Original Article

Assessment of Volume Status in Ventilated Shocked Patients by Ultrasound Guided Inferior Vena Cava Distensibility Index and Central Venous Pressure, (Comparative Clinical Study)

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ABSTRACT

Background: Fluid therapy remains the cornerstone of hemodynamic resuscitation of shocked patients. Fluid resuscitation seeks to rapidly restore the effective circulating blood volume and oxygen delivery to organs. Effective fluid resuscitation can improve the prognosis, while repeated or inappropriate fluid bolus administration is associated with increased mortality and the length of stay. The most commonly used parameter for detecting volume status is still central venous pressure (CVP); however, recently, various methods are being used for volume assessment like inferior vena cava respiratory variability index.

Objective: This study aimed to evaluate the relationship between CVP and ultrasound guided Inferior Vena Cava distensibility index (IVC DI) as a tool to assess the volume status and fluid responsiveness in ventilated shocked patients as regard sensitivity and accuracy.

Methods: Fifty shocked patients were prospectively included in the study. All patients were ventilated in volume control mode. IVC DI measurement was evaluated using ultrasonography and simultaneous CVP values were recorded while patient in supine position.

Results: IVC DI has higher accuracy in predicting hypovolemia in ventilated shocked patients than CVP, Receiver Operating Characteristic (ROC) curve analysis showed that cutoff point 14.5 IVC DI has sensitivity 94% and specificity 100% for predicting hypovolemia while cutoff point 7 CVP has sensitivity 96% and specificity 95.4%. IVC-DI has higher accuracy in predicting fluid responsiveness, ROC curve analysis showed cutoff point 13 IVC DI has sensitivity of 100% and specificity 93.3% for predicting fluid responsiveness while cutoff point 7 CVP has sensitivity 85.2% and specificity of 95.3%.

Conclusions: CVP and ultrasound guided IVC-DI are reliable markers in predicting fluid responsiveness and hypovolemia among ventilated shocked patients with the superiority of IVC-DI.

Key Words: Hypovolemia, Mechanical ventilation, Resuscitation.

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INTRODUCTION

Shock is a state of organ hypoperfusion with resultant cellular dysfunction and death. Mechanisms may involve decreased circulating volume, decreased cardiac output, and vasodilation, sometimes with shunting of blood to bypass capillary exchange beds. Symptoms include altered mental status, tachycardia, hypotension and oliguria. Diagnosis is clinical, including blood pressure measurement and sometimes measurement of markers of tissue hypoperfusion (eg, blood lactate, base deficit). Treatment is with fluid resuscitation, Including blood products if necessary, correction of the underlying disorder, and sometime vasopressors[1].

The fundamental defect in shock is reduced perfusion of vital tissues. Once perfusion declines and oxygen delivery to cells is inadequate for aerobic metabolism, cells shift to anaerobic metabolism with increased production of carbon dioxide and elevated blood lactate levels. Cellular function declines, and if shock persists, irreversible cell damage and death occur[1].

Haemodynamic support for patients in shock is crucial to prevent worsening organ dysfunction, resuscitation should be started while the investigation to determine the cause is ongoing[2]. Determination of intravascular volume

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status in patients admitted to the emergency centre (EC) is critical[3]. An accurate diagnosis of shock state can be challenging because physical signs of hypovolaemic, distributive, cardiogenic, and obstructive shock frequently overlap[4]. 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 haemodynamically unstable patients' resuscitation. Yet, multiple studies have shown that only approximately 50% of haemodynamically unstable patients in the intensive care unit (ICU) and operating theatre respond to a fluid challenge[5].

Traditional invasive intravascular volume assessment modalities, such as pulmonary artery and central venous pressure (CVP) catheters, which provide physiologic data, such as cardiac output and right atrial pressure, are time-consuming and carry significant risks[6]. Traditionally, CVP has been assumed to accurately reflect the intravascular volume and has played a central role in guiding fluid management decisions for decades[7]. This invasive method has several complications, such as arrhythmias, cardiac chamber injury, vascular-nerve injury, pneumothorax, haemothorax, local bleeding, haematoma, infection, thrombosis, occlusion, pulmonary embolism, post-phlebitis syndrome, which may occur with catheter placement and may be inaccurate in patients with Severe tricuspid regurgitation or right ventricular failure[8].

The inferior vena cava (IVC) is the largest vein in the venous system with low pressure. To a certain extent, vein expansion reflects venous pressure variations. This variation also reflects the excess of the intravascular volume. As a result, the IVC diameter may be a useful diagnostic tool in the assessment of hypovolaemia and hypervolaemia[8]. There is growing interest in researching the venous collapsibility index (VCI) as a non-invasive, easily repeatable, and portable alternative to traditional invasive haemodynamic monitoring approaches[5]. Studies in intensive care unit patients revealed that measurements of the respiratory variation in IVC diameter can be used to predict fluid responsiveness in mechanically ventilated patients. There are few researches on the accuracy and feasibility of the caval index to predict fluid responsiveness in the emergency situations[9].

Numerous hemodynamic variables could be predictors of fluid responsiveness. Traditional static pressure indexes such as Central Venous Pressure (CVP) or Mean Arterial Pressure (MAP) had a limited predictive value for fluid resuscitation. Dynamic indices have shown to be good predictors of fluid responsiveness in recent years, especially the indices relying on heart-lung interactions, such as inferior vena cava respiratory variability index, Velocity-Time Integral (VTI) in left ventricular inflow tract, stroke volume variation (SVV), and so on. VTI or SVV was able to reliably predict the fluid loading response and was superior to traditional pressure indexes for adults. The predictive value of these dynamic variables remains unclear. Apart from this, VTI and SVV monitoring need highly skilled operators to ensure measurement accuracy and require specialized pieces of equipment that are not available in every hospital. These make them more difficult to perform in the clinical environment[10]. Thus, more ICU physicians are willing to choose the inferior vena cava (IVC) as a point-of-care parameter of volume status assessment due to their convenience for measuring[11-13].

AIM OF THE STUDY

Primary aim: Comparison between ultrasound guided inferior vena cava distensibility index and central venous pressure in ventilated shocked patients as regard to volume status and fluid responsiveness.

Secondary aim: Assessment of volume status in ventilated shocked patients after central venous pressure measurement and ultrasound guided inferior vena cava distensibility index and comparison between both as regard to correlation, sensitivity and specificity.

PATIENTS AND METHODS

This prospective comparative correlational observational study was conducted on 50 ventilated shocked patients at the New Jaddah Clinic Hospital-JEDAH-KSA from June 2021 to December 2023 after obtaining clearance from institutional research and ethics committee and written informed consent from the first degree relatives.

Inclusion criteria:

This study included patients ≥18 years old who were admitted to ICU with signs and symptoms of any type of shock and need supportive mechanical ventilation.

Exclusion criteria:

Families or relatives who declined to engage were eliminated. Additionally patients with intra-abdominal hypertension ≥12cmH_2O, Severe tricuspid regurgitation, Right ventricular failure, High PEEP settings and Pregnant females were excluded from the study.

Resuscitation effort:

After taking detailed medical history from the relatives and physical examination, hemodynamic monitoring and vital signs and diagnosis of shock was confirmed by low blood pressure SPB <90mmHg, tachycardia HR >110b/m (aexcept for neurogenic shock) and delayed capillary refill time >6 sec, cold clammy extremities, low temperature <36.5 ^{0}C and confusion or disturbed conscious level.

All shocked patients are placed in Trendelenburg position and the head rotated to the opposite side and ultrasonography was performed by using SonoSite EDGE ultrasound system equipped with 5-7.5MHz T-linear probe. Cannulation of the right internal jugular vein was performed by portex 8.5 Fr x 20cm 3 lumen central venous catheter under complete aseptic condition, then measurement of both CVP and distensibility index of IVC in the same setting (once diagnosis of shock state was confirmed) and reading was recorded as a baseline data then, resuscitation was started by fluid replacement.

Intravenous fluid resuscitation of 20ml/kg of crystalloid (normal saline as a bolus 1–2 litre NaCl 0.9%) within 120min. The targets were: a systolic blood pressure not less than 90mmHg, a MAP (mean arterial pressure) >60mmHg and >80mmHg in head trauma patients, a CVP of 8-12mmHg, and a urine output >0.5ml/hr.

The patient was reassessed after the first bolus, and if vital signs did not improve, another bolus was administered. Reassessment again if there is no improvement, a vasopressor as Norepinephrine (0.05–1mcg/kg/min) was started.

The patients' haemoglobin and haematocrit were also assessed; if haemoglobin was less than 7gm/d and haematocrit less than 25%, the patient required a transfusion of packed RBCs (red blood cells). In cardiogenic shock, fluids are cautiously administered, guided by CVP.

Another measurement of CVP and IVC DI were taken after fluid resuscitation.

Mechanical ventilation:

All shocked patient included in the study were intubated and ventilated due to hemodynamic compromise and impairment of ventilation with altered mental status in most patients with volume control mode, synchronized intermittent mandatory ventilation (SIMV) with Zero Positive End Expiratory Pressure, Zero (PEEP). Other ventilator parameters (eg, Fio2, VT, RR, PS and plateau pressure) adjusted according to ABG and patients response.

Age, sex, pulse, blood pressure, BMI, respiratory rate (RR), oxygen saturation (SO2), capillary refill, and urine output were determined for all patients.

Size estimation:

Power analysis was conducted using the MedCalc Statistical Software version 13.0.2 (MedCalc Software, Ostend, Belgium'') to determine the representative sample. According to the previous study conducted by Basakyidiz and Serkan Ozsoylu, 2022, the correlation of inferior vena cava diameter and distensibility index with central venous pressure in shocked patients was -0.9. Considering a confidence level of 95%, and a power of 80%, the representative sample should be at least 50 patients in the study group.

Procedures and Measurement:

All enrolled patients received ultrasound monitoring. IVC measurements were performed with a SonoSite EDGE (Fujifilm SonoSite, Bothell, WA,) with a 1 MHz to 5 MHz curvilinear probe. The longitudinal plane of the IVC was observed from the subxiphoid area and right midaxillary line. In the subxiphoid area, the standard measurement site was 2cm to 3cm distal to the cavoatrial junction, and the maximum IVC parameter and minimum IVC parameter were measured during breath cycle using M-mode. Next, the site of the longitudinal measurement was moved to the center of the screen and was followed by 90° clockwise probe rotation to obtain the cross-section of the IVC. Maximum and minimum IVC areas were measured during the breath cycle using B-mode. At the end of expiration, the IVC long axis diameter and short axis diameter were also recorded.

IVC diameter distensibility index was calculated as: (maximum IVC diameter − minimum IVC diameter)/ minimum IVC diameter×100%.

CVP was recorded soon after IVC measurement. In the supine position, CVP was measured manually, using manometer. Reference point was taken at the intersection point of mid- axillary line with the fourth costal cartilage and measurement was recorded in cm of H_2O.

Ethical Consideration:

An informed consent was obtained from family. The data that were obtained from participants are confidential. The study participants are not identified by name in any report or publication concerning this study. Before the participants were admitted in this study, the purpose and nature of the study, as well as the risk-benefit assessment was explained to their family.

Statistical analysis:

Data collected throughout history, basic clinical examination, laboratory investigation and outcome measures coded, entered and analyzed using Microsoft Excel software. Data were then imported into Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. According to the type of data quantitative continues group represent by mean±Standard deviation (mean±SD) and Pearson correlation coefficient(r).

The Pearson correlation coefficient is a descriptive statistic, meaning that it summarizes the characteristics of a dataset. Specifically, it describes the strength and direction of the linear relationship between two quantitative variables.

Although interpretation of the relationship strength (also known as effect size) vary between disciplines, the table below gives general rules of thumb:

Pearson correlation coefficient(r) value	Strength	Direction
Greater than 0.5	Strong	Positive
Between 0.3 and 0.5	Moderate	Positive
Between 0 and 0.3	Weak	Positive
0	None	None
Between 0 and -0.3	Weak	Negative
Between -0.3 and -0.5	Moderate	Negative
Less than -0.5	Strong	Negative

RESULTS

The current study included 50 patients their age ranged between 40-70 years with mean value of 53.73±3.034y. 64% were male and 36% were females with BMI ranged between 18.43-35.91 with mean value of 26.47±2.23 as shown in Table (1).

Table 1: Demographic data and anthropometric measures of the studied population:

		N= 50
Gender	Male	32(64%)
	Female	18(36%)
Age (years)	Range	40-70
	Median(IQR)	55(5)
	Mean±SD	53.73±3.034
BMI	Range	18.43-35.91
	Mean±SD	26.47±2.23

Vital data and capillary refill time of the studied population, their HR ranged between 90-140b/m with mean value of 110.7±10.26b/m. RR ranged between 10-24 cycle/minute with mean value of 15.34±2.18 cycle/m. O_2 saturation ranged between 88-96% with mean value of 92.23±1.31%. Temperature ranged between 35.5-38.9ºC with mean value of 36.85±0.55ºC. The SBP ranged between 65-110mmHg with mean value of 90.65±9.78mmHg. The DBP ranged between 40-75mmHg with mean value of 55.93±6.43mmHg. Capillary refill time ranged between 3.5-6 second with mean value of 4.18±0.82s. as shown in Table (2).

Table 2: Vital data and capillary refill time of the studied population:

	N= 50			
	Min	**Max**	**Mean**	**SD**
HR (beat/min)	90	140	110.7	10.26
RR (cycle/min)	10	24	15.34	2.18
Temperature (ºC)	35.5	38.9	36.85	0.55
S.BP (mmHg)	65	110	90.65	9.78
D.BP (mmHg)	40	75	55.93	6.43
MBP (mmHg)	62	82	74.12	5.81
Spo_2 saturation (%)	88	96	92.23	1.31
Capillary refill time (sec)	3.5	6	4.18	0.82

Haematological data of the studied population, their Hb ranged between 7-11.2gm/dl with mean value of 9.81±1.23gm/dl and Haematocrit HCT ranged between 21-33.6% with mean value of 29.43±1.54% as shown in Table (3).

Table 3: Haematological data of the studied population:

	N= 50			
	Min	**Max**	**Mean**	**SD**
Haemoglobin (gm/dl)	7	11.2	9.81	1.23
Haematocrit (%)	21	33.6	29.43	1.54

The arterial blood gases data of the studied population, the results were, their PH ranged between 7.17-7.45 with mean value of 7.30±0.06, $PaCo_2$ ranged between 26-68mmHg with mean value of 40.61±8.16mmHg, PaO_2 ranged between 40-78mmHg with mean value of 50.13±8.70mmHg and HCO_2 ranged between 8-26mEq/L with mean value of 16.81±4.62mEq/L as shown in Table (4).

Table 4: Arterial blood gases data of the studied population on admission:

	N= 50			
	MIN	**Max**	**Mean**	**SD**
P^H	7.17	7.45	7.30	0.06
$PaCO_2$ (mmHg)	26	68	40.61	8.16
PaO_2 (mmHg)	40	78	50.13	8.70
HCO_3 (mEq/L)	8	26	16.81	4.62
Serum lactate (mmo/L)	2.3	6.6	4.2	4.23

CVP of the studied population ranged between 7-12 with mean value of 8.12±1.34 and IVC DI ranged between 11-23 with mean value of 16.42±2.65 as shown in Table (5).

Table 5: CVP and IVC distensibility index of the studied population after fluid resuscitation:

	N= 50			
	Min	**Max**	**Mean**	**SD**
CVP	7	12	8.12	1.34
IVC DI	11	23	16.42	2.65

There is statistically significant moderate positive correlation between (CVP) central venous pressure and (IVC DI) Inferior Vena Cava Distensibility Index of the studied population and the PH as (r= 0.348) (P-value= 0.006), mean arterial blood pressure (MBP) as (r= 0.421) (P-value= 0.001) and Hb level as (r= 0.301) (P-value= 0.017), while there is statistically significant weak negative correlation between CVP and IVC DI of the studied population and $PaCO_2$ as (r= -0.283) (P-value= 0.026) while the other parameters showed no significance correlation as shown in Table (6).

Table 6: Pearsons correlation coefficient (r) between CVP and IVC distensibility index and clinical data of the studied population:

	CVP		IVC DI	
	R	***P*-value**	***R***	***P*-value**
Hb	0.301	0.017*	0.320	0.010*
SBP	0.275	0.032*	0.242	0.051
DBP	0.371	0.004*	0.341	0.007*
MBP	0.421	0.001*	0.409	0.001*
P^H	0.348	0.006*	0.344	0.007*
Age	-0.021	0.751	-0.061	0.621
PCo_2	-0.283	0.026*	-0.294	0.002
RR	-0.112	0.317	-0.102	0.424
O_2	-0.241	0.052	-0.272	0.027*
HR	-0.131	0.310	-0.0179	0.162
BMI	-0.082	0.510	-0.104	0.411

As regard to the volume status of the studied population CVP and IVC DI were significantly lower in hypovolemic subjects than non-hypovolemic subjects. There was 21 patients hypovolemic with CVP mean value of 7.671±0.501 and IVC DI mean value of 12.771±1.082 while 29 patients non hypovolemic with CVP mean value of 9.751±0.801and IVC DI mean value of 17.561±1.631 as shown in Table (7).

As regard to fluid responsiveness CVP and IVC DI were significantly lower in fluid responsive subjects than non-fluid responsive subjects. There was 19 fluid responder with CVP mean value of 6.710±0.552 and IVC DI mean value of 12.571±0.013 while 31 patients non fluid responder with CVP mean value of 8.522±1.033 and IVC DI of 17.340±1.731 as shown in Table (8).

As regard to the volume status the cutoff point CVP of 7cmH_2O has sensitivity of 96% and specificity of 95.4% for predicting hypovolemia as shown in Table (9).

As regard to the volume status. The cutoff point 14.5% IVC DI has sensitivity of 94% and specificity of 100% for predicting hypovolemia as shown in Table (10).

As regard to fluid responsiveness the cutoff point CVP of 7cmH_2O has sensitivity of 84.6% and specificity of 96% for predicting fluid responsiveness as shown in Table (11).

As regard to fluid responsiveness the cutoff point 13% IVC DI has sensitivity of 100% and specificity of 93.2% for predicting fluid responsiveness as shown in Table (12).

Table 7: The relation between CVP and IVC distensibility index and volume status of the studied population:

		Volume status		Independent student t test	
		Hypovolemic	**No hypovolemia**		
		***N*= 21**	**N= 29**	***t***	***P*-value**
CVP	Range	6-9	7-12	-10.707	<0.0001
	Mean±SD	7.671±0.501	9.751±0.801		
IVC DI	Range	12-15	15-23	-10.794	<0.0001
	Mean±SD	12.771±1.082	17.561±1.631		

Table 8: The relation between CVP and IVC distensibility index and fluid response of the studied population:

		Fluid response		Independent student t test	
		Fluid responsive	**Non-fluid responsive**		
		***N*= 19**	***N*= 31**	***t***	***P*-value**
CVP	Range	6-9	7-12	-8.791	<0.0001
	Mean±SD	6.710±0.552	8.522±1.033		
IVC DI	Range	12-15	15-23	-10.452	<0.0001
	Mean±SD	12.571±1.013	17.340±1.731		

Table 9: Sensitivity, specificity of CVP for prediction of hypovolemia:

Cutoff point	Area under curve (AUC)	Std.Error	Sensitivity	Specificity	Asymptotic 95% Confidence Interval	
					Lower Bound	**Upper Bound**
7	0.979	0.017	96%	95.4%	0.946	1.000

Table 10: Sensitivity, specificity of IVC DI for prediction of hypovolemia:

Cutoff point	Area under curve (AUC)	Std.Error	Sensitivity	Specificity	Asymptotic 95% Confidence Interval	
					Lower Bound	**Upper Bound**
14.5	0.990	0.006	94%	100%	0.979	1.000

Table 11: Sensitivity ,specificity of CVP for prediction of fluid responsiveness:

Cutoff point	Area under curve (AUC)	Std.Error	Sensitivity	Specificity	Asymptotic 95% Confidence Interval	
					Lower Bound	Upper Bound
7	0.932	0.030	85.6%	95.2%	0.873	0.992

Table 12: Sensitivity ,specificity of IVC DI for prediction of fluid responsiveness:

Cutoff point	Area under curve	Std. Error	Sensitivity	Specificity	Asymptotic 95% Confidence Interval	
					Lower Bound	Upper Bound
13	0.990	0.008	100%	93.2%	0.974	1.000

DISCUSSION

Haemodynamic support for patients in shock is crucial to prevent worsening organ dysfunction, resuscitation should be started while the investigation to determine the cause is ongoing. Determination of intravascular volume status in patients admitted to the ICU is critical. An accurate diagnosis of shock state can be challenging because physical signs of hypovolemic, distributive, cardiogenic and obstructive shock frequently overlap[14].

Fluid resuscitation is the basic therapy for some types of shocks, especially hypovolemic and septic shock. The aim of fluid resuscitation is to increase cardiac output to increase tissue perfusion. Unfortunately, cardiac output increases after fluid loading in only approximately 50% of patients[15]. Moreover, too much fluid infusion may lead to more fluid shift into extravascular space and result in organ edema and dysfunction[16]. A positive net fluid balance was also confirmed to be associated with mortality[17]. Therefore, it is necessary to evaluate fluid responsiveness before fluid resuscitation.

The IVC has the largest diameter of the entire venous system; it is a thin-walled, valveless, retroperitoneal vessel, responsible for returning large volumes of deoxygenated blood from the lower extremities and abdomen to the right atrium. With 85% of total plasma volume in the venous circulation, the IVC is an important blood reservoir, and modifications of circulating volume result in IVC calibre variations. Indeed, evidence of a "flat vena cav" (e.g., an IVC with an anteroposterior diameter of less than 9mm) at multiple levels is associated with significant hypovolaemia in trauma patients[18]. Patient position and decubitus can influence circulating blood volume and IVC diameter by gravity: the IVC is smaller when the patient is in the left lateral position and larger when the patient is in the right lateral position[19].

In addition to circulating volume, other important factors can lead to variations in IVC diameter during the respiratory cycle, such as right heart function and the gradient between intrathoracic and intra-abdominal pressure. In recent years, the use of ultrasonography has become increasingly widespread in intensive care units. In this way, a non invasive, painless, cheap, easy, and objective method, specifically in adult patients, could be performed. One of the benefits of ultrasonography is to evaluate the volume status of patients with the help of inferior vena cava (IVC) (that receives all the blood from below the diaphragm) diameter and vena cava collapsibility index (the percentage decrease in IVC diameter with inspiration) measurements in the nonventilated spontaneously breathing patients[20].

Overall, a statistically significant non-linear correlation was described between the sonographic dimensional parameters of IVC and CVP[21]. Most studies demonstrated a moderate correlation between measurements of IVC diameter or collapsibility and CVP or RAP[22]. Cut-off values of 2cm diameter and cIVC of 40% provided the best diagnostic accuracy in predicting a RAP above or below 10mmHg[23-25]. According to the current updated American and European guidelines, an IVC diameter ≤2.1cm and collapsibility >50% during inspiration suggest a RAP between 0–5mmHg while a diameter >2.1cm with <50% inspiratory collapse indicates a high RAP of 10–20mmHg; a mean pressure value of 8mmHg is used if the clinical picture does not follow the proposed pattern[26].

However, opposite physiology occurs during positive pressure ventilation. During positive pressure ventilation, when the pressure outside the intrathoracic vessels exceeds the pressure inside, the intrathoracic parts of the IVC collapse, and the extrathoracic parts become distend. Then, the distensibility indices of IVC increase. In the inspiratory phase of positive pressure ventilation, pleural and right atrial pressures increase and venous return to the heart decreases. Thus, while the diameter of IVC increases during inspiration, it decreases during expiration. IVC-DI measures respiratory variations of the maximum and minimum IVC diameters. Therefore, the distensibility index of the IVC (IVC-DI) is used in patients with mechanical ventilation[27]. IVC-DI= [(maximum diameter–minimum diameter)/(minimum diameter)]×100%.

The Distensibility Index of Inferior Vena Cava (IVC DI) It is the amount of increase of vena cava diameter after inspiration on a mechanical ventilated patient. This increase will rise when preload is reduced and so can be used to know when a patient is volume responsive, it does not give CVP or the preload of the right heart, but only if it is responsive to more fluid or not. In controlled ventilation, the IVC expand in inspiration and reduces in expiration, this variation is abolished when Right Atrial Pressure (RAP) is high .The absence of IVC respiratory variation predict fluid unresponsiveness. Large variations of IVC accurately predicts fluid responsiveness[28].

The variability of IVC in mechanically ventilated patients is represented by IVC -DI and IVC distensibility variability (IVCdv)[29]. The use of variability of IVC in mechanically ventilated patients is recommended by the consensus on shock and hemodynamic monitoring of the European Society of Intensive Care Medicine as a dynamic measurement index of fluid responsiveness[30].

The main aim of this study was to assess the ultrasound guided central venous pressure versus inferior vena cava distensibility index in ventilated shocked patients simultaneously.

The main results of this study were as follows:

The current study included 50 patients, their age ranged between 40-70 years with mean value of 53.73±3.034 years, 36% were female and 64% were males.

The present study also showed that was no significant correlation between ages, HR, RR and BMI with CVP or IVC distensibility index.

This was consistent with Ibrahim *et al.,*[31]. who enrolled 67 critical ill patients with mean age of 42±14.51 years and predominance of males (65%) the study revealed that there was no significant association between age and sex and BMI with CVP or IVC distensibility index.

The present study also showed that there was statistically significant positive correlation between CVP and IVC distensibility index of the study population and the blood pressure.

In agreement with the present study Ibrahim *et al.,*[31] revealed that there was a statistical significance increase in SBP, DBP and mean ABP among cases that had CVP >10. However there was negative correlation between IVC distensibility index and SBP.

In concordance with present study Celik *et al.,*[32] revealed that there was significant association between IVC and distensibility index and SBP and Hb level.

In Agreement with the current study Yanagawa *et al.,*[33] confirmed this finding and found IVC distensibility index to correlate with hypovolemia and Hb level of trauma patients with class 3 and 4 shock states.

In agreement with present study Rahim -Taleghani *et al.,*[34] showed that there was significant correlation between CVP with PH and HCO_3 in patients with septic shock, the same results were reported by Baratloo *et al.,*[35].

Results were supported by Atallah *et al.,*[36] who revealed that there was significant association between CVP and fluid responsiveness.

In agreement with the current study Saber *et al.,*[37] showed that there was significant association between IVC-DI and fluid responsiveness in mechanically ventilated patients with septic shock.

In contrast with the current study El-Gazzar *et al.,*[38] revealed that there was no significant difference between fluid responsiveness subjects as regarding CVP and IVC-DI in mechanically ventilated patients after CABG, the disagreement may be due to difference in inclusion criteria.

In agreement with the current study Saber *et al.,*[37] 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 95.5% for predicting fluid responsiveness. Also at cutoff point 14.5 IVC DI has sensitivity of 85% and specificity for predicting fluid responsiveness.

According to Huang *et al.,*[39] had an AUC of 0.82 (95 percent confidence interval: 0.79-0.85), a sensitivity of 69% in mechanically ventilated shocked patients. ICV DI was proven to be a valid predictor of fluid responsiveness in critically patient with cutoff 18% differentiating responder from non-responder group.

Also, in agreement with the current study Akyıldız and Özsoylu[40] revealed that Inferior Vena cava distensibility index has higher sensitivity and specificity than pulse pressure variation for estimating intravascular volume, along with the advantage of non-invasive bedside application. A moderate positive correlation was found between pulse pressure variation and vena cava distensibility index (r= 0.475, p<0.01), while there were strong negative correlations of central venous pressure with pulse pressure variation and vena cava distensibility index (r= –0.628, p<0.001 and r= –0.760, p<0.001, respectively). In terms of predicting hypovolemia, the predictive power for vena cava distensibility index was >16% (sensitivity, 90.5%; specificity, 94.7%) and that for pulse pressure variation was >14% (sensitivity, 71.4%; specificity, 89.5%).

Saritas *et al.,*[41] revealed that ICV DI was the most effective at estimating intravascular volume. A sensitivity of 100% and specificity of 63% were identified for the group of patients under 0mmHg pressure support and 5mmHg positive end expiratory pressure (PEEP) while the group with 10mmHg pressure support and 5mmHg

PEEP presented 98% sensitivity and 68% specificity. Finally, an inversely proportional relationship was found between CVP and IVC DI, thus an IVC DI <18% was associated with a CVP >15cm H_2O which was found in hypervolemic state.

In the different result was reported by Vignon *et al.,*[42] of a sample of 319 patients with acute circulatory failure. The 13% IVC DI cutoff point showed a sensitivity of 44% and specificity of 85%. Compared to other predictive fluid responsiveness indices such as pulse pressure variations and respiratory variations in superior vena cava diameter, the IVC DI showed a lower predictive value than the others.

Mohmmad Abdelfattah *et al.,*[43] conducted that no statistically significant difference was observed between the predictive performance of pulse pressure variation (PPV) and IVC DI. findings indicate that the performance of PPV for predicting fluid responsiveness was similar to that of IVC DI. PPV and IVC DI are moderately predictive of fluid responsiveness. All shocked patients receiving mechanical ventilation requiring fluid challenge. Fluid responders were identified when cardiac output increased more than 15% after the first fluid challenge. Only the non-responders received a second fluid challenge (SFC) to define delayed responders. A total of 38 shocked patients were enrolled in this study. Twenty-one patients (55.3%) were fluid responders. The area under the receiver operating characteristic (AUROC) curve of PPV was 0.78^0.08 with a best cutoff of 10.5 (sensitivity: 76.2%; specificity: 70.6%). The AUROC curve of IVC DI was 0.75^0.07, and the best cutoff value to predict fluid responsiveness was 16.5% with a sensitivity of 71.43% and specificity of 76.5%.

In a meta-analysis, Si *et al.,*[44] suggested that IVC DI can be accurately used in mechanically ventilated patients, but may not be suitable in patients mechanically ventilated with a low TV or a high PEEP.

In contrast Yao B. *et al.,*[45] They revealed that Inferior Vena Cava Area Diameter Ratio (IVC DR) and Inferior Vena Cava Area Diameter Index (IVC ADI) had stronger diagnostic efficacy for predicting fluid responsiveness than Inferior Vena Cava Diameter Distensibility Index IVC-sx DDI and IVC-rm DDI in mechanically ventilated patients. The specificity of IVC DR in predicting fluid responsiveness was strong, but the sensitivity was weak. In contrast, the sensitivity of IVC ADI in predicting fluid responsiveness was strong, but the specificity was weak. Finally they conclude that the IVC area distensibility index and its diameter ratio in cross-section had more value than the IVC diameter distensibility index for predicting fluid responsiveness in mechanically ventilated patients. Thus, it still needs further research to confirm the value of IVC DI.

CONCLUSION

The use of ultrasound in the analysis of IVC indices IVC DI, beside CVP measurement is essential for rapid non-invasive diagnosis with good applicability in patient management. Finally Inferior vena cava distensibility index was found to be superior with higher accuracy than central venous pressure in predicting fluid responsiveness and hypovolemia among ventilated shocked patients. Further studies with large sample size and longer follow up are needed to confirm this study results.

CONFLICT OF INTERESTS

There are no conflicts of interest.

REFERENCES

1. Salmon AH., Satchell SC. (2017). Endothelial glycocalyx dysfunction in disease: Albuminuria and increased microvascular permeability. J Pathol 226:562–74, 2012. doi: 1. Taha M., Elbaih A. Pathophysiology and management of different types of shock. Narayana Med J. 6(1):14–39.

2. Citilcioglu S., Sebe A., Ay M.O., *et al.* (2014). The relationship between inferior vena cava diameter measured by bedside ultrasonography and central venous pressure value. Pakistan J Med Sci. 30(2): 310–315.

3. Seif D., Mailhot T., Perera P., *et al.* (2012). Caval sonography in shock: a noninvasive method for evaluating intravascular volume in critically ill patients. J Ultrasound Med. 31(12):1885–1890.

4. Marik P.E., Monnet X., Teboul J.L (2011). Hemodynamic parameters to guide fluid therapy. Ann Intensive Care. 21(1):1. 1.

5. Stawicki S.P., Kent A., Patil P., *et al.* (2015). Dynamic behavior of venous collapsibility and central venous pressure during standardized crystalloid bolus: a prospective, observational, pilot study. Int J Crit Illness Injury Sci. 5(2):80–84.

6. Stone M.B. and Huang J. (2013). Inferior vena cava assessment: correlation with CVP and plethora in tamponade. Glob Heart. 8(4):323–327.

7. Marik P.E., Baram M., Vahid B. (2008). Does central venous pressure predict fluid responsiveness? a systematic review of the literature and the tale of seven mares. Chest. 134(1):172–178.

8. Agarwal D., Soucy Z., Surana A., *et al.* (2012). Role of inferior vena cava diameter in assessment of

volume status: a meta-analysis. Am J Emerg Med. 30(8):1414–1419.

9. Izakovic M. (2008). Central venous pressure—evaluation, interpretation, monitoring, clinical implications. Bratislava Med J. 109(4):185–187.

10. Monnet X., Marik PE., Teboul JL. (2016). Prediction of fluid responsiveness: an update. Ann Intensive Care. 6:111.

11. Cecconi M., De Backer D., Antonelli M., Beale R., Bakker J., Hofer C., *et al.* (2014). Consensus on circulatory shock and hemodynamic monitoring. task force of the European society of intensive care medicine. Intensive Care Med. 40:1795–815.

12. Eskesen TG., Wetterslev M., Perner A. (2016). Systematic review including re-analyses of 1148 individual data sets of central venous pressure as a predictor of fluid responsiveness. Intensive Care Med. 42:324–32.

13. Gottlieb M., Hunter B. (2016). Utility of central venous pressure as a predictor of fluid responsiveness. Ann Emerg Med.68:114–6.

14. Seif D., Mailhot T., Perera P., Mandavia D. (2012). Caval sonography in shock: a non-invasive method for evaluating intravascular volume in critically ill patients. Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine, 31(12), 1885-1890.

15. Ansari BM., Zochios V., Falter F., Klein AA. (2016). Physiological controversies and methods used to determine fluid responsiveness: a qualitative systematic review. Anaesthesia. 71;1:94–105.

16. Cordemans C., De Laet I., Van Regenmortel N., Schoonheydt K., Dits H., Huber W., Malbrain ML. (2012). Fluid management in critically ill patients: the role of extravascular lung water, abdominal hypertension, capillary leak, and fluid balance. Ann Intensive Care 2 (Suppl 1):S1.

17. Boyd JH., Forbes J., Nakada TA., Walley KR., Russell JA. (2011). Fluid resuscitation in septic shock: a positive fluid balance and elevated central venous pressure are associated with increased mortality. Crit Care Med 39 2:259–265.

18. Jeffrey, RB., Federle MP. (1988). The Collapsed Inferior Vena Cava: CT Evidence of Hypovolemia. AJR Am. J. Roentgenol. 150, 431–432.

19. Nakao S., Come PC., McKay RG., Ransil BJ. (1987). Effects of Positional Changes on Inferior Vena Caval Size and Dynamics and Correlations with Right-Sided Cardiac Pressure. Am. J. Cardiol. 59,125–132.

20. Muller L., Bobbia X., Toumi M., Louart G., Molinari N. (2012). Respiratory variations of inferior vena cava diameter to predict fluid responsiveness in spontaneously breathing patients with acute circulatory failure: need for a cautious use. Critical Care .16.

21. Beigel R., Cercek B., Luo H., Siegel RJ. (2013). Noninvasive Evaluation of Right Atrial Pressure. J. Am. Soc. Echocardiogr. 26, 1033–1042.

22. Ciozda W., Kedan I., Kehl DW., Zimmer R., Khandwalla R., Kimchi A. (2016). The Efficacy of Sonographic Measurement of Inferior Vena Cava Diameter as an Estimate of Central Venous Pressure. Cardiovasc Ultrasound, 14, 33.

23. Moreno FL., Hagan AD., Holmen JR., Pryor TA., Strickland RD., Castle CH. (1984). Evaluation of Size and Dynamics of the Inferior Vena Cava as an Index of Right-Sided Cardiac Function. Am. J. Cardiol. 53, 579–585.

24. Lang RM., Bierig M., Devereux RB., Flachskampf FA., Foster E., Pellikka PA., Picard MH., Roman MJ., Seward J., Shanewise JS. *et al.* (2005). Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology. J. Am. Soc. Echocardiogr. 18, 1440–1463.

25. Brennan JM., Blair JE., Goonewardena S., Ronan A., Shah D., Vasaiwala S., Kirkpatrick JN., Spencer KT. (2007). Reappraisal of the Use of Inferior Vena Cava for Estimating Right Atrial Pressure. J. Am. Soc. Echocardiogr. 20, 857–861.

26. Lang RM., Badano LP., Mor-Avi V., Afilalo J., Armstrong A., Ernande L., Flachskampf FA., Foster E., Goldstein SA., Kuznetsova T. *et al.* (2015). Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J. Am. Soc. Echocardiogr. 28, 1–39.

27. Cavallaro F., Sandroni C., Antonelli M. (2008). Functional hemodynamic monitoring and dynamic indices of fluid responsiveness. Minerva Anestesiologica. 74:123–135.

28. Long E., Oakley E., Duke T., Babl FE. (2017).Dose respiratory variation in inferior vena cava diameter predict fluid responsiveness: a systemic review and meta-analysis? Shock: Injury, Inflammation, and Sepsis: Labotatory and Clinical Approaches, 47(5), pp.550-559.

29. Basu S., Sharron M., Herrera N., Mize M., Cohen J. (2020). Point-of-care ultrasound assessment of the inferior vena cava in mechanically ventilated critically Ill children. J Ultrasound Med. 39(8):1573-9.

30. Cecconi M., De Backer D., Antonelli M., Beale R., Bakker J., Hofer C., *et al.* (2014). Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine. Intensive Care Med. 2014;40(12): 1795-815.

31. Ibrahim AE., Ahmed FM., Ahmed FI., Farid DM. (2022). Central venous pressure versus internal jugular vein or inferior vena cava collapsibility indices to predict fluid status in critically ill patients. The Egyptian Journal of Hospital In Medicine, 89(1), 4416-4422.

32. Celik OF., Akoglu H., Celik A., Asadov R., Onur OE., Denizbasi A. (2018). Initial inferior vena cava and aorta diameter parameters measured by ultrasonography or computed tomography doesn't correlate with vital signs, haemorrhage or shock markers in trauma 5Tpatients. Ulus Travma Acil Cerrahi Derg, 24(4), 351-358.

33. Yanagawa Y., Nishi K., Sakamoto T., Okada Y. (2005). Early diagnosis of hypovolemic shock by sonographic measurement of IVC trauma patients. Journal of Trauma and Acute Care Surgery, 58(4), 825-829.

34. Rahim- Taleghani S., Fatemi A., Moghaddam MA., Shojaee M., Abushouk AI., FForouzanfar MM., Baratloo A. (2017). Correlation of CVP with venous blood gas analysis parameters; a diagnostic study. Turkish Journal of Emergency medicine, 17(1), 7-11.

35. Baratloo A., Rahmati F., Rouhipour A., Motamedi M., Gheytaanchi E., Amini F., Safari, S. (2014). Correlation of blood gas parameters with CVP in patients with septic shock; a pilot study Bulletin of emergency and trauma, 2(2), 77-81.

36. Atallah HA., Gaballah KM., Khattab AN. (2019). Fluid responsiveness in hemodynamically unstable patients: a systemic review. Menoufia Medical Journal, 32(2), 397.

37. Saber HM., ElMaraghil SK., Naguib MK., Abd-Elbaset AS., Elkholy MB. (2022). Respirophasic carotid basic peak systolic velocity variation as a predictor of Volume Responsiveness in mechanically ventilated patients with septic shock. Egyptian Journal of Critical Care Medicine, 9(2), 35-39.

38. El-Gazzar M., Soubih A., Sanad O., Rashid H., El Nahhas A. (2022). The sonographic measurement of inferior Vena Cava diameter versus the central venous pressure in assessing fluid responsiveness in patients after Coronary Artery Bypass Graft. The Egyptian Cardiothoracic Surgeon, 4(3), 51-57.

39. Huang H., Shen Q., Liu Y., Xu H., Fang Y., (2018). Value of variation index of inferior vena cava diameter in predicting fluid responsiveness in patients with circulatory shock receiving mechanical ventilation: a systemic review and meta analysis. Critical Care, 22(1), 1-7.

40. Akyıldız B., Özsoylu S.(2022). Comparison of vena cava distensibility index and pulse pressure variation for the evaluation of intravascular volume in critically ill children Jornal de Pediatria, page 99-103.

41. Saritaş A., Zincircioglu Ç., Uzun Saritaş P., Uzun U., Köse I., Senoglu N. (2019). Comparison of inferior vena cava collapsibility, distensibility, and delta indices at different positive pressure supports and prediction values of indices for intravascular volume status. Turk J Med Sci. 49:1170–8.

42. Vignon P., Repessé X., Bégot E., Léger J., Jacob C., Bouferrache K., *et al.* (2017). Comparison of echocardiographic indices used to predict fluid responsiveness in ventilated patients. Am J Respir Crit Care Med.; 195(8):1022-32.

43. Abdelfattah, Mohiedden MW., Elgammal SS., Elsayed KM. (2020). Distensibility Index of Inferior Vena Cava and Pulse Pressure Variation as Predictors of Fluid Responsiveness in Mechanically Ventilated Shocked Patients, May 2020. Journal of Emergency Medicine Trauma and Acute Care (1).

44. Si X., Song X., Lin Q., Nie Y., Zhang G., Xu H., Chen M., Wu J., Guan X. (2020). Does End-Expiratory Occlusion Test Predict Fluid Responsiveness in Mechanically Ventilated Patients? A Systematic Review and Meta–Analysis. Shock, 54, 751–760.

45. Yao B., Liu JY., Sun YB., Zhao YX Li LD. (2019). The value of the inferior vena cava area distensibility index and its diameter ratio for predicting fluid responsiveness in mechanically ventilated patients. Shock. 52:37–42.