ORIGINAL ARTICLE

Is there a relationship between the diameter of the inferior vena cava and hemodynamic parameters in critically ill patients?

SA Aydin, F Ozdemir, G Taskin, G Ocakoglu[1], H Yıldırım[2], O Koksal

Departments of Emergency and [1]Biostatistics, Faculty of Medicine, Uludag University, Bursa, [2]Department of Emergency, Kutahya Government Hospital, Kutahya, Turkey

Abstract

Introduction: The early detection of critically ill patients together with the rapid initiation of effective treatment in emergency departments(ED) increase the survival rates.

Aim: This study investigated whether a correlation exists between haemodynamic parameters of critically ill patients and the diameter of the inferior vena cava (IVC).

Materials and Methods: A cross-sectional study was performed included patients aged ≥ 18 years with an unstable haemodynamic and/or respiratory status who were referred to the ED for non-traumatic issues. IVC diameters were measured by ultrasound (US) and then central venous pressures (CVP) were measured. Anteroposterior (AP) and mediolateral (ML) diameters of the IVC, both in the inspirium (IAP, IML) and expirium (EAP, EML), were measured by US.

Results: 102 patients were evaluated with a median age of 59. The relationship between the diameters of IVC and CVP was evaluated and significant correlation was found in IAP, EAP according to CVP values ($p<0.001$). ROC analyses were performed and significant relationship was found between the EAP diameter with haemoglobin (Hmg), haemotocrit (Hct), and central venous oxygen saturation (ScvO2) and also significant correlation was detected between the IAP diameter and white blood cell (WBC).

Discussion: We detected significant correlation between the CVP and the IVC diameter in our study compatible with recent studies besides, significant correlation was found between the diameter of the IVC and CVP values as well as between the EAP diameter and Hmg, Hct, ScvO2 levels.

Conclusion: Measurement of IVC diameters, especially EAP may be useful at the monitoring of critically ill patients in ED.

Key words: Central venous pressures, critically ill patients, inferior vena cava

Date of Acceptance: 12-Apr-2015

Introduction

The early detection of critically ill-patients and a subsequent rapid initiation of effective treatment in emergency department (ED) increases the survival rates of these patients.[1,2] Of primary importance, respiratory or hemodynamic support should be used to stabilize their condition.[3,4] Invasive and noninvasive parameters have been used for the diagnosis, management, and follow-up of respiratory and hemodynamic stabilization.[4-6]

Address for correspondence:
Dr. SA Aydın,
Department of Emergency Medicine, Faculty of Medicine,
Uludag University, Gorukle 16049 Bursa, Turkey.
E-mail: akkose@uludag.edu.tr

Regardless of the cause of the patient's status, the blood/fluid volume of the patient is clearly of critical importance. Achievement of hemodynamic stabilization and treatment

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/1119-3077.163281

of shock usually require the administration of blood products, fluid and/or vasoactive agents. The volemic status of patients is estimated by the measurement of systolic blood pressure (SBP) via catheterization of the pulmonary arteries or central veins. Many recent studies have demonstrated correlations among the diameter of the inferior vena cava (IVC) measured by ultrasound, the volemic status of the patient, and the central venous pressure (CVP).[5-11]

This study was designed to investigate whether a correlation exists between the diameter of the IVC and laboratory findings and basic and advanced hemodynamic parameters used in the management of critically ill patients.

Materials and Methods

This was a cross-sectional study performed between December 01, 2013 and April 01, 2014. This study was performed in an ED of a university hospital. The study protocol was approved by the Ethics Committee of the Faculty of Medicine, Uludag University. This study included nontraumatic patients aged ≥18 years with SBP <100 mmHg, heart rate >100/min and/or breath rate >20/min with alert mental status, who arrived in the ED. The IVC diameters were measured using bedside ultrasound (BUS) and CVP were measured by means of central venous catheterization. All patients' demographic data laboratory parameters including hemoglobin (Hmg), hemotocrit (Hct), white blood cell (WBC) and hemodynamic parameters such as CVP, SBP, and heart rate were recorded. Advanced hemodynamic parameters as pH, base deficit (BD), levels of bicarbonate, lactate, and central venous oxygen saturation ($ScvO_2$) were also measured.

Ultrasonographic measurements

The anteroposterior and mediolateral diameters of the IVC, both in the inspirium (IAP, and IML) and expirium (EAP, and EML), were measured. Measurements of IVC diameters were performed by emergency medicine specialists who were experienced and certified in ultrasonographic applications. For the measurements, the SIUI Apogee 3.5 MHz abdominal probe was used. All of the BUS measurements were obtained with the patients in the supine position were repeated twice, and the average of the two measurements was used.

Inferior vena cava diameters were measured both in the subxiphoid sagittal as well as the subxiphoid transverse views. For the subxiphoid sagittal view, the transducer was placed in the subxiphoid region using the liver as the acoustic window to visualize the IVC at the level of its entry into the right atrium [Figure 1]. For the subxiphoid transverse view, the transducer was placed in the subxiphoid region using the liver as the acoustic window to visualize the IVC at the level of entry of the left renal vein into the IVC [Figure 2]. The distensibility index of the IVC was the ratio of IVC_{max} - IVC_{min}/IVC_{min} expressed as a percentage (dIVC%) (maximal end-expiratory IVC diameter − minimal end-inspiratory diameter IVC/ minimal end-inspiratory IVC diameter).

Statistical analysis

For continuous variables, descriptive statistics (median, minimum, and maximum) were used. For comparisons between hemodynamic values and IVC diameters, the Mann–Whitney U-test was used. Receiver operating characteristic (ROC) analysis was performed to determine cut-off values of the hemodynamic parameters estimated based on IVC diameters. The area under the ROC curve was calculated, together with related specificity and sensitivity values. Cut-off values were calculated in consideration of the Youden index criteria. Statistical evaluations were performed using SPSS version 20 (IBM Corp., Released 2011, IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA) and MedCalc 13.1 (MedCalc Software, Ostend, Belgium). A $P < 0.05$ was accepted as statistically significant.

Results

A total of 102 patients with a median age of 59 (range: 31–83 years) were evaluated in the study. Each measurement of the IVC diameter was compared with all of the hemodynamic parameters. First, correlations between IVC diameters and CVP values were investigated, and a difference was seen between IAP diameter groups relative to CVP levels ($P < 0.001$). In the group with an IAP ≥ 1.50 cm ($n = 35$), the median CVP value was 13 (1–27) cmH_2O while in the group with an IAP < 1.50 cm ($n = 67$), the median CVP value was 7 (0–25) cmH_2O.

In the group with an IML ≥1.50 cm ($n = 50$), the median CVP value was 10 (1–25) cmH_2O while in the IML <1.50 cm ($n = 52$) group, the median CVP value was 7 (0–27) cmH_2O and difference between IML diameter groups relative to CVP levels was not statistically

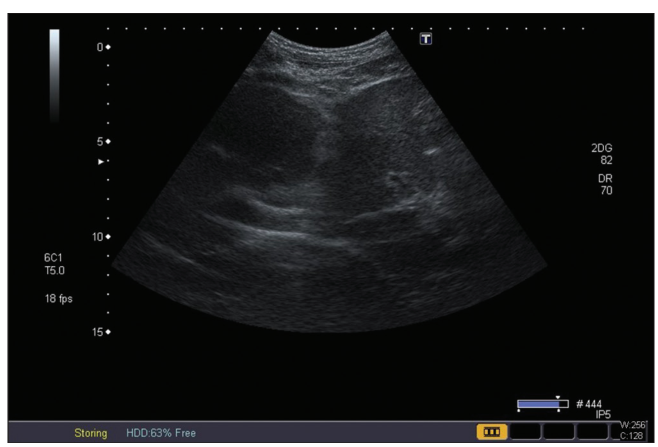

Figure 1: Subxiphoid sagittal view of inferior vena cava

Table 1: Results of ROC analysis for IAP, IML, EAP and EML

	Sensivity	Specifity	Cut-off value	AUC	*P*
IAP	76.12	52.94	≤12	0.67	<0.001*
IML	78.43	46.94	≤12	0.61	0.073
EAP	81.54	61.11	≤12	0.70	<0.001*
EML	77.27	42.86	≤12	0.58	0.172

*$P<0.001$. AUC=Area under ROC curve, IAP=Anteroposterior diameter of IVC (inspirium phase), IML=Mediolateral diameter of IVC (inspirium phase), EAP=Anteroposterior diameter of IVC (expirium phase), EML=Mediolateral diameter of IVC (expirium phase), IVC=Inferior vena cava

Table 2: Results of ROC analysis of some laboratory parameters

	Cut-off	*P*	AUC	Sensivity	Specifity
Hmg (EAP)	≤11.8	0.001*	0.71	100.00	42.35
Hct (EAP)	≤35	0.016*	0.66	94.12	44.71
$ScvO_2$ (EAP)	≤75	0.005*	0.66	82.21	57.14
WBC (IAP)	≤12.500	0.034*	0.62	67.31	57.14

*$P<0.05$. Hmg=Haemoglobin, Hct=Hematocrit, $ScvO_2$=Central venous oxygen saturation, WBC=White blood cell, EAP=Anteroposterior diameter of IVC (expirium phase), IAP=Anteroposterior diameter of IVC (inspirium phase), AUC=Area under ROC curve

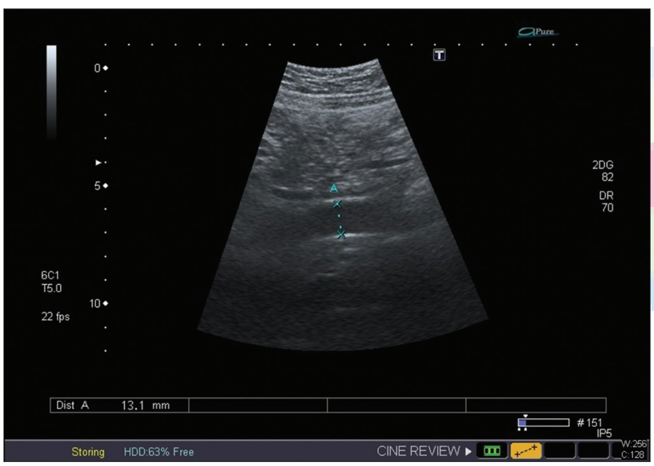

Figure 2: Subxiphoid transverse view of inferior vena cava

significant ($P = 0.070$). A significant difference was found between the EAP diameter groups for CVP levels ($P = 0.001$). In the group with an EAP ≥1.50 cm ($n = 37$), the median CVP value was 13 (1–27) cmH_2O whereas in the group with an EAP <1.50 cm ($n = 65$), the median CVP value was 7 (0–20) cmH_2O. A significant difference in CVP levels was not observed between the EML diameter groups ($P = 0.178$). In the group with an EML ≥1.50 cm ($n = 57$), the median CVP value was 10 (1–25) cmH_2O while in the group with an EML <1.50 cm ($n = 45$), the median CVP value was 7.5 (0–27) cmH_2O. An ROC analysis was performed to determine cut-off values of CVP and other haemodynamic parameters relative to IVC diameters. The area under the ROC curve was calculated together with sensitivity and specificity values. The ROC analysis in cases with a CVP ≤12 cmH_2O is summarized in Table 1.

We did not find significant correlation between all IVC diameters and basic and advanced hemodynamic parameters. On the other hand, significant correlations were detected at some of laboratory parameters related to IVC diameters. In cases with Hmg level ≤ 11.8 g/dL, the EAP was ≥ 1.50 cm with 100% sensitivity and 42.35% specificity. In cases with Hct ≤ 35, the EAP was ≥ 1.50 cm with 94.12% sensitivity and 44.71% specificity. In cases with $ScvO_2$ ≤ 75, the EAP was ≥ 1.50 cm with 82.21% sensitivity and 49.02% specificity. In cases with WBC ≤ 12.500, the IAP was ≥ 1.50 cm with 67.31% sensitivity and 57.14% specificity [Table 2]. We also did not find any significant correlation between dIVC% and hemodynamic parameters.

Discussion

As demonstrated in various investigations, IVC diameter is not affected by compensatory vasoconstriction, which is the body's response to hypovolemia. Therefore, it reflects the volemic status of the body better than other arterial parameters, such as BP, pulse rate, and aortic diameter.[5,8] Only a few studies have investigated correlations between the IVC diameter and hemodynamic parameters.[9,12,13] In one of these studies,[12] the IVC diameter was reported to be a better predictor than the pulse rate, and BP of acute blood loss. However, we have not encountered any study that compares the IVC diameter and pulse pressure in predicting estimated blood loss. In our study, all of the basic hemodynamic parameters, including pulse pressure, were compared and no significant correlations were found.

In recent years, the use of ultrasonographic measurement of the IVC diameter for evaluating volemic status and guide fluid resuscitation therapy in ED has gained popularity.[3,4,8,13] Many studies have focused on the relationship between the IVC diameter and fluid volume and contradictory results have been declared.[1,4,8,11,14,15] Volemic status of patients has been estimated via pressures calculated by means of catheterizations of the pulmonary artery or the central vein. Because measurement of pulmonary artery pressure is a challenging procedure, it is rarely used in ED and CVP measurement is more frequently preferred.[2,5] The CVP is a reliable parameter in the prediction of the volemic status of an organism in which there is normal myocardial function and an absence of any compression of the superior vena cava or occlusion of this vein.[5,8]

In recent years, an increasing number of studies have compared CVP and the IVC diameter. In some of these studies, a significant correlation was found between the CVP and the IVC diameter, most evaluated EAP, while some did not detect such a correlation.[1,3-5,8,9,11,14-16] We evaluated both inspirium and expirium measurements of IVC similar to study of Akilli *et al.*[12] and detected significant correlation between the CVP and the IVC diameter.

Various indicators that are accepted as advanced haemodynamic parameters, such as lactate and bicarbonate levels, BD, and pH, are widely used in the evaluation of shock. These indicators are enable in the early detection of hypoperfusion developing at the tissue level when vital signs are within normal limits.[2,5] Few studies have investigated the relationship between the diameter of the IVC and advanced hemodynamic and laboratory parameters.[9,12,13] In our study, no significant correlation was found between diameter of the IVC and advanced hemodynamic parameters. A significant correlation was detected only between the EAP diameter and Hmg, Hct and correlation between IAP and WBC levels was also statistically significant.

Mixed venous oxygen saturation ($SmvO_2$) and $ScvO_2$, have also been used to monitor critically ill patients and can indicate an early onset of hypoperfusion in the presence of normal vital signs.[2,17] Measurement of the $SmvO_2$ requires pulmonary artery catheterization. Because it is an expensive, complicated, and invasive procedure, pulmonary artery catheterization is not a procedure often performed in ED. Central venous catheterization is not as invasive as pulmonary artery catheterization, and it allows for measurement of the $ScvO_2$ and CVP. Due to similarities found in many studies between $ScvO_2$ and $SmvO_2$ values, measurement of the $ScvO_2$ has been more frequently preferred in ED.[2,17,18] This study is the first to compare IVC diameters and $ScvO_2$ values. A significant correlation was detected only between the EAP diameter and $ScvO_2$ levels.

As a result of analyses performed, a significant correlation was found between the diameters of the IVC and CVP values as well as between the EAP diameter with Hmg, Hct, $ScvO_2$ levels and IAP with WBC. It was presumed that if a strong correlation was found between IVC diameters and basic and advanced hemodynamic parameters, then the use of IVC diameter could be suggested as a hemodynamic parameter in critically ill patients. In conclusion, measurement of IVC diameters, especially EAP may be useful at the monitoring of critically ill patients in EDs.

References

1. Ng L, Khine H, Taragin BH, Avner JR, Ushay M, Nunez D. Does bedside sonographic measurement of the inferior vena cava diameter correlate with central venous pressure in the assessment of intravascular volume in children? Pediatr Emerg Care 2013;29:337-41.
2. Cabarias JG, Manning J. Fluid and blood resuscitation. In: Emergency Medicine: A Comprehensive Study Guide. 7th ed. New York: McGraw-Hill; 2010.
3. Thanakitcharu P, Charoenwut M, Siriwiwatanakul N. Inferior vena cava diameter and collapsibility index: A practical non-invasive evaluation of intravascular fluid volume in critically-ill patients. J Med Assoc Thai 2013;96 Suppl 3:S14-22.
4. Wiwatworapan W, Ratanajaratroj N, Sookananchai B. Correlation between inferior vena cava diameter and central venous pressure in critically ill patients. J Med Assoc Thai 2012;95:320-4.
5. Wilson M, Davis DP, Coimbra R. Diagnosis and monitoring of hemorrhagic shock during the initial resuscitation of multiple trauma patients: A review. J Emerg Med 2003;24:413-22.
6. Szopinski J, Kusza K, Semionow M. Microcirculatory responses to hypovolemic shock. J Trauma 2011;71:1779-88.
7. Yanagawa Y, Nishi K, Sakamoto T, Okada Y. Early diagnosis of hypovolemic shock by sonographic measurement of inferior vena cava in trauma patients. J Trauma 2005;58:825-9.
8. Dipti A, Soucy Z, Surana A, Chandra S. Role of inferior vena cava diameter in assessment of volume status: A meta-analysis. Am J Emerg Med 2012;30:1414-9.e1.
9. Nagdev AD, Merchant RC, Tirado-Gonzalez A, Sisson CA, Murphy MC. Emergency department bedside ultrasonographic measurement of the caval index for noninvasive determination of low central venous pressure. Ann Emerg Med 2010;55:290-5.
10. Schefold JC, Storm C, Bercker S, Pschowski R, Oppert M, Krüger A, *et al.* Inferior vena cava diameter correlates with invasive hemodynamic measures in mechanically ventilated intensive care unit patients with sepsis. J Emerg Med 2010;38:632-7.
11. Stawicki SP, Braslow BM, Panebianco NL, Kirkpatrick JN, Gracias VH, Hayden GE, *et al.* Intensivist use of hand-carried ultrasonography to measure IVC collapsibility in estimating intravascular volume status: Correlations with CVP. J Am Coll Surg 2009;209:55-61.
12. Akilli B, Bayir A, Kara F, Ak A, Cander B. Inferior vena cava diameter as a marker of early hemorrhagic shock: A comparative study. Ulus Travma Acil Cerrahi Derg 2010;16:113-8.
13. Corl K, Napoli AM, Gardiner F. Bedside sonographic measurement of the inferior vena cava caval index is a poor predictor of fluid responsiveness in emergency department patients. Emerg Med Australas 2012;24:534-9.
14. Juhl-Olsen P, Vistisen ST, Christiansen LK, Rasmussen LA, Frederiksen CA, Sloth E. Ultrasound of the inferior vena cava does not predict hemodynamic response to early hemorrhage. J Emerg Med 2013;45:592-7.
15. Walsh JT, Hildick-Smith DJ, Newell SA, Lowe MD, Satchithananda DK, Shapiro LM. Comparison of central venous and inferior vena caval pressures. Am J Cardiol 2000;85:518-20, A11.
16. De Lorenzo RA, Morris MJ, Williams JB, Haley TF, Straight TM, Holbrook-Emmons VL, *et al.* Does a simple bedside sonographic measurement of the inferior vena cava correlate to central venous pressure? J Emerg Med 2012;42:429-36.
17. The American College of Surgeons. Advanced Trauma Life Support for Doctors (ATLS), Student Course Manuel. 7th ed. Chicago: The American College of Surgeons; 2004.
18. Spahn DR, Cerny V, Coats TJ, Duranteau J, Fernández-Mondéjar E, Gordini G, *et al.* Management of bleeding following major trauma: A European guideline. Crit Care 2007;11:R17.

How to cite this article: Aydin S, Ozdemir F, Taskin G, Ocakoglu G, Yıldırım H, Koksal O. Is there a relationship between the diameter of the inferior vena cava and hemodynamic parameters in critically ill patients?. Niger J Clin Pract 2015;18:810-3.

Source of Support: Nil, **Conflict of Interest:** None declared.