Original Article

 Pak Armed Forces Med J 2015; 65(2): 235-38

CORRELATION OF INFERIOR VENA CAVA (IVC) DIAMETER AND CENTRAL VENOUS PRESSURE (CVP) FOR FLUID MONITORING IN ICU

Amir Khalil, Aslam Khan, Arshad Hayat

Military Hospital Rawalpindi

ABSTRACT

Objective: To determine intravascular fluid status in critically ill patients using inferior vena cava diameter and correlating it with central venous pressure.

Study Design: Cross sectional study.

Place and Duration of Study: Intensive care department, Military Hospital Rawalpindi from Jan 2013 to Aug 2013.

Material and Methods: We included 115 adult patients of both genders in age range of 18 to 87 years by consecutive sampling admitted in intensive care unit. Ultrasound guided IVC diameter was assessed in supine patients. Data was simultaneously collected from the CVP catheter. Variables included in study were age, gender, CVP, IVC diameter.

Results: CVP ranged from -4 to 26 cm H2O with mean of 8 cm H2O (SD = 6.24). Mean IVC diameters increased with increase in CVP. Correlation between CVP and max IVC diameter was moderate and significant ($r = 0.53$, $p < 0.001$). Correlation between CVP and min IVC diameter was also moderate and significant ($r = 0.58$, $p < 0.001$).

Conclusion: A simple bedside sonography of inferior vena cava diameter correlates well with extremes of CVP values and can be helpful in assessing intravascular fluid status in these patients.

Keywords: Central venous pressure, Inferior vena cava diameter, Ultrasonography.

INTRODUCTION

It is important for critical care physicians to address the hemodynamic status of critically ill patients for an appropriate guide to fluid therapy and inotropes[1]. Different techniques are employed for this purpose which include physical examination, central venous pressure (CVP) measurement, biochemical markers, estimate of the vascular pedicle width, pulmonary artery catheters, sonographic inferior vena cava (IVC) diameter assessment and various catheter devices[2] CVP measurements are the most frequently employed through estimation of the preload. However CVP measurement requires insertion of central venous catheters which can be costly, time consuming and can lead to complications.

Bedside ultrasonography is readily available in intensive care setups. It is safe, cheap and non-invasive. Ultrasound of inferior vena cava (IVC) is a tool that can provide a rapid and non-invasive means of gauging preload and the need for fluid resuscitation[3] Few studies in past have shown correlation between CVP and IVC measurements[4] This non invasive rapid measurement of CVP is especially important in critical care settings. It can help in differentiating hypovolemic, septic and cardiogenic shock. Changes in volume status will be depicted by change in the diameter of the IVC[5].

This study examined the correlation between CVP and the IVC diameter as measured by a bedside ultrasonographic technique.

PATIENTS AND METHODS

This cross sectional study was carried out in the department of critical care, Military Hospital Rawalpindi, from Jan 2013 to August 2013. Non-intubated Adult patients of both genders in age range of 18 to 87 years admitted in intensive care unit were included in the study who were able to breathe spontaneously and lie supine, already had CVP catheter (subclavian or internal jugular vein) in place. Patients less than 18 years of age, those with severe orthopnoea, unable to lie supine, marked obesity, pneumothorax, mediastinal masses, intra-cerebral bleed and tricuspid regurgitation

Correspondence: Dr Amir Khalil, Critical Care Medicine, MH Rawalpindi
Email: docamirkhalil@gmail.com
Received: 10 Feb 2014; Accepted: 24 Feb 2014

were excluded from study. One hundred and fifteen patients were included in the study through non-probability consecutive sampling. Informed written consent was taken from all patients or their attendants. We asked our patients to lie supine and used ultrasound machine to take ultrasound images of IVC diameter. A portable ultrasound machine with 17 mm curved probe and cardiac transducer for IVC imaging 1-5 MHz, 21 mm phase array was used. Subxiphoid approach was used to visualize IVC. We measured maximum anteroposterior diameter of IVC (IVCd-max) at end expiration just caudal to the confluence of the hepatic veins in longitudinal plane using M mode and leading edge technique (inner edge to inner edge of vessel wall). In addition minimum IVC diameter (IVCd-min) was measured at end inspiration during normal spontaneous breathing. All the readings were taken by team of two intensive care physicians and assistant nurse. This team had sought specialised training in use of bed side ultrasonography by specialist radiologists. Data was simultaneously collected from the CVP catheter. CVP measurement was done by same team of two intensive care physicians and assistant nurse using CVP manometer at midaxillary level with patient lying supine. Three readings were taken for each patient and mean of three readings was taken. We divided CVP values into three groups , less than 7 cmH2O, 7 to 15 cm H_2O, more than 15 cm H_2O. Patients were grouped on the basis for decision making in fluid management.

Data had been analyzed using SPSS version 18. Mean and standard deviation (SD) were calculated for quantitative variables. Frequency and percentages were calculated for qualitative variables. Pearson correlation coefficient was calculated to study relationship between CVP and IVC diameter. A *p*-value< .05 was considered as significant.

RESULTS

Total 115 patients were included in the study. Average age of patients was 52 ± 7.23 years with male to female ratio of 1.6:1. Sepsis was prevailing diagnosis in 41 (35.6%) patients, hypovolemic shock in 25 (21.7%) patients, renal failure in 18 (15.6%) patients, acute pulmonary oedema in 12 (10.4%) patients, acute respiratory distress syndrome in 6 (5.2%) patients, other causes in 13 (11.3%) patients. CVP ranged from -4 to 26 cm H_2O with mean of 8 cm H_2O (SD = 6.24). Maximum IVC diameter ranged from 7mm to 26 mm with mean of 14.5 mm (SD = 4.2) while minimum IVC diameter ranged from 3.7 mm to 18.5mm with mean of 10.3 mm (SD = 3.5). Mean IVC diameters significantly increased with increase in CVP as shown in figure. CVP was moderately correlated with max IVC diameter and min IVC diameter. Correlation coefficient between CVP and max IVC diameter was r = 0.53 ($p < 0.001$) and that of between CVP and min IVC diameter is r = 0.58 ($p < 0.001$). (Table).

DISCUSSION

In critically ill patients assessment of intravascular volume status is essential[5] It is required for diagnostic and therapeutic management of acute and chronic disorders in patients requiring intensive care. A variety of devices and parameters including CVP, pulmonary artery catheter, esophageal Doppler, arterial wave form analysis ,tissue Doppler and IVC ultrasonography are employed for this purpose[6]. The range of available tests employed reflects the fact that no single method is universally accepted or considered gold standard in all types of critically ill patients. Moreover, each test has its own limitations, risks like being less accurate, invasive , expensive, time consuming or operator dependent[7].

CVP catheters are among most commonly used for assessment of intravascular volume and for therapeutic fluid and drug administrations[8]. CVP has been, and often still is, used as a surrogate for preload, and changes in CVP in response to infusions of intravenous fluid have been used to predict volume-responsiveness (i.e. whether more fluid will improve cardiac output). However there is increasing evidence that CVP is not a true reflection of preload and doesn't correlate well with volume responsiveness and can lead to serious management problems and is even related to adverse patient outcome[9]. In addition, CVP catheterisation is invasive, expensive, time consuming and requires considerable expertise.

Another useful and simple method of assessing intravascular volume is by IVC diameter and collapsibility[10] IVC diameter can be assessed by use of bedside ultrasonography which is simple, cheap, less time consuming and readily available in most of emergency departments, intensive care units[11]. IVC is a high capacitance vessel that can distend and collapse. Thus, in volume depletion, it is easily collapsible and has a smaller diameter. With fluid replacement, the collapsibility reduces and the diameter increases. In fluid overload, IVC diameter increases and vein collapsibility reduces. These Changes in volume status will be detected in ultrasonographic evaluation of the IVC, where increased or decreased collapsibility of the vessel will help clinicians and intensivists in guiding clinical management of the patient. Different approaches are used for sonographic evaluation of IVC, we used subxiphoid approach based on its simplicity and reliability. Different studies have validated that maximum diameter of IVC and its collapsibility can give an estimate of CVP and prove to be a useful substitute for more invasive investigations[2]. In states of low intravascular volume, the percentage collapse of the vessel will be proportionally higher than in intravascular volume overload states. This is quantified by the calculation of the IVC collapsibility index. In addition , the liver or diaphragm may tend to tether the IVC in the "open" position in the most proximal portions. Valvular disease, particularly tricuspid dysfunction, and certain forms of right heart structural abnormalities are other important confounding conditions.

Our study has demonstrated that simple bedside ultrasound view can yield a statistically significant correlation between CVP and IVC diameter. These results are validated by studies across the globe supporting the correlation between CVP and IVC diameter[5,9,11,12]. Some of these studies, however, used complex imaging and measuring techniques such as formal transesophageal echocardiography, caval or collapsibility indices, and repeated reviews and multiple readings taken during the ventilatory cycle[12,13].

Table: Correlation between CVP and IVC diameter.

CVP cm H_2O	Correlation coefficient (r)	*p*- value
Max IVC diameter (mm)	0.53	< 0.001
Min IVC diameter (mm)	0.58	< 0.001

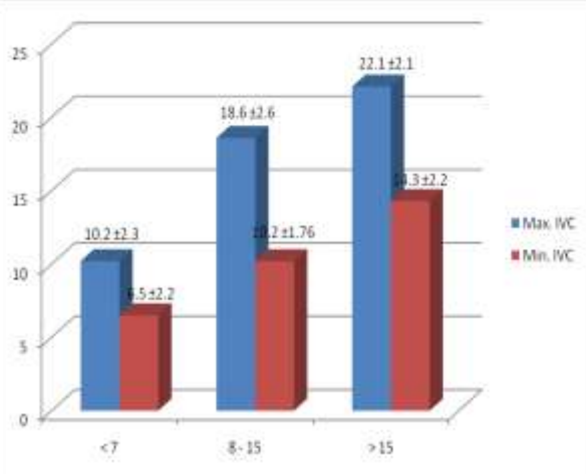

Figure: CVP and its corresponding IVC diameter values.

These Studies have reported *r* values in the 0.66–0.86 range for right atrial and IVC diameter correlations[5,9,11,13].

Yanagawa , validated the value of IVC indices in trauma patients presenting with hypovolemic shock[14]. Snead and colleagues showed significant correlation between IVC and CVP in ICU patients[15]. Vignon highlighted the potential value of this technique, but encouraged further study[16]. Nagdev et al. reported a 50% collapse of the IVC diameter during a respiratory cycle as being strongly associated with a low CVP[17]. Alternatively, a preliminary report by Gaspari et al. supports the conjecture that IVC respiratory collapse is not as good as diameter measurements in estimating fluid status[18]. Our study has few limitations , we didn't include patients on ventilatory support in our study, moreover most of our patients already had CVP in place for about 24 hours and were being managed on basis of CVP readings while we checked IVC dimensions. It is important to consider if a sonographically measured IVC accurately reflects CVP especially in the context of the limitations of imaging which is operator dependent. Moreover whether CVP is a useful guide to fluid status in a given patient.

CONCLUSION

Sonographically determined estimate of IVC may be valuable. A simple bedside sonography of inferior vena cava diameter correlate well with extremes of CVP values and can be helpful in assessing intravascular fluid status in these patients.

CONFLICT OF INTEREST

This study has no conflict of interest to declare by any author.

REFERENCES

1. Magder S. More respect for the CVP. Intensive Care Med 1998; 24: 651–53.
2. Durairaj L, Schmidt GA: Fluid therapy in resuscitated sepsis: Less is more. Chest 2008; 133: 252–63.
3. Demeria DD, MacDougall A, Spurek M. Comparison of clinical measurement of jugular venous pressure versus measured central venous pressure. Chest 2004; 126: 747.
4. National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network, Wheeler AP, Bernard GR, et al. Pulmonary-Artery verses central venous catheter to guide treatment of acute lung injury. N Engl J Med 2006;3 54: 2213–24.
5. Brennan JM, Blair JE,Goonewardena S. Reappraisal of the use of inferior vena cava for estimating right atrial pressure. J Am Soc Echocardiogr 2007; 20: 857–61.
6. Stawicki SP, Hoff WS, Cipolla J. Use of the esophageal echo-Doppler to guide intensive care unit resuscitations: a retrospective study. IJCCM 2007; 11: 54–60.
7. Rivers E, Nguyen B, Havstad S. Early Goal-Directed Therapy Collaborative Group: Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 2001; 345: 1368–77.
8. Stawicki SP, Braslow BM, Panebianco NL. 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
9. Dönmez O, Mir S, Özyürek R, Cura A, Kabasakal C. Inferior vena cava indices determine volume load in minimal lesion nephrotic syndrome. Pediatr Nephrol 2001;16:251–5.
10. Fields JM, Lee PA, Jenq KY. The interrater reliability of inferior vena cava ultrasound by bedside clinician sonographers in emergency department patients. Acad Emerg Med 2011; 18:98–101.
11. Keller AS, Melamed R, Malinchoc M. Diagnostic accuracy of a simple ultrasound measurement to estimate central venous pressure in spontaneously breathing, critically ill patients. J Hosp Med 2009; 4: 350–55.
12. American College of Emergency Physicians. Emergency ultrasound imaging criteria compendium. American College of Emergency Physicians. Ann EmergMed 2006; 48: 487–510.
13. Carr BG, Dean AJ, Everett WW. Intensivist bedside ultrasound (INBU) for volume assessment in the intensive care unit: a pilot study. J Trauma 2007; 63: 495–500.
14. Yanagawa Y. Early diagnosis of hypovolemic shock by sonographic measurement of inferior vena cava in trauma patients. J Trauma 2005; 58: 825–9.
15. Snead G, Tayal V, Jones A, Haley M. Prospective evaluation of sonographic inferior vena cava and internal jugular vein measurements to estimate central venous pressure. Acad Emerg Med 2007; 14(5 Suppl): s99.
16. Vignon P. Evaluation of fluid responsiveness in ventilated septic patients: back to venous return. Intensive Care Med 2004; 30: 1699–701.
17. Nagdev AD, Merchant RC, Tirado-Gonzalez A. Emergency department bedside ultrasonographic measurement of the caval index for noninvasive determination of low central venous pressure. Ann Emerg Med 2010; 55: 290-95.
18. Goonawardena SN, Gemignani A, Ronan A. Comparison of hand-carried ultrasound assessment of the inferior vena cava and N-terminal pro-brain natriuretic peptide for predicting readmission after hospitalization for acute decompensated heart failure. JACC Cardiovasc Imaging 2008; 1: 595–601.

....