Original Article

Agreement in Evaluation of Inferior Vena Cava Collapsibility Index by Medical Students Using Ultrasound Compared to Emergency Physicians

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Background: An inferior vena cava (IVC) ultrasound is a useful tool for evaluation of fluid status in emergency patients. However, Thai medical students have never been trained to do IVC ultrasound.

Objective: To ascertain whether medical students with minimal training could perform IVC ultrasounds.

Materials and Methods: A prospective observational study was conducted among sixth-year medical students who were trained to perform an IVC ultrasound by watching a video clip and doing hands-on practice. The patients, who were older than 18 years and required volume status evaluation, were initially scanned by emergency physicians and then by students. The agreement in IVC measurements between the emergency physicians and the medical students were determined using intraclass correlation coefficient (ICC).

Results: Forty medical students performed IVC ultrasounds. A very high inter-observer reliability was observed between IVC collapsibility index (IVC-CI) measured by the students and the physicians (ICC 0.74, 95% CI 0.56 to 0.85). A Bland-Altman plot analysis showed the mean difference in the IVC-CI was 0.89, with a 95% limit of agreement ranging from –33.59% to +31.80%. The sensitivity and specificity of the IVC ultrasounds correlated with the clinical data for evaluation of the hypovolemic status were 95% (95% CI 75.13 to 99.87) and 100% (95% CI 83.16 to 100.00), respectively.

Conclusion: After minimal training, the medical students could obtain IVC images; however, their measurement accuracies were poor, as indicated by the wide 95% limit of agreement.

Keywords: Inferior vena cava, Ultrasound, Medical student

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The evaluation of volume status in critically ill patients is a crucial skill for clinicians in an emergency department (ED). Many tools have been proven to be effective in determining volume status, including central venous pressure (CVP) measurements and inferior vena cava (IVC) ultrasounds[1-3]. However, a CVP measurement is an invasive procedure with potentially serious complications. Moreover, studies have demonstrated that it is a poor predictor of volume responsiveness[1,4,5].

With the increasing availability of ultrasound in EDs, IVC ultrasound has become widely used to evaluate volume status. In addition to being non-invasive, ultrasounds can be performed repeatedly without patient exposure to radiation, which enable clinicians to assess volume status with dynamic parameters. The change in diameter of the IVC during respiration reflects the volume status, and the variations in IVC diameter can be calculated to give the IVC collapsibility index (IVC-CI). This is

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obtained by taking the difference between the IVC maximum diameter (IVCmax diameter) and the IVC minimum diameter (IVCmin diameter), dividing the result by the IVCmax diameter, and then multiplying the figure by 100 to obtain a percentage. An IVC-CI of more than 50% indicates hypovolemia and responsiveness to the fluid loading[2,6].

Ultrasound training has been integrated into the undergraduate curriculum of many institutes[7-9]. The content of the ultrasound programs varies among the schools, ranging from ultrasound-assisted basic science learning to ultrasound use in clinical practice[7]. Recent literatures have demonstrated that medical students have the ability to perform ultrasounds accurately, and that ultrasound training improves the learning of basic knowledge[10-12]. However, in Thailand, ultrasound-skill development is not considered essential. The ultrasound systems taught to medical students are Focused Assessment with Sonography in Trauma (FAST) and basic obstetric ultrasounds.

Considering the importance of an IVC ultrasound as a practical tool for medical students to evaluate volume status as well as the limited time available for didactic teaching sessions in an ED, the authors developed a video clip of IVC ultrasound techniques for medical students working in the ED. The authors hypothesized that with minimal training (through the video clip and hands-on practice), medical students should be able to correctly obtain an IVC ultrasound. Therefore, the present study aimed to compare the results between the IVC measurements performed by medical students and those by emergency physicians. The secondary objective was to promote the ability of medical students to assess the volume status of patients using clinical assessment and an IVC study.

Material and methods

This prospective observational study was conducted between September and October 2016 at the ED of Siriraj Hospital, Mahidol University, which is an academic hospital with more than 20,000 non-trauma ED visits annually. The undergraduate curriculum is a six-year program. Medical students are trained to perform FAST while they are rotating through the trauma division, surgical department, and basic obstetric ultrasound during their rotation through the gynecologic-obstetric department. None of the medical students had any experience with IVC ultrasounds. The present study was approved by the Siriraj Institutional Review Board.

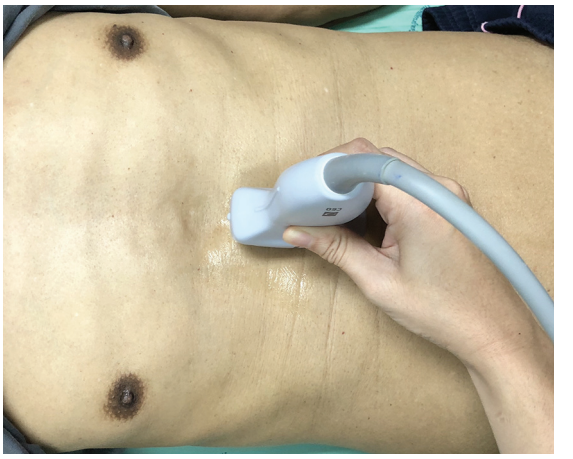

Figure 1. Probe orientation for inferior vena cava ultrasound.

Participant selection

The sixth-year medical students that was on duty in the ED during the study period and that had given written informed consent to participate in the present study were enrolled.

The inclusion criteria for the patients were aged older than 18 years and required an evaluation of their volume status. The patients were excluded if they had trauma, valvular heart disease, pulmonary hypertension, or emergency conditions (such as ST-segment elevation myocardial infarction, post-cardiac arrest, impending respiratory failure, post intubation, or hypotension).

Study protocol

While on duty in the ED, the participating medical students watched a 10-minute video on how to perform an IVC ultrasound and interpret the results. The video had been created and approved by three emergency physicians who had recognized expertise in administering and interpreting ultrasound scans. After watching the video, the medical students practiced performing an IVC ultrasound by scanning a patient in the ED under an emergency physician's supervision.

The IVC studies were performed by using a curvilinear probe (Sonosite X-Porte, C60xp probe, 8-5 MHz). The patients were scanned in the supine position during spontaneous respiration and the ultrasound transducer was placed in the sagittal plane at the subxiphoid area (Figure 1). A longitudinal view of the IVC was obtained. The M-mode was used to capture the variations in the diameter of the IVC arising through respiration, and an IVC measurement

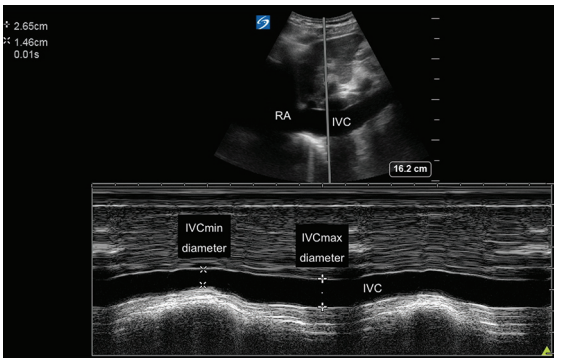

Figure 2. Inferior vena cava measurement in M-mode.

RA=right atrium, IVC=inferior vena cava, IVCmin diameter=inferior vena cava minimum diameter, IVCmax diameter=inferior vena cava maximum diameter

was taken 2 cm past the junction of the right atrium and the IVC (Figure 2). The IVC-CI was calculated using this formula:

$$\text{IVC-CI} = \frac{\text{IVCmax diameter} - \text{IVCmin diameter}}{\text{IVCmax diameter}} \times 100$$

After written informed consent was given, a patient who met the selection criteria was scanned by an emergency physician. The scan was then repeated by one of the medical students who was blinded when the emergency physician was scanning. Each medical student performed only one ultrasound scan on one patient. Video clips of the IVC studies conducted by both the physician and the student were recorded. Duration of ultrasound scanning of both groups were also recorded.

After the IVC scanning, each medical student reviewed the patient's history and the physical examination details recorded in the patient's medical record before being asked to determine whether that patient was in a hypovolemic or non-hypovolemic state. The final decision regarding the volume status was made by the emergency physician treating the patient. An IVC-CI of more than 50% indicated hypovolemia[2,6].

The baseline characteristic of the patients, including age, sex, body mass index, and final diagnosis, were also recorded.

Outcomes

The primary outcome was the determination of an agreement in IVC measurement between the medical students and those of the emergency physicians. The secondary outcome was an assessment of the accuracy of the students' evaluations of the patients' hypovolemic status.

Statistical analysis

Based on the findings of a prior study[3], the authors estimated that the mean difference in the maximum diameters obtained by the medical students and the emergency physicians would be 0.2 cm. With a standard deviation of 0.4, 90% power and a two-sided alpha level of 0.05, an enrollment of 44 subjects was required.

The baseline characteristics were presented as frequencies and percentages, mean ± standard deviation. The measurements of the IVC and the duration of the ultrasound examination were presented as mean ± standard deviation. The difference in IVC measurement between the medical students and the emergency physicians was calculated using paired t-test. The agreement in IVC measurements between the medical students and the emergency physicians was described using intraclass correlation coefficient (ICC). A Bland-Altman plot analysis was performed to determine the mean difference and the 95% limit of agreement between the two groups of sonographers. The accuracy of the medical students' evaluation of the hypovolemic status was described using sensitivity and specificity. Data analyses were performed using SPSS Statistics for Windows, version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Forty-four medical students performed IVC ultrasounds. However, four students were excluded from the study as two could not obtain optimal views of the IVC, while the other two misinterpreted the aorta to IVC. The remaining 40 students were enrolled in the present study.

The mean age of the patients scanned was 69.5 years. Of the 40 patients, 24 (60%) were males. The most common patient diagnosis was sepsis (40%), followed by pneumonia (15%) and congestive heart failure (12.5%) (Table 1).

The mean IVC-CI calculated by the students and physicians were 40.10±21.62% and 40.99±24.07%, respectively (Table 2).

The mean duration of the ultrasound scanning was 2.02 minutes for the medical students and 0.57 minutes for the emergency physicians (Table 2).

The inter-observer reliability in IVC-CI measured by the students and the physicians was very high (ICC 0.74, 95% CI 0.56 to 0.85) (Table 3).

A Bland-Altman plot analysis of the IVC studies is shown in Figure 3. The mean difference in the IVC-CI results was 0.89%, with the 95% limit of agreement ranging from –33.59% to +31.80%.

Table 1. Baseline characteristics of the patients

Characteristic	n=40 n (%)
Age (year); mean±SD	69.5±17.5
Male	24 (60.0)
Body mass index (%); mean±SD	23.2±4.8
Diagnosis	
Sepsis	16 (40.0)
Pneumonia	6 (15.0)
Congestive heart failure	5 (12.5)
Acute kidney injury	4 (7.5)
Tracheobronchitis	3 (7.5)
Hypovolemia from poor intake	2 (5.0)
Gastrointestinal bleeding	2 (5.0)
Diabetic ketoacidosis	1 (2.5)
Hypertensive emergency	1 (2.5)

SD=standard deviation

Table 2. IVCmax diameter, IVCmin diameter, IVC-CI, and duration of examination

	6th year medical student* (n=40) Mean±SD	Emergency physician** (n=40) Mean±SD	p-value
IVCmax diameter (cm)	1.60±0.49	1.56±0.49	0.47
IVCmin diameter (cm)	1.01±0.55	0.98±0.57	0.43
IVC-CI (%)	40.10±21.62	40.99±24.07	0.74
Duration of examination (minute)	2.02±1.06	0:57±0.35	<0.001

IVCmax diameter=maximum diameter of inferior vena cava; IVCmin diameter=minimum diameter of inferior vena cava; IVC-CI=inferior vena cava collapsibility index; n=numbers of ultrasound performing; SD=standard deviation

* Performed by 40 medical students, ** Performed by 4 emergency physicians

Table 3. ICC of IVCmax, IVCmin, and IVC-CI measurement between medical students and emergency physician

	ICC (95% CI)	p-value
IVCmax diameter	0.73 (0.54 to 0.85)	<0.001
IVCmin diameter	0.88 (0.79 to 0.94)	<0.001
IVC-CI	0.74 (0.56 to 0.85)	<0.001

ICC=intraclass correlation coefficient; IVCmax diameter=maximum diameter of inferior vena cava; IVCmin diameter=minimum diameter of inferior vena cava; IVC-CI=inferior vena cava collapsibility index; CI=confidence interval

Of the 40 patients, 20 (50%) were hypovolemic. Based on the clinical data and the IVC studies, the medical students determined that 19 patients were hypovolemic and 21 were non-hypovolemic. The sensitivity was 95% (95% CI 75.13 to 99.87) and specificity was 100% (95% CI 83.16 to 100.00).

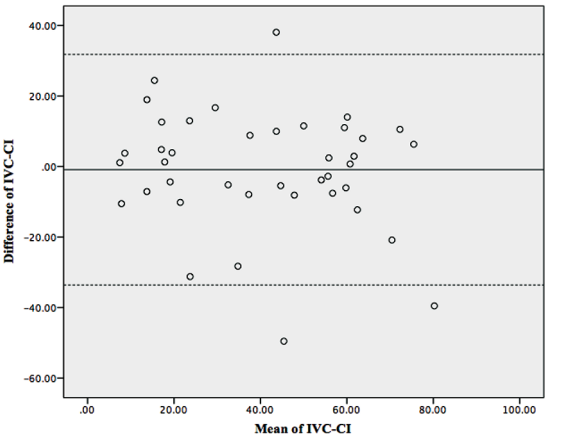

Figure 3. The Bland-Altman plot analysis of inferior vena cava collapsibility index.

IVC-CI=inferior vena cava collapsibility index

Discussion

The current study found a high inter-observer reliability between the IVC measurements between the medical students and those of the emergency physicians. However, Bland-Altman analysis revealed that most of the difference of IVC-CI measurement between two operators was between –20% and 20% with the 95% limit of agreement of –33% to 32%, which was significantly wide enough to affect volume status assessment and clinical outcome. For example, if IVC-CI measured from the medical student was 40%, the true IVC-CI might have been 10% or 70%. This might be implied that the medical students were not capable of performing IVC ultrasound correctly.

A literature review revealed two studies that had compared the IVC measurements of inexperienced and professional sonographers. Bowra et al[3] compared trainee doctors with skilled emergency physicians after the trainees had attended a 2-hour didactic session and practiced for a limited period. They demonstrated that the 95% limit of agreement of differences in the IVC studies between the two groups were too wide and could adversely affect decisions on fluid therapy. Lorenzo et al also compared the performance of inexperienced ED nurses, who received a training, included didactic period and hands-on practice on the first session and repeated practice in the second and third session[13].

A moderately strong correlation between the IVC studies of those two operators was revealed.

The present study results were consistent with Bowra et al regarding a wide 95% limit of agreement of the difference between IVC studies measured by the two groups. This might be explained by the fact that ultrasound is an operator dependent procedure and operators require time to practice before becoming experts. A number of studies have demonstrated that competency in IVC scanning is achieved through repetitive practice[14-16]. Therefore, with a short practice period, the medical students might not have enough experience to perform IVC ultrasound correctly. In addition, the medical students might perform IVC ultrasound with incorrect technique. IVC measurements were commonly misinterpreted because the inner wall was not clearly seen on the screen when using the M-mode and the IVC was moved to the lateral during respiration resulted in false inspiratory collapse[17].

Apart from the ability to optimize the IVC scanning, a clinical correlation with the findings is crucial to evaluate the fluid status. The authors chose to divide the volume status into hypovolemia and non-hypovolemia states because the cut point of the IVC-CI for hypovolemia has been well-established by previous studies[2,6]. The authors also divided the volume status that way to make it easy for the beginners to make decisions. The present study demonstrated that the medical students could use clinical data and IVC findings to determine if the patients were hypovolemic with a high sensitivity and specificity. However, most of the patients enrolled in the present study had clear clinical data that was highly suggestive of the patients' volume status. Therefore, the medical students' high sensitivity and specificity might have resulted more from the clinical data than the ultrasound findings.

The current study had some limitations. Firstly, it was a single-center study with only a small number of participants. In addition, using the measurements from emergency physicians as the standard preference might not be an accurate gold standard. Moreover, the enrolled patients had certain diagnoses that could be used to easily predict their fluid status, and the surrounding events, such as the intravenous access, that could not be blinded; therefore, the medical students might have used these advantages to make their decisions on the patients' volume status.

The authors suggest that a future study conduct with enough hands-on practice and the careful selection of patient-participants to ensure they have equivocal volume status. This will enable to conclude whether novices can perform IVC ultrasounds accurately and evaluate volume status by correlating clinical data with ultrasound findings.

Conclusion

After minimal training, the medical students could obtain IVC images; however, the accuracy of their measurements was poor, as indicated by a wide 95% limit of agreement.

What is already known on this topic?

IVC ultrasound is useful for evaluation of volume status in critically ill patient in ED[2,6]. Many institutes in Western countries have taught ultrasound to medical students. Ultrasound training was found to be beneficial to medical students in both pre-clinical and clinical year[10-12]. However, in Thailand, the ultrasound training that have been taught to medical students was the FAST. The medical students have never been taught to performed IVC ultrasound.

What this study adds?

This study created a 10-minute video clip to teach the medical students to perform IVC ultrasound and determine whether the medical students could perform IVC ultrasound accurately. The result found that after minimal training, the medical students could obtain IVC images; however, the accuracy of their measurements was poor, as indicated by a wide 95% limit of agreement.

Conflicts of interest

The authors declare no conflict of interest.

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