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Abstract

Purpose: To assess the correlation between inferior vena cava echocardiographic indices and central venous pressure, right atrial pressure and thus to practice, assessment of inferior vena cava, as a guide for the status of right side of the heart.

Materials and Methods: In this descriptive cross-sectional study, a total of (60) patients (males and females) with their age ranging between (18–80) years were admitted to the respiratory care unit. Echocardiographic assessment of inferior vena cava hemodynamics (IVC expiratory, IVC inspiratory diameters and IVC collapsibility index) were carried out. In addition to the standard echocardiography examination, right heart function measurements (Tricuspid Annular Plane Systolic Excursion and right atrial area), in spontaneously and mechanically ventilated, patients were done.

Findings: Both IVCe and IVCi diameters showed strong negative correlation with collapsibility index, (r= -0.920 for IVCe and r= -0.964 for IVCi) (P<0.001). There was a positive correlation between TAPSE and IVC-CI (r=0.857, P<0.001). Moreover, RA area was negatively correlated with collapsibility index (r = -0.892, P <0.001). IVC-CI in mechanically ventilated patients (40.11± 1.782) compared to spontaneous breathing (48.91± 1.811) (P <0.001)

Implications to Theory, Practice and Policy: There was a linear relationship of IVC collapsibility index with TAPSE but an inverse relation with RA area. Evaluation of IVC diameter and its collapsibility index was an easy and non-invasive method to estimate CVP and RAP and so evaluate right heart performance of critically ill patients. Its use is more helpful in patients who are spontaneously breathing than those who are mechanically ventilated. The study tried to find an estimate predictor of right atrial pressure.

Keywords: *Right Atrial Pressure, Inferior Vena Cava*

INTRODUCTION

Right ventricular size and function play a crucial role in evaluating patients with pulmonary hypertension, cardiomyopathies, pulmonary embolism, right ventricular infarction, pulmonary, acute respiratory distress syndrome and tricuspid valvular heart disease and intracardiac shunts, therefore right ventricular dysfunction is major element in the hemodynamic compromise that intensivists encounter in these clinical scenarios [1]. In recent years, right ventricular function in left heart disease has received more and more attention. Right ventricular dysfunction strongly influences functional state and survival [2].

Assessment of right heart dimensions and functional parameters can play an important role in diagnosis, prognostication, and monitoring of therapeutic response, across a variety of pathologies. Echocardiography remains the first-line imaging modality for right heart assessment. There is a growing evidence base to guide right heart quantification, and more robust normal values are being developed, including those for emerging techniques such as RV diastolic function assessment, strain and three-dimensional echocardiography [3].

Right Atrial Pressure (RAP) is a haemodynamic variable that provides important diagnostic and prognostic information in both cardiovascular and pulmonary disease patients [4]. RAP is a composite metric of right heart function and reflects RV diastolic function, right atrial compliance, and volume status and it is a well-established prognostic metric, and it is routinely used to guide clinical decision-making in patients with pulmonary arterial hypertension and other acquired forms of heart failure [5,6].

The Central Venous Pressure (CVP) is the intravascular pressure in the great thoracic veins. It is conventionally measured at the junction of the superior vena cava and the right atrium and provides an estimate of the Right Atrial Pressure (RAP). Measurement of central venous pressure is a critical component of the complete hemodynamic assessment of a patient. CVP is considered a good approximation and equivalent to right atrial pressure which in turn is a major determinant to right ventricular filling. High CVP is known to be associated with volume overload states while low CVP is associated with volume depleted states. Therefore, CVP is a good indicator of right ventricular preload [7,8].

The Inferior Vena Cava (IVC) is a compliant vessel whose size and shape vary with changes in CVP and intravascular volume. Therefore, sonographic measurement of the IVC represents an effective and noninvasive method of estimating CVP [9]. However, several factors may affect IVC size. Under normal physiologic conditions, IVC diameter decreases and venous return increases during inspiration due to negative intrathoracic pressure and positive intra-abdominal pressure. IVC diameter also decreases during ventricular systole. Additionally, patient position may affect IVC diameter, as the diameter is smallest when the patient is in the left lateral position and largest when the patient is in the right lateral position. Awareness of these variables is critical to the accurate collection and interpretation of sonographic IVC measurements [9].

Al though RAP is a composite metric of right heart function, the use of invasive measures carries high risk of procedure complications. Therefore, the noninvase cheap and reproducible echocardiographic assessment will be more helpful.

MATERIALS AND METHODS

This descriptive cross-sectional study was carried out in the respiratory care unit (RCU), Medical City Complex, Baghdad, Iraq. A total of (60) patients (males and females) with their age ranging between (18–80) years were admitted to the respiratory care unit. The study was conducted during the period from January to May 2022.

Patients with moderate to severe tricuspid regurgitation, atrial fibrillation, severe decompensated heart failure, raised abdominal pressure, pregnancy, morbid obesity, patients unable to lie in supine position, and those whose ultrasound was not possible due to wound dressings, were excluded from our study.

Age, sex, body weight and height, detailed medical history, primary illness, vital signs (like blood pressure, heart rate, respiratory rate), complete clinical examination and standard 12 lead electrocardiogram (ECG) were recorded. A data form was used to collect the relevant information pertaining to the study variables.

All the echocardiographic examinations were performed by the same physician throughout the study using a Vivid Machine. IVC measurements were evaluated from the supine position, using the subcostal view and the IVC was imaged in a longitudinal plane. The intrahepatic segment of the IVC was visualized as it entered the right atrium. The IVC diameter was measured 2 cm caudal to the hepatic vein-IVC junction, or approximately 3–4 cm from the junction of the IVC and right atrium. minimum and maximum diameters of IVC were calculated in every respiratory phase. Assessment of the following IVC parameters were carried out; IVCmax, maximum IVC diameter at end-expiration (IVCe), maximum IVC diameter at end-inspiration (IVCi), and IVC collapsibility index (IVCCI) (expressed in percentage). Right atrial pressure was estimated based on IVC measurements.

1. Tricuspid annular plane systolic excursion (TASPE) and Right atrium area.
2. Standard echocardiographic evaluation was performed

The study enrolled Critical care patient because they expected to have high risk of right sided heart dysfunction
The IVC diameter and CI were customized and measured in critically ill patients as mentioned in previous reports

The study was approved by the Ethics Committee of the College of Medicine, Baghdad University and informed consent was taken from patients.

Statistical Analysis

The data were analyzed by SPSS (Statistical Package for the Social Sciences) version 17.0 (SPSS Inc., IBM, Chicago, Illinois, USA). Two types of statistics were done: descriptive statistics (e.g., percentage, mean, and SD) and analytic statistics, which included the following tests: Paired 2 test, and analysis of variance test. Pearson correlation coefficient was used to assess the correlation. A P value less than 0.05 was considered to be significant

FINDINGS

Of the 60 patients, 35 (58.3%) had normal IVC expiratory diameter (IVCe less than 21 mm) and 25 (41.7 %) had abnormal IVC expiratory diameter (IVCe more than 21 mm). Moreover, 25 patients (41.3 %) had normal collapsibility index (IVC-CI more than 50%) and 35 (58.3 %) had abnormal collapsibility index (IVC-CI less than 50%).

Of the 60 patients 32 (53 %) had normal TASPE (more than 17 mm) and 28 (47 %) had abnormal TAPSE (less than 17 mm). Moreover, 30 patients (50 %) had normal RA area (less than 20 cm^2) and 30 (50 %) had abnormal RA area (more than 20 cm^2).

Table 1: Inferior Vena Cava Diameters and their Correlation with the Collapsibility Index in the Studied Patients

Parameter	Mean±SD (mm)	Range (mm)	r	P
IVC Expiratory Diameter	19.72± 3.05	14-26	-0.920	<0.001*
IVC Inspiratory Diameter	10.9± 3.81	6-20	-0.964	<0.001*

The mean±SD collapsibility index was 44.95±10.76, which ranged from 23% to 62%, whereas the mean±SD IVC expiratory diameter and inspiratory diameter were 19.72±3.05 and 10.9±3.81, respectively (Table 1), and both diameters showed strong negative correlation with collapsibility index, (r= -0.920 for IVCe and r= -0.964 for IVCi) (P value less than 0.001) (Figure 1).

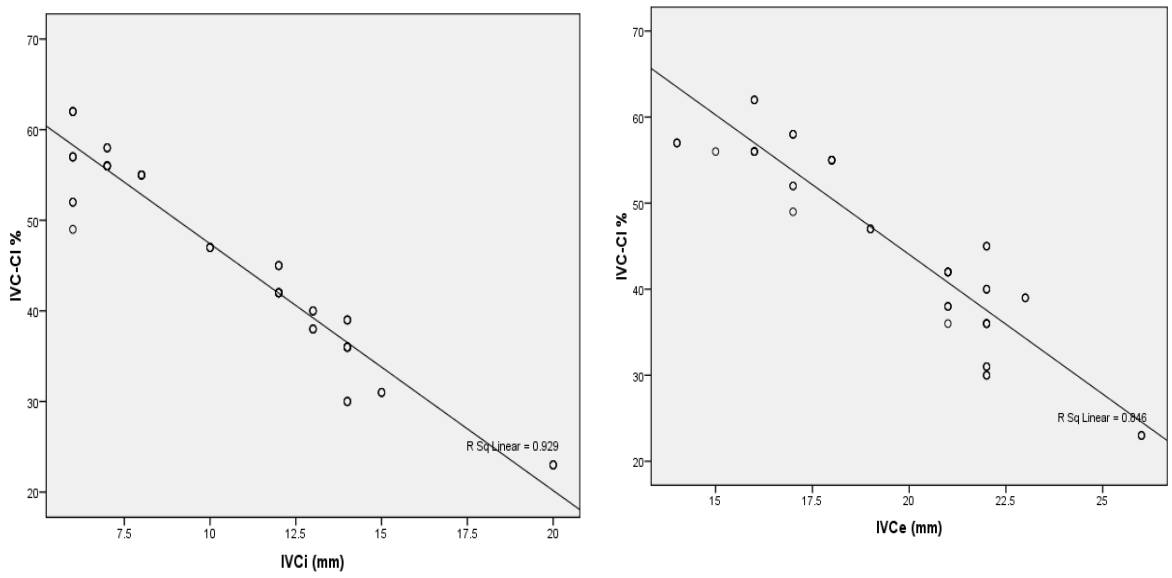

Figure 1: IVC, Inferior Vena Cava

A Strong Negative Correlation was Revealed between Collapsibility Index (IVC-CI) and IVC Expiratory Diameter (R = -0.920, P <0.001) and IVC Inspiratory Diameter (R = -0.964, P <0.001*)*

The mean ± SD TAPSE was 16.47± 1.47 which ranged from 14 mm to 19 mm, whereas the mean±SD of RA area was 20.1±4.48 (ranged 14 to 28). Both TAPSE and RA area showed a statistically significant strong correlation with collapsibility index. There was positive correlation between TAPSE and IVC-CI (r = 0.857, P value less than 0.001). Moreover, RA area was negatively correlated with collapsibility index (r = -0.892, P value less than 0.001) (Figure 2).

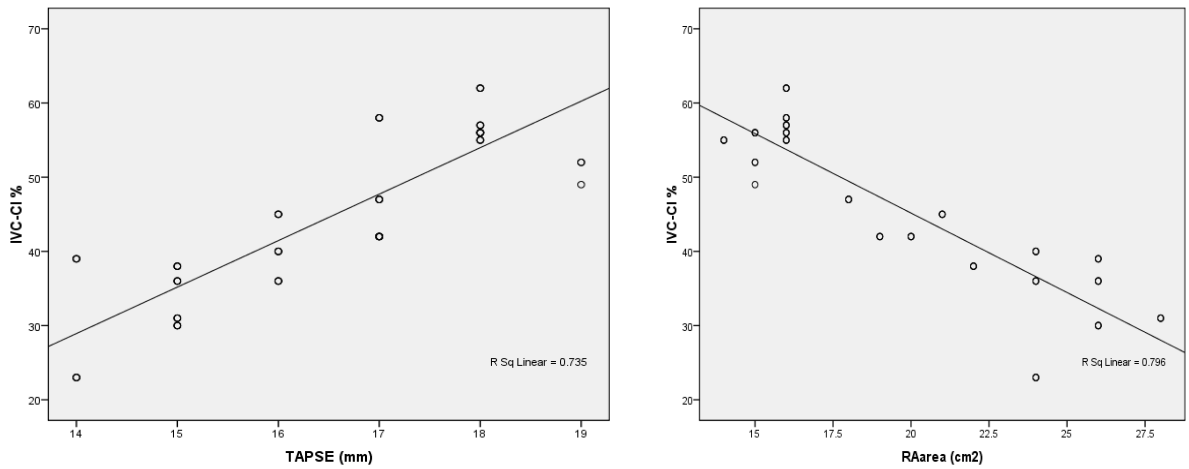

Figure 2: Correlations between Inferior Vena Cava Collapsibility Index (IVC-CI) and Right Heart Performance Echocardiographic Measures (TAPSE and Right Atrial Area).

Strong Positive Correlation between TAPSE and IVC-CI (R = 0.857, P <0.001) was Observed Whereas Strong Negative Correlation was Found between RA Area and IVC-CI (R = -0.892, P <0.001).

No significant difference was found in the TAPSE of patients on mechanical ventilation (16.22±0.222) compared to spontaneous ventilation (16.70±0.311) (P> 0.05). There was statistically significant difference in the mean IVC-CI in mechanically ventilated patients (40.11± 1.782) compared to spontaneous breathing (48.91± 1.811) (P< 0.001) (figure 3).

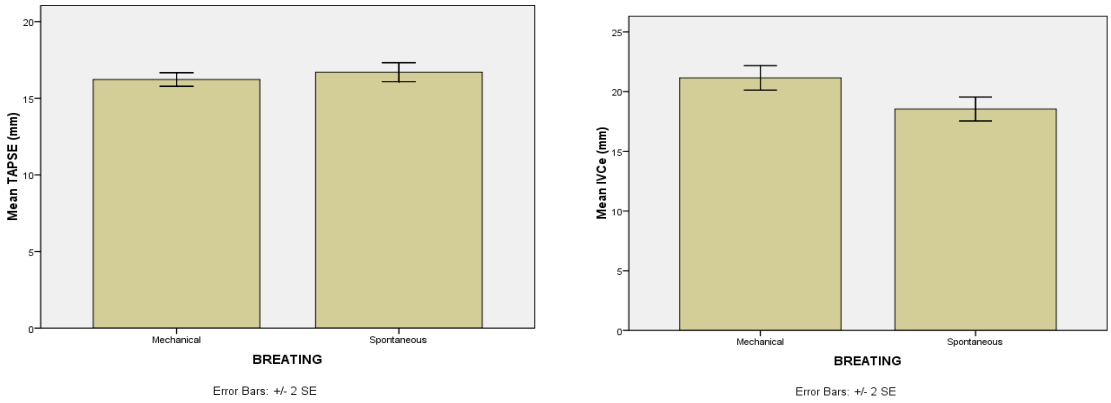

Figure 3: Shows the TASPE (Mm) and IVC-CI (%) in Study Patients according to Breathing Modality (Mechanical Versus Spontaneous Breathing).

No Significant Difference was Found in the TAPSE Whereas IVC-CI Was Significantly Different. AS These Echocardiographic Indices are Good Indicators of Right-Side Heart in Critically Ill Patients

Conclusion

Echocardiographic measurement of the IVC at the point of care provides insight into hemodynamics in a rapid and noninvasive manner and can impact clinical decision making. The role of IVC-Echocardiography in the determination of right heart performance focused on correlating IVC diameter (size) with measured CVP. More recent works, however, have demonstrated more correlations of IVC diameter with CVP [7].

Although the specific threshold values for IVC size, IVCCI, CVP, and RAP varied slightly across studies, the diagnostic accuracy of IVC measurements parameters was generally high. Several studies support the use of sonographic measurements of IVC diameter to estimate CVP or RAP in spontaneously ventilating patients. Positive correlations were consistently reported between IVC size and CVP or RAP, and negative correlations were consistently reported between IVCCI and CVP or RAP. Although the correlations were generally only moderately strong, the diagnostic performance justifies the current guideline recommendations for estimation of right-sided filling pressure [10].

The correlations between IVC dimension and CVP in mechanically ventilated patients were generally weak and inconsistently observed. Furthermore, the use and magnitude of Positive end-expiratory pressure (PEEP) varied greatly across studies of mechanically ventilated patients. Positive pressure ventilation leads to increased intrathoracic pressure, decreased systemic venous return, and increased volume of venous blood in the IVC. The dimension and distensibility of the IVC is consequently affected. Therefore, the use of IVC measurements to estimate RAP in mechanically ventilated patients is usually unreliable. A study by Jue et al, despite only a modest correlation between RAP and IVC dimension, these authors did find that

an IVC diameter of 1.2 cm or less had 100 % specificity for a right atrial pressure less than 10mmHg, albeit with poor sensitivity (25 %) [11]. Therefore, a small IVC in the setting of mechanical ventilation may still point toward the absence of elevated RAP. In addition, the correlation of IVCe and RAP may still be valid in the absence of PEEP [12].

Nagdev et al. [13] reported that CI >50% was strongly associated with a CVP <8 mm Hg. Kircher et al, [14] came to a similar conclusion, reporting that CI >50% was indicative of right atrial (RA) pressures <10 mm Hg, whereas CI <50% indicated RA pressures >10 mm Hg. IVCe has previously been recommended as the preferred IVC parameter by which CVP or RAP are estimated. The strength of the correlations between CVP and IVCe, IVCi, and IVC max were similar. This is reflected in the most recent guidelines by the ASE, which do not specify an optimal phase of the respiratory cycle during which the maximal IVC diameter is measured. eRAP ivc is obtained by examining the dimension and respiratory collapsibility of IVC. In clinical practice, eRAP fundamental in the diagnostic workup of PAH and elevated eRAP is associated with worse prognosis in heart failure (HF) and pulmonary hypertension (PAH) [5].

In the present study, it is seen that echocardiographic evaluation of IVC diameter (IVC expiratory diameter and inspiratory diameter) is inversely correlated with the collapsibility index. These results validate the outcomes of a study carried by Abdelwahab et al., who concluded that echocardiographic evaluation of IVC is more helpful in patients who were breathing spontaneously [14].

In this study, we showed that the assessment of IVC hemodynamics by echocardiography (size and collapsibility) is reproducible, correlates with the right heart function, can predict the estimated RAP and CVP and reflects disease severity.

Both TAPSE and RA area are correlated with inferior vena cava collapsibility index. We observed a strong linear correlation between TAPSE and IVC-CI and strong inverse relationship between RA area and IVC-CI. More importantly, we showed that the assessment of IVC size and collapsibility, which is part of routine echocardiographic assessment, provided a good estimate of RAP and so right heart performance. These results were also in agreement with Azzam et al., who studied the relationship of IVC diameters and CVP and proved that IVC-CI is sensitive and safe alternative to CVP for assessing fluid status and right heart performance in acutely ill patients. Similarly, Wiryana et al. determined a strong correlation between IVC-CI and CVP [15]. Shalaby et al., found noteworthy correlation amongst CVP and IVCe and IVC-CI. They also determined that this relationship is most favorable in calculating CVP <10 cm H2O in ICU patients [16,17].

The results of the current study revealed a decrease, but still significant, in TAPSE of mechanically ventilated patients. Furthermore, we observed that the assessment of IVC collapsibility is reduced in mechanically ventilated patients. This result was also in accordance with a study performed by Stawicki et al., who also observed the effect of PEEP on IVC-CI and noticed that as the patients without PEEP (i.e. on spontaneous breathing) had more collapsibility when matched with the patients with PEEP (i.e. on mechanical ventilation); and thus, perceived greater mean collapsibility index in non-intubated patients as compared with intubated patients [18].

we recommend large size multi-center study to prove validity and sensitivity of these echocardiographic indices in assessing right side heart function in critically ill patients

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