ORIGINAL RESEARCH

Correlation between Central Venous Pressure and Inferior Vena Cava Sonographic Diameter; Determining the Best Anatomic Location

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Abstract

Introduction: The correlation of central venous pressure (CVP) with inferior vena cava (IVC) sonographic diameter has been reported in several studies. However, few studies have attempted to find the best anatomic location of measurement. Therefore, the purpose of this study was determining the best anatomic location to find precise correlation between CVP and IVC diameter using transesophageal echocardiography (TEE). **Methods:** In the present diagnostic accuracy study, patients in need of central venous catheterization and TEE were enrolled. Maximum diameter of IVC were measured during expiratory phase of respiratory cycle at the level of diaphragm, 2cm above the diaphragm and at the point of entry into the right atrium using SonoSite TEE device. CVP was measured using an electronic transducer connected to the central venous line. The best location for sonography was determined via calculating and comparing area under the receiver operating characteristics (ROC) curve (AUC). **Results:** 39 patients were enrolled (53.8% female). Mean CVP was 6.8 ± 1.4 mmHg and 25 (64.1%) patients had normal CVP, while 14 (35.9%) showed elevated CVP (> 6 mmHg). Evaluating AUC showed that IVC diameter (p = 0.01), aorta diameter (p = 0.01) and IVC / aorta ratio (p = 0.004) had acceptable correlation with CVP. Point of entry of IVC into the right atrium with AUC of 0.98 (95% CI: 0.95 – 1.00) was the location of highest correlation with CVP. **Conclusion:** Based on the present findings, the IVC sonographic diameter and IVC / aorta ratio had acceptable correlation with CVP at the level of IVC entry into the right atrium.

Keywords: Central venous pressure; vena cava, inferior; aorta, thoracic; echocardiography, transesophageal

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Introduction:

Dehydration is the main cause of morbidity and mortality in critically ill patients and assessment of intravascular volume status (IVS) is essential for their management (1, 2). However, diagnosis of dehydration and intravascular volume loss is sometimes difficult (3). Some clinical signs and symptoms are assessed for determining IVS but they have low sensitivity and specificity (4). It could be determined by measuring peripheral blood pressure, but in many conditions, it does not reflect accurate intravascular volume status. Hypotension is detected in late stage of shock, especially when compensatory mechanisms fail (5). Central venous pressure (CVP) is one of the indices of IVS and early goals of goal-directed therapy approach (6, 7). A common and conventional procedure for measuring CVP is inserting a catheter in a central vein such as internal jugular, subclavian, and femoral veins. However, the major problem with this procedure is the probability of some dangerous and sometimes lethal complications such as arterial puncture, pneumothorax, hemothorax, misplacement in carotid artery, infection, and other rare complications such as cardiac tamponade etc. In addition, central venous catheter insertion is a time consuming and invasive procedure (8-12). Recently, researchers and physicians have attempted to measure CVP with non-invasive procedures such as ultrasonography, transthoracic echocardiography, and transesophageal echocardiography (TEE). They have reported a correlation between sonographic inferior vena cava (IVC) diameter and CVP (1, 9, 13-16). Donahue et al. found a direct correlation between internal jugular vein sonographic diameter and CVP (17). However, few studies have attempted to find the best anatomic location and cut points. Therefore, the purpose of this study was determining the best anatomic location to find precise correlation between CVP and IVC diameter using TEE.

Methods:

Study design and setting

In the present prospective cross-sectional study, the correlation of sonographic IVC diameter, aorta diameter, and IVC / aorta ratio with CVP were evaluated. Patients in need of catheterization and TEE who were referred to a teaching hospital in Tabriz, Iran, from 2013 to 2015 were enrolled. This study was approved by the Ethics Committee of Tabriz University of Medical Sciences. The patients or their relatives had signed the informed written consent form before initiation of the study and the researchers adhered to the principles of Helsinki declaration.

Participants:

Over the course of the study, all patients over 18 years old who needed central venous catheterization and TEE were included. Consecutive sampling was used and the patients' need for catheterization and TEE was determined by an independent cardiologist. Those who were prohibited from assuming a supine position (severe orthopnea, intracerebral pressure rising), patients who had moderate-to-severe tricuspid regurgitation, congestive heart failure, broncho-pulmonary dysplasia, body mass index > 30, and renal and liver diseases were excluded.

Measurements:

Central venous catheterization and TEE were done in the operating room. After central catheterization using Seldinger technique, CVP was measured using electronic transducer connected to the CV line inserted in the right internal jugular vein by central approach while the patient was placed in a 15-degree Trendelenburg position (18). IVC and aorta diameter were measured using TEE (SONOS 5500; Philips Medical Systems, Andover, MA) and a 3.5 MHz probe. All the ultrasonographies were done by a trained cardiology fellow who was blind to the patients' CVP. IVC and aorta diameter were measured at end-expiration and end-diastole in 2-dimensional long-axis mid-esophageal bicaval view. Measurements were done in the level of diaphragm, 2 centimeters above the diaphragm and at the point of entry into the right atrium and recorded in millimeter. All evaluations were done in the supine position.

Statistical analysis

Sample size was determined to be about 45 patients considering minimum correlation coefficient of IVC diameter and CVP to be 0.48 with 95% confidence interval (CI) ($\alpha = 0.05$) and 90% power ($\beta = 0.1$). Analyzes were done with SPSS 20. Spearman's rank correlation test was used to determine the relationship between sonographic IVC diameter and CVP. Best index (IVC diameter, aorta diameter, or IVC / aorta ratio) and best measurement location (the level of diaphragm, 2cm above the diaphragm and at the point of entry into the right atrium) were determined via calculating and comparing area under the receiver operating characteristics (ROC) curve (AUC). Normal CVP was considered 2-6 mmHg for this purpose (19). In all analyses, $p < 0.05$ was considered as significance level.

Table 1: Baseline characteristics of the patients

Variable	Mean (SD)	Median	Minimum	Maximum
Age (year)	62.1 (5.8)	61	54	83
Weight (kg)	69.5 (11.0)	68	53	94
Height (cm)	161.3 (7.3)	160	145	178
SBP (mmHg)	110 (9.6)	110	95	130
DBP (mmHg)	63.8 (6.9)	63	45	80
HR (beat/min)	71.3 (12.4)	73	45	90
CVP (mmHg)	6.8 (1.04)	7	4	9
IVC diameter (mm)				
Point of entry into the right atrium	23.2 (3.6)	22	18	31
2cm above the diaphragm	18.6 (2.6)	19	12	23
Level of diaphragm	17.1 (3.4)	17	10	25
Aorta diameter (mm)				
Point of entry into the right atrium	24.6 (2.1)	25	21	29
2cm above the diaphragm	22.4 (1.6)	23	19	27
Level of diaphragm	21.3 (1.6)	21	19	27
IVC/Aorta ratio				
Point of entry into the right atrium	0.94 (0.09)	0.96	0.78	1.12
2cm above the diaphragm	0.83 (0.13)	0.86	0.52	1.05
Level of diaphragm	0.81 (0.16)	0.81	0.48	1.09

SBP: systolic blood pressure, DBP: diastolic blood pressure, HR: heart rate, CVP: central venous pressure, IVC: inferior vena cava.

Table 2: Correlation of CVP with IVC and aorta diameters, and IVC/Aorta ratio

Index	R	95 % CI	P
IVC			
Point of entry into the right atrium	0.85	0.73-0.92	<0.001
2cm above the diaphragm	0.48	0.19-0.69	0.002
Level of diaphragm	0.68	0.47-0.82	<0.001
Aorta			
Point of IVC entry into the right atrium	0.68	0.45-0.81	<0.001
2cm above the diaphragm	0.44	0.15-0.66	0.005
Level of diaphragm	0.15	-0.17-0.44	0.37
IVC/Aorta ratio			
Point of IVC entry into the right atrium	0.69	0.48-0.83	0.001
2cm above the diaphragm	0.43	0.16-0.68	0.007
Level of diaphragm	0.53	0.26-0.72	0.001

IVC: Inferior vena cava; CI: Confidence interval.

Table 3: area under ROC curve of IVC and aorta diameters, and IVC/Aorta ratio in estimation of CVP

Index	AUC	95 % CI	P
IVC			
Point of entry into the right atrium	0.98	0.95-1.0	0.01
2cm above the diaphragm	0.78	0.62-0.93	
Level of diaphragm	0.81	0.66-0.96	
Aorta			
Point of IVC entry into the right atrium	0.89	0.79-0.98	0.01
2cm above the diaphragm	0.64	0.45-0.84	
Level of diaphragm	0.53	0.45-0.84	
IVC/Aorta ratio			
Point of IVC entry into the right atrium	0.96	0.92-1.0	0.004
2cm above the diaphragm	0.67	0.48-0.85	
Level of diaphragm	0.80	0.66-0.94	

IVC: Inferior vena cava; AUC: Area under curve; CI: Confidence interval.

Results:

Over the course of the study, 39 patients were included (53.8% male; mean age 62.1 ± 5.8 years). Baseline characteristics of the patients are summarized in table 1. Mean CVP was 6.8 ± 1.4 mmHg and 25 (64.1%) patients had normal CVP, while 14 (35.9%) showed elevated CVP (> 6 mmHg).

The relationship of CVP with IVC and aorta diameter

Table 2 shows the relationship of CVP with sonographic IVC diameter, aorta diameter, and IVC / aorta. As can be seen, CVP had a significant correlation with IVC diameter at the point of entry into the right atrium (r = 0.85; p < 0.001), 2cm above the diaphragm (r = 0.48; p = 0.002), and in the level of diaphragm (r = 0.85; p < 0.001). At the same time, aorta diameter showed a significant correlation with CVP at the point of entry into the right atrium (r = 0.68; p < 0.001) and 2cm above the diaphragm (r = 0.44; p = 0.005). IVC / aorta ratio also had a significant correlation with CVP at all 3 points.

Comparing diagnostic values of IVC and aorta diameter

Evaluation of area under the ROC curve showed that the best point for determining CVP was at the point of entry into the right atrium for IVC diameter (p = 0.01), aorta diameter (p = 0.01), and IVC / aorta ratio (p = 0.004) (figure 1A-C). Therefore, to identify the best index among the 3, their area under the ROC curve was compared at this point (table 3 and figure 1-D). Based on the findings, IVC diameter (AUC = 0.98; 95% CI: 0.95-1.0) and IVC / aorta ratio (AUC = 0.96; 95% CI: 0.92-1.0) had higher diagnostic values compared to aorta diameter (AUC = 0.89; 95% CI: 0.79-0.98) at this point (p = 0.01).

Discussion:

This study was conducted to find the precise anatomic location with the best correlation between CVP and IVC diameter, aorta diameter, or IVC/aorta ratio. Based on the present findings, the IVC diameters and IVC / aorta ratio had acceptable correlation with CVP. In addition, the point of IVC entry into the right atrium was the best anatomic location to estimate CVP. Ultrasound is a non-invasive, easy, available, and useful tool for assessment of volume status (20). Wiwatworapan et al. showed that when end-expiratory IVC diameter was lower than 10 mm, the CVP would be 10 cmH_2O, (sensitivity 77% and specificity 91%) and when end-expiratory IVC diameter was 15 mm, CVP would be 15 cmH_2O (sensitivity 90%

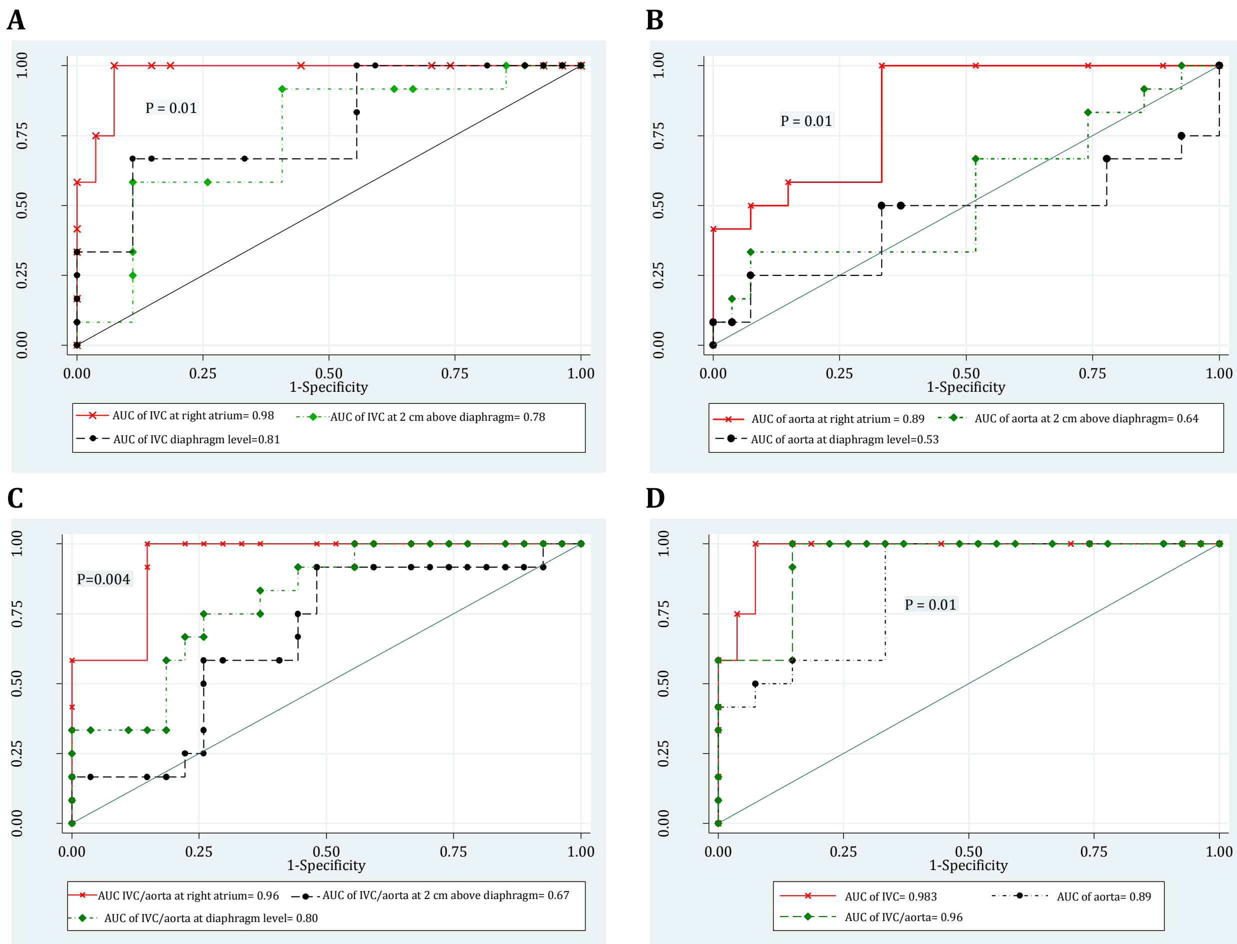

Figure 1: Comparison of area under the curve of inferior vena cava (IVC) diameter (A), aorta diameter (B), and IVC / aorta ratio (C) in different points in estimation of central venous pressure and comparison between the three indices (D).

and specificity 89%) (21). Baumann et al. measured CVP using ultrasound and concluded that although estimation of CVP by ultrasound is easy, but absolute values differ from invasive measurements of CVP and IVC indices alone can't be used to accurately estimate intravascular volume status (22). In line with our study, Arthur et al. reported a statistically significant correlation between IVC diameter and CVP (16). In addition, De Lorenzo et al. compared different anatomic locations such as subxiphoid, mid-abdomen and suprailiac to find best anatomic location for calculating the correlation between CVP and IVC diameter. They reported that suprailiac view had better correlation with CVP compared to other anatomic locations but measurement of CVP using ultrasound had low yield (23). Yet, some studies demonstrate that an increase or decrease in the collapsibility of IVC can be helpful in management of patients in poor condition. Based on the findings of those studies, the combination of absolute IVC diameter and collapsibility level, which is known as Caval index, is a better estimation of CVP compared to absolute IVC diameter and can be a good replacement for invasive tests (24-26). The mechanism of this method is based on the fact that the negative pressure generated while inhalation leads to an increase in venous return to heart and IVC collapse. While exhaling, venous return decreases and IVC diameter goes back to the basic state (25, 27, 28). In the present study, Caval index could not be assessed, as the ultrasonography film could not be recorded in the device used. Therefore, it is recommended to take this into account in future studies. Another limitation of this study was the little sample size, yet the minimum power calculated for this study was 85%; so it seems that little sample size has not affected the results of this study.

Conclusion:

Based on the present findings, the IVC sonographic diameter and IVC / aorta ratio had acceptable correlation with CVP at the level of IVC entry into the right atrium.

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