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## Accuracy of Ultrasonography Performed by Critical Care Physicians for the Diagnosis of DVT

Pierre D. Kory, MD, MPA; Crescens M. Pellecchia, DO; Ariel L. Shiloh, MD; Paul H. Mayo, MD, FCCP; Christopher DiBello, MD; and Seth Koenig, MD

**Background:** DVT is common among critically ill patients. A rapid and accurate diagnosis is essential for patient care. We assessed the accuracy and timeliness of intensivist-performed compression ultrasonography studies (IP-CUS) for proximal lower extremity DVT (PLEDVT) by comparing results with the formal vascular study (FVS) performed by ultrasonography technicians and interpreted by radiologists.

**Methods:** We conducted a multicenter, retrospective review of IP-CUS examinations performed in an ICU by pulmonary and critical care fellows and attending physicians. Patients suspected of having DVT underwent IP-CUS, using a standard two-dimensional compression ultrasonography protocol for the diagnosis of PLEDVT. The IP-CUS data were collected prospectively as part of a quality-improvement initiative. The IP-CUS interpretation was recorded and timed at the end of the examination on a standardized report form. An FVS was then ordered, and the FVS result was used as the criterion standard for calculating sensitivity and specificity. Time delays between the IP-CUS and FVS were recorded.

**Results:** A total of 128 IP-CUS were compared with an FVS. Eighty-one percent of the IP-CUS were performed by fellows with < 2 years of clinical ultrasonography experience. Prevalence of DVT was 20%. IP-CUS studies yielded a sensitivity of 86% and a specificity of 96% with a diagnostic accuracy of 95%. Median time delay between the ordering of FVS and the FVS result was 13.8 h.

**Conclusions:** Rapid and accurate diagnosis of proximal lower extremity DVT can be achieved by intensivists performing compression ultrasonography at the bedside. *CHEST 2011; 139(3):538-542*

**Abbreviations:** 2-D = two-dimensional; CFV = common femoral vein; FVS = formal vascular study; IP-CUS = intensivist-performed compression ultrasonography study; PE = pulmonary embolism; PLEDVT = proximal lower extremity DVT; PV = popliteal vein; SFV = superficial femoral vein

Venous thromboembolic disease is common in the ICU and has been shown to lead to significant morbidity and mortality when undiagnosed.<sup>1-3</sup> A rapid and accurate diagnosis of DVT in critically ill patients who often have marginal cardiopulmonary reserve is imperative. Ultrasonography, the primary modality for diagnosis of DVT in the ICU, is limited by the

frequent lack of around-the-clock availability of both technicians and interpreting specialists. Even when ultrasonographers and radiologists are available, the process of ordering, performing, interpreting, and reporting the examination leads to significant delays in both the diagnosis and the institution of appropriate therapy.

Clinicians with focused training in ultrasonography can perform accurate proximal lower extremity DVT (PLEDVT) studies in symptomatic outpatient populations.<sup>4-8</sup> In ICU patients, the clinical signs and

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**Affiliations:** From the Beth Israel Medical Center (Drs Kory and Pellecchia), New York; the Montefiore Medical Center (Dr Shiloh), New York; and the North Shore-Long Island Jewish Medical Center (Drs Mayo, DiBello, and Koenig), New Hyde Park, NY.

**Correspondence to:** Pierre D. Kory, MD, MPA, Beth Israel Medical Center, Division of Pulmonary, Critical Care and Sleep Medicine, 7th Floor, Dazian Bldg, 16th St and 1st Ave, New York, NY 10003; e-mail: pkory@chpnet.org

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symptoms are frequently unreliable or absent and the ultrasound examination is often limited by obesity, edema, and surgical dressings.<sup>9,10</sup> In addition, ultrasonography for DVT in similar asymptomatic, high-risk inpatients has lower sensitivity than in outpatients.<sup>11-15</sup> Given these challenges, the ability of intensivists to perform accurate DVT studies in the critically ill is unknown. We report on the accuracy of intensivist-performed compression ultrasonography (IP-CUS) for the diagnosis of PLEDVT in critically ill patients.

## MATERIALS AND METHODS

### *Study Population*

This was a multicenter study of a convenience sample of patients receiving IP-CUS from November 2008 to March 2010 at three university hospitals in New York City (Beth Israel Medical Center, Long Island Jewish Medical Center, and Montefiore Medical Center). Data were collected prospectively and placed in a deidentified database for purposes of quality assessment of IP-CUS. The institutional review board of each participating institution (Beth Israel #142-09, Montefiore #10-02-042X, Long Island Jewish #09-224) approved the study, and a requirement for informed patient consent was waived.

Patients admitted to the medical, surgical, or cardiothoracic ICUs under the care of intensivists trained in critical care ultrasonography were included in the study cohort. If DVT, pulmonary embolism (PE), or both were suspected by the critical care physician, an IP-CUS was done. Since not all intensivists in the participating ICUs were trained in lower extremity compression ultrasonography, IP-CUS examinations were not performed sequentially and represent a convenience sample. The studies were performed for the following indications: unilateral or bilateral leg swelling, tenderness, erythema, or the clinical suspicion of a PE causing dyspnea, tachycardia, hypoxemia, shock, or cardiac arrest.

### *Procedure*

At all three hospitals, critical care attending physicians and fellows routinely use bedside ultrasonography to guide diagnosis and management of critically ill patients. All participating fellows ( $n = 18$ ) received formal training in critical care ultrasonography during the third month of their first year of fellowship at a 3-day critical care ultrasonography training course. This course included formal training in the performance of two-dimensional (2-D) compression ultrasonography for DVT. This training consisted of a 1-hour didactic lecture followed by 2 hours of hands-on experience using live models and 1 hour of image interpretation review of normal and abnormal vascular ultrasound findings. All participating attending physicians ( $n = 4$ ) received formal training in the performance of 2-D compression ultrasonography studies for DVT during their fellowship training. A protocol for IP-CUS was taught at the fellows course, consisting of three compressions along the common femoral vein (CFV), two compressions along the popliteal vein (PV), and sequential compression along the superficial femoral vein (SFV) in 2-cm increments if the CFV and PV sites were both fully compressible. All compressions were done using 2-D imaging with transverse views. DVT was diagnosed by the inability to fully compress a vein segment. Examinations were performed using portable ultrasound machines (M-Turbo [Sonosite; Bothell, Washington] broadband L25  $\times$  6-13 MHz transducer or Logiq Book XP [General Electric; Fairfield, Connecticut] broad-

band 8L-RS 4-10MHZ transducer). The IP-CUS did not include routine use of Doppler. On occasion, the examiner used color Doppler to localize the vein but used it for no other purpose. Results of the IP-CUS were recorded prospectively on a standardized report template at the time of the examination. IP-CUS performed by fellows were not routinely reviewed by attending physicians.

All IP-CUS results were compared with a confirmatory, formal vascular ultrasound study (FVS), ordered per protocol at the time of IP-CUS. All FVS were performed by an ultrasonography technician and included evaluation of the CFV, SFV, and PV using triplex scanning (B-mode compression, color augmentation, and spectral Doppler ultrasound). FVS studies were then interpreted by an attending radiologist or vascular specialist who was unaware of the results of the IP-CUS study at the time of their reading. This FVS report was used as the criterion for comparison.

In cases in which the FVS and IP-CUS results were discordant, the interpreting physician of the FVS was shown the IP-CUS images. Changes to the FVS report after this review were recorded in the database and used in a secondary analysis of accuracy.

### *Data Collection*

One investigator at each institution collected all local IP-CUS report forms. The results were entered into a database. The investigator at each institution then performed a retrospective review of the FVS image database and entered the result for comparison. Patient information was deidentified in accordance with the Health Insurance Portability and Accountability Act and included the age, sex, location, admitting diagnosis, comorbidities, ICU day number, and hospital day number. IP-CUS data included the date and time the study was performed, indication for the study, presence of a femoral catheter, scanning time, anatomic site of clot if found, and initiation of treatment based on results. FVS data included the date and time the study was ordered, date and time of the FVS report, the anatomic site of clot if found, and whether anticoagulation was initiated prior to interpretation.

### *Statistical Analysis*

Sensitivity, specificity, and positive and negative predictive values of IP-CUS were calculated, using the FVS as the criterion standard. Mean and median time delays from initial order to FVS result were calculated. A second analysis of accuracy was also performed. In this analysis, the final report generated by the attending radiologist after a review of the image sets from the discordant IP-CUS and FVS was used as the criterion standard.

## RESULTS

One hundred thirty-two IP-CUS were performed for the indications shown in Table 1. IP-CUS in four patients were not included because of death occurring prior to performance of the confirmatory FVS, leading to 128 studies included for analysis. None of the four patients who died had an IP-CUS that showed a DVT. The four deaths were attributed to pneumonia, lymphoma causing multiorgan failure, post-arrest anoxic injury, and COPD, respectively. IP-CUS were performed by 18 fellows and four attending physicians among the three institutions. Eighty-one percent of studies were performed by fellows with  $< 2$  years' experience after their initial training course. The overall prevalence of PLEDVT was 20%.

**Table 1—Indications for Performance of Lower Extremity CUS**

Indication for CUS Exam	No. of Studies Performed (%)
Lower extremity swelling/erythema/tenderness	40 (31)
Suspicion for PE, unspecified	36 (28)
Suspicion for PE causing respiratory failure	19 (14)
Suspicion for PE causing hypoxemia	14 (11)
Suspicion for PE causing hypotension/tachycardia	9 (7)
Suspicion for PE causing cardiac arrest	3 (2)
Other <sup>a</sup>	7 (6)

CUS = compression ultrasonography study; PE = pulmonary embolism.  
<sup>a</sup>Other: heparin-induced thrombocytopenia, incidental finding during catheter insertion, fever of unknown origin.

Overall, IP-CUS examinations were discordant with the FVS in nine patients, with six false positives and three false negatives. This led to an IP-CUS sensitivity of 86%, a specificity of 96%, and a diagnostic accuracy of 95%.

In the nine discordant cases, the radiology attending physician was shown the IP-CUS images by the intensivists to determine appropriate management of the patient. In four cases of DVT found by IP-CUS but not by FVS, the radiologist or vascular specialist agreed with the IP-CUS image and interpretation, and changed the FVS result to positive for DVT, despite the lack of visualization of thrombus in the FVS image set. This occurred once each at two institutions and twice at a third.

In the five other discordant cases, the radiologist confirmed the findings and interpretation of the FVS images. In two cases of DVT found by IP-CUS, the finding was deemed a false positive (in one, chronic thickening was mistaken for DVT, and in the other, a lack of compressibility due to the presence of a femoral catheter was wrongly attributed to thrombus). In three cases of negative IP-CUS, the FVS revealed the presence of thrombus, thus deeming the IP-CUS a false negative.

When calculating accuracy by comparing the IP-CUS result to the “final” FVS interpretation recorded by the attending radiologist or vascular specialist, the IP-CUS sensitivity was 88%, specificity 98%, and diagnostic accuracy 96%. Using this method, accuracy was calculated for the initial FVS using the above final report as the criterion standard. This showed the initial FVS to have a sensitivity of 85%, specificity of 100%, and a diagnostic accuracy of 97%.

Median time delay between IP-CUS and the FVS among the three institutions was 13.8 h. Individual time delays among institutions were 7.3, 8.0, and 29.3 h. Of the 26 DVTs found, 20 involved the region of the CFV, four were isolated to the PV and two were isolated to the SFV.

## DISCUSSION

Our results show that IP-CUS yields immediate and accurate results when compared with an FVS. This suggests that the front-line intensivist may diagnose or exclude PLEDVT by performing 2-D compression ultrasonography at the bedside. This has major advantages, as it avoids the time delay intrinsic to FVS, saving a median of 13.8 h among the three hospitals studied. In turn, this allows the intensivist to initiate immediate therapy for thromboembolic disease, to avoid unnecessary therapy while waiting for FVS, and to avoid unnecessary diagnostic testing in the event of delayed FVS. The IP-CUS is an example of the usefulness of ultrasonography in critical care medicine and supports the idea that an ultrasound machine should be part of standard ICU equipment.

Other investigators have reported that non-radiologists can perform ultrasonography studies for PLEDVT with a high degree of accuracy.<sup>4-8,16</sup> Blaivas and colleagues<sup>4</sup> found that emergency medicine physicians with 5 h of training achieved 98% agreement with FVS. Magazzini et al<sup>7</sup> reported that emergency medicine physicians who underwent 6 h of lectures and 1 day of training by a radiologist achieved a positive predictive value of 95% and a negative predictive value of 100% when compared with FVS. In hospitalized patients, none of whom were critically ill, Trottier and colleagues<sup>16</sup> showed that self-trained clinicians achieved a sensitivity of 94% and a specificity of 99% for PLEDVT when compared with FVS. These studies demonstrate that clinicians with focused training can achieve high accuracy for the diagnosis of PLEDVT using ultrasonography in the noncritically ill. Our study confirms these results in critically ill patients. In the present study, 69% of patients were without any localizing signs or symptoms of PLEDVT, a population in whom ultrasonography for DVT has low sensitivity and is more difficult to perform.<sup>10-15</sup> To our knowledge, this is the first study demonstrating that bedside clinicians can achieve high accuracy in a population of critically ill patients largely without localizing signs or symptoms suggesting DVT.

Standard FVS uses 2-D imaging with compression, spectral Doppler, and color Doppler. We have shown that the sole use of 2-D imaging with compression yields results that are of similar accuracy to an examination that includes the use of Doppler. We conclude that Doppler examination is not necessary and relying solely on lack of compression to diagnose intraluminal thrombosis is sufficient. This confirms, in a critically ill population, what others have found in the noncritically ill.<sup>5,11,17,18</sup>

An FVS that includes color and spectral Doppler takes up to 30 min to perform, a prohibitive time commitment for the busy intensivist. Blaivas et al,<sup>4</sup>

Jang et al,<sup>8</sup> and Magazzini et al<sup>7</sup> reported 3-, 10-, and 13-min durations for their clinician-performed examinations, respectively. The average time required for our IP-CUS was 12.5 min, thus making it feasible for busy intensivists to perform their own tests. The simplicity, rapidity, and immediate result of a CUS-only examination protocol reduces the need for unnecessarily complex, multimodality examinations performed by trained ultrasonography technicians. At operator discretion, color Doppler was used during IP-CUS solely to aid in identifying venous anatomy but not for confirming presence of thrombus, a technique that has been shown to decrease the frequency of indeterminate studies.<sup>4</sup>

The IP-CUS examination was limited to the proximal veins secondary to the undefined clinical relevance of isolated calf DVT in the ICU, the much lower sensitivity of ultrasonography in diagnosing calf DVT, and the increased time this would require.<sup>10,11,19,20</sup> Further, the risks of treatment of calf DVT in the ICU likely outweigh any benefit given that: (1) PE results almost solely from proximal veins, (2) only a small minority (10%) of distal DVT will extend proximally,<sup>21</sup> (3) an ICU study searches for evidence of an immediate risk or cause of PE or symptomatic DVT, and (4) the American College of Chest Physicians guideline gives a weak recommendation for treating isolated calf DVT (IIB: weak, benefits only marginally outweigh risks) compared with the demonstrated increased risks of anticoagulation in the critically ill.<sup>10,21-23</sup>

Our study used a three-point scanning protocol, with imaging of the CFV, PV, and SFV. This protocol differs from the two-point method wherein the CFV and PV but not the SFV are imaged. The two-point examination is accurate and well validated in the symptomatic outpatient population.<sup>11,17,18,24</sup> We used the three-point protocol based on studies showing a higher incidence of clots isolated to the SFV in asymptomatic patients.<sup>15,25</sup> The overall sensitivity of 88% in our sample would have decreased to 82% if the SFV had not been included. We recommend against using a two-point examination in critically ill patients without physical findings consistent with DVT.

There was a median delay of 13.8 h between the order and final interpretation of the FVS, with only 50.0% (64/128) reported the same day. The delay was due to lack of both immediate and around-the-clock availability of the ultrasonography technicians and radiologists needed to perform and interpret the study. Although these delays may not be the norm in other institutions, they were present at all three large urban teaching hospitals included in this study. In the ICU, the clinical question as to whether thromboembolic disease contributes to the patient's condition requires an immediate answer in order to avoid unnecessary alternative diagnostic testing, such as CT scan or the

empirical use or denial of anticoagulation. A delay in diagnosis could adversely impact patient outcome. Compared with FVS, IP-CUS clearly improves the timeliness of diagnosis of PLEDVT as well as reduces resource use in the ICU.

We used the initial FVS report as the gold standard for diagnosis. The results of the intensivist-performed examinations were not completely concordant with FVS. In four cases, the IP-CUS found PLEDVT, but the FVS did not. On review of the intensivist-performed study, the radiologist changed the final FVS report from negative to positive, resulting in a major impact on patient management. Intensivists need to be aware that ultrasonography technician-performed studies may yield false-negative results. Alternatively, in two instances, the IP-CUS identified PLEDVT, but the FVS did not, and in three instances FVS identified PLEDVT but the IP-CUS did not. This underlines the need for adequate training of intensivists in the performance of compression ultrasonography in order to reduce false-negative and false-positive scans.

This study has methodologic limitations. Although data collection was prospective, the decision to perform an IP-CUS was not driven by protocol, and so the study consists of a convenience sample. Selection bias in reference to patient type, time of day, time of week, and operator experience are of major concern in terms of study design. Despite this, the DVT prevalence rate of 20% is similar to the overall prevalence rate of 22% reported from a meta-analysis of ultrasonography accuracy studies for PLEDVT done in high-risk, asymptomatic patient populations.<sup>12</sup>

Another limitation is that the IP-CUS and the FVS were not performed contemporaneously. In the false-negative IP-CUS studies, it is possible that DVT formed during the time delay between performance of the two studies. Conversely, in the false-positive IP-CUS studies it is possible that the DVT migrated during the time period between the two studies. We also did not perform interoperator variability assessment of the ICU clinicians, and we did not perform any clinical follow-up of the patients. Finally, we also reported on accuracy after the FVS interpreting physician was shown the discordant IP-CUS studies, a possibly biased method (ie, they may be more reluctant to call the FVS a false negative or more inclined to call the IP-CUS a false positive). This occurred prior to this retrospective analysis of accuracy and was done in an attempt by the intensivists to ensure appropriate interpretation and management of their patients.

It is unknown whether these results are generalizable. Although the study was performed at three different institutions, the attending physicians all had a similar training background in ultrasonography

(all came from the same fellowship training program), and the fellows all had similar training at a standard course. Before adopting an IP-CUS strategy, the intensivist must be sure to achieve similar competence as the attending physicians and fellows involved in the present study.

## CONCLUSIONS

Critical care clinicians can perform IP-CUS with an accuracy that compares favorably with certified technician-performed FVS. Competence in IP-CUS may be achieved with a short training period. A major advantage to an intensivist-performed study is that it avoids the time delay in the diagnosis and management of DVT that is characteristic of FVS.

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*Dr Pellecchia:* contributed to identifying the purpose of the project, designing the study, creating the data collection instrument, performing all database management and analysis, and creating the tables.

*Dr Shiloh:* contributed to writing and revising the manuscript.

*Dr Mayo:* contributed to writing and revising the manuscript.

*Dr DiBello:* contributed to designing the data collection instrument and performing data collection and database management.

*Dr Koenig:* contributed to identifying the purpose of the project, designing the study, creating the data collection instrument, and writing and revising the manuscript.

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