Abstract:

Background: Bedside ultrasound is emerging as a useful tool in the assessment of intravascular volume status by examining measurements of the inferior vena cava (IVC). Many previous studies do not fully describe their scanning protocol.

Objectives: The objective of our study is to evaluate which of three commonly reported IVC scanning methods demonstrates the best inter-rater reliability.

Methods: Three physicians visualized the IVC in the three planes and utilized M-mode to measure the maximal and minimal diameter during quiet respiration. Pair-wise correlation coefficients were determined using Pearson Product Moment Correlation.

Results: The most reliable pair of measurements (inspiratory and expiratory) was using the anterior mid-axillary line longitudinal view with a Kappa value for both at 0.692.

Conclusion: Imaging with the anterior mid-axillary longitudinal approach using the liver as an acoustic window provides the best inter-rater reliability in measurements of the IVC. Likewise, our findings demonstrate that IVC measurements differ based on anatomic location

Keywords: Intravascular volume status, inferior vena cava, bedside ultrasound

Introduction

Central venous pressure (CVP) monitoring is advocated as the most accurate measure to assess for hydration and volume status in the treatment of cardiogenic and non-cardiogenic shock. However, CVP monitoring requires the insertion of an invasive catheter with risks including infection, hemorrhage, pneumothorax, dysrhythmias, and venous thrombosis. Furthermore, placement of the catheter is expensive and time and resource consuming in a busy emergency department.

Bedside ultrasound is emerging as a useful tool in the assessment of intravascular volume status. Bedside ultrasound measurements of the inferior vena cava (IVC), including IVC diameter, the degree of collapse of the IVC on inspiration versus expiration and the IVC/aorta diameter index, are all proposed non-invasive alternatives to CVP monitoring in assessing hydration status.[1-5] However, different studies have proposed different approaches to imaging the IVC. Lyon et. al. and Kosiak et. al. and others used a subxyphoid approach to view the IVC along the longitudinal axis, using the liver as a sonographic window.[1,5-7] Pershad et. al. and Blehar et al measured the IVC in the subxyphoid transverse axis just caudal to the hepatic vein confluence.[8,9] To our knowledge, no previous study has determined the inter-observer variability in measurements using different approaches to IVC imaging and measurements.

The objective of our study is to evaluate which of the three most commonly reported IVC scanning methods (Figure 1) demonstrates the best inter-rater reliability: 1. subxyphoid longitudinal plane (SXL) (Figure 2) 2. subxyphoid transverse plane (SXT) (Figure 3) and

3. anterior mid-axillary line longitudinal (AML) (Figure 4) using the liver as a sonographic window.

Methods

We selected healthy volunteers for a prospective observational study. The protocol was approved by the institutional review board at our institution.

The bedside ultrasound examinations were performed by 3 physicians, one attending physician who had completed an emergency ultrasound fellowship and two fellows in emergency ultrasound. The three physicians had each completed at least 175 technically adequate ultrasound scans prior to this study. Each physician spent approximately one hour reviewing the principles and techniques of IVC scanning prior to study initiation. These included visualizing the IVC in the three planes and utilizing M-mode to measure the maximal and minimal diameter. Wallace et.al. suggest that M-mode measurements may be inaccurate because the movement of the diaphragm during respiration can result in caudal displacement of the IVC.[10] With a stationary probe, this physiologic variation is also possible when visualizing the structure in a B-mode cine loop. Therefore, we chose to perform IVC evaluation in M-mode for the ease of interpretation of location of maximal and minimal diameters as well as their measurements in one screen image.

Our sample consisted of medical students rotating through the department and family members who were accompanying patients in the emergency department. No individual was there to seek medical care in the emergency department. Inclusion criteria included any patient > 18 years of age willing to participate in the study. Individuals < 18 years of age or refused to participate were excluded from the study. No attempt was made to control for past medical history, medication use or hydration status.

Volunteers were placed in the supine position with the head at 0 degrees. A Sonosite Titan portable ultrasound machine was used with a C15 (2-4 MHz) broadband transducer on the abdominal setting. Subjects received no instructions on how to breath and all measurements were taken during quiet respiration. Identification of the IVC by anatomic landmarks was confirmed with color Doppler imaging. Three IVC views were obtained 1. subxiphoid in a longitudinal plane (SXL), 2. subxiphoid in a transverse plane (SXT) and 3. anterior mid-axillary line in a longitudinal plane (AML), using the liver as a sonographic window.

For each view, the IVC was observed during three respiratory cycles. M-mode assessment was performed 2 centimeters distal to the junction of the IVC and the right atrium, at a point where the two walls were parallel (Figure 5). The probe was held perpendicular to the vessel during the measurements. A cine loop was recorded during three respiratory cycles. Using frame-by-frame review, calipers were used to measure minimal and maximal diameters in millimeters during inspiration and expiration. The internal diameter of the IVC was used for all measurements. No attempt was made to evaluate if the measurements were taken during systole or diastole. All three sonographers performed measurements separately and in succession, without the volunteer shifting position between scans.

All measurements were collected and organized into a database. For each volunteer, the three measurements for IVC diameter during inspiration and the three measurements for

IVC diameter during expiration were averaged for each view. The data was analyzed using pairwise correlation. The data was continuous so the Pearson Product Moment Correlation was used. This allowed the most reproducible measurements between operators for each of the views.

Results

14 adult volunteers were enrolled in the study. Measurements of the IVC in each of the three anatomic locations were obtained in all patients. 141 paired inspiratory and expiratory measurements were recorded for SXL view, 138 for the SXT view, and 138 for the AML view. For each volunteer, we averaged the three measurements for each view for IVC diameter during inspiration and the three measurements for IVC diameter during expiration. We present the measurements in millimeters using means and standard deviations (parenthesis) in Table 1. The average IVC diameter during expiration was 19.5 mm for the SXL view, 18.7 for the SXT view, and 19.1 for the AML view. Inspiratory IVC measurements were 13.3, 12.7, and 14.1 respectively. Respiratory variation was best observed through the SXL approach with an average change in diameter of 6.27 mm compared to 6.03 mm and 4.92 mm for the SXT and AML approaches respectively.

Operators 1 and 2 each recorded individually 51 paired inspiratory and expiratory measurements in the SXL view, 51 in the SXT view, and 51 in the AML view. Operator 3 recorded 39 paired measurements in the SXL view, 36 in the SXT view, and 36 in the AML view. Average measurements of the IVC varied by operator and are summarized in Table 2. There was a statistically significant difference in the respiratory change obtained using the SXT approach ($P<0.05$). There was no significant difference in the measurements obtained by the other approaches.

Because only operators 1 and 2 performed measurements on all of our volunteers (operator 3 scanned 12 volunteers), Operator 3 was excluded from inter-observer agreement analysis because data for all volunteers was not recorded. We analyzed the pairwise correlation between operators using the Pearson Product Moment Correlation, assuming the data to be parametric (Table 3). We used an alpha of 0.05 for statistical significance. The highest inter-rater agreement for IVC diameter measurements was the inspiratory view using the SXT approach. However, the most reliable pair of measurements (inspiratory and expiratory) was using the AML view with identical pairwise correlations for both at 0.692.

Discussion

Multiple previous studies have demonstrated that ultrasonographic imaging of the IVC is a useful non-invasive alternative to CVP monitoring in assessing patients' hydration status in the emergency department. However, different studies have proposed imaging from different anatomic locations and there is no agreement as to which is the most reliable method for obtaining IVC measurements. We know based on results from previous studies that measurements of the IVC will vary by anatomic location. In one study it was demonstrated that the percentage collapse of the IVC will vary between anatomic locations.[9] However, to our knowledge there is no previous study that describes the interobserver variability in measurements using different approaches to IVC imaging.

Our study is the first to investigate the interobserver variability in measurements of the IVC using three different approaches: 1. subxyphoid longitudinal plane (SLP) 2. subxyphoid transverse plane (STP) and 3. anterior mid-axillary line longitudinal (AML) using the liver as a sonographic window. The results of this study suggest that the AML approach provides the best inter-rater reliability, however, the results are very close and all 3 approaches provide a good inter-rater reliability in obtaining IVC measurements. Our study also reiterates that IVC measurements will vary by anatomic location. Therefore when different observers will be imaging the IVC, measurements should always be obtained from a consistent anatomic location, especially when investigating correlation to CVP. We caution that future studies should clearly describe the scanning approach used and whether there was consistency throughout the investigation in the anatomic location chosen for imaging.

Limitations

There are several limitations to this study. First, the study was performed in adult presumably healthy volunteers. However, we collected neither demographic data nor parameters that would indicate the individual's intravascular volume status. This prospective observational convenience sample of people was small in size (14) and more people would need to be enrolled to power these trends in our findings and draw strong conclusions. In addition, only operators 1 and 2 scanned all the volunteers and therefore operator 3 had to be excluded from inter-observer agreement analysis.

Conclusion

Imaging through the anterior mid-axillary longitudinal approach using the liver as an acoustic window provides the best inter-rater reliability in measurements of the inferior vena cava. Likewise, our findings demonstrate that IVC measurements differ based on anatomic location making it difficult to draw comparisons between previous research studies. It is our hope that this brief report will encourage further researchers to standardize the anatomic approach in measuring IVC diameter as a non-invasive marker of hemodynamic status.

References

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Article Summary:

1. Why is this topic important? Assessing intravascular volume status is necessary when caring for the critically ill. Bedside ultrasound of the inferior vena cava offers a non-invasive mean of this assessment.
2. What does this study attempt to show? There are a number of ways to measure the inferior vena cava sonographically. This study examines the inter-rater reliability of three different scanning techniques.
3. What are the key findings? The anterior mid-axillary line longitudinal view had the best inter-rater reliability.
4. How is patient care impacted? Using this non-invasive bedside tool is safer for patients. Standardizing the scanning method of inferior vena cava measurements as a marker of intravascular volume status will make it easier to compare future research studies.