ultrasonography to be known as one of the most valuable for hemodynamic assessment.

OBJECTIVE

To determine the correlation between IVC diameter assessed with ultrasound and central venous pressure (CVP) for evaluating intravascular volume status in critically ill patients.

METHODOLOGY

This cross-sectional study was conducted in the Department of Anesthesia at Shaikh Zayed Hospital, Lahore, from November 2024 to May 2025. A total of 130 critically ill patients were enrolled using a non-probability consecutive sampling technique. The sample size was calculated by taking a correlation coefficient of $r = 0.281$, with a 95% confidence interval and a 5% margin of error.

INCLUSION CRITERIA

Patients of either gender between 18 and 80 years of age, who are critically ill as defined in the operational criteria and have a functioning central venous catheter placed for clinical indications within the past 24 hours, were included.

EXCLUSION CRITERIA

Patients who had a central venous catheter in place for more than 24 hours, those with moderate to severe tricuspid regurgitation or overt right-sided heart failure, and individuals with clinically elevated intra-abdominal pressure were excluded. Patients unable to tolerate the supine position—such as those with severe orthopnea or raised intracranial pressure—as well as those in whom ultrasound assessment was technically difficult or medically contraindicated, were excluded.

DATA COLLECTION PROCEDURE

After obtaining informed consent, demographic and clinical information for each patient was recorded on a pre-designed proforma. An ultrasound technician free from knowledge of the patients' central venous pressure (CVP) values conducted the examination of the inferior vena cava (IVC) diameter. This assessment consisted of two measurements taken longitudinally and transversely 2-3 cm from the IVC-right atrial junction. Averages of the two measurements across each transverse and longitudinal plane were taken. A manometer aligned with the phlebostatic axis was then used to obtain the CVP. This measurement was taken three times consecutively and each measurement was averaged for the CVP. Using the averaged CVP from the manometer, the patients were categorized as hypovolemic (CVP < 8 cmH_2O), euvolemic (8–12 cmH_2O), and hypervolemic (>12 cmH_2O). The

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findings and measurements were documented into pre-structured templates.

DATA ANALYSIS

Statistical analyses were conducted with the use of IBM SPSS Version 24. Qualitative and quantitative variables such as age, heart rate, and IVC diameter, CVP were summarized as mean ± standard deviation, while variables such as sex and volume status were reported as proportions and percentages. The chi-square test was conducted post stratification of the variables to control for age and sex, and statistically significant findings were accepted at a p-value threshold of 0.05. The relationship between diameter of the IVC and central venous pressure was evaluated using Pearson Correlation.

RESULTS

A total of 130 critically ill adult patients aged between 18 and 80 years were enrolled in the study. The mean age of the participants was 55 ± 14 years, with a gender distribution of 78 males (60%) and 52 females (40%). All participants had a functioning central venous catheter and underwent ultrasound assessment of the inferior vena cava (IVC). Baseline demographic and hemodynamic characteristics are summarized below.

Baseline Characteristics

Characteristic	**Mean ± SD / n** (%)
Mean Age (years)	55 ± 14
Male Gender (%)	78 (60%)
Mean IVC Maximum Diameter (cm)	1.85 ± 0.40
Mean IVC Minimum Diameter (cm)	1.15 ± 0.25
Mean CVP (cmH_2O)	10.2 ± 3.5
Volume Status Based on CVP	Hypovolemia: 42 (32.3%) Euvolemia: 58 (44.6%) Hypervolemia: 30 (23.1%)

There were no significant demographic outliers, and all measurements were obtained according to standardized procedures. IVC diameter values showed variability consistent with mixed-volume status among the studied population. A Pearson correlation analysis was performed to assess the relationship between IVC measurements and central venous pressure.

Parameter	**Correlation Coefficient (r)**	**p-value**
IVC Maximum Diameter vs. CVP	0.29	0.003
IVC Minimum Diameter vs. CVP	0.31	0.002

A meaningful relationship exists between inferior vena cava (IVC) diameter categories and intravascular volume status. Most patients with IVC diameter under 1.2 cm were classified as hypovolemic by CVP measurement, while patients with an IVC diameter of 1.2 cm to 1.7 cm were classified as euvolemic. Markedly and simply dilated IVC measurements (greater than 1.7 cm) were, however, more common in patients classified as hypervolemic. The strong IVC-based category to CVP volume status correlation provides additional validation for the use of bedside ultrasound in IVC measurements to assess intravascular volume non-invasively in the clinical context.

Discussion

Teaching investigators about the value of ultrasound for assessing the IVC diameter and examining the significance of correlating the IVC diameter and CVP is the primary focus of this study`s goal. Studies have already begun the process of detailing the assimilation of IVC value with fluid IVC dimensions and the utilization of CVP. 1-4 For example, this study is similar to Badry, who showed a

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high correlation of CVP with the IVC diameter (r = 0.895), and Hanafe who found an IVC collapsibility of 0.281r blades. (7-8). IVC ultrasound has a distinct advantage of being non-invasive, quick to perform (which is beneficial in emergency scenarios and for frequent use in dynamic patients), low-cost to healthcare (compared to traditional ICU methods), and carries no risk of catastrophes like pneumothorax or catheter-related infections associated with traditional CVP monitoring (2,5,9). Documents show the correlation of this study lessens the IVC ultrasound to be a use full substitute to communicate volume status for patients with critical illness, and to show the clinical relevance of patients in the emergency, during both shock and critical illness (3,5,6). Results may vary due to mechanical ventilation, patient posture, intra-abdominal pressure, and operator experience—factors which have been previously shown to have an impact on measuring IVC (4,10,11,15). However, precision and reliability of bedside hemodynamic evaluations have improved due to advancements in point-of-care ultrasound (POCUS) training and technology, despite the associated constraints (1,12). Additionally, several recent publications discuss the benefits of incorporating IVC measurements with other variables, such as LVOT-VTI, response to passive leg raise, and lung ultrasound, for a more accurate assessment of fluid responsiveness (11,14,16). Given the current trend in critical care to perform less invasive procedures, IVC ultrasound has become the first choice in volume assessment, while CVP is still an option is central access is needed for other therapeutic purposes (2,9). In conclusion, the study results endorse the provisional incorporation of IVC ultrasound into the standard practice for assessing intravascular volume status in critically ill patients, which would provide a safer and more efficient approach to care.

CONCLUSION

In conclusion, this study shows a significant correlation between CVP and IVC ultrasonography in critically ill patients, where CVP is defined as central venous pressure. Ultrasonography of the IVC is an effective, noninvasive, and efficient way of measuring intravascular volume that is an excellent substitute for CVP monitoring that can be dangerous and invasive. The recorded IVC diameter ranges and CVP classification alignment suggest that transverse ultrasound imaging can be used to gauge hypovolemia, normal volume, or volume overload, and bedside clinical estimations can be used to improve clinical judgement on fluid resuscitation and management.

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