Original Article

Ultrasound Derived Inferior Vena Cava Diameter and Collapsibility Index to Predict Central Venous Pressure Prior and After A Fluid Challenge in Spontaneous Breathing Preoperative Patients

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ABSTRACT

Background: Central venous pressure (CVP) is indicator of preload and used to determine intravascular volume status. An invasive method such as central venous catheter placement is required in order to measure CVP. However, it is associated with many complications. Instead, sonographic measurement of inferior vena cava (IVC) represents effective and non-invasive method of estimating CVP and recommendations are provided by the American Society of Echocardiography (ASE). There are various methods to calculate and estimate CVP using ultrasound. One of the ultrasonographic (US) technique for obtaining the JVP from a high-resolution B-mode sonogram sequences (US-JVP), recording the changes in IJV-CSA (cross section area) over the cardiac cycle (CC) has been proposed which appears to have potential as an approach for estimating CVP.

Patients and Methods: It is a prospective double blinded observational study conducted at tertiary hospital among 40 consenting patients.

Results: We found that 27 patients (67.5%) had correct prediction of CVP by USG with measured CVP after transducing central venous catheter at baseline (supine position). Similarly, 19 patients (47.5%) had correct prediction of CVP with measured CVP after passive leg raising. We found that 14 patients (35%) had 10% rise in mean arterial pressure on passive leg raising. We denoted these patients as Responders. We found that both responders and non-responders had poor correlation with CVP prediction. Also IVC diameters and collapsibility index did not predict the fluid responsiveness of the patients. Spearman correlation coefficient was used to study correlation between two quantitative variables. In our study, we found a strong positive correlation between predicted CVP (determined by USG parameters) and measured CVP (determined by transducing central venous catheter on monitor) at baseline (supine position) and after passive leg raising. Multivariate regression analysis was done to find the significant predictor of CVP which was found to be IVC maximum diameter (*p value 0.01*) determined by USG.

Conclusion: Bedside USG in preoperative patients can be used as a simple and reliable method to calculate IVC diameters and collapsibility index to predict CVP. It requires minimal training and correlates well with real time transduced CVP. In our study of 40 patients we aimed to study the ability of the ultrasound guided measurements of the Inferior Vena Cava in predicting the Central Venous Pressure (CVP). A strong positive correlation was found between the predicted CVP and measured/transduced CVP in supine position 8 (baseline) and after passive leg raising. On multivariate regression analysis, the IVC maximum diameter determined by USG was found to be the significant predictor of CVP. No significant correlation was noted between IVC parameters, Collapsibility index and CVP values to predict fluid responsive nature of the patients.

Key Words: Central venous pressure (CVP), collapsibility index (CI), inferior vena cava (IVC) diameters, passive leg raising (PLR).

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INTRODUCTION

Central venous pressure (CVP) is indicator of preload and used to determine intravascular volume status. An invasive method such as central venous catheter placement is required in order to measure CVP. However, it is associated with many complications. Instead, sonographic measurement of inferior vena cava (IVC) represents effective and non-invasive method of estimating CVP[1,2] and recommendations are provided by the American Society of Echocardiography (ASE). There are various methods to calculate and estimate CVP using ultrasound. One of the ultrasonographic (US) technique for obtaining the JVP from a high-resolution B-mode sonogram sequences (US-JVP), recording the changes in IJV-CSA (cross section area) over the cardiac cycle (CC) has been proposed which appears to have potential as an approach for estimating CVP.

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Aims And Objectives:

The primary objective is: Estimation of Central venous pressure using Inferior vena cava diameter and collapsibility index. To study the extent of correlation between inferior vena cava diameter and collapsibility index and invasive central venous pressure.

The secondary objective is: To study the effect of volume bolus by passive leg raising on the IVC measurements and the CVP.

PATIENTS AND METHODS

It is a prospective double blinded observational study conducted at tertiary hospital among 40 consenting patients.

Study Area: Operation theatre, Fortis Hospital, Mulund.

Study Population: Adult patients of either sex or age above 18 years.

Study Duration: 6 months after approval by ethics committee.

Study Design: It is a prospective double blinded observational study.

Inclusion Criteria:

1. Informed written consent for the study.

2. Patients above 18 years of age.

3. Patients in whom a central venous catheter was inserted in subclavian vein or internal jugular vein as part of the monitoring, pharmacological support or surgical requirement.

Exclusion Criteria:

1. Patients below 18 years of age.

2. Pregnant patients.

3. Patients with Intra-abdominal tumours.

4. Patients with left ventricular ejection fraction <40%, severe tricuspid regurgitation, mitral and aortic stenosis, pulmonary hypertension.

5. Patients with pericardial effusion and pleural effusion.

6. Patients having chronic obstructive pulmonary disease.

7. Contraindications of passive leg raising (pain/ fracture).

Sample size justification:

According to the previous study on the relationship between inferior vena cava diameter measured by bedside ultrasonography and central venous pressure value by Serenat *et al*., SPSS 18.0 package program was used for statistical analysis of data. Correlations between continuous measurements were analyzed by Spearman Correlation Coefficient. Statistical significance level for all tests was taken as $p<0.05$. Forty five patients were included in that study.

$Z\ 1\text{-}\alpha /2^2\ SD^2/d^2$

Where,

Z= value at a specified level of confidence [95%] is 1.96

SD= Standard deviation taken from a pilot study conducted by Serenat *et al*., where expiratory

diameter of IVC (SD=9) in patients with spontaneous breathing

d= absolute precision = 0.03

For this study we had to take at least 36 subjects after getting ethical consideration.

But we included 40 patients in our study.

Sample Size: 40 patients

Patients who gave informed written consent were enrolled in our study after the approval of ethics committee. The patients fulfilling the inclusion criteria were recruited in the study. A data collection form was made in order to gather standard data from patients including age, sex, disease diagnosis, IVC diameter values and collapsibility index before and after central venous catheter placement and after passive leg raising test, heart rate, blood pressure, MAP and saturation (SPO2) level. A central venous catheter was secured under all aseptic precautions and transduced by first anaesthetist. The measured (transduced) CVP and hemodynamic parameters were recorded by first anaesthetist after ensuring proper levelling and zeroing of the transducer. The second anaesthetist (senior anaesthetist with more than 5 years of experience with USG) performing ultrasonography was blinded to the measured (transduced) CVP reading by means of a screen. The IVC measurements were taken in supine position at baseline and after 30 seconds of passive leg raising. Collapsibility index was calculated from the IVC diameter measurements using the formula IVC (maximum diameter) – IVC (minimum diameter)/ IVC (maximum diameter) and expressed as percentage. The respective real time measured (transduced)

CVP and the IVC based predicted CVP values were noted. The inferior vena cava diameter was measured with Philips phased array ultrasound transducer cardiac probe from the Subcostal view. Probe was placed in sub xiphoid region and heart localized with cranial angulation of the probe. Then the point where hepatic veins empties into the inferior vena cava was found by sliding the probe and reducing the angulation. On the basis of several studies, the American Society of Echocardiography (ASE) in 2005[3] recommended using maximal IVC diameter 1 to 2 cm from the junction of the right atrium and IVC (1 cm proximal to hepatic veins) at end expiration obtained from subcostal view with IVC viewed in long axis. M mode was applied at this point and maximum and minimum diameters were measured in each respiratory cycle. During central venous pressure measurement, level of the right atrium (Mid Axillary Line) in the supine position was taken as reference (zero) level and monitored by transducer on monitor. The results of CVP were detected in mmHg.

Our modified chart for predicting CVP

IVC max diameter (cm)	IVC collapsibility index (%)	Predicted CVP (mmHg)
<1.5 cm	>50	0-2
<1.5 cm	<50	2-5
1.5-2.1 cm	>50	6-9
1.5-2.1 cm	<50	10-14
>2.1 cm	>50	15-18
>2.1 cm	<50	>19

Statistical Analysis:

After data collection, data entry was done in Microsoft excel and data analysis was done using SPSS software. Data was analysed and statistically evaluated using SPSS-PC-25 version. Quantitative data was expressed in mean ± standard deviation and depends on normality distribution difference between two comparable groups which were tested by Student's (unpaired) t test or Mann Whitney 'U' test while for pre-post comparison Paired t test or Wilcoxon signed rank test was used. Qualitative data were expressed in percentage and statistical differences between the proportions were tested by Chi square test or Fisher's exact test. Spearman correlation coefficient was used to see the correlation between two quantitative variables. Multivariate linear regression model was used to see the significant predictor for CVP. *P value* less than 0.05 was considered statistically significant in our study.

RESULTS

Table 1: Age wise distribution of patients

Age group	No.	Percentage
41-50 years	2	5.0
51-60 years	9	22.5
61-70 years	25	62.5
71-80 years	4	10.0

Table 2: Gender wise distribution of patients

Gender	No.	Percentage
Male	35	87.5
Female	5	12.5

Table 3: Diagnosis in patients

Diagnosis	No.	Percentage
Coronary artery disease	34	85.0
Brain tumour	2	5.0
Cancer lung	1	2.5
Cancer rectum	2	5.0
Thymoma metastasis	1	2.5

Table 4: Surgery done in patients

Surgery	No.	Percentage
CABG	34	85.0
Craniotomy	2	5.0
Lap anterior resection	2	5.0
Thoracotomy	2	5.0

Table 5: Correlation of predicted CVP (based on IVC measurements by USG) with measured CVP (obtained invasively) at baseline

Well Correlated	No.	Percentage
Yes	27	67.5
No (less than predicted range)	6	15.0
No (more than predicted range)	7	17.5

Table 6: Correlation of predicted CVP (based on IVC measurements by USG) with Measured CVP (obtained invasively) Post passive leg raising

Well Correlated	No.	Percentage
Yes	19	47.5
No (less than predicted range)	6	15.0
No (more than predicted range)	15	37.5

Table 7: CVP at baseline and after passive leg raise

Cvp	At Baseline	After Passive Leg Raise
0-2	2(5.0%)	0
2-5	15(37.5%)	6(15.0%)
6-9	14(35.0%)	19(47.5%)
10-14	9(22.5%)	12(30.0%)
>14	0	3(7.5%)

Table 8: Post passive leg raise MAP finding in patients

10% rise in mean arterial pressure	No.	Percentage
Yes (Responder)	14	35.0
No (Non Responder)	26	65.0

9. Effect of PLR (passive leg raising) on different parameters:

• In our study, a statistically significant relationship was found between average IVC maximum diameter (1.38 ± 0.37) with PLR (1.56 ± 0.35). *P value* was significant (*<0.001*). There was a statistically significant increase in IVC maximum diameter and PLR.

• Also statistically significant relationship was found between average IVC minimum diameter (1.02 ± 0.35) with PLR (1.23 ± 0.37). *P value* was significant (*<0.001*)

• The collapsibility index was reduced as compared to baseline value on PLR due to fluid bolus. So a statistically significant relationship was found between collapsibility index with PLR (*p value < 0.01*).

• Measured CVP, Predicted CVP, Mean arterial pressure (MAP), heart rate all these variables had statistically significant relationship with PLR. *P value* was found to be significant.

10. Association of Change in MAP with correct prediction of CVP:

• At Baseline-Out of the 27 patients in whom the Predicted CVP matched with measured CVP, 19 (73.1%) were Non responders and 8 (57.1%) were Responders.

• The predictability of the CVP by USG protocol had no relationship with the patients response to a fluid bolus by PLR. Both the Responders and Non responders had poor correlation with the CVP predictability. The p value was not significant.

11. Comparison of IVC max in Responders compared to non-responders:

• The data was expressed as mean ± standard deviation. There was no significant relationship between inferior vena cava (IVC) maximum diameter and PLR in Responders and Non responders at baseline.

• So IVC maximum diameter was not sensitive in predicting the fluid responsiveness of the patients.

12. Comparison of IVC min in Responders compared to non-responders:

• There was no significant relationship of inferior vena cava (IVC) minimum diameter and PLR in Responders and Non responders at baseline.

• So IVC minimum diameter was not sensitive in predicting the fluid responsiveness of the patients.

• Here we conclude that there was no relationship between the IVC parameters (maximum and minimum diameters) and the fluid responsiveness of patients.

13. Comparison of collapsibility index in Responders compared to non-responders:

• Collapsibility index was calculated from IVC diameters using the formula IVC (maximum diameter) – IVC (minimum diameter)/ IVC (maximum diameter) and expressed as percentage. There was no significant relationship of collapsibility index in Responders and Non responders at baseline and PLR.

• In our study, the collapsibility index is not sensitive in predicting the fluid responsive nature of the patients.

14. Comparison of Measured CVP in Responders compared to non-responders:

• The data was expressed as mean ± standard deviation. Measured CVP was noted after central venous catheter insertion after proper levelling and zeroing of transducer.

• There was no significant relationship of measured CVP in Responders and Non responders at baseline and PLR.

• In our study, the measured CVP is not sensitive in predicting the fluid responsive nature of the patients.

15. Correlation of IVC max, IVC min and CI (collapsibility index) with measured CVP at baseline:

At baseline, measured CVP had strong positive correlation with IVC max (*r value = 0.83; p value <0.001*) and predicted CVP (*r value = 0.88; p value <0.001*) while moderate positive correlation was seen with IVC min (*r value = 0.58; p value <0.001*). No correlation was observed between measured CVP and CI (*r value = 0.01; p value =0.92*)

16. Correlation of IVC max, IVC min and CI (collapsibility index) with measured CVP post passive leg raise:

After PLR, measured CVP had very strong positive correlation with predicted CVP (**r value =0.85; p value <0.001**) while strong positive correlation was seen with IVC max (*r value = 0.79; p value <0.001*) and IVC min (*r value = 0.68; p value <0.001*). No correlation was observed between measured CVP and CI.

17. Multivariate linear regression analysis for prediction of CVP:

After doing multivariate analysis, IVC maximum diameter was found to be significant predictor of CVP (*p value = 0.01*).

DISCUSSION

CVP should be monitored in cases of shock, circulatory failure, massive infusion or transfusion requirement, situations with massive bleeding risk, situations where careful fluid resuscitation is a must such as in paediatric patients or patients with cardiac problems.[5] CVP is a value indicating right atrial pressure or right ventricular filling pressure. It is an indicator of intravascular fluid status and right heart function. There are many factors affecting the value of CVP such as cardiac performance, blood volume, vascular tone, increased intra-abdominal or intrathoracic pressure and vasopressor therapy.[6] An invasive method such as central venous catheter placement is required to measure CVP. Central venous catheter placement, an invasive procedure, has a risk for early and late complications.[7,8] The inferior vena cava (IVC) is a compliant vessel whose size and shape vary with changes in CVP and intravascular volume.[9] Therefore, sonographic measurement of the IVC represents an effective and non-invasive method of estimating CVP.[1,2] However, several factors may affect IVC size.

We conducted this study on 40 consenting individuals above 18 years of age to determine USG derived IVC diameters and collapsibility index to predict CVP at baseline and after passive leg raising in spontaneously breathing pre-operative patients. A central venous catheter insertion was planned in them during the preoperative evaluation. Conditions that affect CVP reading like increase in intra-abdominal and intra-thoracic pressures were excluded from our study. Our study evaluated the ultrasonographic (USG) measurement of Inferior Vena Cava (IVC) diameter and collapsibility index to predict CVP and to study the effect of passive leg raising on IVC diameters and CVP. IVC diameters were calculated in supine position at baseline and after 30 seconds of passive leg raise using M mode on USG. CVP was predicted by applying a simple formula and compared with the real time transduced CVP on monitor.

In our study, we found that 27 patients (67.5%) had correct prediction of CVP by USG with measured CVP after transducing central venous catheter at baseline (supine position). Similarly, 19 patients (47.5%) had correct prediction of CVP with measured CVP after passive leg raising. We also studied the effect of passive leg raising on mean arterial pressures. We found that 14 patients (35%) had 10% rise in mean arterial pressure on passive leg raising. We denoted these patients as Responders. We found that both responders and non-responders had poor correlation with CVP predicted by USG and measured CVP. Also IVC parameters (maximum and minimum diameters) and collapsibility index did not predict the fluid responsiveness of the patients. However, on passive leg raising we found a significant increase in average IVC maximum and minimum diameters from baseline values and a significant decrease in collapsibility index values.

Spearman correlation coefficient was used to study correlation between two quantitative variables. In our study, we found a strong positive correlation between predicted CVP (determined by USG parameters) and measured CVP (determined by transducing central venous catheter on monitor) at baseline (supine position) and after passive leg raising. Multivariate regression analysis was done to find the significant predictor of CVP which was found to be IVC maximum diameter (*p value 0.01*) determined by USG. Our study is unique as we included spontaneous breathing preoperative patients planned for elective surgery. Most of the studies in literature have been conducted on mechanically ventilated patients and patients admitted with emergency and critical conditions.

In 1979, Natori *et al*.[10] first described measuring IVC diameter and its change during respiration. Under normal physiologic conditions, IVC diameter decreases and venous return increases during inspiration due to negative intrathoracic pressure and positive intra-abdominal pressure. This study suggest that the inferior vena caval configuration with ultrasonography is a valuable non-invasive clinical aid for estimating central venous pressure and for analysing inferior vena caval hemodynamics in various clinical conditions. Also patient positioning may also affect IVC diameters. In our study, all patients demonstrated similar phasic changes in size with spontaneous breathing ruling out significant cardiac and respiratory conditions which could have impacted the readings.

Serenat *et al*.[4] found a statistical significant relationship between average IVC diameters measured by ultrasonography at the end of inspiration and expiration with average CVP in spontaneous breathing patients. However no such statistical significant relationship was found in mechanically ventilated patients. They included patients admitted in emergency department with emergency conditions. The patients had the diagnosis of malignancy (35.6%), sepsis (13.3%), pneumonia, asthma, chronic obstructive pulmonary disease (11.1%). 11 patients (24.4%) required mechanical ventilation while 34 (75.6%) patients had spontaneous respiration. They found that IVC measurements can guide intravascular volume status in emergency patients non-invasively.

Rudski LG *et al*.[11] estimated right atrial pressure on the basis of IVC diameter and collapse. IVC diameter $\leq$ 2.1 cm that collapses >50% with a sniff suggests a normal RA pressure of 3 mm Hg (range 0-5 mm Hg), whereas an IVC diameter > 2.1 cm that collapses <50% with a sniff suggests a high RA pressure of 15 mm Hg (range 10-20 mm Hg). In indeterminate cases in which the IVC diameter and collapse do not fit this paradigm, an intermediate value of 8mm Hg (range 5-10 mm Hg) may be used. In our study we measured the IVC diameters in spontaneous breathing patients and aimed to measure more narrow absolute values rather than wide range of predicted values.

Mintz *et al*.[12] studied the real time IVC ultrasonography and its use in assessing right heart function. He stated that there is a reciprocal relationship between pressure and flow, when flow increases, pressure decreases. Thus, during inspiration vena cava pressure decreases and flow increases. This study showed that the alterations in size and pulsation and timing of IVC events are determined by alterations in right-heart dynamics.

Weerapan W *et al*.[13] studied the correlation between IVC diameter and central venous pressure in critically ill patients. The correlation between CVP and IVC diameter measured by a 2-dimensional, long-axis sub xiphoid view at the end-expiratory phase with bedside ultrasonography were evaluated. This study indicated that the measurement of the IVC diameter has a good correlation with CVP in Thai population and useful for assessment of the volume status. We found a similar strong correlation between measured CVP and IVC diameter based predicted CVP in our chosen patient population.

Moreno *et al*.[14] evaluated the size and dynamics of inferior vena cava as an index of right sided cardiac function. 2D and M mode echocardiography was performed in subjects to calculate IVC diameters and collapsibility index. This study concluded that subcostal orthogonal 2D echo of IVC is useful to determine size and collapsibility index and aids in identifying patients with right sided cardiac disease. In his study however, the IVC diameters were poorly correlated with RAP while collapsibility index did correlate with measured RAP. Similarly, Kircher BJ *et al*.[1] found a strong relationship between collapsibility index and the measured RAP. This is in contrast to our study where collapsibility index correlated poorly with measured CVP. It may be noted that unlike in our study, the IVC measurements and transduced CVP measurements were not performed simultaneously but at a variable interval extending upto 24 hours in both the aforementioned studies.

S Capomolla *et al*.[15] investigated whether a combination of IVC variables measured by Doppler echocardiography could provide a reliable non-invasive estimate of right atrial pressure in patients with congestive heart failure. IVC maximum and minimum diameters were calculated and its collapsibility index and systolic fraction of forward IVC flow were measured and correlated with single and multilinear regression analysis. This study found that in patients with congestive heart failure indices derived from Doppler measurements of IVC can be used to produce an accurate, strong and non-invasive estimate of right atrial pressure.

Ciozda *et al*.[16] supported the use of sonographic measurements of IVC diameter to estimate CVP or RAP (right atrial pressure) in spontaneously breathing patients. Positive correlations were consistently reported between IVC size and CVP and negative correlations were consistently reported between IVC collapsibility index and CVP in this study. Our study shows a very strong correlation of the IVC maximum diameter and a strong relationship of IVC minimum diameter with the measured CVP. Similarly, Ilyas A *et al*.[17] in their study of the relationship between IVC diameters and collapsibility index with CVP in assessment of intravascular volume in critically ill patients found a strong positive correlation between CVP and maximum and minimum IVC diameter. Simonson JS *et al*.[18] in their study in spontaneously breathing healthy volunteers measured the CVP simultaneously as in our study. Similar to our study, the authors noted a good association with the IVC minimum diameter and the measured CVP.

Brennan JM *et al*.[19] in their study found that the original traditional classification which divided the IVC measurements into three groups of High ,low and intermediate was inadequate and proposed that more narrow ranges be used to measure CVP. Their scale was based on the IVC diameter above and below 2.1 cm and collapsibility index less or more than 35% and 55%. Even then there was a group where the IVC was less than 2.1 cm and collapsibility index was less than 35% where the CVP was deemed indeterminate. In our study we proposed a more elaborate scale in an attempt to provide more narrow ranges for the CVP estimations. More number of cases in diverse clinical situations will be needed to further ratify the applicability of the proposed scale.

We also attempted to study the usefulness of the IVC parameters with regards to all important requirement of predicting volume responsiveness. As discussed below, multiple studies have studied their relationship in critical and emergency patients but not in preoperative patients.

Das aditi *et al*.[20] studied the effectiveness of CVP and IVC collapsibility index in predicting fluid responsiveness in paediatric patients with shock. She found that most of the enrolled patients were fluid responders (66%). Fluid responder group had lower mean CVP value and higher mean IVC collapsibility index value than those of in fluid non-responder group. There was significant inverse correlation between CVP and IVC collapsibility index in both responders and non-responders. She concluded that IVC collapsibility index has better sensitivity but poor specificity to predict fluid responsiveness. In contrast, in our study, we found that IVC collapsibility index was not sensitive in predicting the fluid responsive nature of the patients.

Garg M *et al*.[21] studied the efficacy of ultrasonographically measured IVC collapsibility index in comparison to CVP in predicting fluid responsiveness in septic shock patients. She found that with fluid infusion, a negative correlation was observed between CVP and IVC collapsibility index. CVP and IVC collapsibility index are negatively correlated with fluid resuscitation and both methods can be used for resuscitation, with IVC collapsibility index being non-inferior to CVP in patients of septic shock on ventilation. In our study in spontaneous breathing preoperative patients, we observed that on fluid loading by PLR, the IVC maximum and minimum diameters were significantly increased reflecting the effect of fluid loading on the IVC. Similarly, IVC collapsibility reduced demonstrating the beneficial effect on the hemodynamic system.

Placid siroraj *et al*.[22] studied the correlation of ultrasound guided measurement of inferior vena cava diameter to central venous pressure to assess the volume status of intensive care unit patients. This study found that the inferior vena cava collapsibility index can be used as a non-invasive alternative to the CVP measurement, which has been the gold standard to assess the volume status in ICU patients. It is less time consuming and also eliminates the complications associated with central venous catheter insertion. In our small study, we were unable to show any predictive value of the IVC measurements and indices in predicting the fluid responsiveness while using a 10% MAP rise to define a fluid responder.

Stone MB *et al*.[23] studied the IVC assessment correlation with CVP and plethora in tamponade. Despite controversy in the existing evidence, many clinicians advocate the use of inferior vena cava ultrasound in the assessment of intravascular volume status in critically ill patients. Respirophasic variation in IVC diameter may provide useful information regarding intravascular volume status, particularly in patients with high and low caval indices. In our study we had very few patients with collapsibility index over 50% (3 patients in our study) and severely hypovolemic patients were not encountered.

Common static measures of intravascular volume include CVP and pulmonary capillary wedge pressure. Despite the widespread use of CVP, multiple studies have demonstrated that both CVP and pulmonary capillary wedge pressure are unreliable markers of intravascular volume in critically ill patients and consistently fail to identify fluid responders.[24,25] In contrast, dynamic measures of intravascular volume are far more accurate predictors of intravascular volume and fluid responsiveness and are dependent on changes in intrathoracic pressure during the respiratory cycle. These include pulse pressure variation (PPV), stroke volume variation (SVV), vena cava collapsibility/distensibility indices and bio impedance/bio reactance technology. In our study, we used >10% rise in mean arterial pressure after PLR as an indicator to determine fluid responsiveness and may not have been sensitive enough to pick up all the instances of a significant increase in stroke volume.

Patel C *et al*.[26] studied the usefulness of sonographic measurements of IVC diameters during resuscitation of patients with trauma. He found that the IVC diameter was smaller in those patients with hypotension on presentation as compared to those with normotension. Patients with >50% collapsibility of IVC required aggressive resuscitation as compared to those with <50% collapsibility. This study showed that the measurement of IVC diameter can be used as a reliable tool to guide resuscitation in trauma patients and can help to predict significant hypovolemia, in patients having normal blood pressure.

Thanakitcharu P *et al*.[27] studied inferior vena cava diameter and collapsibility index (IVC-CI) to evaluate the intravascular volume status of critically-ill patients. Evaluation of intravascular volume status was performed by bedside ultrasonography to measure the IVC diameters (IVCD), both end-inspiratory (Iivcd) and end-expiratory (Eivcd). The authors concluded that the IVC-CI can provide a useful guide for non-invasive intravascular volume status assessment of critically-ill patients.

Mohammed MA *et al*.[28] studied the Correlation of inferior vena cava diameter and collapsibility index with central venous pressure in shocked patients and made a similar assessment of the usefulness of the collapsibility index in predicting volume responsiveness. However, in our study, the collapsibility index is not sensitive in predicting the fluid responsive nature of the patients.

Murthi SB *et al*.[29] studied the Ultrasound assessment of volume responsiveness in critically ill surgical patients receiving a bolus of crystalloid, colloid or blood. A positive volume response (+VR) was defined as a ≥15% increase in stroke volume (SV). This study concluded that in a clinically relevant heterogeneous population, Ultrasound is moderately predictive of volume response. Inferior vena cava diameter change is not predictive while IJ change and VTI are the best measures, especially when used together. In our study, we found the same that IVC diameters were not sensitive in predicting fluid responsiveness of the patient.

Orso D *et al*.[30] studied the accuracy of Ultrasonographic Measurements of Inferior Vena Cava to determine Fluid Responsiveness. The aim of this study was to systematically review all the previously published studies assessing the accuracy of the diameter of IVC or its respiratory variations measured through ultrasound in predicting fluid responsiveness in critically ill ventilated or not, adult or paediatric patients. They included 26 studies that investigated the role of caval index (IVC collapsibility or distensibility) and 5 studies on IVC diameter. An extreme heterogeneity of included studies was highlighted. Ultrasound evaluation of the diameter of the IVC and its respiratory variations does not seem to be a reliable method to predict fluid responsiveness. We are in agreement of the findings and agree that there is no relationship between IVC diameters and fluid responsiveness of the patient.

Airapetian N *et al*.[31] studied the inferior vena cava respiratory variability to predict fluid responsiveness in spontaneously breathing patients. Echocardiography and Doppler ultrasound were used to record the aortic velocity-time integral (VTI), stroke volume (SV), cardiac output (CO) and IVC collapsibility index (Civc) ((maximum diameter (IVCmax) –minimum diameter (IVCmin))/ IVCmax) at baseline, after a passive leg-raising manoeuvre (PLR) and after 500 ml of saline infusion. This study concluded that the IVCmax was not predictive of fluid responsiveness. In contrast, it was found that Civc > 42 % may predict an increase in CO after fluid infusion in spontaneously breathing patients in the ICU. In our study we found all IVC measurements and indices poorly correlating with the prediction of fluid responsiveness. However, in comparison to other studies where a fluid bolus has been administered, a PLR may be said to be a more non-invasive and reversible protocol for simulating a fluid bolus.

Douglas *et al*.[32] proposed the 2019 ACC/AHA/ASE Key Data Elements and Definitions for Transthoracic Echocardiography. It determined the IVC diameter with sniff and IVC collapse with sniff or sharp inhalation. In this guideline, the sniff test was recommended to help estimate right atrial pressure as normal (0-3)(<2.1 and >50% collapse), intermediate (4-10)(not fitting in other two groups) and high (10-20)(>2.1 and <50% collapse). But the perioperative phase is different, so more data is required and more studies need to be done for standard guidelines. Also standardizing an inspiratory sniff is difficult and may be difficult in a sick tachypnoeic patient.

We are in agreement with Millington SJ[33] who in his critical appraisal predicted that the IVC measurements will gain wide popularity due to its easy application and may well evolve as the modern day central venous pressure. However its application for predicting fluid responsiveness may not be possible for the vast majority of the cases. More studies would be needed to see if a combination of IVC measurements with other cardiac measurements like Right atrial size and hepatic inflow studies can help provide a reliable and practical alternative.

CONCLUSION

Bedside USG in preoperative patients can be used as a simple and reliable method to calculate IVC diameters and collapsibility index to predict CVP. It requires minimal training and correlates well with real time transduced CVP. In our study of 40 patients we aimed to study the ability of the ultrasound guided measurements of the Inferior Vena Cava in predicting the Central Venous Pressure (CVP). A strong positive correlation was found between the predicted CVP and measured/transduced CVP in supine position (baseline) and after passive leg raising. On multivariate regression analysis, the IVC maximum diameter determined by USG was found to be the significant predictor of CVP. No significant correlation was noted between IVC parameters, Collapsibility index and CVP values to predict fluid responsive nature of the patients.

ABBREVIATIONS

IVC - Inferior vena cava

CVP - Central venous pressure

CI - Collapsibility index

cIVC - IVC collapsibility index

PLR - Passive leg raising

USG - Ultrasonography

RAP - Right atrial pressure

PAP - Pulmonary artery pressure

Diam - Diameter

ASE - American society of echocardiography

cIVC - Respiratory variations of IVC

MAP - Mean arterial pressure

PPV (ΔPP) - Pulse pressure variation

SV - Stroke volume

SVV - Stroke volume variation

CO - Cardiac output

Iivcd - IVC diameter at end of inspiration

Eivcd - IVC diameter at end of expiration

VTI - Velocity time integral

TR velocity - Tricuspid regurgitation velocity

IJ - Internal jugular vein

Avg - average

P value - Level of significance

TTE - Transthoracic echocardiography

PASP - Pulmonary artery systolic pressure

CONFLICT OF INTEREST

There are no conflicts of interest.

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