CLINICAL INVESTIGATIONS

Lower-extremity Doppler for Deep Venous Thrombosis—Can Emergency Physicians Be Accurate and Fast?

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Abstract. Clinical diagnosis of lower-extremity (LE) deep venous thrombosis (DVT) requires confirmation by an imaging study before committing the patient to anticoagulation therapy. Studies have shown that demonstrating compressibility of leg veins under ultrasound is accurate for ruling out DVTs when performed by vascular specialists. Although LE Doppler has become the preferred test for diagnosing DVTs, it is not always available 24 hours per day. **Objectives:** To evaluate the accuracy and speed with which emergency physicians (EPs) could perform LE color duplex ultrasonography for the detection of DVT. **Methods:** Patients presenting to an urban community emergency department (ED) between August 1, 1998, and March 3, 1999, were enrolled into this prospective study. The EPs, who underwent brief and standardized training, scanned patients at high risk for DVT with leg pain, swelling, or both. Physicians performed color duplex ultrasound examinations with compression at the common femoral and popliteal veins. The time until completion of the ED scan was recorded with a standardized method. The vascular laboratory performed a complete duplex ultrasound examination within eight hours. **Results:** One hundred twelve patients were enrolled in the study, with 34 positive for DVT. The median examination time was 3 minutes 28 seconds (95% CI = 2 min 45 sec to 4 min 2 sec; IQR 3 min 9 sec). Times ranged from 1:02 to 18:20 minutes. The ED results had a high correlation with vascular laboratory studies, giving a kappa of 0.9 and a 98% agreement (95% CI = 95.4% to 100%). **Conclusion:** Emergency physicians can perform LE duplex ultrasound examinations accurately and quickly. **Key words:** emergency medical services; ultrasonography; deep venous thrombosis; Doppler; emergency physicians. ACADEMIC EMERGENCY MEDICINE 2000; 7:120–126

LOWER-extremity (LE) thrombosis is a significant medical problem in the United States, with an incidence of approximately 260,000 cases per year. By some estimates this disease process leads to pulmonary embolism and 50,000 deaths annually.[1] To prevent thromboembolism, it is imperative to correctly diagnose deep venous thrombosis (DVT). This fact leads to the performance of 500,000 LE duplex ultrasound examinations each year.[2]

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Venography, once the diagnostic test of choice for LE DVT detection, has been largely replaced by LE duplex ultrasonography in recent years.[2] This noninvasive diagnostic method approaches venography in accuracy for diagnosis of proximal DVT. However, it falters when calf venous thrombosis is present, showing a sensitivity of approximately 40% to 70%.[3] Standard LE duplex ultrasound guidelines have included repeat examinations at day 1 and days 5–7 after a normal study. This protocol was initiated to catch the 20% of calf thrombi that will propagate proximally.[2] Some recent studies have indicated that one repeat examination at five to seven days after the negative result may suffice.[3]

While most emergency departments (EDs) are able to obtain LE duplex examinations for patients with suspected DVTs during business hours, the examination itself takes an average of 37 minutes and often results in patient absence from the department of well over an hour.[4] During evenings

and weekends, often the busiest time in many EDs, an LE duplex examination is not always readily available. In our institution a vascular technologist is called in if the emergency physician (EP) gains approval for the examination from the radiologist. The technician has one hour to reach the hospital, and the total process, from paging the radiologist to receiving the results of the study, can often take two hours or more.

Many EDs have no access to vascular studies during off-hours and are forced to admit even relatively low-risk patients suspected of having LE DVTs. These patients are started on heparin and await an LE duplex study the following morning. Hospitalizing a patient to await a test presents a tremendous cost. Furthermore, it is possible that initiation of anticoagulant therapy prior to diagnostic testing the following day could create false-negative studies in a small number of cases. Some EPs now send such patients home on low-molecular-weight heparin to return for an outpatient study the next morning. This approach may be less costly, but both strategies place the patient at a finite risk for bleeding complications.[5]

In the future, access to LE duplex examinations will likely decrease further as reimbursement for this modality continues to fall. Poppiti et al. state that in many instances reimbursement is actually below operating expenses.[4] They cite that technical costs for personnel time are fixed at 37% to 46% of laboratory expenses, thus leaving little room for cost cutting. In our institution LE duplex examinations performed during off-hours by on-call technicians cost the hospital an average of $70–100 more per patient. This often means that reimbursement falls below the cost of performing the examination. The frequency with which technicians are called in at night is cited as contributing to personnel turnover and a resulting shortage.

The delays associated with diagnosing DVTs have led investigators to look for simplifying and shortening the LE duplex examination. For years some authors have argued that a simplified version of the standard duplex examination can be performed and is just as accurate. Instead of painstakingly checking every centimeter of every deep vein in the LE for quality of blood flow, phasicity with breathing, and venous compression, the examiner checks for venous compression at two specific sites. The common femoral and superficial femoral veins are compressed in cross section. The popliteal vein is then compressed in cross section. Normal compression is synonymous with absence of DVT. When the vein cannot be completely compressed, a DVT is thought to be present. Studies show a sensitivity as high as 95–100% and a specificity up to 99%.[4,6]

To date, only a few studies exist that evaluate EPs' ability to perform LE duplex ultrasound examinations. In 1997 Jolly et al. evaluated the ability of two emergency medicine (EM) attending physicians to perform LE duplex examinations after being trained by a vascular technologist.[7] Although the authors were highly accurate, they performed full-length duplex ultrasound examinations and required extensive training. The authors spent an unspecified amount of time in training with vascular technologists and were then required to accurately perform up to 30 proctored examinations.[7] This study was retrospective and no mention was made of how long the examinations took to perform. Frazee et al. looked at a simplified approach by EPs for evaluating the lower extremities for DVT with ultrasound. However, the authors did not have the availability of color flow on their equipment. The use of color to visualize blood flow can be critical in identifying vascular anatomy in obese and edematous patients. Frazee et al. found that their results were indeterminate in 19% of the patients.[8] This was largely due to difficulty identifying anatomy in obese and edematous patients.

We set out to examine how accurately EPs can evaluate all patients regardless of body type or comorbidities with LE duplex ultrasound examinations. Equally important, we wanted to measure the time it would take to perform the test. Further, we sought to decrease the number of indeterminate results encountered by Frazee et al. in their study.[8]

METHODS

Study Design. This was a prospective observational study that evaluated the accuracy of EPs performing LE duplex examinations when compared with LE duplex examinations performed by a vascular laboratory. A convenience sample of patients suspected of having a DVT and meeting high-risk criteria were enrolled in the study when one of the five participating attending EPs was available (Table 1). One of the study physicians was on call to perform duplex examinations. All patients received an LE duplex examination performed by an EP and a duplex study from the vascular laboratory within eight hours. The institutional review board approved the research and written patient consent was waived.

Study Setting and Population. This study included a convenience sample of patients suspected of having a DVT and meeting defined criteria seen between August 1, 1998, and March 3, 1999. The study was performed at a high-acuity urban community hospital ED. The department has an EM residency program and sees approximately 65,000 patients per year.

TABLE 1. Risk Factors for Lower-extremity Deep Venous Thrombosis

- Surgery in the preceding three months (abdominal, pelvic, lower-extremity)
- Rehabilitation in the preceding three months for stroke, spinal cord injury, cast
- Lower-extremity trauma necessitating surgery or cast in the preceding three months
- Diagnosed as having cancer in the preceding three years
- Any symptoms of undiagnosed cancer (i.e., weight loss, night sweats)
- Pregnancy within the preceding three months
- Previous blood clot in the leg or lung
- Close relatives with unexplained blood clots or history of protein S or C or antithrombin III deficiency
- Taking oral birth control
- Smoking
- Presence of systemic lupus erythematosus or nephrotic syndrome
- Central venous line in place more than three days in the preceding three months
- One calf that is 2 cm larger in circumference than the contralateral side
- History of congestive heart failure
- Primarily bedridden

Study Protocol. A total of 112 patients were enrolled in the study. Five attending EPs received identical training in performing LE duplex ultrasonography consisting of two hours of didactics and three hours of hands-on training. Three of the EPs (MB, MJL, JPW) are RDMS (registered diagnostic medical sonographer)-certified and have performed more than 350 scans each, in applications not related to LE ultrasonography. The other two EPs (RAH, JK) are not RDMS-certified and also have performed more than 350 ultrasound examinations each, in applications not related to LE ultrasonography.

All patients who were suspected of having a DVT and met high-risk criteria were enrolled when a study physician was available. High-risk criteria were defined as suspicion of DVT and having any two or more risk factors listed in Table 1. The study EPs were not blinded to historical information and physical examination findings. The radiologists and technologists were blinded to EP duplex examination results. However, all historical and physical examination data were made available to them.

Measurements. Patient data and study results were recorded on a standardized form. Study physicians recorded vein compressibility, presence of blood flow on color Doppler, and augmentation in both the femoral and popliteal veins. Time was recorded on a stopwatch, beginning when the probe was placed on the patient and ending when the duplex study was completed.

Vein compressibility was noted to be normal when the vein was seen to compress completely with the lumen disappearing from view on the ultrasound monitor (Fig. 1). If incomplete collapse was seen, vein compressibility was noted to be abnormal (Fig. 2). This was diagnostic of a DVT.

Presence of spontaneous blood flow in the vein of interest was judged to be normal when color appeared in the vein on Doppler ultrasound (Fig. 3). Normal augmentation was noted to be present when blood flow through a vein (as denoted by color on the screen) was greatly enhanced with compression of the extremity distal to the point of interest (Fig. 4). Lack of augmentation is thought to be suggestive of an occlusion in the vein segment between the site of compression and the transducer. The EPs used an Aloka 2000 (Aloka

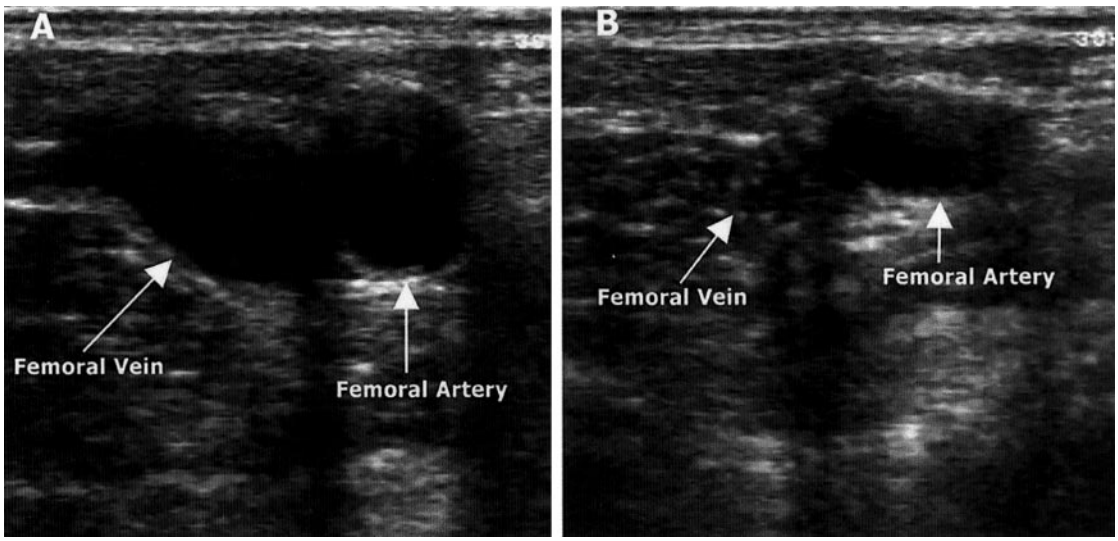

Figure 1. The femoral artery and vein are side by side in this case (**A**). As pressure is applied, the vein readily collapses (**B**).

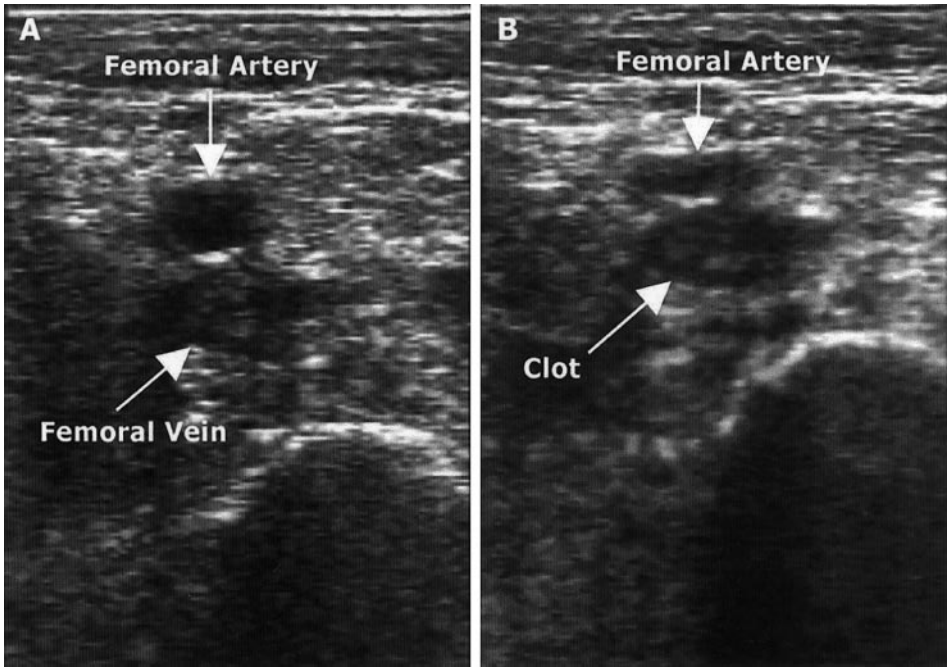

Figure 2. The common femoral artery is on top of the femoral vein (**A**). The femoral artery is beginning to collapse under pressure, while the lumen of the vein underneath is kept open by clot (**B**).

Inc., Wallingford, CT) ultrasound machine with color and power Doppler capability. A 5.0-MHz linear array probe was used for the examinations.

Duplex studies performed by the vascular laboratory were read by one of two radiologists during the day. Both subspecialize in ultrasound examinations, with more than 15 years' experience with the modality each. Nighttime attending radiologists did not have ultrasound fellowship training. All nighttime studies were further overread by one of the ultrasound subspecialists the next morning. There was no attempt to measure intra- and interobserver variability among the radiologists or the EPs.

Data Analysis. All patient information was entered into a Microsoft Excel 7.0 database (Redmond, WA). Descriptive statistics and correlation analysis were performed using a commercially available software package (Analyse-it, Leeds, Great Britain) and confirmed by a professional medical statistician. Vascular laboratory study results were used as the criterion standard.

RESULTS

A total of 112 patients had ED duplex studies; all went on to receive a duplex examination from the vascular laboratory within eight hours. Patient weight ranged from 52 to 200 kilograms. A total of 34 patients (30%) were found to have DVTs on ED duplex examination. Of these, 21 patients had DVTs in the popliteal and femoral veins. Twelve patients had DVTs isolated to the popliteal vein. One patient had an isolated femoral vein DVT without a popliteal vein DVT.

The vascular laboratory agreed with the ED finding in 110 of the 112 patients for proximal DVTs. One disagreement was a patient who was very combative and had to be sedated prior to the vascular laboratory study. His study was suboptimal but was thought to be positive for a popliteal DVT in the ED. The vascular laboratory duplex study was negative. Another patient who was seen to have a popliteal DVT on the ED duplex examination was believed to be negative on the vascular laboratory duplex study. Due to his strongly suggestive clinical presentation, the patient underwent venography approximately 90 minutes later. The venogram confirmed a popliteal DVT initially missed on the vascular laboratory duplex examination. This was the only patient who went on to receive venography.

Two isolated calf DVTs were found by the vascular laboratory in patients who had no proximal DVTs. Of these two patients, one was admitted and placed on heparin, the other was discharged home on aspirin. The admitted patient was sent home on warfarin and was symptom-free with a negative follow-up study at three months. The patient discharged home from the ED had a follow-up ultrasound study one week later, at which time his calf DVT had apparently resolved according to his primary care physician. He was continued on daily aspirin therapy and was symptom-free three months later.

The median time for ED duplex examinations

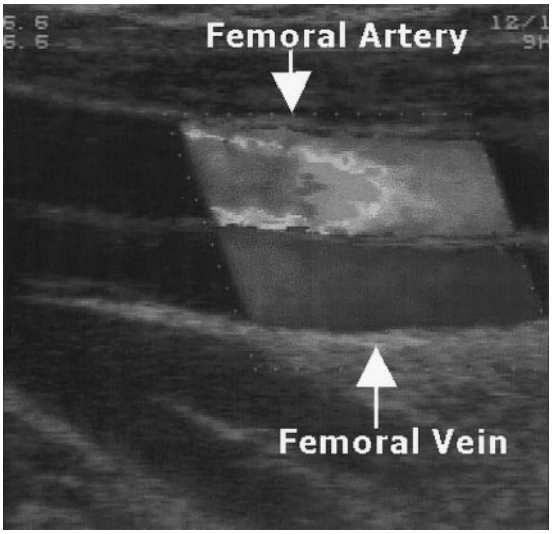

Figure 3. Spontaneous blood flow is seen in this longitudinal view of the femoral vein and artery.

was 3 minutes 28 seconds (95% CI = 2 min 45 sec to 4 min 2 sec). Since the vascular laboratory studies, which are being used for comparison, are not 100% sensitive and specific, reporting a sensitivity and specificity was thought to be inappropriate and a correlation test was used. The kappa coefficient of agreement was used.[9] Percent agreement was 98% (95% CI = 95.4% to 100%). High correlation was seen with kappa of 0.9.

Presence or absence of augmentation was not consistent with existence of DVT, as shown in Table 2. A total of 224 vein segments were studied (femoral and popliteal) among the 112 patients enrolled. Deep venous thrombosis was present in 54 vein segments but 17% (95% CI = 6.4% to 27%) of them unexpectedly had normal augmentation. One hundred seventy vein segments were free of DVT. However, 12% (95% CI = 7.4% to 17%) of them had abnormal augmentation that would have been suggestive of a DVT. Three episodes of saphenous vein thrombosis were diagnosed in patients without DVT, which explained their pain. Also diagnosed were six Baker's cysts. The vascular laboratory confirmed all findings.

DISCUSSION

Acute DVT is a serious health problem that is frequently seen in EDs but can be difficult to diagnose. Making a diagnosis of DVT clinically is disappointingly difficult, with accuracy rates of only 58–70%.[10] Faced with a disease process that contributes to 50,000 deaths per year, EPs bear a large burden of accurately diagnosing patients with DVTs.[1] With the recent shift toward duplex ultrasonography, DVT diagnosis is now less time-consuming and noninvasive compared with venography.

When a vascular laboratory is readily available to perform lower-extremity duplex examinations, EPs can have the laboratory accurately diagnose DVTs and feel comfortable discharging patients with negative results.[3] However, in many institutions vascular laboratory services are unavailable during off-hours and weekends. Alternatively, many institutions rely on a call system for technologists during those hours. While calling in a technician does allow the EP to obtain an LE duplex study, it delays patient disposition for hours.

Study unavailability has led some centers to the practice of treating all patients who are believed to have a reasonable possibility of a DVT. Patients are admitted with prophylactic heparin until an LE duplex can be performed. The addition of low-molecular-weight heparin to the medical arsenal and recent studies confirming the safety of dis-

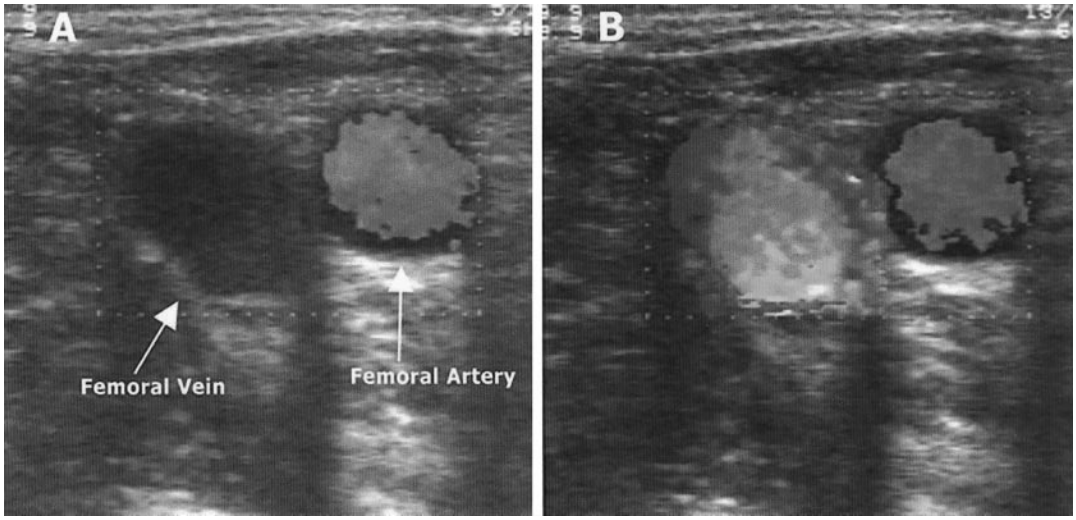

Figure 4. The femoral vein and artery are seen, with blood flow noted in the artery (**A**). With compression of the calf (augmentation), a prominent pulse of blood is seen in the vein (**B**).

charging patients with DVT for outpatient treatment have allowed some patients to be sent home to obtain an outpatient duplex study. This is likely cost saving compared with admitting the patient, but anticoagulating patients does carry a small risk for bleeding.[5]

The difficulties faced by EPs with DVT diagnosis have led some to explore bedside ultrasonography for the detection of DVT in the ED. In 1997 Jolly et al. retrospectively evaluated the ability of two EPs to perform lower-extremity duplex examinations after being trained in the hospitals vascular laboratory. The authors enrolled a total of 15 patients in the study, and returned a sensitivity of 100% and specificity of 75%. No mention was made of the time it took to perform the examinations. As the examinations performed were standard vascular laboratory duplex examinations, they were likely more than 30 minutes per patient.[7]

Frazee et al. performed bedside LE ultrasound examinations in their ED using a simplified approach. Vein compressibility was assessed at the common femoral and popliteal veins.[8] Sixty-five patients completed the study; 19% of the scans, however, were considered to have indeterminate results due to difficulty visualizing the anatomy. The study returned a specificity of 93% and a sensitivity of 74%, with a negative predictive value of 97% and positive predictive value of 50%.[8] This simplified approach has been well documented to be effective and safe in internal medicine and vascular surgery literature.[1,4,6]

Our results show that a simplified LE duplex examination not only is accurate but also can be done quickly at bedside by the managing EP. The training required is minimal. While an EP in a busy ED could not afford to devote 37 minutes to scanning one leg, he or she could tolerate 3 minutes and 28 seconds. With a high correlation between ED examinations and those of the vascular laboratory, we believe that we could safely send patients home who had negative results on our examination. No proximal DVTs were missed during the study.

We were able to eliminate the modest percentage of indeterminate results in the study by Frazee et al. The indeterminate findings were most likely a result of Frazee et al.'s inability to use color Doppler on their equipment. We found that augmentation and spontaneous blood flow were not helpful in diagnosing or ruling out a DVT. Patients who were found to have DVTs sometimes had normal augmentation and those without DVT occasionally had abnormal augmentation findings. However, using color Doppler to locate the vascular structures (Fig. 1) in obese and edematous patients was responsible for our ability to eliminate indeterminate results.

TABLE 2. Number of Vein Segments (Femoral and Popliteal) that Had Normal or Abnormal Flow and Augmentation with Presence or Absence of Deep Venous Thrombosis (DVT)

	DVT Present	DVT Absent
Vein segments with normal augmentation	9	157
Vein segments with abnormal augmentation	45	13
Vein segments with normal blood flow	8	155
Vein segments with abnormal blood flow	46	14

The popliteal DVT, which was found in the ED duplex examination but was missed in the vascular laboratory, only to be confirmed on venography, reminds us that duplex ultrasonography is not infallible for detection of proximal DVT.

LIMITATIONS AND FUTURE QUESTIONS

This study is limited by the criterion standard used. Some authorities may argue that the use of vascular laboratory duplex results rather than venography may lead to missed DVTs. Further, we did not evaluate patients for the presence of calf DVTs. However, calf DVTs do not present the risk associated with proximal thrombosis, and the 20% that propagate to the popliteal and above would be caught on follow-up studies that need to be obtained in five to seven days.

Another limitation has to do with our definition of examination time. Obviously, the machine must be located, moved to the patient, plugged in, and turned on, and patient information must be entered. This may take from 1 to 5 minutes. However, theoretically and practically, these functions need not be done by the busy EPs. Others considering a similar study or protocol should be aware of our definition.

A larger sample size would have been desirable. However, to the best of our knowledge, this is the largest such study in the emergency literature to date. No follow-up was obtained for these patients. Future studies will need to follow the patients released from the ED without an immediate study from the vascular laboratory to evaluate how care and cost are impacted.

CONCLUSIONS

Emergency physicians are able to accurately detect proximal DVTs and are able to do so in a timely manner with an LE duplex examination at the bedside. Introducing this diagnostic modality into more EDs could result in reduction of unnecessary admissions and anticoagulation. This application

can further decrease time spent in the ED when vascular technologists are not readily available.

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REFLECTIONS

In your opinion, what was the most important obstacle that had to be overcome in the development of emergency medicine as a specialty board?

"Turf problems. We were a threat to all specialties, especially surgery ($urgery)."

R. R. HANNAS, MD
President of ABEM, 1983–1984
ABEM Director, 1976–1988