MJMR, Vol. 34, No. 1, 2023, pages (102-108).

Open Access
ISSN:2682-4558

Research Article

Ultrasound guided measurement of inferior vena cava diameter, common carotid artery diameter versus central venous pressure for estimation of intravascular volume status in critically ill patients.

Asmaa Samir Badry[1], Nagy Sayed Ali[1], Mostafa Mahmoud Ali[1]
[1] Department of Anesthesiology and Intensive care, Faculty of Medicine, Minia University, Minia, Egypt

DOI: 10.21608/mjmr.2023.178606.1228

Abstract

Background: Bedside assessment of intravascular volume status in critically ill patients is challenging. Fluid management impacts systemic perfusion and may influence the risk of organ failure and mortality. Central venous pressure (CVP) is a hemodynamic parameter that is extensively used. A non-invasive and economical technique like ultrasound in the ICU helps to approach diagnosis and treatment of the critically ill patients. The aim of this study is to know the effect of fluid administration on the diameters of IVC and Common carotid artery in prediction of volume status in critically ill patients. **Methods:** This prospective observational study was conducted in El-Minia University Hospital during the period from March 2021 to Augest 2022. We studied 55 patients their ages group ranged between 20 and 60 years, of both genders; males and females, who admitted to our surgical Intensive care unit (SICU) from the American Society of Anesthesiology (ASA) physical status II and III who were able to breathe spontaneously, lie supine and had central venous catheter (CVC) who required close monitoring and assessment of intravascular volume status. **Results**: In our study, there was a significant positive correlation between CVP, IVC diameters, and CCA, whereas negative correlation with IVC CI. Analysis of the receiver operating characteristic curve (ROC) showed a better diagnostic accuracy of IVC max diameter than IVC CI for predicting low CVP< 8 cmH2O. **Conclusion:** Ultrasound of the inferior vena cava and Common carotid artery may be used as a feasible non-invasive, rapid and simple adjuvant method to assess the intravascular volume and guide fluid responsiveness in critically ill intensive care unit patients.

Keywords: Central venous pressure, diameters IVC, Common carotid artery.

Introduction

Fluid management in the intensive care plays a vital role in the outcome of the patient. Hypovolemia with inappropriate use of vasopressors to maintain the blood pressure reduces the organ perfusion leading to ischemia. On the other hand fluid overload causes cellular swelling and congestion of lungs thereby increasing morbidity and mortality[1]. Central venous catheters have a wide variety of uses such as hemodynamic monitoring, drug administration, total parenteral nutrition, trans-venous pacemaker placement, pulmonary artery catheterization. The central venous pressure is a static measure of volume. The method has been followed widely to assess the volume status and thereby treating the patient accordingly. Insertion of central venous catheter is contraindicated in certain situation as any coagulation disorders, infection over the insertion site[2].

Recently the ultrasound, guided measurement of the IVC diameter and

Common carotid artery diameter can be used as an alternative to central venous catheterization to assess the volume status of patients. It is a dynamic measure of intravascular volume status[3]. The IVC adjusts to the body's volume status by changing its diameter depending on the total body fluid volume. The caval opening increases in size during inspiration, which encourages venous return of blood to the heart through the IVC due to the negative intrathoracic pressure. This results in the collapse of the IVC. During expiration the reverse happens, where due to the positive intra-thoracic pressure the pressure gradient decreases causing a distension of the IVC[4]. Bedside ultrasonography is readily available in intensive care setups. It is safe, cheap and non- invasive. Ultrasound of inferior vena cava (IVC) is a tool that can provide a rapid and non-invasive means of gauging preload and the need for fluid resuscitation[5]. Also studies reported that the diameter of the CCA respond to intravascular volume expansion with significant dilation.

Aim of the work

The aim of this study is to know the effect of fluid administration on the diameters of IVC and Common carotid artery in prediction of volume status in critically ill patients and to know the correlation between Inferior vena cava and Common carotid artery diameters Versus Central venous pressure.

Patients and Methods

This prospective observational study was conducted in El-Minia University Hospital during the period from March 2021 to August 2022 after obtaining approval of the university ethical committee (approval number.133:2021) and written informed consent from all Patients or first degree relatives. We studied 55 patients their ages group ranged between 20 and 60 years, of both genders; males and females, who admitted to our surgical Intensive care unit (SICU) from the American Society of Anesthesiology (ASA) physical status II and III who were able to breathe spontaneously, lie supine and had central venous catheter (CVC) who required close monitoring and assessment of intravascular volume status.

Results

A total of 29 patients were male (52%) and 26 were female (47.3%) with a mean age of 43.3±13.1 years. There was 40 patients ASA II and 15 patients was ASA III. The patients had been under follow up most commonly with the diagnosis of sepsis (33 patients, 60%), blood loss (22 patients, 40%). About 21.8% of patients received norepinephrine while 14.5% received norepinephrine plus epinephrine is summarized in table 1.

Changes in mean arterial blood pressure and heart rate are illustrated in table 2. The mean value of MAP was increased significantly at 30 min, 1hr, 2hrs, 3hrs, 6hrs, 12hrs, 24hrs, and 48hrs as compared to base line value but insignificant at 30min. The mean value of HR was decreased significantly at 30 min, 1hr, 2hrs, 3hrs, 6hrs, 12hrs, 24hrs, 48hrs as compared to base line value.

Changes in Ultrasound parameters and CVP are presented in table 3 The mean values of inferior vena cava maximum (IVC max) and Inferior vena cava minimum (IVC min) diameters were increased significantly at 1hr, 2hrs, 3hrs, 6hrs, 12hrs, 24hrs, 48hrs as compared to base line value except at 30min. The mean value of Inferior vena cava collapsibility index (IVC CI) was decreased significantly at 30 min, 2hrs, 6hrs, 12hrs, 24hrs, and 48hrs as compared to base line value. The baseline value of CCA was 2.9±0.4mm and this value increased significantly at **all times** till it reached to 5.1±0.7mm after fluid administration. Serial CVP monitored at all times showed a gradual significant increase from baseline value of 2±0.8 cm H_2O to 11.2±2.4 cm H_2O except at 30min.

Person's correlation was applied between CVP and U/S parameters. CVP showed positive correlation with IVC max, IVC min diameters and with CCA diameter, whereas a negative correlation to IVC CI as seen in table (4). CVP had a significant relation with U/S parameters as shown in table **5.**

Analysis of Roc curve shows a better diagnostic accuracy of IVC max diameter than IVC CI for predicting low CVP< 8 cmH2O with a cut-off value ≤ 1.38 cm, with a sensitivity 90.48% and specificity 91.82%, positive predictive value (PPV) 95.9%, negative predictive value (NPV) 82%, accuracy 90.91%, AUC (0.965). While for IVC CI at cut-off value> 10.3, the sensitivity 69.35%, specificity 57.23%, PPV 77.4 % and NPV 46.9%, accuracy 65.5% and AUC was 0.682. and for IVC min diameter at cut-off value ≤ 1.25 the sensitivity, specificity, PPV, NPV, accuracy and AUC were 92.26%, 82.39%, 91.7%, 83.4%, 89.1%, 0.955. for CCA diameter has Cut- off value ≤ 4.4 mm with sensitivity 93.15%, specificity 71.7 %, PPV 87.4%, NPV 83.2%, accuracy 86.3% and AUC was 0.937 as shown in table (6).

Table 1: Demographic data and patients characteristics of the studied population

Variables	N=55
Age (years)	43.3±13.1
Gender	
Male	29(52.7%)
Female	26(47.3%)
ASA score	
ASA II	40(72.7%)
ASA III	15(27.3%)
Causes	
Sepsis	33(60%)
Blood loss	22(40%)
Vasopressors	
Norepinephrine	12 (21.8%)
Norepinephrine + Epinephrine	8 (14.5%)

N.B ASA= American Society of Anesthesiology

Table 2: changes in the MAP (mmHg) and HR (bpm) in the study population

Base line		Fluid administration							
		At 30 min	At 1hr	At 2hrs	At 3hrs	At 6hrs	At 12hrs	At 24hr	At 48hrs
MAP	54.9±3.3	56.5±3.1	58.4±2.8	60±2.9	61.2±3.3	63.2±3.3	63.2±3.3	66.8±3.7	69±4.5
P value		0.06	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001
HR	128.4±9.4	121.2±9.5	113.4±9.5	108.9±9.8	102.4±10.9	97.5±9.6	93.5±9.2	87.7±6.7	83.1±7.7
P value		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

MAP= Mean arterial blood pressure. HR= Heart rate.
Data are expressed as mean ± Standard Deviation (SD).

Table (3): Serial changes in parameters over 48hrs in the study population

	Base line	After fluid administration							
		At 30min	T 1hr	At 2hrs	At 3hrs	At 6hrs	At 12hrs	At 24hrs	At 48hrs
IVC max(cm)	1±0.1	1.1±0.1	1.2±0.1	1.3±0.1	1.3±0.1	1.4±0.1	1.5±0.1	1.5±0.3	1.6±0.3
P value		0.07	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
IVC min(cm)	0.8±0.1	0.9±0.1	1±0.1	1.1±0.1	1.2±0.1	1.2±0.1	1.3±0.1	1.4±0.1	1.5±0.2
P value		0.06	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
IVC CI(%)	14.8±4	13.1±4*	12.5±3	11.8±2.9	12.5±3	10.8±2.6	10.2±2.6	9.8±2.5	9.3±2.5
P value		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
CCA (mm)	2.9±0.4	3.2±0.9*	3.4±0.4	3.6±0.5	3.7±0.5	4.1±0.5	4.4±0.6	4.8±0.6	5.1±0.7
P value		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
CVP (cm H_2O)	2±0.8	3.1±0.8	4.2±1.1	5.2±1.1	5.6±1.6	6.8±1.6	7.9±1.6	9.5±1.7	11.2±2.4
P value		0.09	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

IVC max= Inferior vena cava maximum.
IVC min = Inferior vena cava minimum.
IVC CI = Inferior vena cava collapsibility index.
CCA = Common carotid artery.
CVP = Central venous pressure.
*: Significant level at P value < 0.05

Table (4): shows the Correlation between all CVP readings and all other U/S parameters

	CVP	
	r	P value
IVC max diameter	0.895	<0.001*
IVC min diameter	0.890	<0.001*
IVC CI	-0.347	<0.001*
CCA diameter	0.818	<0.001*

*** Significant level at P value < 0.05**
r= correlation coefficient

Table (5): Comparison of U/S parameters between CVP > 8 and < 8 (at all times).

		CVP		P value
		> 8	< 8	
		N=159	N=336	
IVC max diameter	Range Mean ±SD	(1.2-2.2) 1.6±0.2	(0.8-1.9) 1.2±0.2	***<0.001****
IVC min diameter	Range Mean ±SD	(1.1-2) 1.4±0.2	(0.7-1.4) 1.1±0.2	***<0.001****
IVC CI	Range Mean ±SD	(3.2-20.4) 10.2±2.9	(1.4-27) 12.2±3.5	***<0.001****
CCA diameter	Range Mean ±SD	(3.7-7.3) 4.8±0.6	(2-8.8) 3.5±.6	***<0.001****

*: Significant level at P value < 0.05 Data are expressed as mean ±SD.

Table (6): ROC curve analysis of parameters for prediction of CVP < 8 (at all times).

	IVC max diameter	IVC min diameter	IVC CI	CCA diameter
Optimal cutoff point	≤ 1.38	≤ 1.25	> 10.3	≤ 4.4
AUC	0.965	0.955	0.682	0.937
95% CI	0.945-0.979	0.933-0.971	0.639-0.723	0.912-0.957
P value	***<0.001****	***<0.001****	***<0.001****	***<0.001****
Sensitivity	90.48	92.26	69.35	93.15
Specificity	91.82	82.39	57.23	71.7
PPV	95.9	91.7	77.4	87.4
NPV	82	83.4	46.9	83.2
Accuracy	90.91	89.1	65.5	86.3

- *ROC curve analysis*
- *AUC: Area Under Curve*
- *PPV: Positive Predictive Value*
- *NPV: Negative Predictive Value*
- **: Significant level at P value < 0.05*
- *Data are expressed as number and percentage.*

Discussion

In the current study, there was positive correlation between CVP and IVC max, IVC min diameters, whereas a negative correlation to IVC CI. In agreement with our result, Deepak Raj Singh et al., 2021 who revealed positive correlation between CVP and VC diameters and negative correlation with IVC CI [(6).]

In collaboration with our results, Mahrous et al., 2022 who discovered a statistically significant relationship between IVC diameter and CVP. This indicated that a rise in CVP is followed by a reduction in CVI-CI[(5)] .

The current study shows a better diagnostic accuracy of IVC max diameter than IVC CI for predicting low CVP< 8 cmH_2O with a cut-off value ≤1.38 cm a sensitivity of 90.48%, specificity of 91.82%, and accuracy of 90.91%, but there was a negative correlation with IVC CI, where IVC CI > 10.3% can predict low CVP<8 cm H_2O with a sensitivity of 69.35%, specificity of 57.23% and accuracy of 65.5%.

Our results agree with the outcome of Prekker et al., 2013 who found that the area under the curve to discriminate low central venous pressure (< 10 mm Hg) was 0.91 for inferior vena cava diameter, which was significantly higher than the IVC CI 0.66. An inferior vena cava diameter <2 cm predicted a central venous pressure < 10 mmHg with a sensitivity of 85%, specificity of 81% [(7).]

Our findings correlate with Bahman Naghipour and Gholamreza Faridaalaee 2016, who evaluated the correlation of sonographic IVC diameter, aorta diameter, and IVC / aorta ratio with CVP. 39 patients were included (53.8% male; mean age 62.1±5.8 years, Patients in need of catheterization and TEE who were referred to a teaching hospital in Tabriz, Iran, from 2013 to 2015 were enrolled. At this study CVP had a significant c orrelation with IVC diameter at the point of entry into the right atrium (r =0.85) [(8)]

In contrast to our study, Shalaby et al., 2018, who found a better diagnostic accuracy of IVC CI (AUC 0.871, p <0.001) than IVC dmax, for predicting baseline low CVP< 10 cmH2O, where IVC CI >33.33% can predict low CVP with a sensitivity of 76.0% and a specificity of 92.0% [(9).]

In this study we found that the mean of the CCA diameter on admission was 3.2±2.6 and significantly increased all over 48hrs after fluid administration till it reached to 5.1±0.7. In accordance to our study Samaa et al., 2020 who found that the mean diastolic CCA diameter was 5.4± 0.6 (mm) on admission and significantly increased from 5.5 ± 0.7 to 6.6 ± 0.5(mm) after fluid administration ($P < 0.001$) [(10).]

Our findings go hand to hand with Hilbert et al., 2016 who conducted a study at cardiac surgery intensive care unit of the University Hospital Bonn, Germany, the diameter of the CCA measured using bedside ultrasound responds to intravenous fluid expansion with significant dilation[(11).]

In collaboration with our results Marik et al., 2013 who conducted a study during an 8-month period, collected clinical, hemodynamic, and carotid Doppler data on hemodynamically unstable patients in the ICU who underwent a PLR maneuver as part of our resuscitation protocol. We noted a significant increase in the diameter of the common carotid artery in the fluid responders [(12).]

References

1. Douglas, I. S., Alapat, P.M., Corl, K.A., Exline, M.C., Forni, L.G. Holder, A.L,…& Hansell, D.M. Fluid response evaluation in sepsis hypotension and shock: a randomized clinical trial. Chest. 2020; 158(4), 1431-1445.
2. Chopra, S., Luthra, N., Kauthuria, S., Saggar, K., Gupta, S., & Singh, T. Optimal positioning of right internal jugular venous catheter: A randomised study comparing modified peres height formula and distance between insertion point and right third intercostal space. Indian journal of Anaesthesia, 2022; 66(8), 585-590.
3. Ruge, M., &Marhefka, G.D. IVC measurement for the noninvasive evaluation of central venous pressure. Journal of Echocardiography, (2022); 1-11.
4. Millington, S.J. Ultrasound assessment of the inferior vena cava for fluid responsiveness: easy, fun, but unlikely to be helpful. Canadian Journal of Anesthesia/Journal canadien de anesthesie, 2019; 66.6:633-638.
5. Mahrous, M.M., Al Hassanin, A.M.M., & Sabra, M.M. Correlation of Ultrasound Guided Measurement of inferior vena cava diameter to central venous pressure to assess the volume status in septic shock of mechanically ventilated patients. Al-Azhar international medical journal, (2022).
6. Singh, D.R., Thapa, A.S., Limbu, Pandey, S., & Shrestha, S. Correlation of nferior vena cava diameter and IVC collapsibility index with central venous pressure in critically ill surgical patients. Journal of Society of Surgeons of Nepal.,2021; 24. 1: 19-22.
7. Prekker, M.E., Scott, N.L., Hart, D., Sprenkle, M.D., & Leatherman, J.W. Point-of- care ultrasound to estimate central venous pressure: a comparison of three techniques. Critical care medicine, 2013; 41. 3:833-841.
8. Naghipour, B., & Faridaalaee, G. Correlation between central venous pressure and inferior vena cava diameter, determining the best anatomic location. Emergency, 2016; 4.2:83.
9. Shalaby, M.I.M., Roshdy, H.M., Elmahdy, W.M., & El Mezayen, A.E.F. Correlation between central venous pressure and the diameter of inferior vena cava for assessment of the fluid status in intensive care unit patients. The Egyptain journal of Hospital medicine, 2018; 72. 10: 5375-5384.
10. Rashwan, S.A.K., Bassiouny, A.A.E., Badawy, A.A., & Mohammed, A.R. The relation between common carotid artery diameter and central venous pressure for assessment of intravascular fluid status after major surgery; an observational study. Anesthesiology and pain Medicine, 2020; 10.4.
11. Hilbert, T., Klaschik, S., Ellerkmann, R.K., Putensen, C., & Thudium, M. Common carotid artery diameter respond to intravascular volume expansion: an ultrasound observation Sprinerplus, 2016;5.1:1-6.

12. Marik, P.E., Levitov, A., Young, A., & Andrerws, L. The Use of Bioreactance and Carotid Doppler to Determine Volume Responsiveness and Blood Flow Redistribution Following Passive Leg Raising in Hemodynamically Unstable Patients. Chest, 2013;143. 2:364-370.