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The Interrater Reliability of Inferior Vena Cava Ultrasonography Performed by Intensive Care Fellows

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ABSTRACT

Background and aim: Inferior vena cava (IVC) measurements by ultrasonography (USG) is a repeatable and noninvasive tool but it is sonographer dependent and requires experience. The aim of this study is to investigate the interrater reliability of IVC-USG measurements performed by intensive care fellows.

Methods: After training, four first-year intensive care fellows and an experienced ultrasonography trainer performed IVC USG within 5 minutes of each other without the fellows knowing the clinical history, the fluid balance and the previous IVC USG measurements of the patients. The minimum IVC diameter (IVC-min) and the maximum diameter (IVC-max) were measured using both M-mode and B mode. IVC collapsibility index (IVC CI) and the IVC distensibility index (IVC-DI) were calculated. The interrater reliability of the measurements was analyzed using intraclass correlation coefficients (ICC) with 95% confidence intervals (CI).

Results: One hundred and seven IVC-USG measurements were conducted on 29 ICU patients. The trainer measured the median (minimum-maximum) IVC-min as 1.20(0.63-2.60) cm, IVC max as 1.76(0.95-3.09) cm, and calculated IVC-CI as 0.23(0.05-0.68), and IVC-DI 0.30 (0.05-2.10) with B mode. The same measurements with M mode were as 1.34 (0.46-2.53) cm, 1.75 (1.07-3.08) cm, 0.19 (0.09-0.66), and 0.23 (0.10-1.95) respectively. All measurements of all of the fellows showed significant moderate-good correlations with the trainer's measurements and each other (ICC > 0.6-0.8, p<0.001). One fellow's parameters of B mode and M mode IVC collapsibility and distensibility index showed weak correlation to the trainer's and other fellows' parameters. Most correlations between fellows' calculated parameters were also moderate (ICC >504-777, p<0.001).

Conclusion: The interrater reliability of IVC diameters, IVC collapsibility and IVC distensibility measurements performed by intensive care fellows is moderate.

Keywords: ultrasonography, vena cava inferior, reliability, safety, intensive care units

Introduction

Ultrasonographic inferior vena cava (IVC) related measurements are still currently used in evaluation of different kinds of shock, and/or respiratory failure, assessing volume status and fluid responsiveness in critically ill patients despite some criticisms (1-9). Actually, IVC imaging by ultrasonography (USG) has been suggested to be incorporated into evaluations of critically ill patients with combinations of clinical examination and biochemical analysis (10). IVC-USG as part of admission USG examination in the intensive care unit (ICU) has even the potential for predicting outcome as the length of mechanical ventilation was correlated with the diameter of IVC in a previous study (11). IVC-USG also has therapeutic impact on patients' management in the ICU (6,7).

Although ultrasonography is a rapid, affordable, repeatable and noninvasive tool, the major limitations of this method is that it is sonographer dependent and requires training and experience. There are technical limitations arising from the point of measurement, perpendicularity of measurement, foreshortening error, off-axis collapse, confusing the aorta for the IVC, eye ball estimations rather than real measurements, and confounding factors such as tidal volumes, spontaneous breathing, chronically enlarged IVC due to right ventricular failure, elevated intra-abdominal pressure due to obesity or ileus (4). Feasibility and accuracy of IVC imaging performed by medical students and the interrater agreement in estimating IVC measurements performed by emergency medicine residents has been studied (12-16). However, no study

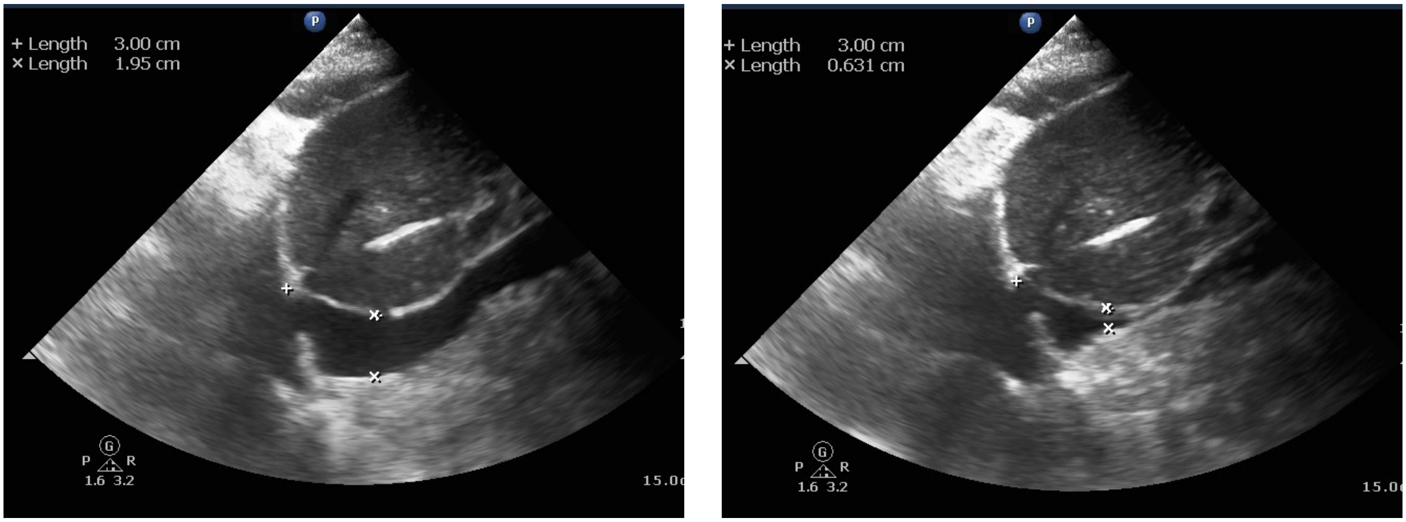

Figure 1. Measurement of the IVC diameters in B mode.

has specifically assessed the interrater reliability of IVC-USG performed by intensive care fellows, who use IVC-USG commonly in clinical practice in the ICU.

Therefore, the aim of this study is to investigate the interrater reliability of IVC-USG performed by intensive care fellows.

Material and Methods

The study was approved by Hacettepe University Ethical committee (Issue:16969557-505, Decision Number: GO 15/289). The study was performed in Anesthesiology Intensive Care Unit (ICU) between 01.12.2015 - 28.02.2016. All patients had IVC diameters measured as part of the admission examination by the ICU attending experienced in USG (a trainer in ICU-USG courses for years who performs >100 IVC-USG examinations per year). All the patients or their relatives were informed about the research study and their consents were requested.

Patients

All adult patients admitted to ICU during the study period were screened for study eligibility. Patients who refused consent, could not lie supine, pregnant patients, obese patients (Body mass index >30cm/m^2), patients in whom IVC diameters could not be measured were excluded from the study.

Fellows

Four first-year intensive care fellows attended 16 hours basic ICU USG training course including basics of USG and 1 hour dedicated to IVC measurements. After the course, each of the four fellows performed IVC USG on four patients under supervision. After this extensive training, the fellows were included into the study. They were called to the ICU to perform IVC USG without knowing the clinical history, the fluid balance and the previous IVC USG measurements of the patients. All four fellows and the experienced sonographer performed the measurements within 5 minutes of each other.

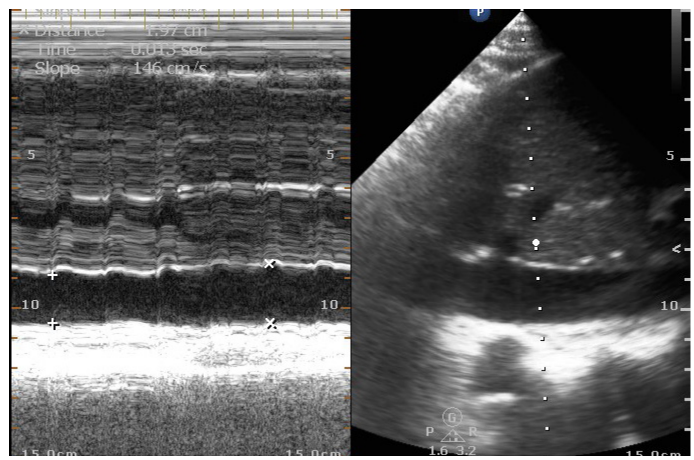

Figure 2. Measurement of the IVC diameters in M mode.

IVC USG measurements

The same USG device was used for all measurements (Philips pure wave, Model name: CX50, Model version: 4.0.2). IVC USG was examined with a 5 Mhz convex probe in patients in the supine position. IVC USG diameters were measured from 2 cm proximal of the entrance of the hepatic vein to the IVC at the sagittal plan from the subxiphoid area.

The minimum IVC diameter (IVC-min) and the maximum diameter (IVC-max) were measured using both B-mode and M- mode (Figures 1&2). IVC collapsibility index was calculated using the formula: (IVC-max – IVC-min)/ (IVC-max). IVC distensibility index was calculated using the formula: (IVC-max – IVC-min)/ (IVC-min).

Data collection and analysis

Demographic data, vital signs, and clinical data were also collected besides IVC measurements. These data included age, gender, Acute Physiology and Chronic Health Evaluation (APACHE) II score, ICU admission diagnosis, whether on mechanical ventilation or spontaneous breathing, whether on vasopressor or not, systolic blood pressure, diastolic blood pressure, heart rate and respiratory rate during USG examination.

Statistical analysis was performed with the SPSS 23.0 program. The normality of distribution was tested with Shapiro-Wilk test. Data with normal distribution was presented as mean±SD. Nonparametric data were presented as median values (minimum–maximum). Categorical data were expressed using frequency and percentages. A p value less than .05 was considered statistically significant. The interrater reliability of the measurements was analyzed using intraclass correlation coefficients (ICC) with 95% confidence intervals (CI). ICC, based on one way random (between trainer and fellows consistency) and two-way random model (inter-fellows consistency) for all the independent variables such as, the minimum IVC diameter (IVC-min) and the maximum diameter (IVC-max)(using both B-mode and M-mode). We suggest that ICC values less than 0.5 are indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability (17).

Results

Twenty-nine patients were consecutively enrolled into study during the study period. The demographic and clinical data of the patients can be seen in Table 1. The patients were admitted to the ICU mostly postoperatively. Of the 21 postoperative patients, 3 had plastic surgery, 9 had orthopedic surgery (5 had femur fracture repair surgery), 1 had urologic surgery, 2 had abdominal surgery, 2 had throat surgery, 2 had gynecological surgery and 3 had thorax surgery.

One hundred and seven IVC-USG measurements were conducted by four fellows and the trainer. The measurements and calculated indexes can be seen in Table 2. All measurements (IVC-min and IVC-max measurements that were measured using both B-mode and M- mode) of all of the fellows showed moderate-good correlations with the trainer's measurements (p<0.001 for all correlations) (Table 3). Meanwhile calculated parameters (IVC CI and IVC DI) of all of the fellows except fellow 2 showed significant moderate correlations with the trainer's calculated parameters (p<0.005). Fellow 2's calculated parameters of B mode and IVC DI of M mode showed weak correlation to the trainer's parameters (ICC; IVC CI (B mode) = 0.253, p: 0.224; IVC DI (B mode)=203; p: 0.683, IVC DI (M mode)=251; p: 0.229 (Table 3).

Fellow 1's measurement of IVC minimum with B mode showed moderate-good correlations with the other fellows (ICC: 0.749-moderate with fellow 2, ICC: 0.715-moderate with fellow 3, ICC: 0.844-good with fellow 4). The same measurement of fellow 2 also showed good correlations with fellow 3 and 4 (ICC:0.770 with fellow 3, ICC:0.869 with fellow 4, respectively). Fellow 3 and 4 also had good correlations with each other regarding the IVC minimum diameter at B mode (ICC:0.835). When the correlations of IVC maximum diameters at B mode analyzed, fellow 1's measurements showed good correlated with fellow 2 and 4 (ICC: 0.805 with fellow 2, ICC: 0.815 with fellow 4, respectively) but moderate correlated with fellow 3's measurement (ICC: 0.575). All other correlations between fellows' measurements IVC-min and IVC-max measurements that were measured using both B-mode and M- mode) showed moderate-good reliability and were statistically significant (ICC > 0.6-0.8 and p<0.001).

Table 1. Patient characteristics and clinical data

	n = 29
Age (years)	59 (19-87)
Gender (male/female)	13 /16
APACHE II score	12 (2-40)
ICU admission diagnosis	
Postoperative	21
Respiratory failure	1
Sepsis	2
Intoxication	4
Post cardiac arrest	1
On mechanical ventilation	7
On vasopressors	2
Mean blood pressure (mmHg)	80 (44-115)
Heart rate (beat/min)	92 (63-142)
Respiratory rate (breaths/min)	19 (13-35)

Data given as number of patients (n) or median (minimum-maximum)

Table 2. The ultrasonographic measurements of IVC diameters (cm) and the calculated IVC collapsibility index (IVC CI)(%) and the IVC distensibility index (IVC DI)(%).

Sonographer	Mode	IVC minimum (cm)	IVC maximum (cm)	IVC CI (%)	IVC DI (%)
Fellow 1	B mode	1.33(0.36-1.21)	1.68(0.79-2.60)	**30(1-72)**	**44(1-261)**
Fellow 1	M mode	1.21(0.20-2.10)	1.75(1.30-2.98)	**40(2-85)**	**68(2-550)**
Fellow 2	B mode	1.15(0.49-3.02)	1.73(1.23-3.17)	**29(2-67)**	**42(2-200)**
Fellow 2	M mode	1.25(0.35-2.87)	1.78(1.07-3.13)	**24(5-67)**	**32(5-206)**
Fellow 3	B mode	1.28(0.30-2.97)	1.64(1.04-3.07)	**18(2-79)**	**22(2-367)**
Fellow 3	M mode	1.21(0.50-2.70)	1.71(1.00-3.73)	**30(1-68)**	**44(0-214)**
Fellow 4	B mode	1.31(0.40-2.61)	1.62(1.07-3.15)	**27(6-64)**	**37(7-175)**
Fellow 4	M mode	1.28(0.44-2.63)	1.74(1.21-3.23)	**28(2-71)**	**40(2-243)**
Trainer	B mode	1.20(0.63-2.60)	1.76(0.95-3.09)	**23(5-68)**	**30(5-210)**
Trainer	M mode	1.34(0.46-2.53)	1.75(1.07-3.08)	**19(9-66)**	**23(10-195)**

Data given as median (minimum-maximum)

Table 3. The intraclass correlation coefficients (ICC) with (95% CI) of IVC measurements and the calculated parameters performed by different sonographers and the trainer.

Sonographer	Mode	IVC minimum (cm)	IVC maximum (cm)	IVC CI	IVC DI
Fellow 1	B mode	0,591 (0,284-0,789)	0.643 (0.359-0.819)	0.644 (0.226-0.860)	0.467 (0.222-0.757)
Fellow 1	M mode	0.719 (0.476-0.861)	0.675 (0.407-0.837)	0.742 (0.439-0.882)	0.562 (0.038-0.800)
Fellow 2	B mode	0.568 (0.259-0.773)	0.798 (0.612-0.901)	**0.253 (0.099-0.653)**	**0.203 (0.285-0.443)**
Fellow 2	M mode	0.642 (0.364-0.816)	0.738 (0.512-0.869)	0.515 (0.038-0.775)	**0.251 (0.230-0.653)**
Fellow 3	B mode	0.684 (0.421-0.842)	0.657 (0.380-0.827)	0.681 (0.307-0.854)	0.455 (0.198-0.752)
Fellow 3	M mode	0.735 (0.501-0.869)	0.784 (0.584-0.895)	0.714 (0.379-0.869)	0.614 (0.152-0.824)
Fellow 4	B mode	0.660 (0.377-0.831)	0.782 (0.574-0.895)	0.625 (0.173-0.831)	0.403 (0.332-0.732)
Fellow 4	M mode	0.684 (0.414-0.844)	0.794 (0.596-0.902)	0.699 (0.337-0.865)	0.516 (0.078-0.783)

When the correlations of IVC CI parameters at B and M mode analyzed, all correlations between fellows' IVC CI parameters showed moderate reliability and were statistically significant (ICC > 0.504-785 and p<0.001).

On the other hand, fellow 1's calculated parameters of IVC DI with B mode showed moderate correlations with the fellows 3 and 4 (ICC: 0.696 with fellow 3, ICC: 0.540 with fellow 4) but fellow 1's parameters were poorly correlated with fellow 2 (ICC: 0.348). Fellow 2 and fellow 3 showed also poor reliability (ICC: 0.319) but fellow 3 and 4 had moderate correlations (ICC:0.527) with each other regarding the IVC DI at B mode. When the correlations of IVC DI parameters at M mode analyzed, fellow 1's measurements were poorly correlated with fellow 2 and 4 (ICC: 0.208 with fellow 2, ICC: 0.249 with fellow 4, respectively). All other correlations between fellows' IVC DI parameters at M showed moderate reliability and were statistically significant (ICC > 0.438-0.777 and p<0.001).

When subgroup analysis was done with layering with the number of examinations performed (≤10 vs >10 or ≤15 vs >15 examinations performed), respiratory rate (≤ 20 vs >20 breaths/min), mean blood pressure (≤70 vs >70 mmHg), spontaneous breathing vs mechanical ventilation, vasopressor use or not, the correlations lost statistical significance (p>0.05, data not shown).

Discussion

In this study, we investigated the interrater reliability of IVC-USG performed by intensive care fellows. We found moderate -good correlations between each fellow and the trainer and also between the fellows regarding directly measured IVC diameters and calculated collapsibility indexes but distensibility indexes had poor-moderate correlations.

In clinical practice, critically ill patients are managed by different ICU physicians during their ICU stay and in intensive care training programs, different fellows usually perform the IVC USG, therefore it is important to know the interrater reliability of the USG measurements as the major limitation of USG is its sonographer dependence.

Similar to our findings, the interrater reliability of IVC measurements has been previously reported to be moderate in emergency physicians (15,16). Different physicians can come to opposite conclusions for the same patient although using the same tool at the same time (4). Increasing the threshold for management decisions is one of the ways to prevent this potential problem. In one study, the expert physician sonologist and junior reader demonstrated moderate interrater reliability with an intraclass correlation of 0.73 and it has been suggested that 25% is a good cutoff value for IVC collapsibility to detect fluid responsiveness (12).

It seems to be more important to know not only the specialty of the physician but content of the training and the type of the patients and the presumed diagnosis in order to discuss further the interrater reliability of IVC measurements. In a prospective observational study, intensivists doing fellowship in critical care were trained for specific focused transthoracic echocardiography protocol for 60 h (2 h/day for 30 days) by cardiologist by using real-time training in the echocardiography laboratory and video demonstrations (18). After that training good reliability (Intraclass correlation estimate for assessing hypovolemia was 0.790-0.902) was found with IVC diameters in hypovolemic patients (18). This higher correlation may be explained by either different training methods may increase the competency of intensivists or the correlation is higher in hypovolemic patients. Yet, it is still important to underline the need for a standard training protocol should be considered not only for IVC measurements but also for focused echocardiography or even transesophageal echocardiography to incorporate this powerful modality into ICU practice (19). To further support the second explanation; good interrater reliability has been reported for maximum IVC diameter<2 cm and respiratory collapse >50 % for the diagnosis of hypovolemia during the evaluation of undifferentiated hypotension in the emergency department (20). Actually, IVC diameters have been suggested to be useful supplement of CVP for the evaluation of preoperative patients with hypovolemia (21). Although our patient group consisted of mostly postoperative patients, they were not all hypovolemic.

Our study also has limitations. First, this research was conducted on a limited number of ICU fellows and on a limited number of ICU patients. Additional studies from patients across a wider range of comorbidities, admission diagnoses and volume status may expand the findings of this study. Second, as discussed above, different training methods may increase the interrater reliability of IVC measurements. Thirdly, this study did not aim to investigate the correlations between IVC measurements and other hemodynamic monitoring techniques. Lastly, use of IVC measurements as a part of a more complete hemodynamic evaluation may also increase the decision assisting capacity of IVC related measurements.

Conclusion

The interrater reliability of IVC diameters, IVC collapsibility and IVC distensibility measurements performed by intensive care fellows is moderate.

AUTHOR CONTRIBUTIONS:

Concept: SBA; **Design:** AE, SBA; **Supervision:** EOE; **Fundings:** BK; **Materials:** KR; **Data Collection and/or Processing:** KR; **Analysis and/or Interpretation**: SBA, KR, AE; **Literature Search:** IK, AE; **Writing Manuscript**: KR, SBA, EOE; **Critical Review:** BK, SBA.

Ethics Committee Approval: Hacettepe University Faculty of Medicine, non-interventional ethics committee (Meeting date: 15.04.2015) in 21.04.2015. Application was made in 2015. Since the study is an educational study, permission from the ethics committee was not required by university ethics commitee.

Informed Consent: For patients who are not intubated, from them; For intubated patients, permission was obtained from patient relatives.

Peer-review: Externally peer-reviewed.

Conflict of Interest: Authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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