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Inferior Vena Cava Dispensability Index versus Central Venous Pressure in Volume Status Assessment in Shocked Patients

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ABSTRACT

Background: The central venous pressure [CVP] remains the most frequently used variable to guide fluid resuscitation in shocked patients and is considered a direct measurement of the blood pressure in the right atrium and vena cava. The ultrasound-guided measurement of the inferior vena cava [IVC] and its changes with respiration has recently been utilized to calculate a patient's fluid status.

The Aim of the work: This work aimed to compare ultrasound guided inferior vena cava dispensability index to central venous pressure in shocked patients and to assess the volume status in shocked patients after measurement of CVP and IVC dispensability index [IVC DI].

Patients and Methods: The study was conducted on 60 shocked patients, who were selected from the ICU, Al-Azhar University Hospitals.

Results: At cutoff point 7.5 cmH_2O, CVP has a sensitivity of 97% and specificity of 96.3% for prediction of hypovolemia. Also, at cutoff point 15.5, IVC-DI has sensitivity of 93.9% and specificity of 100% to predict hypovolemia. In addition, CVP at cutoff point 8.5 cmH_2O has sensitivity of 50% and specificity of 55% for predicting fluid responsiveness. Also, at cutoff point 14.5 IVC DI has sensitivity of 100% and specificity of 91.9% for predicting fluid responsiveness.

Conclusion: Ultrasound guided CVP and IVC DI were reliable markers in predicting fluid responsiveness and hypovolemia among shocked patients. IVC DI was superior than central CVP.

Keywords: Ultrasound; Inferior Vena Cava; Dispensability index; Venous Pressure; Shock.

INTRODUCTION

Shock is a life-threatening condition that leads to global tissue hypo perfusion and circulatory collapse. Bedside ultrasound is a useful tool for diagnosing some types of shock [1].

The central venous pressure can be measured using a central venous catheter advanced via the internal jugular vein and placed in the superior vena cava near the right atrium. A normal central venous pressure reading is between 8 to 12 mmHg. This value is altered by volume status and/or venous compliance [2].

The ultrasound-guided measurement of the IVC diameter and its changes with respiration has recently been utilized to calculate a patient's fluid status. It is often used to evaluate patients' volume status as an alternative to central venous catheterization. It is a dynamic measure of intravascular volume status because it reflects the volume changes that happen with respiration. The IVC adapts to the body's volume condition by modifying its diameter based on total body fluid volume. The IVC distends with insufflation as enhanced intra thoracic pressure results in higher RV afterload and a transient boost in pulmonary artery pressure with a whole net reduction in venous return [3].

Inferior vena cava [IVC] diameters are assessed during a normal respiratory cycle. While patients are supine, the IVC diameters are measured 2 to 3 cm from the right atrial border in a long-axis subxiphoid or subcostal view with a 4–2 MHz curvilinear probe based on the best available view [4].

The IVC collapsibility index is calculated by the following formula: IVC collapsibility index = [maximum diameter on expiration – [minimum diameter on inspiration/maximum diameter on expiration]]. In mechanically ventilated patients, the IVC distensibility index is calculated using the formula: IVC distensibility index = [[maximum diameter on inspiration–minimum diameter on expiration]/minimum diameter on expiration] [5].

This study was aimed primarily to compare between ultrasound guided inferior vena cava dispensability index and central venous pressure in shocked patients regarding their accuracy. And aimed secondarily to assess volume status in shocked patients after measuring of central venous pressure [CVP] and inferior vena cava dispensability index [IVC DI].

PATIENTS AND METHODS

This prospective comparative study was conducted on 60 shocked patients. They were selected from the intensive care unit [ICU], Al-Azhar university Hospital [Damietta]. This study began in October 2022 and continued until the end of October 2023.

We included adults [age [≥18 years old] who were presented to the emergency room [ER] with signs and symptoms of shock [any type] and admitted to ICU.

Ethical aspects: The study protocol reviewed and approved by the institutional review board, of Damietta faculty of Medicine [Al-Azhar University]. The study was completed and prepared in accordance with Helsinki guidelines for research conduction and reporting.

Methods: The clinical assessment of each patient included thorough history taking, complete physical examination [vital signs, capillary refill time and other clinical manifestation] and routine laboratory investigation [CBC, ESR, coagulation profile, liver and renal function tests and arterial blood gases]. Treatment interventions were completed according to our institution protocol for treatment of shock.

Ultrasound measurement of IVC diameters: The IVC collapsibility [in spontaneously breathing patients] and distensibility [in mechanically ventilated patients] indices were measured with bedside ultrasound. A Mindray ultrasound device [North American Distributor for Mindray, Foundation in China] with a 3.5-5 MHz convex probe was used for ultrasound training in our department and was used for the measurements. All ultrasound measurements were carried out by the same PICU fellow, who was experienced in bedside ultrasound. Measurements were performed while the patient was in the supine position. IVC images were acquired in the sagittal section. Images of the IVC draining into the right atrium were obtained while the probe was in the sub xiphoid area, using the liver as the acoustic window. The minimum IVC diameter on inspiration and the maximum IVC diameter on expiration were recorded using the M-mode just beyond the point, where the hepatic veins drain into IVC. The maximum IVC diameter on inspiration and the minimum IVC diameter on expiration were measured using the same ultrasound scanning method. In mechanically ventilated patients, the

IVC distensibility index was calculated using the following formula: IVC distensibility index ¼ [[the maximum diameter on inspiration - the minimum diameter on expiration]/the minimum diameter on expiration]

Statistical analysis: Statistical package for social science [SPSS] software, version 20 [IBM® Armonk, USA] was used to perform the statistical analyses of patient data. The continuous variables were expressed by the means, standard deviation [SD], minimum and maximum. However, the qualitative variables were expressed by the relative frequency and percentages. Values of CVP and IVC DI were correlated with other variables. Pearson's correlation efficient was calculated to assess these correlations. P value <0.05 was considered significant.

RESULTS

The current work included 60 patients, 34 of them [56.7%] were males and 26 [43.3%] were females. Their age ranged between 48 to 65 years [the mean ± SD was 54.683 ± 4.006 years]. Patient weight ranged between 52 and 91 kg [mean ± SD 74.22 ± 11.24 kg], while length ranged between 142 to 184 cm [mean ± SD 164.35 ± 8.54 cm]. Furthermore, the body mass index [BMI] ranged between 19.57 to 32.89 kg/m^2 [mean ± SD 27.42 ± 3.30 kg/m^2]. The vital data reflected clinical signs and symptoms of shock. The heart rate [HR] ranged between 101 to 145 b/min [118.78 ± 12.76 b/min] and the mean respiratory rate [RR] [25.82 ± 3.18 cycles/min] [ranged between 22 and 35]. The mean temperature was 36.66±0.53 [range 35.3 to 38.2 ºC], while mean systolic and diastolic blood pressure were [103.65 ± 12.76 and 61.92 ± 7.76 mmHg, respectively]. The mean arterial pressure ranged between 67 to 97 [the mean 79.08 ± 6.90 mmHg]. The oxygen saturation percentage ranged between 91 to 96% [mean ± SD 93.70 ± 1.23]. Finally, the capillary refill time ranged between 3.5 to 6.5, the mean ± SD was 4.27 ± 0.95 seconds.

Hematological and ABGs were presented in table [1]. It reflected lower hemoglobin levels [Anemia] with high white blood cells, normal platelet count, with variability in arterial blood gases. The CVP ranged between 6 and 11 with a mean of 7.87±1.24 cmH_2O. On the other side, the ICV DI ranged between 12 and 22 [the mean ±SD value was 15.93±2.44] [Table 1].

In the current work, the CVP was positively and significantly correlated with IVC DI. The correlation is powerful [near complete, r =0.976]. In addition, CVP was positively and significantly correlated with pH, SBP, DBP, MBP, and hemoglobin and inversely correlated with CRT and PCO_2. In addition, IVC DI was significantly and proportionately correlated with pH, and arterial blood pressure [systolic, diastolic and mean values]. But, it negatively and significantly correlated with O2 saturation, CRT and PCO2 [Table 2].

According to volume status, patients were divided into those who had hypovolemia [n =27] and those with no hypovolemia [n =33]. Table [3] reflected that, the hypovolemic patients had significantly lower CVP and IVC DI.

According to fluid response, patients were assigned to one of each two groups, the fluid-response [n=22] and non-responsive [n=38]. Patients with fluid-response had significantly lower values of CVP and IVC DI, than those who had no fluid response [Table 4].

Table [5] reflected sensitivity and specificity of CVP and IVC DI in predication of hypovolemia and fluid-responsiveness. Results showed that, ICV DI was more specific in predication of hypovolemia and more sensitive for prediction of fluid-responsiveness than CVP.

Table [1]: Hematological, ABGs, CVP and IVC DI among study populations

		Statistical measures			
		Min	Max.	Mean	SD
Hematological data	Hemoglobin	6.5	12.8	10.62	1.93
	WBCs x10^3 /cc	2.6	33.6	11.37	7.13
	Platelets x10^3/cc	84	612	305.27	115.36
Arterial blood gases	pH	7.12	7.47	7.32	0.07
	PCO2	28.00	72.00	42.60	8.26
	PaO2	30.00	79.00	51.53	8.72
	HCO3	11.00	30.00	19.71	4.74
CVP		6	11	7.87	1.24
IVC DI		12	22	15.93	2.44

Table [2]: Correlation between each CVP and IVC DI with clinical data of the study population

	CVP		IVCDI	
	r	p	r	p-value
IVCDI	**0.976**	**<0.001***		
Age	-0.022	0.866	-0.066	0.615
HR	-0.135	0.306	-0.181	0.166
RR	-0.114	0.387	-0.104	0.428
O2	-0.250	0.054	**-0.284**	**0.028***
CRT	**-0.527**	**<0.001***	**-0.494**	**0.000***
P^{H}	**0.344**	**0.007***	**0.344**	**0.007***
PCO2	**-0.285**	**0.028***	**-0.295**	**0.022***
PaO2	0.046	0.728	-0.010	0.938
HCO3	0.215	0.100	0.220	0.091
SBP	**0.276**	**0.033***	0.254	0.050
DBP	**0.370**	**0.004***	**0.342**	**0.007***
MBP	**0.415**	**0.001***	**0.409**	**0.001***
HB	**0.303**	**0.019***	**0.329**	**0.010***
WBC	0.216	0.097	0.229	0.078
plat	0.124	0.344	0.135	0.304
BMI	-0.086	0.513	-0.106	0.421

Table [3]: Relation between volume status and each of CVP and IVC DI

		Volume status		Independent student t test	
		Hypovolemia	No hypovolemia		
		N=27	N=33	t	P-value
CVP	Range	6 - 8	6 - 11	-10.709	<0.001*
	Mean ± SD	6.778 ± 0.506	8.758 ± 0.902		
IVC DI	Range	12 - 15	15 - 22	-10.799	<0.001*
	Mean ± SD	13.778 ± 1.086	17.967 ± 1.704		

Table [4]: Relation between fluid response and each of CVP and IVC DI

		Fluid response		Independent student t test	
		Fluid-responsive	Non-fluid responsive		
		N=22	N=38	t	p-value
CVP	Range	6 - 8	7 - 11	-8.794	<0.0001
	Mean ±SD	6.727 ± 0.550	8.526 ± 1.033		
IVC DI	Range	12 - 15	15 - 22	-10.452	<0.0001
	Mean ±SD	13.500 ± 1.012	17.342 ± 1.835		

Table [5]: Sensitivity and specificity of CVP and IVC DI in prediction of hypovolemia and fluid-responsiveness

		Cutoff	AUC	Sensitivity %	Specificity %	Asymptotic 95% CI	
						LB	UB
Hypovolemia	CVP	7.5	0.980	97%	96.3%	0.948	1.000
	IVC DI	15.5	0.992	93.9%	100%	0.978	1.000
Fluid responsiveness	CVP	7.5	0.934	84.2%	95.9%	0.874	0.994
	IVC DI	14.5	0.992	100%	91.9%	0.976	1.000

DISCUSSION

Clinical determination of the intravascular volume in critically ill and injured patients can be extremely difficult. This is problematic because fluid loading is considered the first step in hemodynamically unstable patients' resuscitation. Yet, multiple studies have shown that only approximately 50% of hemodynamically unstable patients in the intensive care unit [ICU] and operating theatre respond to a fluid challenge [6].

The present study showed that there was no significant association between age or Body mass index [BMI] with CVP or IVC distensibility index. This was consistent with **Ibrahim *et al.*** [7] who enrolled 67 critically ill patients with mean age of 42.3 ± 14.51 years and male predominance [65%]. The study revealed that there was no significant association between age, sex or BMI with CVP or IVC distensibility index.

The present study showed statistically significant positive correlation between CVP, ICV DI the blood pressure and significant negative correlation between CVP and ICV distensibility index of the study population and CRT. These results are supported by the systematic review carried out by **Hutchinson and Shaw** [8] who revealed that CVP play a significant role in the hemodynamic monitoring of the critically ill patients. In addition, **Ibrahim *et al.*** [7] showed that there was a statistically significance increase in SBP, DBP and MABP among cases that had CVP >10 than who had CVP ≤10. Also, there was a negative correlation between ICV with SBP. Our results are in line with **Çelik *et al.*** [9] who revealed that there was a significant association between ICV distensibility index and SBP.

However, **Jassim *et al.*** [10] reported that there was no significant association was found between CVP and MAP or HR. This could be attributed to different inclusion and exclusion criteria and sample size.

In our work, there was a statistically significant, positive correlation between CVP, ICV DI and hemoglobin levels. Similar association had been reported by **Çelik *et al.*** [9].

As regard association between CVP, and ICV DI with pH and PaCO2, our results agree with **Rahim-Taleghani *et al.*** [11] who reported a significant correlation between CVP with pH and HCO_3 in patients with septic shock. The same results were reported by **Baratloo *et al.*** [12].

The most important finding of the current study is the significantly positive correlation between CVP and ICV distensibility index. This agrees with **Ibrahim *et al.*** [7] who reported a statistically significant positive correlation between CVP and ICV DI.

Regarding the relation between CVP and IVC distensibility index and volume status, it was revealed that CVP and IVC DI were significantly lower in hypovolemic subjects than non-hypovolemic subjects. In a comparative study to gauge the relationship between stroke volume variation [SVV] and inferior vena cava distensibility index [IVC-DI] as a measure of fluid responsiveness in mechanically ventilated hypotensive ICU patients, **Kaur *et al.*** [13] showed a direct link between IVC-DI and SVV usage during a clinical setting of low blood pressure suspicious of being attributable to hypovolemia. Furthermore **Dalimunthe *et al.*** [14] revealed that a significant correlation positive was found between CVP and volume status [r= 0,940, p= <0,001] but it had negative correlation with IVC-DI [r= -0,573, p=0,008].

The association between CVP, and IVC DI with fluid response showed significant reduction in fluid responsive subjects than non-fluid responsive subjects. The results were supported by **Atallah *et al.*** [15] who revealed that there was significant association between CVP and fluid responsiveness. In addition, **Saber *et al.*** [16] showed a significant association between IVC-DI and fluid responsiveness in mechanically ventilated patients with septic shock. Comparable results were reported by **Ali Khalil *et al.*** [17]

In contrast to the current study, **El-Gazzar *et al.*** [18] revealed that there was no significant difference between fluid responsive subjects than non-fluid responsive subjects as regard CVP and IVC-DI in mechanically ventilated patients after CABG, the disagreement may be due to the difference in inclusion criteria.

Our results indicated that IVC-DI have higher accuracy in predicting hypovolemia and fluid responsiveness. These results are in line with **Saber *et al.*** [16] who showed that IVC-DI have higher accuracy than CVP in predicting fluid responsiveness. At cutoff point 7.5 CVP has sensitivity of 84.2% and specificity of 95.9% for predicting fluid responsiveness. Also, at cutoff point 14.5 IVC DI has sensitivity of 85% and specificity of 90% for predicting fluid responsiveness.

According to **Huang *et al.*** [19], IVC-DI had an AUC of 0.82 [95% CI: 0.79–0.85], a specificity of 80%, and a sensitivity of 69% in mechanically ventilated shocked individuals. The IVC-DI has been proven to be a valid predictor of fluid responsiveness in critically ill patients who are mechanically ventilated, with a cut-off value of 18%, differentiating responders from non-responders in the research group.

In addition, **Ali Khalil *et al.*** [17] showed that IVC distensibility index [IVC DI] can be used in prediction of fluid responsiveness. IVC-DI index cutoff value was > 12.6% with sensitivity

80% and specificity 80%. However, **Ismail *et al.*** [20] showed that CVP, despite having a good sensitivity of 88.6%, high specificity of 100%, and a significant p-value, is not a reliable detector of fluid responsiveness due to its small AUC value and low 95% CI.

In conclusion, the current study showed that ultrasound guided central venous pressure and inferior vena cava distensibility index we reliable markers in predicting fluid responsiveness and hypovolemia among shocked patients. Inferior vena cava distensibility index was found to be superior with higher accuracy than central venous pressure in predicting fluid responsiveness and hypovolemia among shocked patients. However, the current study was limited by small sample size, the lack of control group, being a single center study and relatively short follow up period. Thus, further studies with a larger sample size and longer follow-up are needed to confirm our results and to identify risk factors of adverse events.

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