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Original Contributions

EMERGENCY DEPARTMENT COMPRESSION ULTRASOUND TO DIAGNOSE PROXIMAL DEEP VEIN THROMBOSIS

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□ **Abstract—Emergency Department (ED) patients with suspected deep vein thrombosis (DVT) require an objective vascular study such as ultrasound (US) to confirm the diagnosis prior to treatment or disposition. A simple compression US test of the common femoral vein and popliteal vein reliably detects proximal DVT in symptomatic patients. Application of compression US in the ED by Emergency Physicians (EPs) has been tested in a single previous study. We evaluated the ability of ED compression US, performed by EPs, to diagnose proximal DVT as compared to duplex US performed in a vascular laboratory. A prospective, observational study was conducted on a convenience sample of patients presenting to an ED with lower extremity symptoms and signs suggestive of DVT. Patients with a history of DVT in the symptomatic extremity were excluded. Final diagnosis of DVT was made by color-flow duplex US performed in a vascular laboratory. ED compression US was performed by one of six EP sonographers. In compression US, DVT was diagnosed by the inability to compress the common femoral vein or popliteal vein. The examination was considered indeterminate if the veins could not be clearly identified or compressibility was equivocal. For statistical analysis, an indeterminate examination was considered positive. In those cases where ED compression US was discordant with duplex US, and not indeterminate, we retrospectively reviewed the US findings. There were 76 patients who completed the study, and 18 patients (24%) were diagnosed with DVT by duplex US, among whom ED compression US was positive in 14, negative in 2, and indeterminate in 2. Among 58 patients diagnosed without DVT by duplex US, there were 4 false-positive ED compression US examinations and 10 indeterminate examinations. In all, ED compression US was indeterminate in 12 patients (15.8%). Compared to duplex US, ED compression US had a sensitivity of 88.9% (95% C.I. 65.3–98.6%) and specificity of 75.9% (62.8–86.1). Negative predictive value was 95.7% (85.2–99.5). Among ED patients with the clinical diagnosis of possible DVT, negative ED compression US greatly reduces the likelihood of DVT, such that discharge and outpatient follow-up can be considered. Because of limited specificity, positive results require confirmation, but may justify immediate treatment pending follow-up testing. Indeterminate results can be expected in a significant number of patients and mandate further testing prior to disposition.**

□ **Keywords— deep venous thrombosis; compression ultrasound; emergency department**

INTRODUCTION

Lower extremity pain and swelling is a common problem seen in the Emergency Department (ED). Of the many possible causes, proximal deep vein thrombosis (DVT), defined as thrombus in or above the popliteal vein, is among the most serious because it can result in pulmonary embolism. The diagnosis of DVT requires a confirmatory test because clinical signs and symptoms are

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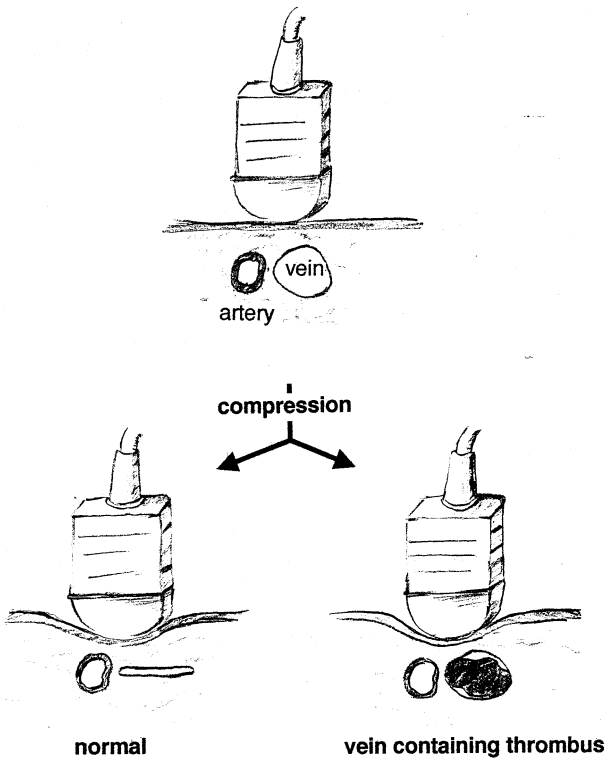

Figure 1. Compression ultrasound demonstrating the effect on a normal vein and a vein containing thrombus.

unreliable, and therapy involves anticoagulation with its inherent bleeding risks. Ultrasound (US) has emerged as the modality of choice to diagnose proximal DVT because it is widely available, noninvasive, and accurate (1).

In compression US, the ability of the US probe to compress the common femoral vein (CFV) and popliteal vein (PV) is assessed by using B-mode imaging. Normal veins are easily compressible, whereas those containing thrombus are not (Figure 1). If available, color flow Doppler may be used to identify vessels, but assessment of flow is not part of the compression US examination. In large clinical trials involving ambulatory patients without prior history of DVT, this simple test, performed by expert sonographers, has been shown to accurately diagnose proximal DVT (2,3).

Duplex US involves the assessment of venous flow characteristics, as well as compressibility, to diagnose DVT (4,5). Duplex US combines color flow Doppler technology with B-mode imaging. At our institution, duplex US is regarded as a gold standard test to diagnose DVT.

The objective of this study was to evaluate the ability of ED compression US performed by Emergency Physicians (EP) to diagnose proximal DVT compared to formal duplex US performed in a vascular laboratory.

MATERIALS AND METHODS

This was a prospective, observational study conducted at an urban county hospital. The study protocol was approved by an Institutional Review Board and study subjects signed a statement of informed consent. Between February 1, 1997, and August 31, 1998, a convenience sample of subjects who presented to the ED with symptoms and signs considered by the examining EP to be suggestive of DVT were enrolled. Although specific inclusion criteria were not stated, examining physicians were encouraged to enroll patients when a formal duplex study was being seriously considered. Exclusion criteria were a prior history of DVT in the symptomatic extremity or a prior vascular study of which the results were known.

ED compression US was performed by one of six EPs (three attendings, three senior residents) each of whom had extensive experience with other applications of US. All six are privileged by the hospital to perform limited ED US and had completed the widely accepted training guidelines set out by Mateer et al. (6). The EPs underwent a 2-h practical training session in the technique of lower extremity venous compression US conducted by a vascular technician. Examinations were performed by using an Aloka 650 CL US machine with a 7.5 MHz probe or 3.5 MHz probe (for very obese patients). Patient demographics and US examination findings and result, which could be positive, negative, or indeterminate for DVT, were prospectively recorded on a standardized data collection sheet. In 15 cases, formal duplex US was performed prior to ED compression US for logistical reasons of vascular laboratory or EP sonographer availability. In such cases, EP sonographers were blinded to the results of the formal duplex US examination.

In ED compression US, DVT was diagnosed by the inability to fully compress the CFV or PV. The maximum pressure applied with the US probe was that which began to distort or partially compress the adjacent artery. If both the CFV and the PV were compressible, the examination was considered negative. Comparison with the contralateral extremity was done at the examiner's discretion. The examination was considered indeterminate if the CFV or PV could not be definitively identified. Results of ED compression US were not allowed to influence patient treatment or disposition.

Final diagnosis of DVT was made by color flow duplex US performed by a single certified vascular technician and read by a single attending vascular surgeon (as are all vascular studies at our institution), both of whom were blinded to the results of ED compression US. In addition to vein compressibility, the following duplex signs of DVT were assessed: color Doppler flow void,

lack of flow augmentation, visible thrombus, dilated veins, and valvular incompetence. Integration of these signs to arrive at a final diagnosis of DVT was left to the discretion of the vascular laboratory. Duplex US yielded positive or negative results only; there were no indeterminate studies.

For the purpose of statistical analysis, an indeterminate ED compression US result was considered a positive. Sensitivity, specificity, and positive and negative predictive values of ED compression US were calculated, with 95% confidence intervals, by using duplex US results as the criterion standard. Correlation between results of ED compression US and duplex US was assessed by calculating the κ coefficient.

ED compression US results that were discordant with the duplex US result, and not indeterminate, were considered false positives or false negatives. In a post hoc analysis of the four false-positive and two false-negative cases, we compared in detail the duplex US findings to the ED compression US findings. In the two false-negative cases, we also reviewed the patient's medical record for details of the clinical course.

RESULTS

Eighty-four patients were enrolled in the study and underwent ED compression US. Two patients were excluded because of a prior history of DVT in the symptomatic extremity. Six patients never underwent a duplex US examination, either because they left the ED against medical advice or underwent alternative testing for pulmonary embolism. Seventy-six subjects were available for final analysis. This represents 82% of all ED patients undergoing formal duplex US for suspected lower extremity DVT. Forty-eight patients (63.2%) were men, and the mean age was 49 years.

The results are summarized in Table 1. Eighteen patients (23.6%) were diagnosed with DVT by duplex US. Among these, ED compression US was positive in 14, negative in 2, and indeterminate in 2. Proximal DVT was ruled out by duplex US in 58 patients, among whom ED compression US was negative in 44, positive in 4, and indeterminate in 10.

In all, 12 ED compression US studies (15.8%) were considered indeterminate. Two of the 12 patients whose ED compression US examinations were indeterminate had proximal DVT diagnosed by duplex examination. There were 8 indeterminate examinations among the first 38 patients enrolled and 4 among the second 38. Considering indeterminate results as positive, the sensitivity of ED compression US for the diagnosis of proximal DVT was 88.9% (95% CI 65.3–98.6%). Specificity was 75.9% (62.8–86.1). Negative predictive value was 95.7% (85.2–99.5), and positive predictive value was 53.3% (34.3–71.7). Correlation between ED compression US and duplex US was good, as determined by a κ value of 0.58.

Table 1. Comparison of ED Compression US and Duplex US

	Duplex US		
	Positive	Negative	
ED compression US			
Positive	14	4*	18
Negative	2†	44	46
Indeterminate	2	10	12
	18	58	

* Actual positive, †actual false negative (Indeterminate examinations were treated as positive for statistical analysis).

ED compression US:	
Sensitivity	88.9% (95% C.I. 65.3–98.6%)
Specificity	75.9% (62.8–86.1)
Negative predictive value	95.7% (85.2–99.5)
Positive predictive value	53.3% (34.3–71.7).

The location of thrombus found by ED compression US (the noncompressible vein segment) in the 10 confirmed cases in which it was noted was as follows: 6 CFV, 2 PV, and 2 both CFV and PV. Among patients without proximal DVT, there was one case of a ruptured baker's cyst found by ED US and confirmed in the vascular laboratory.

A detailed analysis of discordant results was done by comparing thermal images and written records in the vascular laboratory to the ED US thermal images and study data sheets. Analysis of the four false-positive ED compression US examinations revealed the following: in one case, noncompressible clot in the lesser saphenous vein was mistaken for popliteal clot; in another, inguinal lymphadenopathy was mistaken for CFV clot. In a third case, the duplex US examination also found the PV to be noncompressible, but without other duplex signs of DVT present the study was interpreted as negative for proximal DVT. In the fourth case, all vein segments were compressible on duplex US examination, and no explanation for the false-positive ED compression US could be found.

There were two cases of false-negative ED compression US examinations, for which we reviewed the details of the duplex US examination and the clinical record. In both cases, the CFV and PV were found to be freely compressible by duplex US examination (in agreement with the ED compression US findings). However, because other duplex signs of DVT were present, the overall interpretation was positive for proximal DVT. Both patients were ultimately diagnosed by the treating physicians as having lower extremity cellulitis. Neither pa-

tient underwent further vascular studies such as venography. A 2-year telephone follow up of both patients confirmed the absence of any subsequent lower extremity thromboembolism.

DISCUSSION

For ED patients with unexplained lower extremity pain and swelling, the current diagnostic state of the art is to obtain a lower extremity US examination to exclude DVT prior to patient disposition (7,8). In an ED population undergoing US for suspected DVT, the study will be negative in approximately 75% of patients. The predictive value of a positive or negative study depends on the pretest clinical likelihood of disease (9). A positive lower extremity US examination generally confirms the diagnosis of proximal DVT. With the possible exception of those with a high pretest probability of disease, a negative US examination excludes the diagnosis (7). In patients with an initial negative US examination, serial testing is recommended to detect extension of an isolated calf DVT.

In most centers, lower extremity US is performed in the Radiology Department or vascular laboratory, which may delay timely diagnosis and disposition of ED patients, particularly during off hours when technicians must be called from home. The growing availability and expertise in ED US offers the possibility of rapid bedside evaluation of suspected DVT. In the first of two published studies to address this approach, Jolly et al. demonstrated that EPs could perform a formal color flow duplex US examination with 100% sensitivity and 75% specificity compared to a vascular laboratory. But as the authors comment, "a difficult exam may take 30 min," and "the logistic difficulties of this technique may render it impossible" (10).

ED compression US with the aid of color flow Doppler was studied by Blaivas et al. (11). EPs used vein compressibility as the primary diagnostic criterion, producing a near perfect correlation with their institution's vascular laboratory ($\kappa = 0.9$). The addition of color flow Doppler aided in the identification of artery and vein anatomy, but assessment of flow was found not to be independently helpful in the diagnosis or exclusion of DVT.

Although duplex US continues to be widely used by radiology and vascular departments to evaluate proximal DVT, earlier literature clearly demonstrates that limited compression US examination, of symptomatic ambulatory patients when performed by expert sonographers, is highly accurate in excluding or confirming the diagnosis (2,3,12,13). In a study by Lensing comparing limited compression US to venography in 220 outpatients, compression US was 100% sensitive and 99% specific for proximal DVT (2). Two later studies directly compared compression US with full duplex US. In both, the vein compression test was positive in every case of proximal DVT diagnosed by full duplex US (4,14).

The objective of our study was to evaluate the ability of EPs using limited compression US at the bedside to diagnose proximal DVT compared to duplex US performed in a vascular laboratory. In our study, ED compression US had a sensitivity of 88.9% for detecting proximal DVT and a negative predictive value of 95.7%, suggesting that a negative examination greatly reduces the likelihood of a proximal DVT. Although this result must be viewed cautiously in light of the wide confidence intervals caused by a small sample size, it supports the concept of using ED compression US to make immediate decisions about management and disposition. In the setting of low pretest probability of DVT, a negative ED compression US examination might allow the patient to be discharged to undergo a formal study as an outpatient within 48 h. As suggested by Anand et al., if the pretest probability of DVT is high, a negative US examination would generally require venographic confirmation prior to disposition (7).

The diminished sensitivity in this study was due to two proximal DVTs being diagnosed by duplex US that apparently were missed by ED compression US. Based on a retrospective review of these two cases, and analysis of the patients' clinical course, we suspect that the duplex US results were incorrect (if so, sensitivity of ED compression US would have been 100%). In both cases the duplex and ED compression US examinations actually agreed that the CFV and PV were fully compressible. However, the duplex examination was considered positive because three or more other duplex signs of DVT were present. We doubt this was a correct overall interpretation of the duplex US findings. A prominent textbook on vascular US technique stresses the preeminence of vein compressibility compared to other duplex signs when evaluating DVT (5). Taken together with the numerous studies demonstrating the accuracy of compression US, this suggests that in the face of normal vein compressibility, a duplex US study should not be interpreted as positive for DVT (2,5,14). Furthermore, on the basis on clinical findings such as fever and leukocytosis, both patients in question were diagnosed with lower extremity cellulitis by the treating physician. Despite the official duplex US results, neither patient was given a discharge diagnosis of DVT nor anticoagulated with heparin, enoxaparin, or coumadin.

The second main finding of this study was the high frequency of indeterminate results on ED compression US. When the EP sonographer was unable to confidently identify the CFV and PV, the examination was considered indeterminate. The large number of indeterminates

is related to the fact that US is very dependent on patient characteristics as well as the experience of the person acquiring and interpreting the images. Our EP sonographers began examining patients and enrolling them in the study with little prior experience in vascular or compression US. As expected, there appeared to be a learning curve for performing and confidently interpreting compression US. There were eight indeterminate examinations among the first 38 patients enrolled and only four among the second 38.

On the other hand, even when performed by a very experienced EP sonographer, a significant percentage of ED compression US examinations are likely to be indeterminate for technical reasons, particularly when diagnosed without the aid of color flow imaging. The most frequently encountered problem was that the PV is impossible to locate definitively, particularly in obese patients. In such cases, further testing, such as duplex US or venography, is required. The study by Blaivas et al. confirms that the addition of color flow Doppler improves the ability to identify the deep veins and assess compressibility, thereby reducing the frequency of indeterminate examinations (11).

The third main finding of this study was the specificity of ED compression US of 75.9% and positive predictive value of 53.3%. The diminished specificity is largely due to the statistical problem presented by indeterminate compression US examinations. ED compression US had three possible results, whereas the criterion standard had only two. Therefore, for the purpose of calculating test performance characteristics, we considered indeterminate examinations to be positive. Unfortunately, the resulting low specificity is misleading. If indeterminates are excluded prior to calculating specificity, leaving only the four actual false positives in the numerator, the specificity of ED compression US is 91.7% (80.0–97.7). Positive predictive value would be 77.8% (52.4–93.6). Such an approach to the data, which excludes indeterminate examinations prior to analysis, is more in line with the clinical algorithm we propose. Patients in whom ED compression US is indeterminate require further testing prior to treatment or disposition, exactly as if no test were done.

Excluding indeterminate results prior to calculating specificity and positive predictive value focuses on the fact that there were four actual false positives out of 18 positive ED compression US examinations. As stated in the Results section, we identified the reason for three of the four false-positive studies. Such mistakes likely reflect the inexperience of the EP sonographers and the learning curve associated with performing and interpreting compression US. From this small study, with such wide confidence intervals around specificity, it is impossible to conclude how a positive ED compression US examination should affect clinical management. Although it remains to be demonstrated in a larger study, it may be that a technically adequate examination that is positive for DVT, and concordant with clinical likelihood, confirms the diagnosis with sufficient accuracy to begin therapy. Low molecular weight heparin could be administered immediately and a confirmatory test, such as duplex US or venography, obtained prior to long term anticoagulation.

This study suffers from the following limitations. Small sample size resulted in wide confidence intervals. Our study population was a convenience sample representing 82% of all ED patients undergoing formal duplex US for suspected DVT during the study period. The missing patients, while few, may represent selection bias. Also, this study did not report the average time required to complete an ED compression US examination. Time and ease of use have limited the clinical utility of bedside duplex US in one previous study (10). The use of comparison views of the contralateral extremity was not protocol driven, but rather left to the discretion of the examiner.

We made no attempt to rate clinical likelihood of DVT prior to testing. As a result, we were unable to interpret the extent to which test accuracy was influenced by the pretest probability of disease. We felt this was justifiable. Although assessing pretest probability is essential for the interpretation of any test result, most practice protocols dictate diagnostic testing, usually US, given any degree of suspicion of DVT.

The criterion standard in this study and the de facto gold standard at our institution, duplex US, is not a universally accepted gold standard test for proximal DVT. Also, duplex US was performed by a single technician and interpreted by a single vascular surgeon. There was also no assessment of interoperator variability between the EP sonographers performing compression US. And there was only limited long-term clinical follow up.

Although no firm conclusions can be drawn from this preliminary study of ED compression US to diagnose proximal DVT, our results suggest the following. It would seem that a negative ED compression US excludes DVT with sufficient accuracy to withhold immediate ED therapy, provided the clinical probability of DVT is not high. Because of limited positive predictive value, a positive result requires confirmation. Inability to confidently identify the PV frequently leads to indeterminate results, which mandate further testing prior to treatment or disposition. The addition of color flow Doppler capability likely would reduce the importance of this problem (11,14). A larger study is needed to clarify the role of ED US in making this important diagnosis.

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