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Research Article

Correlation of Ultrasound Guided Inferior Vena Cava Collapsibility Index with Central Venous Pressure to Assess the Volume Status in Postoperative Intensive Care Unit Patients: A Prospective Observational Study

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ABSTRACT

Background: Accurate assessment of intravascular volume status is a vital aspect of management of intensive care unit (ICU) patients. Inferior vena cava (IVC) diameter and IVC collapsibility index have surfaced as promising methods to accurately predict hypovolemia. But no such study has evaluated it's their utility in postoperative patients.

Methods: The study aimed to assess the correlation between ultrasound guided IVC collapsibility index (IVC CI) and CVP for volume status in intensive care unit patients. Hundred spontaneously breathing patients receiving postoperative care in our surgical ICU between November 2019 to march 2021were enrolled into the study. Maximum IVC diameter (IVC_{dmax}) at end-expiration, minimum IVC diameter at end-inspiration (IVC_{dmin}) and IVC CI were measured. Simultaneous CVP recordings were obtained.

Results: A positive correlation was noted between IVC maximum diameter and CVP ($p = <0.001$) and between IVC Minimum Diameter and CVP. ($p = <0.001$) A negative correlation between IVC CI and CVP was seen ($p = <0.001$). Mean IVC CI was highest in the hypovolemic group. The area under the ROC curve (AUROC) for IVC CI predicting hypovolemia was 0.943 (95% CI: 0.9 - 0.986), thus demonstrating excellent diagnostic performance. At a cut off of ≥58.416%, IVC CI predicts hypovolemia with a sensitivity of 93.8%, and a specificity of 84%.

Conclusion: IVC CI can be used to guide fluid therapy due to its excellent diagnostic accuracy in predicting hypovolemia in postoperative patients in ICU.

Introduction

One of the most challenging aspects of managing patients in the intensive care unit (ICU) is the bedside assessment of intravascular volume status. Postoperative fluid management plays a vital role in postoperative outcome. Deficient postoperative fluid replenishment within the first for days postoperatively is significantly associated with adverse outcome. Systemic perfusion is affected by fluid management and this in turn influences the risk of organ failure and mortality [1]. Some studies suggest early goal directed therapy including aggressive fluid resuscitation targeted to central venous pressure (CVP) and physiological variables while others demonstrate that excessive fluid resuscitation and markedly positive net fluid balance is associated with higher rates of complications and increased mortality [2-3]. This highlights the importance of fluid balance in critically ill patients.

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Estimation of fluid balance is done using invasive hemodynamic monitoring, either static parameters (central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP) and right ventricular end-diastolic volume) or dynamic parameters (stroke volume variability (SVV), pulse pressure (PPV), changes in aortic flow velocity, and the diameter of inferior vena cava (IVC) or superior vena cava SVC) [3].

CVP is one of the most extensively used hemodynamic parameters. it is influenced by factors like posture, venous return, right ventricular compliance and peripheral venous tone. But CVP cannot be relied upon in conditions like ventricular failure, pulmonary vascular disease, right ventricular disease, patients with tense ascites, and valvular heart disease [4-5].

Measurement of IVC diameter using bedside ultrasound (USG) is a potentially useful non-invasive adjunct for estimation of intravascular status and fluid responsiveness [6-8]. It can be used to measure the IVC collapsibility to approximate the right atrial pressure in spontaneously breathing patients. Previous studies included patients in sepsis, shock and preoperative patients. This study is probably the first one to assess these parameters of patients in the postoperative period.

The aim of the study was to assess the correlation between ultrasound guided IVC CI and CVP for volume status in post-operative intensive care unit (ICU) patients.

Methods

This cross sectional study was conducted between November 2019 and march 2021 after registration with clinical trial registry of India (CTRI/2020/06/026185) and approval from the institutional ethical committee. All spontaneously breathing patients of both gender, above the age of 18 years, having a central venous catheter (CVC) terminating in distal superior vena cava (SVC), with a BMI 18-30 kg.m-2 were included in the study. Patients with normal preoperative 2D echocardiography findings were selected.

Patients who were being mechanically ventilated, had raised intra-abdominal pressure, dilated bowel loops, sepsis, BMI >30 kg.m-2 hemodynamic instability, tricuspid regurgitation, raised right atrial pressure (RAP) or pulmonary artery pressure (PAP) or those who were unable to lie supine were excluded from the study.

The Sample size was calculated based on a previous study of Abid Ilyas, et al observed strong negative correlation between CVP and IVC collapsibility index (r= -0.827) and strong positive correlation between CVP and maximum IVC diameter (r = 0.371) and minimum IVC diameter (r = 0.572). Taking this value as reference, the minimum required sample size with 95% power of study and 5% level of significance is 89 patients. To reduce margin of error, total sample size taken was 100 [9].

Written Informed consent was obtained from all the patients, and they were assured that the identity of the respondents would be kept anonymous.

All USGs were performed by the same experienced anaesthesiologist who possessed more than 5 years' experience in vascular sonography. Before collection of USG data, study ultra-sonographer was blinded to CVP monitoring. Bedside ultrasound images were got in a systematic manner with the patient supine to calculate the dimensions and collapsibility of the IVC. SonoSite M turbo ultrasound machine (Sonosite Inc, Bothell W, USA) with curvilinear probe (1-5 MHz) was used. Transducer was placed in subxiphoid region in longitudinal plane. IVC diameter was measured 3-4 cm caudal to junction of IVC and right atrium. M-mode was used to take 10-s cine loop of the IVC over two or three respiratory cycles. The maximum IVC diameter (IVCdmax) was noted as the maximum anterior-posterior distance at end-expiration using the leading-edge technique (inner edge to inner edge of the vessel wall). In addition, the minimum IVC diameter was noted at end-inspiration (IVCdmin).

The IVC collapsibility index is the difference between the maximum and minimum IVC widths divided by the maximum IVC width, presented as a percentage (Figure 1).

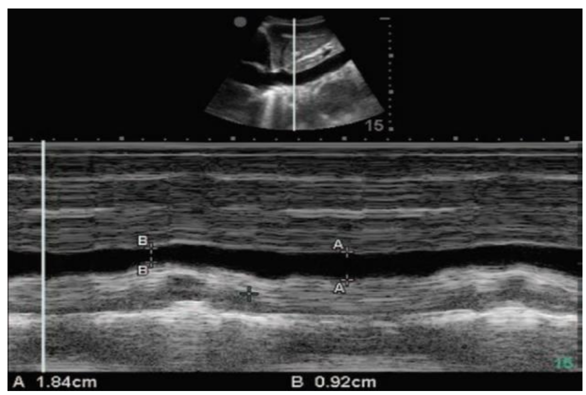

Figure 1- Measurement of IVC CI in 2D and M mode

Measurement "A" is the IVCdmax, "B" is the IVCdmin

Immediately after the ultrasound image acquisition, study personnel obtained a simultaneous recording of the CVP waveform. The CVP was noted at end expiration from the distal lumen of the CVP catheter with the patient supine and the pressure transducer zeroed at the mid-thoracic position.

A patient with CVP of less than 8 cmH2O was counted as hypovolemic. The patients with CVP between 8 to 12 cmH2O were noted euvolemic and patients having CVP more than 12 cmH2O were considered hypervolemic. Patients were then categorised into two groups on the basis of presence or absence of hypovolemia. The primary objective was to assess intravascular volume status in terms of ultrasound guided collapsibility index and central venous pressure.

In statistical analysis Categorical variables were presented in number and percentage (%) and continuous variables was presented as mean ± SD and median. Normality of data was tested by Kolmogorov-Smirnov test. If the normality was rejected, then non parametric test was used. Quantitative variables were compared using ANOVA/Kruskal Wallis Test/Shapiro-Wilk Test (when the data sets were not normally distributed) between hypovolemia, euvolemia and hypervolemia. Pearson correlation coefficient / Spearman rank correlation coefficient (for non-parametric data) was used to correlate quantitative variables with each other. A p value of <0.05 was considered statistically significant. Statistical analysis was done using statistical package for social sciences (SPSS) version 21.0.

Results

100 patients receiving care in intensive care unit were enrolled into the study. Demographic data and distribution of IVC parameters and CVP is shown in (Table 1).

Table 1- Demographic details

Demographic data	**Mean ± SD || Median (IQR) || Min-Max || Frequency (%)**		
Age (Years)	43.26 ± 11.64 || 42.00 (33.00-53.00) || 25.00 - 72.00		
Age			
21-30 Years	11 (11.0%)		
31-40 Years	36 (36.0%)		
41-50 Years	24 (24.0%)		
51-60 Years	20 (20.0%)		
61-70 Years	8 (8.0%)		
71-80 Years	1 (1.0%)		
Gender			
Male	51 (51.0%)		
Female	49 (49.0%)		
Height (m)	1.63 ± 0.10 || 1.64 (1.54-1.71) || 1.45 - 1.78		
Weight (Kg)	61.03 ± 7.08 || 61.50 (55.00-66.25) || 50.00 - 75.00		
BMI (Kg/m2)	23.16 ± 2.54 || 23.14 (21.43-24.24) || 18.51 - 29.49		
BMI			
18.5-22.9 Kg/m2	45 (45.0%)		
23.0-24.9 Kg/m2	38 (38.0%)		
25.0-29.9 Kg/m2	17 (17.0%)		
DIAGNOSIS	Frequency	Percentage (%)	95% CI
Open nephrectomy	8	8.0%	3.8% - 15.6%
Ca Urinary Bladder	8	8.0%	3.8% - 15.6%
Open Abdominal hysterectomy	17	17.0%	10.5% - 26.1%
Laparoscopic hysterectomy	8	8.0%	3.8% - 15.6%
Post Lap Nephrectomy	7	7.0%	3.1% - 14.4%
Post modified radical mastectomy (MRM)	8	8.0%	3.8% - 15.6%
Post Pyeloplasty	8	8.0%	3.8% - 15.6%
Post Radical Nephrectomy	17	17.0%	10.5% - 26.1%
Post THR	1	1.0%	0.1% - 6.2%
Post TKR	1	1.0%	0.1% - 6.2%
Post Op Strangulated Hernia	17	17.0%	10.5% - 26.1%
IVC parameters and CVP distribution			
	Mean (SD)	Median (IQR)	Range
IVC dmax (cm)	1.30 (0.24)	1.28 (1.12-1.45)	0.84 - 1.85
IVC dmin (cm)	0.75 (0.32)	0.72 (0.48-1.01)	0.24 - 1.55
IVC CI (%)	43.73 (18.38)	42.16 (29.97-60.2)	8.2 - 77.12
CVP	10.73 (3.56)	10 (8-13)	5 - 20

There was a significant difference between the 2 groups of hypovolemia versus no hypovolemia in terms of IVCdmin and IVC CI ($p < 0.001$), with the mean IVC CI being highest in the hypovolemic group (Table 2).

Table 2- Comparison of the 2 subgroups of hypovolemia or no hypovolemia in terms of IVCdmax diameter, IVCdmin diameter and IVC Collapsibility Index

Parameter	**Hypovolemia**		**P value**
	Yes	**No**	
	Mean (SD)		
IVC dmax (cm)	1.17 (0.17)	1.32 (0.24)	0.007
IVC dmin (cm)	0.38 (0.07)	0.82 (0.30)	<0.001
IVC CI (%)	67.37 (6.44)	39.23 (16.35)	<0.001

IVC dmax: IVC maximum diameter; IVC dmin: IVC minimum diameter; IVC CI: IVC collapsibility index

The observed mean IVCdmax 1.30 ± 0.24 cm, while the mean IVCdmin was 0.75 ± 0.32 cm. The mean IVC CI was 43.73 ± 18.38 %. The mean CVP was 10.73 ± 3.56 cmH2O. Participants with CVP <8 cmH2O was 16.0% while 56.0% patients had CVP 8-12 cmH2O and 28.0% had CVP >12 cmH2O. A positive correlation was observed between IVCdmax and CVP($p<0.001$) as well as between IVCdmin and CVP ($p = <0.001$) (Figure 2-3).

In contrast to this, there was a strongly negative correlation between IVC CI and CVP, and this correlation was statistically significant ($p = <0.001$). (Figure 4)

ROC curve showing a comparison of the diagnostic ability of IVCdmax, IVCdmin and IVC CI is shown in (Figure 5).

Of these, IVC CI was found to possess the best diagnostic accuracy for hypovolemia in terms of AUROC, sensitivity and specificity. Area under the ROC curve (AUROC) for IVC CI predicting hypovolemia vs no hypovolemia was 0.943 (95% CI: 0.9 - 0.986), thus demonstrating excellent diagnostic performance. ($p <0.001$). At a cut off of ≥58.416 %, IVC CI predicts hypovolemia with a sensitivity of 93.8%, and a specificity of 84% (Figure 6).

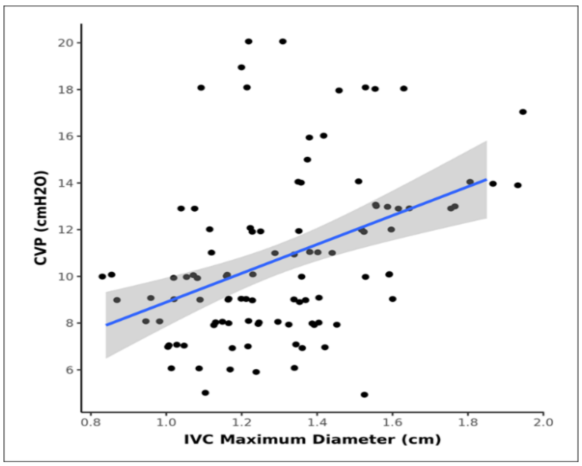

Figure 2- Correlation between IVC Maximum Diameter (cm) and CVP

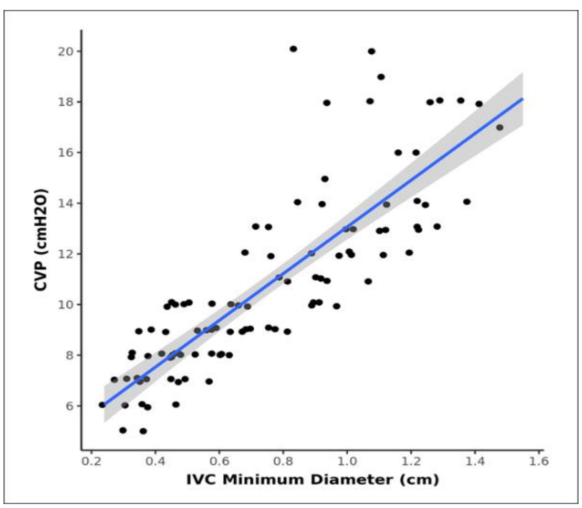

Figure 3- Correlation between IVC Minimum Diameter (cm) and CVP

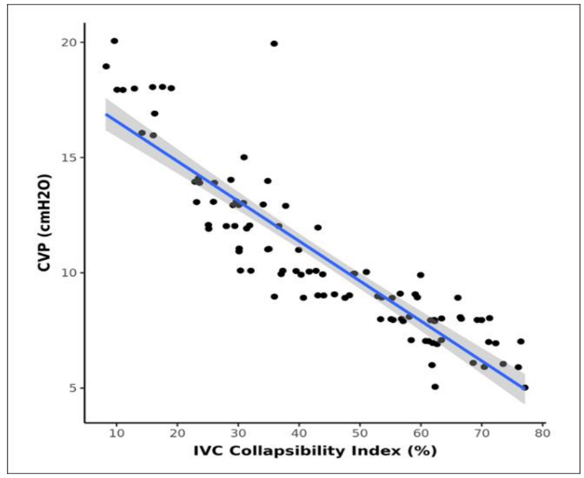

Figure 4- Correlation between IVC Collapsibility Index and CVP

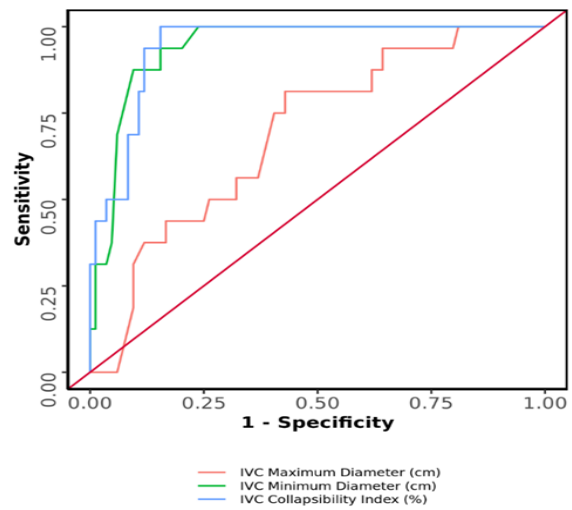

Figure 5: ROC Curve Analysis Showing Diagnostic Performance of IVCdmax, IVCdmin and IVC CI

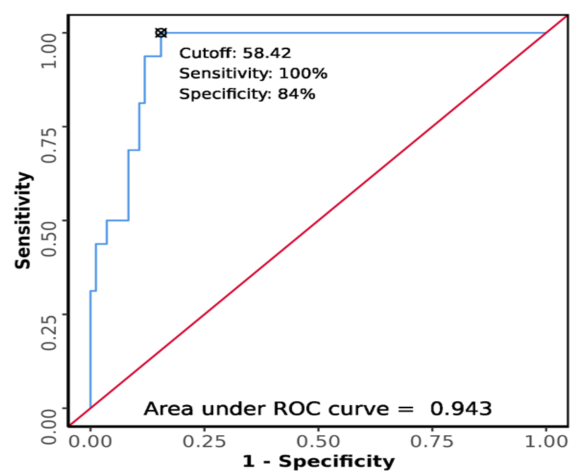

Figure 6- ROC Curve Analysis showing IVC CI cut off for predicting Hypovolemia vs No Hypovolemia

Discussion

Perioperative hypotension is a common cause of morbidity and mortality. While it is closely managed intraoperatively, it may easily be missed in the postoperative period. Postoperative fluid deficit within the first four days postoperatively is significantly associated with adverse outcome [1]. This can be prevented by accurate identification of hypovolemia. Assessment of intravascular volume status can take into account both static and dynamic parameters. Static pressure measurements like CVP and PCWP have little utility to assess volume status or fluid responsiveness. There is a need for accurate diagnostic tests to support or refute clinical assessments. Newer dynamic measurements hold great promise for accurately determining fluid status. There exists ample research on the correlation of IVC parameters with CVP [10] and their accuracy for prediction of fluid responsiveness in spontaneously breathing or mechanically ventilated, patients with medical illness or undergoing spinal of general anaesthesia. But no studies, to the best of our knowledge, have assessed the same in postoperative patients. Our study has thus been conducted in post surgical spontaneously breathing ICU patients.

Our study reveals a positive correlation of IVC maximum and minimum diameters with CVP and a consistent strong negative correlation of IVC CI with CVP in ICU patients which is similar to previous studies [9].

A statistically significant negative correlation was found between IVC CI and CVP ($p <0.001$). Similar to this, Thanakitcharu P et al, observed that, of their 70 critically ill patients, 64.3% of which were mechanically ventilated, the IVC CI was $45.69 \pm 16.16\%$ in the 15 % hypovolemic patients while it was $31.23 \pm 16.77\%$, and $17.82 \pm 12.36\%$ in the euvolemic (32.9%) and hypervolemic patients (51.4%). The strongest correlation was thus obtained between IVC CI and CVP ($p < 0.001$) which is similar to that observed in our study [11].

Another study by Ilyas A et al too, found a negative correlation between CVP and IVC CI ($p < 0.0005$); and a positive correlation between CVP and IVC maximum diameter ($p < 0.05$) and IVC minimum diameter ($p < 0.05$) [9].

Stawicki PS et al also derived statistically significant correlation between CVP and IVC CI. They found significant decrease in mean CVP with increase in IVC CI when the patients were divided into 3 groups based on IVC CI range (<0.20, 0.20 to 0.60, and >0.60) ($p<0.023$). Less than 5% of patients with IVC-CI <0.20 had CVP >7 mmHg, more than 40% had a CVP >12 mmHg and >60% of patients with IVC-CI >0.6 had CVP <7 mmHg [12].

We observed that at a cut off value of ≥58.416, the IVC CI predicts hypovolemia with a sensitivity of 93.8%, and a specificity of 84%. Several studies in the past have demonstrated variable cut off values of IVC CI in different patient populations.

Nagi and colleagues assessed 58 spontaneously breathing patients in sepsis for IVC CI value that predicts fluid responsiveness. They concluded that IVC CI of 32% and above was highly predictive of fluid responsiveness with a sensitivity and specificity of 72.41 % and 82.76 % respectively [13].

In the study by Szabo M et al, the ROC curve analysis for IVC CI to predict hypovolemia after induction of anesthesia showed an AUC of 64.8% (95% CI 52.1–77.5%). They selected a cut-off of 50% of the IVC CI which had a sensitivity of only 45.5%, but the specificity was high at 90.0% [14].

Airapetian and colleagues, evaluated IVC respiratory variability to preduct fluid responsiveness in 59 spontaneously breathing patients. They revealed that IVC size and respiratory variability do not predict fluid responsiveness. But IVC CI of > 42 % accurately predicts response to fluid administration [15].

This variability in values of IVC CI is possible due to variable patient populations involved in these studies, small sample size, or lack of inter or intra observer variability. The cutoff obtained in our study is similar to the 50 % cut off stated in the guidelines laid down by Rudski et al. [16]. Limitations of our study include that it had a small sample size and that we were unable to include postoperative patients in whom surgical dressings hindered the IVC sonography.

Conclusion

We conclude that Inferior vena cava collapsibility index (IVC CI) can be used to guide fluid therapy due to its excellent diagnostic accuracy in predicting hypovolemia in postoperative patients in intensive care unit.

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