Is the inferior vena cava diameter measured by bedside ultrasonography valuable in estimating the intravascular volume in patients with septic shock?

Mortaza Talebi Doluee (MD), Hamidreza Reihani (MD), Vahide Farzam (MD) *

1Emergency Medicine Department, Imam Reza Hospital, Mashhad University of Medical Sciences, Mashhad, Iran.

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Introduction: Resuscitation should be initiated immediately in shock. Early goal-directed therapy is an established algorithm for the resuscitation in septic shock. The first step is to maintain cardiac preload. Central venous pressure (CVP) plays an important role in goal-directed therapy. Central venous catheterization is invasive and time-consuming in emergency conditions. There are some alternative and noninvasive methods for estimating the intravascular volume such as measuring the inferior vena cava (IVC) diameter by ultrasonography.

Methods: We searched PubMed, Google scholar, and Scopus databases with keywords (central venous pressure OR venous pressure OR CVP) AND (ultrasonography OR sonography) AND (sepsis OR septic shock) AND (inferior vena cava OR IVC).

Result: The search resulted in 2550 articles. The articles were appraised regarding the relevance, type of article, and statistical methods. Finally, 12 articles were selected. The number of patients was between 30 and 83 cases (mean age=57-67 years), intubated and non-intubated in each study. The IVC diameter was measured in respiratory cycle by bedside ultrasonography in longitudinal subxiphoid view and caval index was calculated, then they were compared with the CVP measured by central venous catheter.

Discussion: CVP is an indicator of intravascular fluid status and right heart function. CVP measurement is an invasive method and of course with some complications. The IVC is the biggest vein of venous system with low-pressure; expansion of the vein reflects intravascular volume.

Conclusion: It seems that IVC diameter measured by ultrasonography could be used as an alternative method for the determination of CVP in the emergency or critical patients.

Introduction

Many patients in emergency department with pale appearance, sweating, tachypnea, tachycardia, and weak pulse are in shock (1). Shock may occur due to various etiologies. Resuscitation should be initiated immediately in all patients with shock, according to the etiology. Early goal-directed therapy is an established algorithm for the resuscitation in septic shock (2). In this approach, patients are resuscitated within the first 6 hours to reach standards of adequate preload, central venous pressure...
Results
The search resulted in 2550 articles, 230 cases were selected based on the title, and then abstracts were reviewed. Fifty-one articles were found relevant and full texts were appraised for the study design. Finally, 12 articles were selected (Figure 1).

In these 12 studies, evaluation was performed in patients admitted to the emergency department and intensive care unit. The number of patients was 30 and 83 cases in each study. The mean age was 57 to 67 years. Some patients were intubated and some were non-intubated. The underlying diseases were mostly associated with hypovolemia, sepsis, or other non-traumatic medical illnesses. Table 1 shows the characteristic data of the included articles.

Methods
The question of this study is considered in a systematic review of literature which is prepared based on preferred reporting items for systematic reviews and meta-analyses (PRISMA statement) (3). Google Scholar, PubMed, and Scopus were used as the main databases to search the most relevant articles related to the aim of this review. No time limitation was posed to the literature search (since 1st January 2015), except a definite search strategy with specific keywords which were as follows: (central venous pressure OR venous pressure OR CVP) AND (ultrasonography OR sonography) AND (sepsis OR septic shock) AND (inferior vena cava OR IVC). The non-published articles, non-indexed journals, and non-English resources were not reviewed.

Relevant articles were searched based on inclusion and exclusion criteria to prevent any bias and irrelevant issues. All the articles which studied the comparison of IVC diameter by ultrasonography with CVP were eligible to be included in this review. The studies in trauma or children patients were excluded. Those which applied computed tomography scan or other methods for IVC diameter estimation and case reports were not included. Studies were first extracted based on the title and abstract obtained through initial search. Eventually, all the full texts of the articles were studied to limit the results to the most relevant articles. References of the extracted articles were also studied to prevent missing any additional article.

Table 1. Characteristic data of the included studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year Reference</th>
<th>Number of patients</th>
<th>Mean age (years)</th>
<th>Ward</th>
<th>Disease</th>
<th>Technique</th>
<th>Condition</th>
<th>Type</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Lorenzo</td>
<td>2012</td>
<td>72</td>
<td>67</td>
<td>ED</td>
<td>CVP</td>
<td>IVC</td>
<td>Measure</td>
<td>CVP</td>
<td>found between caval index and CVP (7).</td>
</tr>
<tr>
<td>Minutiello</td>
<td>2009</td>
<td>73</td>
<td>63</td>
<td>ED</td>
<td>sepsis</td>
<td>N/A</td>
<td>N/A</td>
<td>IVC diameter measured in inspiration and expiration and CVP calculated</td>
<td>There was a correlation between CVP and caval index (r=0.74) and caval index and CVP. If the caval index was equal or more than 58%, it could predict a CVP less than 8 mm Hg with a sensitivity of 91%, and specificity of 94% (95% CI of 94% to 99%), the PPV of 87% and the NPV of 95%.</td>
</tr>
<tr>
<td>Nagdev</td>
<td>2010</td>
<td>63</td>
<td>N/A</td>
<td>ED</td>
<td>sepsis</td>
<td>N/A</td>
<td>IVC diameter measured in inspiration and expiration and CVP calculated</td>
<td>There was a correlation between CVP and caval index (r=0.74) and caval index and CVP. If the caval index was equal or more than 58%, it could predict a CVP less than 8 mm Hg with a sensitivity of 91%, and specificity of 94% (95% CI of 94% to 99%), the PPV of 87% and the NPV of 95%.</td>
<td></td>
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<tr>
<td>Schuhknecht</td>
<td>2009</td>
<td>73</td>
<td>63</td>
<td>ED</td>
<td>sepsis</td>
<td>N/A</td>
<td>IVC diameter measured in inspiration and expiration and CVP calculated</td>
<td>There was a significant correlation between CVC-CI ranges and mean CVP. There was a great correlation between inspiratory and expiratory indexes of IVC and CVP.</td>
<td></td>
</tr>
<tr>
<td>Shoukat</td>
<td>2009</td>
<td>65</td>
<td>65</td>
<td>ED</td>
<td>N/A</td>
<td>N/A</td>
<td>IVC collapse index measured</td>
<td>A caval index of +20% indicate normal CVP and a caval index &lt; 20% is related to an elevated value of CVP.</td>
<td></td>
</tr>
</tbody>
</table>

CVP, perfusion, mean blood pressure (BP), and normalization of oxygen delivery (central venous oxygen saturation [ScvO2]) of 70% or lactate clear- ance of 10%. The first step in goal-directed therapy is to maintain the cardiac preload. It is difficult to estimate cardiac preload in an emergency situation. Heart rate, BP, capillary refill, and adequate urine output could be used to estimate intravascular volume in not severely ill patients, but in critically ill patients, CVP plays an important role in goal-directed therapy (1).

Central venous catheterization insertion is an invasive and time-consuming emergency procedure with various complications such as hematoma, hemothorax, pneumothorax, infection, and vascular injuries. Besides, catheter could not be inserted in patients with coagulopathy, insertion site infection, and unstable anatomy (2). There are some alternative and noninvasive methods for estimating the intravascular volume such as measuring the IVC diameter by ultrasonography (1). Thus, we decided to review the studies that utilized the bedside ultrasonography technique, its accuracy, and reliability for estimating the intravascular volume.

Estimating the intravascular volume.

Figure 1. Flowchart of the selection process of articles
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CVP less than 8 mmHg was 91%, and the specific predictive value (PPV) of 87% (95% confidence in sensitivity of 85%, specificity of 81%, and positive diameter <2 cm estimated a CVP of <10 mmHg with a ≥20% indicated normal CVP and caval index <20% respectively) (10). In this study, caval index >75% represented intravascular volume under mechanization, cardiac and circulatory depressions and microcirculatory dysregulation happens.

In the emergency department, bedside ultrasonographic evaluation of IVC diameter could provide valuable information besides clinical context to determine the cause of shock (19). Moreover, the IVC diameter could be measured frequently during the process of resuscitation and it could provide an estimation of CVP noninvasively. In trauma patients, many different mechanisms result in shock and this technique could be very valuable in these patients to control the shock etiology. In hemorrhagic shock, acute blood loss compensates by sympathetic activation, vasoconstriction, and an increase in cardiac contractility and rate. Serial monitoring of IVC diameter is important in a patient with ongoing blood loss could be valuable (20).

Discussion
CVP monitoring is applied in emergency department in the patients who are in shock, heart failure and the patient who may need cardio pulmonary resuscitation with massive amount of fluid or blood with or without existing heart problem (15). CVP shows the right atrial or ventricular filling pressure. Thus, central venous catheter is applied to have an estimation of right heart function and intravascular volume. In normal physiology, CVP is a reflection of intravascular volume status; it is affected by the blood volume. Thus, IVC diameter could be a good reflection of intravascular volume. Respiration could also affect the size and diameter of thin-wall, the IVC. Therefore, the relation of the IVC diameter decreases due to the negative intrathoracic pressure, and it increases in expiration, valsalva maneuver, and positive pressure ventilation. The evaluation of IVC diameter changes during the respiratory cycle may lead to a more exact estimation of intravascular volume and predicting CVP (18).

Shock state is a clinical situation in which the turpufusion is less than cellular metabolic needs. Shock may happen as the result of hypovolemic, mechanical, distributive, or cardiac causes. During the sepsis, a combination of hypovolemia, vasodilation, cardiac and circulatory depressions and microcirculatory dysregulation happens.

In the emergency department, bedside ultrasonographic evaluation of IVC diameter could provide valuable information besides clinical context to determine the cause of shock (19). Moreover, the IVC diameter could be measured frequently during the process of resuscitation and it could provide an estimation of CVP noninvasively. In trauma patients, many different mechanisms result in shock and this technique could be very valuable in these patients to control the shock etiology. In hemorrhagic shock, acute blood loss compensates by sympathetic activation, vasoconstriction, and an increase in cardiac contractility and rate. Serial monitoring of IVC diameter in a patient with ongoing blood loss could be valuable (20).

Conclusion
It could not be stated with certainty but it seems that CVP diameter measured by ultrasonography is a reliable indicator for the determination of intravascular volume. It could be used as an alternative method in critically ill patients when there is no possibility of central venous catheter insertion, with acceptable sensitivity, specificity, PPV, and NPV.

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Conflict of Interest
The authors declare no conflict of interest.

References