Inferior vena cava diameter as a guide in hypotensive patients for appropriate saline therapy: An observational study

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ABSTRACT

Background: Knowledge of intravascular volume (IV) status of a hypotensive patient is of utmost importance. Clinical evaluation and central venous pressure (CVP) measurement are routinely used as a guide for evaluation of IV in these patients. However, clinical assessment may be inaccurate, and CVP measurement is invasive. Moreover, CVP changes slowly with saline therapy, which is unfavorable for fluid resuscitation.

Aim: Our aim is to find the correlation and sensitivity of inferior vena cava (IVC) diameter measured by ultrasound to provide a noninvasive method for evaluation of IV among patients with hypotension and hypovolemia in the emergency department (ED).

Methods: We measured the IVC diameter of hypotensive patients before and after saline therapy. As all of the patients had central venous line (CV-line) in place, CVP was also measured before and after. Using MedCalc and SPSS software the correlation between these two was determined as expressed with "r." Then, receiver operating characteristic (ROC) curve was sketched.

Results: Ninety-nine patients, 49 (49.5%) males, were evaluated. Mean systolic blood pressure was 90 mmHg with a mean hazard ratio about 104. IVC diameter was 7.44 ± 5.13 mm before and 9.84 ± 5.29 after (P = 0.002) saline therapy. There was a high correlation between IVC diameter and CVP (r = 0.941, P < 0.0001 before saline therapy and r = 0.95, P < 0.0001 after saline therapy). ROC curve for IVC diameter shows a very high sensitivity for all criteria values.

Conclusion: IVC diameter measurement using ultrasonography has excellent correlation with CVP. This method is very sensitive to rapid IV changes thus useful to guide saline therapy in hypotensive patients referred to ED. However, its use in certain subsets of patients' needs further studies.

Key Words: Central venous pressure, inferior vena cava diameter, sonography

INTRODUCTION

Determination of intravascular volume (IV) is vital for practitioner managing critically ill and hypotensive patients in an emergency department (ED). Clinical judgment, along with using invasive methods such as CV line placement to measure the central venous pressure (CVP) and even placement a Swan-Ganz catheter to find filling pressures of the left ventricle (LV) are the possible methods to determine the IV volume and filling pressures. Clinical evaluation has limited accuracy for this purpose in many situations, and may not be
reliable among severely ill patients. Swan-Ganz catheter insertion needs catheterization laboratory facilities although it is a very reliable method for the management of hypotensive patients. CV line insertion also carries the risk of arrhythmia, cardiac chamber injury and perforation, vascular and nerve injury, pneumothorax, hemothorax, local bleeding, hematoma, infection, and pulmonary thromboembolism. However, imaging modalities, i.e., ultrasonography, which is available in many emergency centers, is a good alternative for the methods mentioned above. The aim of this study was to find the relationship between the inferior vena cava (IVC) diameter measured by sonography and CVP to provide a noninvasive method for measurement of IV volume among hypotensive patients to guide saline therapy.

**METHODS**

**Study design**

This was an observational study approved by the Institutional Review Board at Iran University of Medical Sciences and have been performed within 6 months period from June 2017 to December 2017 in Rasule Akram Hospital, Tehran, Iran. All included patients informed and signed written consent prior to participation. All data are confidential and the registered data are anonymized.

**Study setting and population**

Patients presented with severe hypotension need prompt saline therapy were our target population. Patients with hypotension after trauma who are not in life-threatening state (i.e., those with severe shock, major penetrating trauma, under cardiac arrest, need emergency surgery, unconscious, and mechanically ventilated patients) and who had CV line were entered to the study. Hypotension is defined as reduced mean arterial blood pressure >30% from their baseline or systolic blood pressure <90 mmHg. The baseline mean blood pressure was estimated by evaluating their previous outpatient blood pressure registrations if was available. Otherwise, the 90 mmHg was considered as the threshold for hypotension definition. Indications for CV line insertion were mainly included as follows: (1) Need for appropriate venous access if no peripheral venous access could be obtained, (2) Need for hemodynamic (CVP) monitoring as a guide to saline therapy, and (3) Need for bolus injection of certain types of drugs as they can cause necrosis of the soft tissue if are injected via a peripheral vein access.

**Study protocol**

Appropriate saline therapy was applied with an isotonic crystalloid and CVP of each patient was measured and registered twice, before and after saline therapy, by an emergency medicine resident. A different operator also measured IVC diameter for each patient before and after fluid injection using sonography. This operator was an emergency medicine specialist who was trained to use sonography for IVC diameter measurement. A 1–5 MHz curve probe was used; IVC diameter was measured between the confluence of hepatic vein-IVC and IVC-right atrium junction, during expiration. The time difference between CVP and IVC diameter measurement was short (<5 min) both before and after saline therapy.

**Statistical analysis**

We did not determine the sample size via power analysis before data collection. However, post hoc power was calculated according to the findings. For changes of IVC diameter before and after the infusion of saline, using paired t-test, the power was 0.995. Furthermore, for the correlation between IVC and CVP, power was near 1 by using the Pearson correlation coefficient formula. In all the calculations, α was considered as 0.05 statistical tests was considered two-tailed and GPower 3.1 software (Universität Kiel, Kiel, Germany) was used. This can clarify the sufficiency of sample size for the study. We registered patient’s demographic data and baseline clinical characteristics, along with IVC diameter before and immediately after saline therapy. Correlation with CVP and IVC, receiver operating characteristic (ROC) curves for each was evaluated and sketched using MedCalc bvba version 15.6 (Seoul, Korea) and IBM SPSS Statistics 22 (IBM Inc., Armonk, NY, USA). The correlation between two variables was also analyzed for chronic obstructive pulmonary disease (COPD) patients as a subgroup analysis. Using a linear regression model the relationship between CVP and IVC diameter was determined.

**RESULTS**

We measured the IVC diameter and CVP of 99 patients, before and after saline therapy. Median age was 69 (56–77) years, and 49 (49.5%) were male. Table 1 shows baseline demographic and hemodynamic characteristics of the patients. CVP and IVC diameter were significantly increased after saline therapy.

**Central venous pressure measurement**

CVP of two patients was >12 cm H₂O. None of them had background disorder that is responsible for this elevated CVP. There were nine patients with COPD and mild right ventricle (RV) enlargement. All of them had normal to low CVP.

**Inferior vena cava diameter and central venous pressure correlation**

Correlation between CVP and IVC diameter before and after saline therapy was very high (r = 0.94, P < 0.0001 before and r = 0.96, P < 0.001 after saline therapy).
Figure 1 demonstrates a correlation curve of the CVP and IVC diameter. This high correlation was also existed among patients with COPD and mild RV enlargement ($r = 0.94$ and $P < 0.001$).

**Inferior vena cava diameter specificity and sensitivity**

ROC curve for IVC diameter also shows a very high sensitivity for all criteria values (IVC diameter range), but the specificity is very high when the IVC diameter is ≤11.6 (specificity: 91.3%) [Table 2].

ROC curves yielded an area under the curve (AUC) value of 0.973 ($P<0.001$). The comparison between ROC curves of CVP and IVC diameter shows no significant difference between them (AUC 0.973 vs. 0.974, $P: 0.78$) [Figure 2]. The IVC diameter ≤10.9 was the best cut off to predict the CVP <8 with a sensitivity of 90.79% and specificity of 100% [Table 2].

Using linear regression model, the amount of the CVP based on IVC diameter measured by ultrasound is calculated by the following formula with very high accuracy [Figure 3].

$$CVP = (0.651 \times \text{IVC diameter}) + 0.343 \ (r^2 = 0.937)$$

**DISCUSSION**

IV monitoring is very important during saline therapy in hypotensive patients due to hypovolemia referring to ED. Clinical assessment, urine volume, and CVP are used routinely for this purpose. However, these methods are not accurate in many situations, and their response

![Figure 1](image1.png)

**Figure 1:** The correlation curve of the central venous pressure and the inferior vena cava diameter. (a) Before saline therapy. (b) After saline therapy

![Figure 2](image2.png)

**Figure 2:** The receiver operating characteristic curves of the inferior vena cava diameter and the central venous pressure before saline therapy. inferior vena cava pre: inferior vena cava diameter previous to saline therapy.
to saline therapy is recognized after a longer time. Nevertheless, if saline therapy is a noninvasive route to evaluate the IV status before and after saline therapy. The study showed there was an excellent correlation between IVC diameter and CVP before and after saline therapy in patients with hypotension and hypovolemia. Although, there were different background diseases that could affect the baseline and postsaline therapy IVC diameter and CVP, i.e., COPD and end-stage renal disease; however, this excellent correlation existed among them. Venous collapsibility (VC), VC index (VCI) are also useful methods for assessment of IV status before and after saline injection. These two measurements are accurate and relatively fast noninvasive tools to evaluate the IV status after saline injection. Other studies on IVC diameter change with saline injection show it is an accurate method in determination of IV status and its respond to saline injection is abrupt. These studies mostly measured the IVC diameter irrespective to respiratory phase. Several conditions may affect IVC diameter at baseline and after saline therapy, for example, elevated intrathoracic and intrapericardial pressures, right ventricular dysfunction, COPD, etc. Nevertheless, if the physician has the baseline value of IVC diameter, it is possible to use its change after saline therapy as a tool for guidance of saline therapy. This is not true in patients who underwent mechanical ventilation.

In this study, we measured the IVC diameter in end expiration, which results in more accurate measurements. The observed excellent correlation between IVC diameter and CVP in our study was persistent among patients with COPD and different baseline CVPs. However, as we did not include critically ill patients, patients with congestive heart failure, and those with mechanical ventilation, we are not able to explain if this correlation exists in these patients or not. Another limitation of our study is that we did not use LV filling pressures as a comparator with IVC diameter since LV filling pressure measurement is the most accurate method to find the reason of hypotension and IV status before and after saline therapy.

**CONCLUSION**

IVC diameter measurement is a fast and noninvasive method to monitor and evaluate the IV status before and after saline therapy in hypotensive/hypovolemic patients who refer to ED. Its role in different background scenarios has been proved. However, its usefulness in mechanically ventilated patients’ needs more evaluation.

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**Conflicts of interest**

There are no conflicts of interest.

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