

Ultrasound in Emergency Medicine



COMPARISON OF THE ACCURACY OF EMERGENCY DEPARTMENT-PERFORMED POINT-OF-CARE-ULTRASOUND (POCUS) IN THE DIAGNOSIS OF LOWER-EXTREMITY DEEP VEIN THROMBOSIS

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Abstract—Background: Compression ultrasonography is the most effective diagnostic tool in the emergency department (ED) for the diagnosis of deep vein thrombosis (DVT). It has been demonstrated to be highly accurate and cost-effective. **Objective:** The objective of this study was to determine the accuracy of emergency physicians who performed three-point compression ultrasound (US) for suspected above-knee DVT within the context of using Wells score and D-dimer. **Method:** This was a prospective diagnostic test assessment of three-point ultrasound conducted in a district general hospital of patients who presented to the ED with suspected DVT of the lower limb. The accuracy of three-point ultrasound carried out by the emergency physicians was assessed by comparison of the Doppler ultrasound carried out by the Radiology Department as reference standard. The study incorporated ultrasound alongside the Wells score and D-dimer. **Results:** A total of 109 patients (66.1%) had a three-point compression point-of-care ultrasound in the ED and a second ultrasound performed by the Radiology Department. Bedside three-point compression ultrasound of the lower extremity performed by physicians in the ED had a sensitivity of 93.2% (95% confidence interval [CI] 83.8–97.3%) and a specificity of 90.0% (95% CI 78.6–95.7%), with an accuracy of 91.7% (95% CI 85–95.6%). **Conclusions:** Emergency physicians can obtain a

level of competence equivalent to that of radiologists, but it requires substantial training and practice to achieve and maintain this performance. Providers should be aware of their limitations and maintain regular training with ultrasound applications. © 2017 Elsevier Inc. All rights reserved.

Keywords—thromboembolic disease; diagnosis; imaging; ultrasound; emergency department management; DVT

INTRODUCTION

Compression ultrasound is the most accurate noninvasive test for the diagnosis of deep vein thrombosis (DVT). Full compressibility of the femoral or popliteal veins rules out thrombosis at this level (proximal DVTs also occur in the pelvis “iliac vessels,” and these cannot be ruled out via compression of femoral/popliteal veins) (1). Ultrasound is recommended as the initial diagnostic test for patients with intermediate to high pretest probability of DVT in the lower extremities (2). The use of point-of-care-ultrasound (POCUS) in the emergency department (ED) has increased over the past 15 years. Several studies

have demonstrated that emergency physicians are capable and effective in performing ultrasound scanning of DVT (3).

Emergency physicians commonly use a three-point compression technique that focuses on the highest probability areas with similar sensitivity and specificity (1,4–6). However, recent studies have failed to show similar accuracy and have shown that ultrasound performed by emergency clinicians may fail to detect a third of patients with DVT (6–8). Therefore, despite several literature reviews on the efficacy of emergency physician ultrasound for DVT in the ED, controversy remains. There are numerous practices and centers where emergency medicine providers are routinely performing these scans. The emergency medicine community and American College of Emergency Physicians support the notion of emergency physicians providing this care for patients; however, resources, relationships with radiology, and physician interests all play into the equation and controversy as to whether emergency physicians should be performing this specific scan. The primary goal of the study was to identify the accuracy of emergency physicians using a three-point compression ultrasound in the diagnosis of DVT.

METHODS

A prospective cross-sectional study and diagnostic test assessment was carried out of patients presenting to the ED with suspected DVT between March 2012 and May 2014. The study included a convenience sample of patients over 18 years who presented to the ED with suspected DVT of the lower limbs. These patients underwent a three-point compression POCUS performed by the emergency physicians. Patients with suspected DVT were followed up in the DVT clinic and had a formal ultrasound reported by the Radiology Department. The study was performed in a district general hospital with an annual ED census of 30,000. The research ethics committee of the hospital approved the protocol. Patients were followed up via a telephone interview by doctors that participated in the study as well as through the digital software Diraya, an electronic health record in Andalucía, Spain, and the hospital DVT clinic. The follow-up was performed at 3, 6, and 12 months after the first visit to the ED.

In the protocol group, all patients with suspected DVT aged 18 years or older were included. The inclusion criteria in triage was performed by experienced nurses and included patients presenting with signs or symptoms concerning for DVT. The exclusion criteria were patients with an established diagnosis of DVT, diagnosis of DVT in the past 6 months, and recent Doppler ultrasound in the

past 30 days, and low-risk patients by Wells with a negative D-dimer.

All physicians involved in the study were emergency physicians with at least 5 years' experience in the ED after training. The intervention included training in DVT POCUS, all 10 physicians involved had their first 3-day training course between 2008 and 2011, with 4 h dedicated to DVT training, including practice on models. After the course, all physicians began to perform compression ultrasound in patients with suspected DVT over a 6-month period and teaching meetings with the Radiology Department before the protocol was established. All physicians involved had performed more than 30 POCUS for DVT prior to initiation of the protocol.

The new protocol for suspected DVT including POCUS started in March 2012 (Figure 1). The study incorporated the ultrasound to the Wells score and D-dimer. The POCUS examination was considered indeterminate if the veins could not be clearly identified or compressibility was equivocal. An indeterminate examination was considered positive in terms of statistics.

Compression ultrasound of the lower limbs in the ED was performed with a portable ultrasound, the Esaote MyLab 25 (Esaote SpA, Genoa, Italy), using a high-frequency probe (7.5-MHz linear probe). With the patient supine, the suspected affected limb was examined, beginning at the femoral vessels at the inguinal ligament level (common and superficial femoral vein). When the common femoral vein and artery were identified, patients were scanned proximally until the great saphenous vein emptying into the common femoral vein was seen, which is an area that is prone to high rates of DVT due to increased turbulence. Subsequently, they were scanned distally to the junction of the common femoral, superficial femoral, and deep femoral veins. The last step included the popliteal fossa for visualization of the popliteal vein and artery; the examination included 2 cm distal to the popliteal vein and the proximal aspects of its trifurcation into the anterior tibial vein, the posterior tibial vein, and the peroneal vein. The calf veins were not explored and calf augmentation or respirophasic variation were not performed. Transverse images were obtained, however, longitudinal images were obtained in certain patients to clarify the anatomy or confirm an abnormality, especially at the deep femoral vein and femoral vein branching and the two branchings of the popliteal vein.

Positive findings for DVT included veins that were not compressible or if a thrombus was visualized. Doppler ultrasonography was used in certain cases (e.g., morbidly obese patients or in those with unusual anatomy) to help determine anatomic orientation and avoid potentially misleading structures. Arteries were identified by observing pulsatile flow with color Doppler and the

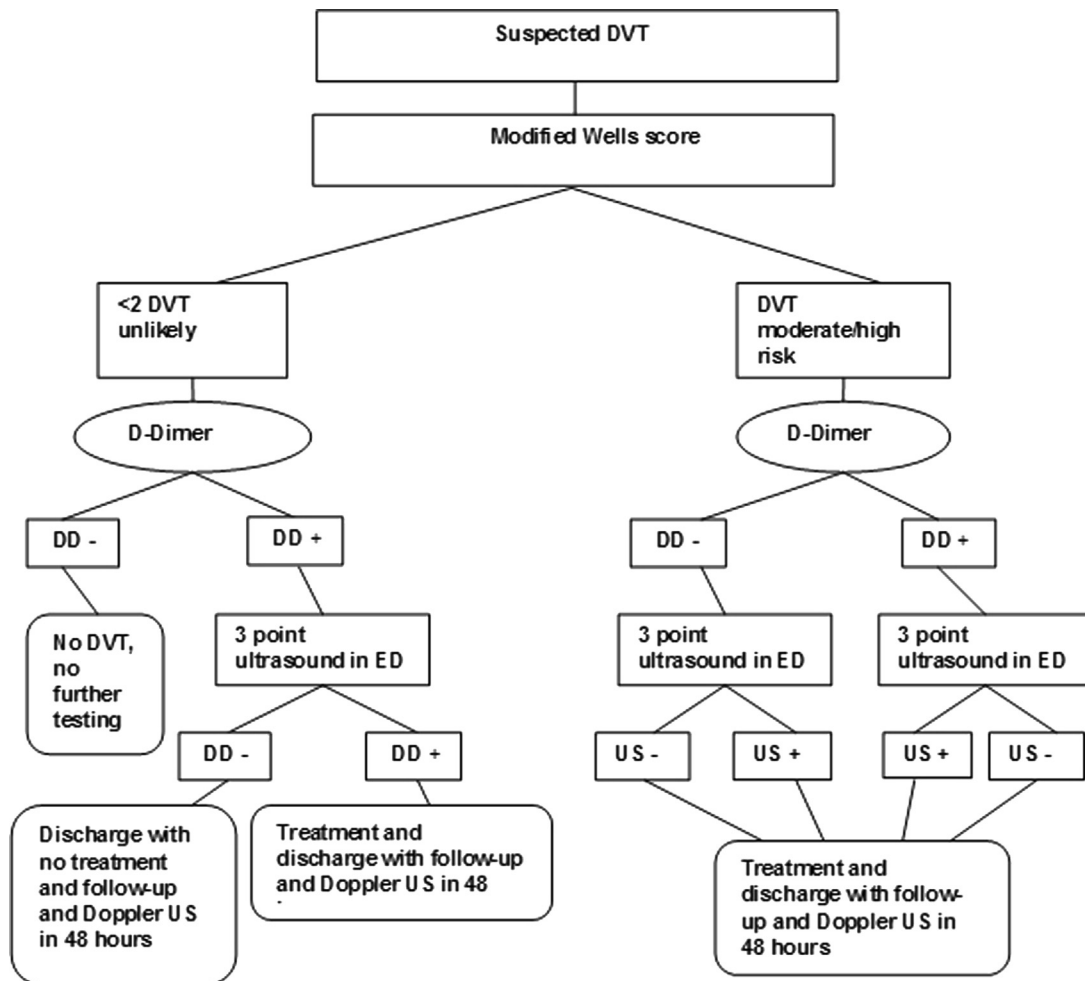


Figure 1. Proposed new diagnostic approach incorporating ultrasound to rule out DVT. DVT = deep vein thrombosis; DD = D-dimer; ED = emergency department; US = ultrasound.

presence of an arterial waveform with spectral Doppler, as opposed to continuous flow and a venous waveform seen in venous structures. Information obtained from Doppler ultrasonography alone was not used as definitive evidence regarding clot presence. The emergency physicians performing the ultrasound save the videos of their scans. The length of time that was required to perform ultrasound was obtained by the junior resident doctor who was present in all ultrasound procedures; junior doctors were instructed to record the start and finish times on the data collection. Time was recorded using the stopwatch and timer of an Android phone (Google, Mountain View, CA) beginning when the ultrasound machine was turned on; it included patient's data recorded in the screen and finished when the study was completed. The Radiology Department performed a complete Doppler examination in < 48 h. The radiologists were blinded to the ED ultrasound results.

In all patients, sociodemographic characteristics such as age (years), sex, reason for ED admission (edema,

pain, or other); past medical history including hypertension, diabetes mellitus, obesity, cardiovascular disease, atrial fibrillation, chronic obstructive pulmonary disease, previous stroke, pregnancy/postpartum period; family history of DVT, previous DVT; clinical characteristics (pain, hyperthermia, erythema, edema, collateral circulation, palpable venous cord, and difference in centimeters between lower limbs); plasma D-dimer, anticoagulation prior to the episode, and their Wells score were collected (9). We reported hospital admission for any of the patients. All the patients that had POCUS ultrasound in the ED were followed up by the DVT clinic for 1 year to monitor for any related complications and the resolution time of the DVT.

We performed an a priori sample size calculation based on a pilot study of 172 patients performed in a similar local Andalusian ED with similar number of attendances and population, calculated from expected Kappa of 0.830, proportion of positive ultrasound by the ED of 91.66%, proportion of positive ultrasound by

the Radiology Department of 93.2%, confidence level of 95.0%, and 4.5% accuracy. The primary outcome was identification of a proximal lower-extremity DVT by the three-point compression technique performed by emergency physicians. The reference standard was the Radiology Department ultrasound. Data were expressed as the median and standard deviation. The normal distribution of data was assessed using the Shapiro-Wilk test. The homogeneity of variances was calculated by the Levene test. The comparison of median between groups was

performed using Student's *t*-test and Mann-Whitney. The chi-squared test was used to compare proportions. Cohen kappa statistics for the study of the correlation between the diagnoses provided by emergency physicians and radiologists were calculated. Operating characteristics consisting of sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio, and accuracy were assessed. Differences or correlations with $p < 0.05$ were considered to be statistically significant. The statistical software package



Figure 2. STARD diagram showing flow of potentially eligible, consented, and studied patients. ED = emergency department; US = ultrasound; DVT = deep vein thrombosis; POCUS = point-of-care ultrasound.

PASW® Statistics 18 (IBM, Armonk, NY) was used for all statistical analysis.

RESULTS

A total of 187 patients presented to the ED with signs or symptoms concerning for DVT; 45 patients were excluded (Figure 2) and 33 patients with a low-risk Wells score and a negative D-dimer did not have a three-point compression POCUS as DVT was excluded. There were 109 patients who had a three-point POCUS scan and a subsequent Radiology Department ultrasound. Table 1 shows descriptive and clinical characteristics, laboratory data, hospital admissions, and complications. At the initial presentation, a patient's risk for DVT was scored as high ($n = 46$ [27.9%]), moderate ($n = 42$ [24.4%]), or low ($n = 59$ [35.8%]). Forty-five patients had a negative ultrasound in the ED and four cases of these cases were diagnosed with DVT in the Radiology Department. Fifty-five cases of DVT were identified in the ED and the Radiology Department confirmed 50 cases. Six

(5%) patients were anticoagulated, 19 (17%) patients were admitted into the hospital, and 10 (11%) patients had complications that included pulmonary embolism, postthrombotic syndrome, and chronic thromboembolic pulmonary hypertension.

Bedside three-point compression POCUS, performed by physicians in the ED, for the evaluation of proximal lower limb deep venous thrombosis had a sensitivity of 93.2% (95% confidence interval [CI] 83.8–97.3%) and a specificity of 90.0% (95% CI 78.6–95.7%). This led to a test accuracy of 91.7% (95% CI 85–95.6%), with a positive predictive value of 91.7% (95% CI 81.9–96.4%) and a negative predictive value of 91.8% (95% CI 80.8–96.8%), positive likelihood ratio of 9.32 (95% CI 4.05–21.47), and negative likelihood ratio of 0.08 (95% CI 0.03–0.19). The median time for ED ultrasound to be completed was 5 min 4 s (interquartile range 6 min 14 s–11 min 27 s, minimum 3 min 45 s, maximum 20 min 6 s). There were 54 DVTs observed in the Department of Radiology reported in location as common femoral and superficial femoral 5 (9.3%); femoral-popliteal (all proximal veins) 24 (44.4%); popliteal, superficial, and common femoral 4 (7.4%); popliteal and distal femoral 14 (25.9%); and popliteal 7 (13%); as local policy the Radiology Department does not scan for calf DVTs. There were 50 DVTs observed in the ED: 25 (50%) were described as femoral to popliteal, 12 (24%) femoral, 12 (24%) popliteal, and one (2%) indeterminate (likely popliteal).

Comparing the results of the ED ultrasound with the Department of Radiology duplex ultrasound for equivalence, Cohen's kappa coefficient is 0.83 (95% CI 0.64–1.02). A histogram shows the results of the 109 POCUS ultrasound performed by 11 emergency physicians (Figure 3). The median number of patients enrolled per physician was 10 (range 8–12 patients).

DISCUSSION

The study demonstrated a good diagnostic accuracy of three-point compression ultrasound for DVT detection in the ED when integrated in a diagnostic protocol that included Wells score and D-dimer for patients with suspected DVT. The systematic review and meta-analysis by Pomero and colleagues suggested that a high sensitivity is possible for ultrasound examinations performed by emergency physicians in patients with suspected DVT (10). However, there was considerable variation in the diagnostic performance of the included studies, with a weighted mean sensitivity ranging from 88.9% to 100%. Specificities ranged from 75.9% to 100%; it is important to mention the significant heterogeneity in the included studies. The studies published subsequent to this review article have less impressive results, with

Table 1. Descriptive and Clinical Characteristics, Laboratory Data, Hospital Admissions, and Complications

	Patients (n = 109)
Age, m ± SD	68 ± 16 (22–89)
Sex (male)	49 (45%)
Reason for ED presentation:	
Edema	33 (30%)
Pain	40 (37%)
Edema + pain	34 (31%)
Other	2 (2%)
Past medical history:	
Hypertension	53 (49%)
Diabetes mellitus	17 (16%)
Obesity	49 (45%)
Ischemic heart disease	29 (27%)
Atrial fibrillation	7 (6%)
COPD	8 (7%)
CVA	11 (10%)
Pregnancy	1 (1%)
Family history	0 (0%)
Previous DVT	4 (4%)
Clinical characteristics	
Pain	101 (93%)
Hyperthermia	58 (53%)
Erythema	55 (51%)
Edema	83 (76%)
Collateral circulation	26 (24%)
Palpable vein	14 (13%)
Difference in cm	78 (72%)
D-dimer > 250 UI	92 (84%)
Previous anticoagulation	6 (5%)
Wells criteria (moderate/high)	96 (88%)
Hospital admission	19 (17%)
Complications	10 (11%)

ED = emergency department; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular disease; DVT = deep vein thrombosis.

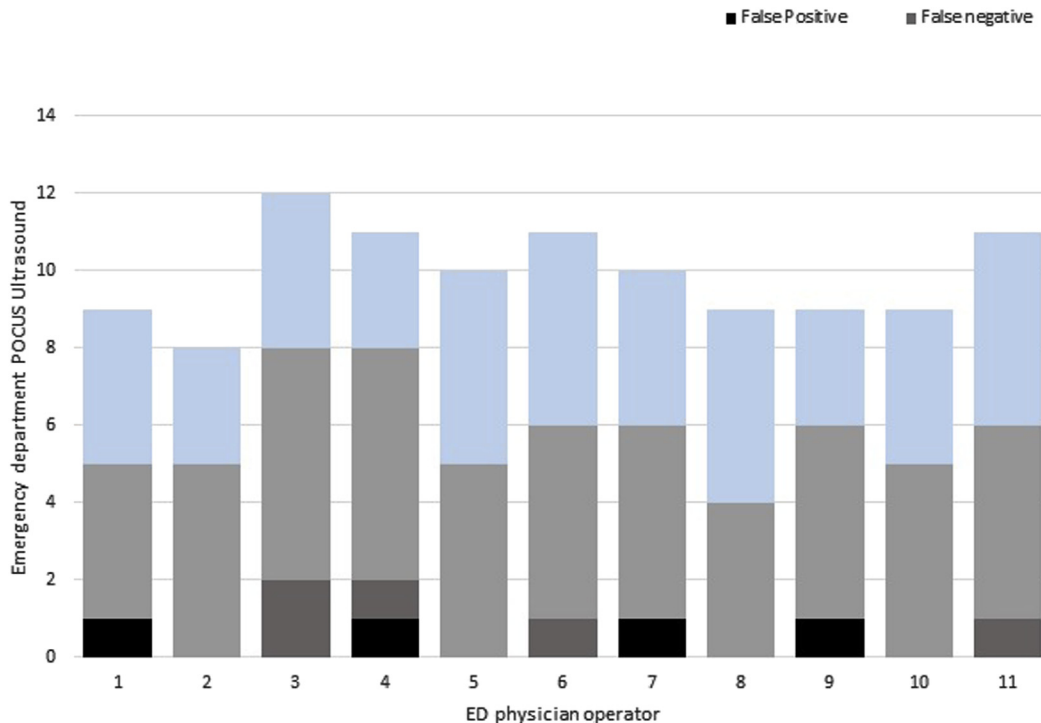


Figure 3. Histogram showing results by operator; 11 emergency physicians are plotted on the horizontal axis with the 109 emergency department (ED) three-point point-of-care ultrasound (POCUS) results.

Crowhurst and Dunn reporting a disappointing sensitivity of 66.7%, Zitek and colleagues reporting a sensitivity of 57.1%, and Kim reporting a sensitivity of 86% (6–8). Adhikari and colleagues' study pointed out that about 6% of DVTs are isolated to the superficial femoral vein or the deep femoral vein (11). These are DVTs that could easily be missed with a two- or three-point compression POCUS scan. In relation to the false positive and false negative cases, the four cases that were not diagnosed with DVT by emergency physicians occurred in the first 8 months of the study and involved four different emergency physicians. All the cases were diagnosed with a popliteal thrombosis; three of the cases were obese patients with difficult visualization and a fourth patient had difficult anatomy.

On the review with the radiologist-performed ultrasound and the recorded images and videos of the POCUS ultrasound in the ED, three cases demonstrated large superficial veins that were mistaken for deep veins and a fourth patient with a previous unknown history of occlusive DVT with distension of the collateral superficial veins, which led to false negative results. Three of these patients had positive D-dimer, were treated with low-molecular-weight heparin in the ED according to the protocol, and after diagnosis were immediately followed up by the DVT clinic. The fourth patient had a negative D-dimer and an unknown history of occlusive DVT

with collateral vein distention. Due to patient communication problems, this history was obtained in the ED. During follow-up, previous history was requested from the previous hospital and treatment was started. Each of the 4 patients with a false negative diagnosis did not have any adverse events related to the treatment received for this event.

Regarding the five cases diagnosed with DVT in the ED and subsequently diagnosed with no DVT in the Radiology Department and identified on review of the POCUS scans, four different physicians were involved in the analysis of the cases. Of these cases, 2 of the patients had a lymph node which was misinterpreted as a DVT in the common femoral vein, 1 patient with a ruptured Bakers cyst had been diagnosed with a popliteal DVT, a case of superficial thrombophlebitis was confused with a popliteal DVT, and a case that was admitted with a confirmed pulmonary embolism by computed tomography pulmonary angiography and femoral DVT by emergency ultrasound performed by the emergency physician had a scan 48 h later that was negative. Although the case was included as a false positive, further consideration was given due to possible thrombus embolization resulting in the patient's pulmonary embolism, recorded images in the ED were not completely clear due to the patient's anatomy. The subjects with false positive and false negative ultrasounds in the ED had a higher

body mass index (34.7 vs 28.5 kg/m²; $p < 0.001$). Overall, 45% of the patients that had an ultrasound in the ED had a body mass index > 30 .

Previous pitfalls that were detected in the training periods included failure to place the probe perpendicular to the skin to achieve direct pressure in compressing vessel walls, technical difficulty in obese patients or those with significant lower-extremity edema, and confusing a lymph node or Baker's cyst with a DVT. The variation of sensitivity and specificity reported in the studies suggests the presence of a significant learning curve associated with this skill, and it is likely to require frequent practice to maintain competency.

One of the disadvantages of lower leg POCUS that has been considered, aside from the variability in quality, is the time that it takes the emergency physician to perform the scan, however, the mean time of 5 min to perform an ultrasound and the added benefit does not seem to be a drawback. Previous study demonstrated a median examination time of 3 min and 28 s (12).

In this study, time was recorded on a stopwatch, beginning when the probe was placed on the patient and ending when the duplex study was completed. In our study, we included the time in which the machine was turned on and the introduction of the patient's details on the ultrasound screen. If we relied only on the D-dimer and Wells score, 109 comprehensive ultrasounds would have been done; the new protocol would have prevented 40 comprehensive ultrasounds and patients receiving unnecessary anticoagulation. Patients with a negative Wells score and negative D-dimer did not have an ultrasound to avoid overestimation of the sensitivity and specificity. The use of Wells' clinical prediction rule and D-dimer assays to determine pretest clinical probability is still important. The D-dimer was included in the protocol for moderate- and high-risk patients; we believe that the best-powered studies added D-dimer to the limited ultrasounds and it remains a component of algorithms in diagnosing DVT.

Limitations

Limitations of the study included the previous experience of emergency physicians in the department and the inclusion of only experienced emergency physicians; no residents were included in the study. The ultrasound training in this study was quite extensive compared with many other published POCUS DVT studies, so this may limit generalizability. We did not examine the calf veins considering that ultrasonography is limited in efficacy at detecting calf thrombus. The sensitivity of ultrasound reduces in relation to calf thrombus to as low as 73% in symptomatic patients and 50% in asymptomatic patients (13). The reference standard was Radiology Department ultrasound, not

contrast venography, so some DVTs may theoretically have been missed. The radiology ultrasounds in our department per protocol do not include calf examination for DVTs. Furthermore, our study has incorporation bias in that POCUS was part of the clinical diagnostic algorithm. The 48-h delay may have affected the test characteristics, as some DVTs may have either improved with anticoagulation or embolized, whereas others may have progressed from calf DVTs to popliteal DVTs. Patients were started on anticoagulation prior to the reference standard ultrasound depending on the POCUS results. There is also likely verification bias because the delay to the formal ultrasound was influenced by the POCUS result. We could not enroll consecutive patients due to lack of availability of trained emergency physicians in ultrasound participating in the study. Parts of the shifts were covered by locum physicians that were not trained in ED ultrasound; therefore, they did not participate in the study. There were no ultrasound-trained physicians in our department on direct clinical care from midnight until 8:00 AM during the week, so the study was temporarily suspended during those hours.

CONCLUSIONS

The use of point-of-care ultrasound has the potential to decrease length of stay for patients in the ED and has important clinical implications given the consequences of both unnecessary treatment and missed diagnosis of the venous thromboembolic disease process. Emergency physicians can obtain a level of competence equivalent to that of radiologists but presuppose substantial training and practice to achieve and maintain this performance. Providers should be aware of their limitations and maintain regular training with ultrasound applications.

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ARTICLE SUMMARY

1. Why is this topic important?

Compression bedside point-of-care ultrasound (POCUS) has been shown to be a safe, rapid, and accurate method for the diagnosis of proximal deep vein thrombosis (DVT) in the emergency department (ED) with a high sensitivity and specificity, however, recent studies has demonstrated different results with low sensitivity and specificity.

2. What does this study attempt to show?

In the present study, we will primarily assess whether three-point compression POCUS combined with a D-dimer test and Wells score can accurately rule out DVT in ED patients.

3. What are the key findings?

The study demonstrated a good diagnostic accuracy of three-point compression ultrasound for DVT detection in the ED when integrated in a diagnostic protocol that included Wells score and D-dimer for patients with suspected DVT.

4. How is patient care impacted?

The use of compression POCUS ultrasound in ED may help avoid unnecessary medical interventions and diagnostic tests, therefore representing potential quality-of-care and cost-saving improvements; however, this involves substantial training and practice to achieve and maintain this performance. Providers should be aware of their limitations and maintain regular training with ultrasound applications.