Al-Azhar International Medical Journal

Volume 3 | Issue 2 Article 22

2-1-2022

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Muhammad Mahrous
Department of anaesthesia and intensive care, Faculty of Medicine, Alazhar University, Cairo, Egypt, mme32020@gmail.com

Anwar Al Hassanin
Department Anesthesiology and Intensive Care Faculty of Medicine, Al-Azhar University, Cairo, Egypt., anwaralhassanin@gmail.com

Mostafa Sabra
Department Anesthesiology and Intensive Care Faculty of Medicine, Al-Azhar University, Cairo, Egypt., moesabra7@gmail.com

How to Cite This Article

Mahrous, Muhammad; Al Hassanin, Anwar; and Sabra, Mostafa (2022) "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*: Vol. 3: Iss. 2, Article 22.
DOI: https://doi.org/10.21608/aimj.2022.101213.1611

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

Muhammad Mahmoud Mahrous[1,*] M.B.B.Ch, Anwar Mohamed Al Hassanin[1] MD. and Mostafa Mohamed Sabra[1] MD.

** Corresponding Author:*
Muhammad Mahmoud Mahrous
mme32020@gmail.com

Received *for publication November 02, 2021;* ***Accepted*** *Februrary 22, 2022;* ***Published online*** *Februrary 22, 2022.*

doi: 10.21608/aimj.2022.101213.1611

[1]Department of Anesthesiology and Intensive Care, Faculty of Medicine, Al-Azhar University, Cairo, Egypt.

ABSTRACT

Background: In the intensive care unit, making decisions about fluid treatment is one of the most difficult tasks that physicians encounter on an everyday basis. Nearly all physicians concur that hypovolemia and volume overload both raise morbidity and mortality. Increasing preload, or stressed venous volume is the therapeutic goal of fluid administration, which leads to a higher stroke volume and cardiac output.
Aim of the work: The purpose of this research was to see if there was a relationship between measurements of central venous pressure (CVP) and ultrasound measurements of the inferior vena cava collapsibility index (IVC CI), in the assessment of intravascular volume status in ventilated septic shock patients.
Patients and Methods: Following approval from the Al-Azhar University Ethical Committee, 60 patients aged 20 to 60 years old, both sex, who had been admitted to the ICU of Al-Azhar University hospitals with already inserted central venous catheter(CVC) for appropriate indication took part in a single blinded correlational study. Continuous monitoring of hemodynamic parameters was carried out. Ultrasound guided IVC CI was assessed when patients were lying down, then CVP measurements were taken. Signs of hypovolemia, such as tachycardia, hypotension, and acidosis, were assessed clinically.
Result: In our study group, CVP and IVC-CI had a highly statistically significant negative correlation (p-value<0.001).
Conclusion: In ventilated, crucially sick patients with septic shock, ultrasound guided measurements of IVC-CI can be utilized as a non-invasive, quick, and simple adjuvant procedure for assessing intravascular volume and guiding fluid responsiveness.

Keywords: *Inferior vena cava; collapsibility index; central venous pressure; septic shock.*

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*
Authorship: *All authors have a substantial contribution to the article.*

INTRODUCTION

Sepsis is potentially fatal organ dysfunction induced by an unbalanced host response to an infection, and septic shock is a subset of sepsis in which profound circulatory, cellular, and metabolic anomalies are related to a higher risk of death than sepsis alone.[1]

Whereas guidelines are a beautiful method, there are still several challenges in the therapy of septic shock patients. These involve problems with hemodynamic aims and treatments, as well as difficulties in implementing the recommended therapies.[2]

Physical examination, central venous pressure (CVP)measurement, biochemical parameters, vascular pedicle width estimation, pulmonary artery catheters, inferior vena cava (IVC) diameter evaluation by ultrasound, and different catheter equipment are all used to estimate volume status.[3]

Central venous catheters have a good sort of uses like hemodynamic monitoring, drug administration, total parenteral nutrition, trans-venous pacemaker placement, pulmonary artery catheterization etc. The central venous pressure may be a static measure of volume.[4]

This method has been followed extensively to assess the volume status and thereby treating the patient accordingly. Central venous catheter insertion is contraindicated in varient situations as any coagulation disorders, infection over the insertion site etc. There are reports of the many complications with a central venous catheter e.g. infections, accidental arterial puncture, hematoma, hemothorax, pneumothorax, air embolism, dysrhythmias.[4]

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's a secure technique and it is also relatively cheap. 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.[5]

The IVC adapts to the body's volume condition by modifying its diameter based on total body fluid volume inside the mechanically ventilated patient. The IVC distends with insufflation as enhanced intrathoracic pressure results in higher RV afterload and a transient boost in pulmonary artery pressure with a whole net reduction in venous return.[6]

In medical care settings, bedside ultrasonography is becoming more widely available. It's non-invasive, inexpensive, and safe. IVC measurement guided by ultrasound may be a tool for determining preload and, thus, the need for fluid resuscitation in a quick and non-invasive way.[7]

In critical care settings, this non-invasive, quick measurement of IVC is particularly important. It could be used to distinguish between hypovolemic, septic, and cardiogenic shock. Changes in IVC diameter will represent changes in volume status.[8]

The main aim of the study was to find a correlation, if any, between ultrasound guided measurement of the IVC-CI to CVP in ventilated patients with septic shock.

PATIENTS AND METHODS

This study was conducted from December 2019 to September 2021.The research included 60 patients of both sex who were admitted to the intensive care units (ICUs) of Al-Azhar University hospitals after receiving Al-Azhar University's Ethical Committee's approval and informed consent was taken from patient guardians (first-degree relatives.) , had a functioning central venous catheter inputted for any clinical indication, septic shock, hypotensive patients (mean arterial blood pressure < 65 mmHg or systolic blood pressure < 90 mm Hg) and mechanically ventilated, ventilation mode was standardized using volume-controlled ventilation with a tidal volume of 8ml/kg, a respiratory rate of 12 breaths per minute with no positive end expiratory pressure (PEEP).

Patient's refusal, patients with poor echo window, patients with severe pulmonary hypertension/tricuspid regurgitation, patients with valvular heart disease, patients with increased intra-abdominal pressure, post abdominal surgery, technically difficult ultrasound like morbid obesity were excluded from the study.

All patients included in the study were evaluated by: Patients′ demographic information (age, sex, height, and body weight), a thorough medical and surgical history, a thorough clinical examination(blood pressure, heart rate and capillary refill time), routine laboratory tests as arterial blood gases (ABG).

Standard monitoring was applied, including non-invasive arterial blood pressure, electrocardiography (ECG) and pulse oximetry using the multichannel monitor, and basal readings were taken (blood pressure, heart rate and capillary refill time) at first. The patient placed in the supine position. Then, just below the xiphoid process, a low-frequency (3.5-5 MHz) probe positioned longitudinally with the probe marker towards the patient's head.

Sometimes movement of the probe 1-2 cm to patients right and tilting to heart for a better view. Here we found the IVC was going to enter the right atrium and assessed the changes in IVC diameter during respiration visually. Then M mode switched to and put the pointer in IVC 2-3 cm from where it entered the right atrium. All the measurements were taken in M mode after freezing the ultrasound and using the calliper to measure maximum and minimum diameter. A team of two ICU doctors and an assistant nurse took all the readings. This team sought specialized radiologists to train them in the use of bedside ultrasonography. Mechanically ventilated patients due to positive pressure ventilation during inspiration IVC expands and in expiration IVC collapses. So, we measured in M mode the maximum and minimum diameter of IVC and calculated inferior vena cava collapsibility index or caval index.

$$\text{Collapsibility Index (IVC} - \text{CI)} = \frac{\text{Maximum Diameter} - \text{Minimum Diameter}}{\text{Maximum diameter}}$$

Immediately, CVPs were recorded concomitantly at phlebostatic points with the same team using the manometer method. Three readings were taken and mean of three readings was taken for each patient. So the data recorded were inferior vena cava collapsibility index guided by ultrasound imaging and central venous pressure using the manometer method.

Sample size calculation: 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 Moharam et al, the correlation of inferior vena cava diameter and collapsibility index with central venous pressure in shocked patients was -0.9.[9] Considering a confidence level of 95%, and a power of 80%, the representative sample should be at least 60 patients in the study group.

Statistical analysis:

The statistical package for social sciences, version 23.0, has been utilized to analyze the data that has been collected (SPSS Inc., Chicago, Illinois, USA). When the distribution of the quantitative data was parametric (normal), it was presented as mean ± standard deviation, and ranges, while non-normally distributed variables (non-parametric data) have been represented as median with interquartile range (IQR). To present qualitative variables, numbers and percentages have also been used. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check for normality.

<u>The following tests were done:</u>

Spearman's rank correlation coefficient (rs) has been utilized to evaluate the extent of association between 2 sets of variables when one or both are skewed.

The value of "r" varies between -1 and 1 0 = indicates that there is no linear correlation

1=perfect positive correlation -1=perfect negative correlation

Positive = When the independent variable increases, the dependent variable increases as well.

Negative= When the independent variable increases, the dependent variable decreases.

Scatter plot: a graph in which the two variables' values can be plotted along two axes, with the pattern of the resulting points indicating the presence of correlation.

The confidence interval was established at 95%, and the acceptable margin of error was established at 5%. As a result, the following p-value has been regarded as significant:

Probability (P-value)

P-value $\leq$0.05 has been regarded as significant.
P-value $\leq$0.001 has been regarded as highly significant.

P-value >0.05 has been regarded as insignificant.

RESULTS

The study has been conducted on a wide age group ranging from 33 to 59 years old (mean age of 50.10±6.02 years). With a men-to-women ratio of roughly 2.3:1, there was a male predominance. The range of weight was 57–94kg and mean±SD was 75.45±9.27kg; while range of height was 153–187cm and mean±SD was 170.18±7.91cmand range of body mass index(BMI) [wt/(ht)^2] was 19.3–36.5kg/$m^2$and mean±SD was 26.14±3.59kg/m^2, as displayed in table 2.

Source of infection	Total (n=60)
Respiratory tract	21(35%)
Urinary tract	15(25%)
Gastro intestinal tract	11(18.3%)
Hematogenous	8(13.3%)
Others	5(8.3%)

Table 1: Source of infection in the study group (n=60).

Patient demographics	Total (n=60)
Sex	
Female	18 (30%)
Male	42 (70%)
Age (years)	
Range	33–59
Mean±SD	50.10±6.02
Weight (kg)	
Range	57–94
Mean±SD	75.45±9.27
Height (cm)	
Range	153–187
Mean±SD	170.18±7.91
BMI [wt/(ht)^2](kg/m^2)	
Range	19.3–36.5
Mean±SD	26.14±3.59

BMI=Body mass index

Table 2: Patient demographics among study group (n=60).

Mean BP=Mean blood pressure, S.Lactate= serum Lactate, ABG=Arterial blood gases

Baseline characteristics	Total (n=60)
Mean BP(mmHg)	
Range	47-68
Mean±SD	59.98±5.03
Heart rate (bpm)	
Range	86–123
Mean±SD	103.08±9.42
Capillary refilling (sec.)	
Range	2–6
Mean±SD	3.57±1.2
PH in ABG	
Range	7.03–7.33
Mean±SD	7.21±0.068
PCO2(mmHg) in ABG	
Range	21–41
Mean±SD	28.67±4.86
HCO3(mEq/L) in ABG	
Range	6-19
Mean±SD	11.95±2.79
S.Lactate(mmol/l)	
Range	2.1-8.2
Mean±SD	4.56±1.48

Table 3: Baseline clinical and laboratory data of the study group (n=60).

	Total (n=60)
CVP(CmH_2O)	
Range	-1–14
Mean±SD	6.12±3.30
IVC-CI	
Range	0.06–0.86
Mean±SD	0.43±0.21

Table 4: CVP and IVC-CI descriptive among study group (n=60).

All patients		CVP	IVC-CI
CVP	Correlation Coefficient		-.686**
	Sig. (2-tailed)		<0.001
	N		60
IVC-CI	Correlation Coefficient	-.686**	
	Sig. (2-tailed)	<0.001	
	N	60	

**Highly statistical significant correlation (p<0.001). Using: Spearman's rho Coefficient

Table 5: presented that the relationship between CVP and IVC-CI was highly statistically significant among the study group. It shows that CVP and IVC-CI have a negative relationship (p-value<0.001).

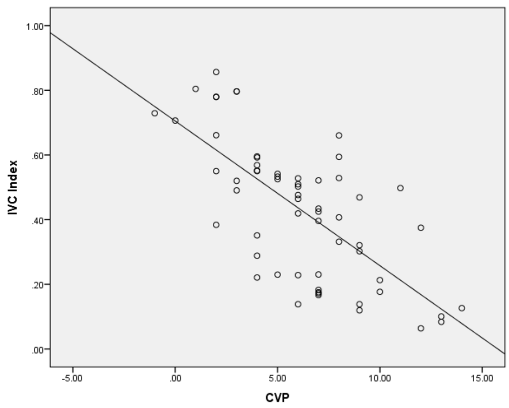

Fig. 1: Scatter plot, significant negative relationship between CVP with IVC-CI among study group.

DISCUSSION

One of the most difficult diagnosing issues that physicians face on an everyday basis is assessing intravascular volume status. In both populations, errors during this evaluation may result in unsuitable treatment and possibly worse results. The history and physical investigation is a mainstay of the acute, fast diagnosing evaluation of volume status, because clinical experiences are often so helpful within the primary patients' work-up.Few clinicians, however, would argue that extra diagnostic tests are necessary to confirm or refute clinical evaluations.[10]

The prognosis of hypovolemia is frequently aided by clinical symptoms as well as laboratory or blood gas data. To estimate cardiac preload and guide fluid treatment, hemodynamic parameters like cardiac filling pressures as well as static volumetric preload parameters are used.[11]

In the prognosis of hypovolemia and fluid ability to respond so-called dynamic hemodynamic parameters like stroke volume varianceas well as pulse pressure variance have recently been discovered to be more accurate. A rise of 10% to 13% in stroke volume is usually cited as expected fluid responsiveness.[12]

CVP monitoring is an anchor of guessing vascular fluid status and cardiac preload in septic patients. This practice, on the other hand, is invasive and not without risks and side effects. As a result, there's a requirement for trustworthy non-invasive modalities of assessment of volume status, which can be relatively safer and barren of all the above complications.[13]

IVC diameter and collapsibility are another straightforward and beneficial technique for evaluating intravascular volume.[14]The IVC may be a high-capacity vessel which distends and collapses. Soit's conveniently collapsible and features a smaller diameter when the volume is depleted.[15]When fluid is replaced, the collapsibility decreases, and the diameter rises. In the presence of fluid overload, IVC diameter rises and vein collapsibility decreases. Decreased or increased collapsibility of the vessel will aid physicians and specialists in helping guide clinical management of the patient, and such modification in volume status will be detected in IVC assessment by ultrasound. For sonographic assessment of the IVC, various strategies are used; we utilized the subxiphoid strategy because of its simplicity and reliability. Several studies have shown that the highest diameter of the IVC and its collapsibility can be used to estimate CVP and can be a good alternative for further invasive investigations.[16]In intravascular volume overload states, the percentage of vessel collapse is higher than in low intravascular volume states. The IVC collapsibility index is frequently used to quantify this.

Using simple bedside ultrasound view, our research discovered a statistically significant relationship between IVC diameter and CVP (r =--.686; p<0.001). This indicated that a rise in CVP is followed by a reduction in CVI-CI.

Coen et al. utilized the variance of IVC diameter to make a decision on fluid resuscitation volume in a study of 47 septic shock patients. They administered 500 mL crystalloid boluses as required to achieve an IVC index of 30-50%, which has been identified as [(maximum IVC diameter-minimum IVC diameter)/maximum IVC diameter] ×100. In 92% of the instances, IVC measurement was possible, and more than one-third of the patients did not require a central venous catheter.[17]Shocked patients had a higher IVC index than non-shocked patients.[18]

Yanagawa et al. conducted a prospective study of 30 trauma cases and discovered that relative differences in IVC diameter can differentiate stable resuscitation responders from transient responders who develop repeated shocks.[19]Feissel et al. found similar outcomes in ventilated septic patients, confirming these outcomes.[20]

Another prospective study was carried out at a tertiary care academic center with a 24-bed medical care unit and a 14-bed anesthesia intensive care unit. In septic ventilated ICU sufferers, Schefold et al. discovered a statistically significant connection between inspiratory and expiratory IVC diameter and central venous pressure (p = 0.004 and p = 0.001, respectively), indicating that IVC diameter was highly associated with CVP.[21] This might be beneficial in preventing unneeded volume expansion in such ill patients. Kadhim and colleagues showed that ultrasound measurements of IVC-CI could be utilized to evaluate non-invasive volume status in ICU sufferers, and that IVC-CI and CVP seem to be closely related.[22]

In a recent comparative study to gauge the relationship between stroke volume variation (SVV) and inferior vena cava distensibility index (dIVC) as a measure of fluid responsiveness in mechanically ventilated hypotensive ICU patients, Kaur, Kaminder Bir, et al. showed a direct link between dIVC and SVV usage during a clinical setting of low blood pressure suspicious of being attributable to hypovolemia.[23]

In a prospective clinical study on twenty-three patients with acute hypotension associated with sepsis and mechanically ventilated, Barbier, Christophe, et al. found that changes in IVC diameter caused by respiratory changes are anexcellent predictor of fluid responsiveness in septic sufferers.[24]

Over the course of three months, Ilyas et al. studied quite a hundred adult medical ICU patients, 47 of whom were on mechanical ventilation. Patients with clinical symptoms of increased abdominal pressure, moderate to severe tricuspid regurgitation, CVP inserted for more than twenty-four hours, or patients for whom the supine position has been contraindicated have been excluded from participating in the study. They discovered a statistically significant negative linear association between the CVP and the IVC-CI ($r=-0.827$, $P<0.0005$).[3] These findings are in line with those of the current research.

In a prospective cross-sectional study of seventy patients in the medical ICU, Thanakitcharu suggested that the IVC-CI could offer helpful guidance for non-invasive intravascular volume condition evaluation of crucially sick patients. The majority of patients (80%) have been admitted to the ICU due to sepsis with hemodynamic instability.[25]

CONCLUSION

Measurements of Central venous pressure significantly correlated with inferior vena cava collapsibility index measurements by ultrasound in mechanically ventilated patients in intensive care units.

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