Journal of Medicine in Scientific Research

Volume 4 | Issue 1 Article 4

Subject Area: Anesthesia

The use of ultrasound indices to evaluate volume status and fluid responsiveness in patients with septic shock

Ashraf A. H. Mahmoud
National Heart Institute, ashraf_soliman@yahoo.com

Wael A. E. El Hakeem
National Heart Institute

Recommended Citation

H. Mahmoud, Ashraf A. and E. El Hakeem, Wael A. (2021) "The use of ultrasound indices to evaluate volume status and fluid responsiveness in patients with septic shock," *Journal of Medicine in Scientific Research*: Vol. 4: Iss. 1, Article 4.
DOI: https://doi.org/10.4103/JMISR.JMISR_39_20

The use of ultrasound indices to evaluate volume status and fluid responsiveness in patients with septic shock

Ashraf A.H. Mahmoud[a], Wael A.E. El Hakeem[b]

Departments of [a]Anesthesia and [b]Critical Care, National Heart Institute, Cairo, Egypt

Abstract

Objective

The purpose of this study is to assess the use of ultrasound indices to evaluate volume status and fluid responsiveness in patients with septic shock.

Patients and methods

A total of 40 successive patients aged above 40 years, with septic shock on admission to the ICU, were enrolled in the study, comprising 26 fluid responders and 14 fluid nonresponders.

Results

Regarding demographic data and other patient characteristics, no statistically significant difference between both the study groups was seen. Regard baseline hemodynamics data, there was no statistically significant difference between both groups. but after fluid bolus, there was a statistically significant difference between both groups. Regarding hemodynamics data. There was no significant difference between both groups regarding maximum inferior vena cava (IVC) diameter, whereas the minimum IVC diameter and internal jugular vein (IJV) area/common carotid artery area were significantly lower in the group of fluid responders compared with the nonresponder group. The caval index was significantly higher in the responder group compared with the nonresponder group, whereas there was no significant difference in the aspect ratio of the IJV between responder and nonresponder groups.

Conclusion

IVC diameter, caval index, IJV area, and IJV/common carotid artery area ratio are useful methods to predict fluid responsiveness in spontaneously breathing patients in septic shock.

Keywords: Fluid, ICU, septic shock, ultrasound

Introduction

Fluid therapy is the cornerstone of management of severe sepsis and septic shock, and adequate fluid resuscitation is recommended worldwide to improve prognosis. However, assessment of volume status and hence fluid responsiveness can sometimes be challenging to the critical care physician. Invasive hemodynamic monitoring of central venous pressure (CVP) is still considered in directing early resuscitative efforts. Unfortunately, there are limitations to the use of CVP. First, the pressure of central filling is not systematically available in the initial phase of shock, because a central venous catheter is not always available. Second, it has been clearly shown that static indices such as CVP do not accurately predict fluid responsiveness, except for value less than 5 mmHg. Therefore, the fluid challenge is often used to test fluid responsiveness. Approximately 50% of fluid challenges are not justified. This exposes patients to deleterious fluid overload [1].

Ultrasound examination has recently been used to provide information regarding responsiveness to fluids. Ultrasound has been introduced as a new substitute to the traditional invasive

Access this article online	
Quick Response Code:	**Website:** www.jmsr.eg.net
	DOI: 10.4103/JMISR.JMISR_39_20

Correspondence to: Ashraf A.H. Mahmoud, MD, Department of Anesthesia, National Heart Institute, Cairo, Egypt. Tel: +20 100 375 3851; E-mail: ashraf_soliman@yahoo.com

Submitted: 13-Mar-2020 **Revised:** 09-Apr-2020 **Accepted:** 18-May-2020 **Published:** 26-Feb-2021

How to cite this article: H. Mahmoud AA, E. El Hakeem WA. The use of ultrasound indices to evaluate volume status and fluid responsiveness in patients with septic shock. J Med Sci Res 2021;4:31-4.

methods, especially static dimensions. Inferior vena cava (IVC) collapsibility (>50%) during normal respiration was proved to be strongly associated with low CVP (<8 mmHg). Respiratory variation in the IVC diameter was used as a guide for fluid therapy in septic shock in both spontaneous breathing and mechanically ventilated patients [2].

Aim

This work aimed to detect the accuracy of ultrasound indices [caval index, subaortic velocity time index (VTI), and ratio between internal jugular vein (IJV) and common carotid artery (CCA)] in predicting fluid responsiveness in severe sepsis and septic shock spontaneously breathing patients in comparison with traditional CVP measurement.

Patients and methods

This study was held in the period of time from February 2018 to October 2019 after obtaining written informed consent from first degree relatives of patients. Inclusion criteria were as follows: 40 successive patients aged above 40 years, with septic shock [diagnosed as a systemic inflammatory response of infectious etiology complicated by circulatory failure in the form of mean arterial pressure (MAP) <65 mmHg or serum lactate >4 mmol/l] on admission to the ICU, were enrolled in the study. Exclusion criteria were as follows: patients with right-sided heart failure, patients with tricuspid\ valve lesion, and mechanically ventilated patients. Patients were managed according to early goal-directed therapy guidelines receiving 500 ml normal saline every 15 min till reaching the goals of initial resuscitation, which included the following targets:

(1) CVP: 8–12 mmHg.
(2) MAP more than or equal to 65 mmHg.
(3) Urine output of more than or equal to 0.5 ml/kg/h.
(4) Central venous (superior vena cava) more than or equal to 70%.
(5) The maximum volume allowed was 60 ml/kg.

The administration of norepinephrine was done if the MAP was less than 65 mmHg despite adequate volume resuscitation. Epinephrine was administered if the MAP was less than 65 mmHg, and norepinephrine dose reached 0.7 μg/kg/min. Red blood cell transfusion was done for patients with hemoglobin less than 7 g/dl to target hemoglobin of 7–9 g/dl. If ScVO2 less than 70% despite adequate resuscitation (MAP ≥ 65 mmHg), transfusion of packed red blood cells was required to achieve hematocrit 30%. All patients had an ultrasound examination before central venous catheter insertion. Ultrasound examination was done two times, using the 6–16 MHz probe, first on admission (T1), and the second time after 20 ml/kg crystalloid infusion (T2). Baseline measured IVC diameter, caval index, the ratio between IJV and CCA, and aspect ratio of IJV were recorded at T1. The change in all these parameters (caval index, the ratio between IJV and CCA, and the aspect ratio of the IJV and CCA) after the fluid bolus was also calculated. Participants were stratified into fluid responders (defined as patients in whom subaortic VTI was recorded by pulse waved Doppler on a five-chamber apical view increased >15% of the baseline value after resuscitation) and fluid nonresponders (defined as patients in whom VTI did not increase >15% after resuscitation). Both groups were compared regarding demographic data, length of ICU stay, and ultrasound indices, which were also compared upon inclusion in the study and after the fluid bolus.

Statistical analysis

Continuous data were expressed as mean (SD) and analyzed using the nonparametric Mann–Whitney test. Categorical data were expressed as frequency (percent) and analyzed using the c2 test. Linear correlations was tested using the Pearson rank method. A *P* value of less than 0.05 was considered statistically significant. Correlations of CVP and IVC minimum diameter, IVC collapsibility index, and IJV area were established. The software used was IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.

Results

A total of 40 successive patients aged above 40 years, with septic shock on admission to the ICU were enrolled in the study. Of them, 26 patients were fluid responders, and 14 patients were fluid nonresponders.

Demographic data and other patient characteristics

Regarding demographic data and other patient characteristics, there were no significant differences between both study groups (responders and nonresponders) (*P*>0.05) (Table 1).

Regarding hemodynamic data, there was no statistically significant difference between the two groups regarding all these data (*P*>0.05) (Table 2).

After fluid bolus, there was a significant difference between responders and nonresponders regarding heart rate (100 ± 12 and 115 ± 24, respectively) (*P* = 0.02). There was also a significant difference in mean blood pressure (MBP) (70.7 ± 4.6 and 62 ± 3.7, respectively) (*P* = 0.03) and systolic blood pressure (101 ± 5.5 and 80 ± 5.5, respectively) (*P* = 0.01). The hemodynamic targets of early goal-directed therapy (CVP >12 cmH2O, MBP ≥ 65 mmHg) were achieved in 20 (77%) patients in the responder group and two (15%) patients in the nonresponder group. Considering each target alone, the MBP target was achieved in 22 (85%) patients of the responder

Table 1: Demographic data and other patient characteristics

	Fluid responders	Fluid nonresponders	Value
Age (years)	8.5±16.4	2.4±13.8	0.42
APACHE II	7.3±6.6	5.1±6.2	0.48
Sex			
Male	1 (42)	(50)	0.12
Female	5 (58)	(50)	0.07
LOS (days)	0.3±2.1	0.7±2.3	0.6

Data are presented as mean±SD, *n* (%). APACHE, acute physiology, and chronic health evaluation score, LOS, length of ICU stay.

group compared with two (15%) patients in the nonresponder group (Table 3).

Ultrasound indices

There was no significant difference between responders and nonresponders regarding the maximum IVC diameter during the respiratory cycle as measured by ultrasound upon inclusion in the study, whereas the minimum IVC diameter was significantly lower in the group of fluid responders compared with the nonresponder group ($P = 0.00$). The caval index was significantly higher in the responder group compared with the nonresponder group.

Regarding IJV area/CCA area ratio, it was significantly lower in the group of fluid responders in comparison with the group of nonresponders ($P = 0.03$), whereas there was no significant difference in the aspect ratio of the IJV between responders and nonresponders ($P = 0.46$) (Tables 4 and 5).

Discussion

This study was designed to estimate the accuracy of newly introduced ultrasound indices, such as the IVC diameter, caval index, IJV aspect ratio, IJV area, and IJV area/CCA area ratio in predicting fluid responsiveness and directing fluid management in septic shock spontaneously breathing patients.

Regarding IVC diameters and caval index, the current evidence supports their value in mechanically ventilated patients, but their validity as predictors of fluid responsiveness in spontaneously breathing patients is still an area of debate and controversy [3]. Moreover, no sufficient data regarding patient outcomes are available to support the use of these parameters as alternatives of the usual CVP reading in early goal-directed therapy of severe sepsis [4].

All studies on measurements of IJV, such as IJV area, aspect ratio, and IJV/CCA area ratio, were aiming at the validation of these measurements as alternatives to the traditional invasively taken CVP value [5]. No study was performed to assess the validity of these measurements as predictors of fluid responsiveness in shocked patients. Fluid responsiveness was defined in this study as an increase in the VTI, as some studies did [6]. Other studies defined fluid responsiveness as an increase in cardiac index [5] or stroke volume index [7].

The results of this study showed that the minimum IVC diameter, caval index, IJV area, and the ratio IJV/CCA are good predictors of fluid responsiveness. These parameters were significantly different between the two groups of fluid responders and nonresponders. A minimum IVC diameter of 0.9 cm predicted fluid responsiveness with a sensitivity of 100% and specificity of 70%. A caval index of 35% had 92% sensitivity and 86% specificity. An IJV area of 0.9 cm2 and IJV/CCA ratio of 1.7 had a sensitivity of 85% in predicting fluid responders and a specificity of 70 and 62%, respectively. All these parameters were poorly correlated to CVP, which confirms that CVP is not an accurate measure to predict fluid responsiveness.

Table 2: Baseline hemodynamic data

	Fluid responders	Fluid nonresponders	Value
HR (b/min)	12±21	27±24	0.18
SBP (mmHg)	1.9±5.9	6±7.5	0.06
DBP (mmHg)	0.7±4.6	2.1±6	0.55
MBP (mmHg)	3.8±3.7	2.1±5.4	0.43
CVP (cmH_2O)	0.5±3.8	0.3±5.6	0.4

Data are presented as mean±SD. CVP, central venous pressure; DBP, diastolic blood pressure; HR, heart rate (b/min=beat/minute); MBP, mean blood pressure; SBP, systolic blood pressure.

Table 3: Hemodynamic data after the fluid bolus

	Fluid responders	Fluid nonresponders	Value
HR (b/min)	00±12	15±24	0.02
SBP (mmHg)	01±5.5	0±5.5	0.01
DBP (mmHg)	0.7±4.6	2±3.7	0.03
MBP (mmHg)	5.9±4.2	2.5±6.2	0.06
CVP (cmH_2O)	3±3.8	2±5.6	0.4

Data are presented as mean±SD. CVP, central venous pressure; DBP, diastolic blood pressure; HR, heart rate (b/min=beat/minute); MBP, mean blood pressure; SBP, systolic blood pressure.

Table 4: Baseline ultrasound indices

	Fluid responders	Fluid nonresponders	Value
IVC maximum diameter (cm)	0.4±0.5	0.7±0.3	0.22
IVC minimum diameter (cm)	0.6±0.4	0.3±0.3	0.00
Caval index (%)	7±18.2	4.5±11.8	0.00
ICV/CCA area	0.7±0.3	0.3±0.6	0.03
Aspect ratio of IJV	0.6±0.4	0.8±0.6	0.45
VTI	9.1±4	2.1±3.4	0.02

Data are presented as mean±SD. CCA, common carotid artery; IJV, internal jugular vein; IVC, inferior vena cava; VTI, velocity time index.

Table 5: Ultrasound indices after the fluid bolus

	Fluid responders	Fluid nonresponders	Value
IVC maximum diameter (cm)	0.1±0.5	0.9±0.4	0.22
IVC minimum diameter (cm)	0.3±0.4	0.4±0.2	0.23
Caval index (%)	2±16.2	2.5±11.8	0.35
ICV/CCA area	0.1±0.3	0.3±0.6	0.42
Aspect ratio of IJV	0.9±0.4	0.8±0.6	0.45
VTI	4.1±3.2	1.1±3.6	0.02

Data are presented as mean±SD. CCA, common carotid artery; IJV, internal jugular vein; IVC, inferior vena cava; VTI, velocity time index

These results support the fact that dynamic indices of fluid responsiveness are much better than static indices. This fact is explained physiologically by the following explanation: not all shocked patients are in the same position on the starling curve. So, when a change in left ventricular preload is made, and this is sensed as a change in cardiac output, this can predict fluid responsiveness better than a single reading of cardiac filling pressures such as CVP or PAoP. This change in preload can be made with the positive pressure of the ventilator or the negative pressure of the patient's respiratory effort.

These results are compatible with the substantial volume of literature that supports that CVP and other static parameters are poor predictors of fluid responsiveness. A systematic review of literature that included 24 studies and 803 patients showed that CVP is a poor predictor of fluid responsiveness [8].

This systematic review concluded that the diameter of IVC measured with ultrasonography is of great value in predicting fluid responsiveness, particularly in patients on controlled mechanical ventilation and those resuscitated with colloids [9]. The results of this study are in the same context, but the patients are all spontaneously breathing and resuscitated with crystalloids. Regarding the IJV area and aspect ratio, few studies tried to link these ultrasound-measured parameters to CVP reading through central venous catheter; however, no studies to the best of our knowledge reported the validity of these parameters in prediction of fluid responsiveness. Studies showed a good correlation between CVP and vertical height of IJV and IJV diameter [10]. These findings are different from the current study that showed the weak correlation between the IJV area and CVP. This difference might be attributed to the different type of patients (the patients of the current study are in severe sepsis and septic shock that differ from all the studies as mentioned earlier in which patients are either volunteers or patients in the emergency department without specification) and also might be because we measured different parameters than these studies. Future research is needed to correlate all these parameters together in a different type of patients [11].

The ratio between IJV and CCA (IJV/CCA ratio) was reported in a pilot study to be a useful indicator for CVP of pediatric burn patients. This differs from the current results; however, there are many differences. The ratio between IJV and CCA (IJV/CCA ratio) was reported in a pilot study to be a useful indicator for CVP of pediatric burn patients, which differs from the current results. However, there are many differences between the current study and the study as mentioned earlier. In the current study, the type of patients were patients in septic shock. Another difference was that the current study was mainly detecting the validity of the IJV/CCA ratio in detecting fluid responsiveness and not only correlating between this ratio and CVP. No study to the best of our knowledge correlated the change in any of the IVC or IJV measurements over time and change in cardiac output (whichever the method of its measurement). The results of this study showed that regarding the sensitive parameters in predicting fluid responsiveness (IJV area and caval index), when observed over time, the change in their values was poorly correlated to the change in VTI. This indicates that the absolute initial values of these parameters are much more important than the change in their values with resuscitation.

Conclusion

IVC diameter, caval index, IJV area, and IJV/CCA area ratio are useful methods to predict fluid responsiveness in spontaneously breathing patients in septic shock.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Dellinger RP, Levy MM, Carlet JM, Bion J, Parker MM, Jaeschke R, *et al*. Surviving Sepsis Campaign: international guideline for management of sever sepsis and septic shock. Crit Care Med 2008; 36:296–327.
2. Beaulieu Y, Marik PE. Bedside ultraongraphy in the ICU: part 1. Chest 2005; 104:368–373.
3. Marx G, Cope T, McCrossan L, Swaraj S, Cowan C, Mostafa SM, Wenstone R, Leuwer M. Assessing fluid responsiveness by stroke volume variation in mechanically ventilated patients with severe sepsis. Eur J Anaesthesiol 2004; 21:132–138.
4. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, *et al*. Surviving Sepsis Campaign: International Guidelines for Management of Severe Sepsis and Septic Shock: 2013. Crit Care Med 2013; 41:580–637.
5. Braunwald E, Sonnenblick EH, Ross J. Mechanisms of cardiac contraction and relaxation. In: Braunwald E, editor. Heart disease. Philadelphia: Saunders; 1998. 389–425.
6. Mandeville JC, Colebourn CL. Can trans-thoracic echocardiography be used to predict fluid responsiveness in the critically ill patient? A systematic review. Crit Care Res Pract 2012; 2012:123–132.
7. Nakao S, Come PC, McKay RG, Ransil BJ. Effects of positional changes on inferior vena caval size and dynamics and correlations with right-sided cardiac pressure. Am J Cardiol 1987; 59:125–132.
8. Barbier C, Loubieres Y, Schmit C, Hayon J, Ricome JL, Jardin F, Vieillard-Baron S. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. Intensive Care Med. 2004; 30:1740–1746.
9. Marik PE, Baram M, Vahid B. Does central venous pressure predict fluid responsiveness? Asystematic review of the literature and the tale of seven mares. Chest 2008; 134:172–178.
10. Siva B, Hunt A, Boudville N. The sensitivity and specificity of ultrasound estimation of central venous pressure using the internal jugular vein. J Crit Care 2012; 27:315–317.
11. Donahue SP, Wood JP, Patel BM, Quinn JV. Correlation of sonographic measurements of the internal jugular vein with central venous pressure. Am J Emerg Med 2009; 27:851–855.