
Duplex Ultrasound in the Emergency Department for the Diagnostic Management of Clinically Suspected Deep Vein Thrombosis

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Abstract

Objectives: To evaluate the accuracy and safety of an emergency duplex ultrasound (EDUS) evaluation performed by emergency physicians in the emergency department.

Methods: Consecutive adult patients suspected of having their first episode of deep vein thrombosis (DVT) presenting to the emergency department were included in the study. All examinations were performed by emergency physicians trained with a 30-hour ultrasound course. Based on EDUS findings, patients were classified into one of three groups: normal, abnormal, and uncertain. Patients with abnormal and uncertain findings were initially treated as having a DVT. Patients with normal EDUS findings were discharged from the emergency department without anticoagulant therapy. A formal duplex ultrasound evaluation was repeated by a radiologist in all patients within 24–48 hours. Patients with normal findings on duplex ultrasound evaluation were followed up for symptomatic venous thromboembolism for up to one month.

Results: A total of 399 patients were studied. The EDUS findings were normal in 301 (75%), abnormal in 90 (23%), and uncertain in eight (2%). All abnormal test results were confirmed by the formal duplex ultrasound evaluation, and three patients (0.8%) with uncertain findings on EDUS examination were subsequently diagnosed as having a distal DVT (positive predictive value, 95% [95% confidence interval, 92% to 95%]; negative predictive value, 100% [95% confidence interval = 99% to 100%]). No patients with normal findings on EDUS examination died or experienced venous thromboembolism at the one-month follow-up.

Conclusions: EDUS examination yielded a high negative predictive value and good positive predictive value, allowing rapid discharge and avoiding improper anticoagulant treatment.

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Patients with suspected deep vein thrombosis (DVT) are frequently evaluated in the emergency department (ED). Duplex ultrasonography (US) is the standard of care for evaluation of symptomatic patients,¹ but US services are frequently unavailable, especially during nights and weekends. The accuracy of compression ultrasonography (CUS) for detection of proximal vein thrombosis has been convincingly demonstrated, showing high sensitivity and specificity when studies are performed in the ED.^{2–5} Large cohort studies

have shown that it is safe to withhold anticoagulant therapy in outpatients suspected of having a first-episode DVT only if a negative result of first CUS evaluation is repeated after 5–7 days⁶ or a negative D-dimer test is available.⁷ Isolated calf vein thrombosis accounts for 20%–30% of symptomatic DVT, about 5% of all patients with suspected DVT. Serial scans are indicated because approximately one fourth of untreated symptomatic calf vein thrombi will extend proximally within one or two weeks.⁸ However, the sequential diagnostic approach appears to be inconvenient for both patients and the health care system because all patients with negative findings on first CUS evaluation (about 80% of suspected cases of DVT) may need a second examination, which is expected to be normal in about 98% of cases.^{6,9}

D-dimer testing was shown to be useful in outpatients with low probability of DVT. This group represents 20%–30% of all patients with suspected DVT. However, the negative and positive predictive value of a D-dimer

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progressively decreases in patients with intermediate and high clinical suspicions of DVT, and typically duplex US or venography is required to reach a definite diagnosis.¹⁰

Recently, comprehensive duplex US, performed in the vascular laboratory, was shown to be a reasonable alternative to two simplified CUS examinations.¹¹⁻¹³ These studies showed that withholding anticoagulation after negative findings on a single duplex US examination, which examines deep veins from the inguinal ligament to the level of the malleolus, is safe in patients with a suspected first episode of DVT. However, when less experienced personnel perform duplex US, the findings may be less accurate.

The aim of this study was to evaluate the feasibility, accuracy, and safety, in terms of anticoagulant treatment decisions, of a single emergency duplex US (EDUS) examination of the entire lower extremity deep venous system performed in the ED by an emergency physician (EP) when compared with formal duplex US examination performed in a vascular laboratory.

METHODS

Study Design

This was a prospective observational study performed on nonconsecutive patients presenting to the ED with a suspected first episode of lower extremity DVT. The study was conducted over a 3.5-year period. The study complied with the Declaration of Helsinki, and all patients enrolled in the study gave written informed consent.

Study Setting and Population

This study was conducted in the ED of Careggi Hospital (Firenze, Italy). The ED is staffed by 15 EPs and has an annual census of 45,000 patients. US equipment was available for use by EPs at all times during the study. The study was conducted between January 2001 and June 2004.

Study Protocol

Patients presenting to the ED during study physician availability with a suspected first episode of DVT of the lower limbs were eligible for enrollment into the study. Patients with terminal illnesses and those who were not able to return to the study center for the follow-up visit were excluded. An attending physician who obtained a clinical history and performed a physical examination saw each patient. Immediately after the clinical assessment, EDUS examinations were performed by one of the two EPs trained during a dedicated 30-hour course consisting of comprehensive lectures and actual patient scanning. The course was completed in five consecutive days, with six hours of lectures on US diagnosis of DVT in the lower limbs and 24 hours of training on patients under the supervision of a radiologist. Certification was given by a national society of vascular ultrasonography (Gruppo Italiano di Ultrasonologia Vascolare) after the EPs completed a multiple-choice questionnaire. The two accredited EPs covered approximately one fifth of the ED schedule.

The EDUS examination consisted of investigation of proximal deep veins with short-axis visualization and compression of the common femoral vein from the inguinal line to its bifurcation into the superficial femoral vein

and profunda femoris, including the saphenous-femoral junction, and of the superficial femoral vein at three levels: proximal, mid, and distal thirds of the thigh. Short-axis images were also obtained of the popliteal vein from the midpopliteal fossa to its trifurcation. The study physicians also investigated the distal deep veins. The gastrocnemius veins, anterior tibial veins, posterior tibial veins, and peroneal veins were investigated at the lower border of the popliteal fossa and at the level of the malleolus. Examinations were completed with color imaging of the flow and with a Doppler analysis of venous flow at both proximal and distal levels. Long-axis images were obtained only in case of uncertain findings or when a DVT was detected. Superficial veins were only examined in the presence of local signs of superficial vein thrombosis. The US examinations in the ED were performed using an ultrasound machine equipped with a 10-MHz linear-array transducer (Megac; Esaote, Genova, Italy).

Deep venous thrombosis was believed to be present when an absence of complete vein collapse was noted during compression and when color-flow imaging and pulsed-wave Doppler analysis confirmed complete or partial obstruction through lack of flow. The findings on EDUS examination were defined as abnormal when both criteria were matched and normal when no criteria were matched, and uncertain findings on compression and color Doppler analysis were not unequivocal.

Patients with abnormal or uncertain EDUS findings were considered as having a DVT and were immediately treated with heparin. In patients with suspected proximal DVT, intravenous heparin was started with a bolus dose of 80 IU/kg and followed by an 18 IU/kg/h infusion rate. The drip rate was subsequently adjusted to maintain the activated partial thromboplastin time between 60 and 90 seconds.¹⁴ Weight-adjusted doses of low-molecular-weight heparin were used in patients with suspected distal DVT. When the findings on EDUS examination were normal, patients were discharged from the ED without anticoagulant therapy.

All patients had a formal duplex US examination performed within 24-48 hours after ED discharge in a vascular laboratory with accreditation in noninvasive vascular testing (Intersocietal Commission for the Accreditation of Vascular Laboratories standard).¹⁵ When the formal duplex US examination revealed a DVT, patients underwent anticoagulant treatment as described in the previous paragraph. When the findings on formal duplex US examination were normal, patients were not treated with anticoagulants but were instructed to immediately return to our ED if they had symptoms of venous thromboembolism. These patients were followed up at one month. Follow-up visits included a history focused on specific symptoms (leg pain, tenderness and swelling, chest pain, dyspnea, hemoptysis, and syncope), queries regarding subsequent hospitalization, and subsequent use of anticoagulants. The outcome measure was symptomatic DVT or pulmonary embolism during follow-up, as confirmed by objective tests.^{1,16}

Data Analysis

Data are expressed as means \pm SD. P-values are two sided, and a p-value of <0.05 was considered to indicate statistical significance. The exact 2-sided 95% confidence interval (CI) was calculated using the exact method for

Table 1
Results of Emergency Duplex Ultrasonography Examinations in Patients with Suspected DVT (*n* = 399)

	DVT Proximal	DVT Distal	Superficial Vein Thrombosis	Uncertain	Abnormal	Normal
Emergency duplex ultrasonography	53 (13.3%)	16 (4.0%)	21 (5.3%)	8 (2.0%)	90 (22.6%)	301 (75.4%)
Formal duplex ultrasonography	53 (13.3%)	19 (4.8%)	21 (5.3%)	—	93 (23.3%)	306 (76.7%)
Therapy	Heparin intravenously	LMWH	LMWH	LMWH	Anticoagulant therapy	—
Admitted	53 (13.3%)	7 (1.8%)	—	8 (2%)	68 (17.0%)	32 (8.0%)

LMWH = low-molecular-weight heparin; DVT = deep vein thrombosis.

obtaining a CI for a binomial proportion. Fisher's exact test was used for the comparison of noncontinuous variables expressed as proportions. Calculations were performed with SPSS statistical package (version 8.0; SPSS Inc., Chicago, IL).

RESULTS

A total of 399 patients were enrolled in the study, with a mean (\pm SD) age of 64.5 (\pm 18) years and a median of 69 (range, 18–99) years. A total of 212 (53%) were female. A total of 345 patients had a clinically suspected DVT (pain, edema, local signs), and 54 patients were included as part of an assessment of a suspected pulmonary embolism as confirmed by objective tests. The findings on EDUS examination were abnormal in 90 patients (23%). DVT was diagnosed in 69 patients (17%): 53 proximal (77%) and 16 distal (23%). Isolated superficial vein thrombosis was revealed in 21 patients (5%) (Table 1). The mean (\pm SD) time of the EDUS examination was 13 (\pm 3) minutes.

Eight patients (2%; 95% CI = 0.9% to 3.9%) had uncertain findings on EDUS examination. They were treated as having a DVT and remained in the hospital until the formal duplex US examination was performed. Formal duplex US examination revealed a distal DVT in three of these patients (0.8%; 95% CI = 0.2% to 2.2%).

A total of 301 patients (75%; 95% CI = 70.9 to 79.6%) had normal findings on EDUS examination; 32 were admitted to the hospital because of comorbidities. The others were discharged without anticoagulant therapy.

The prevalence of venous thrombosis in our cohort was 23% (95% CI = 19.3% to 27.7%). Considering all venous thrombosis, the calculated sensitivity and specificity of EDUS examination was 100% and 98.4%, respectively. Positive predictive value was 94.9%, and negative predictive value was 100%. The overall accuracy of EDUS examination was 98.7% (Table 2). No patient was lost to follow-up. None of the patients with initial normal findings on EDUS examination experienced a symptomatic DVT during the one-month follow-up. Moreover, no patients with normal findings on EDUS examination died or experienced a pulmonary embolism.

DISCUSSION

Our study indicates that EDUS examination of proximal and distal deep leg veins performed by EPs as a stand-alone diagnostic test is accurate and safe in outpatients

suspected of having a first episode of DVT. Previous studies showed a good feasibility of CUS of deep proximal veins in the ED.^{2–5} However, if only proximal veins are explored, a repeat scan is needed to exclude propagation of calf thrombi. Recent studies have considered the role of a single examination of the entire deep venous system and found that it is safe to withhold anticoagulants after negative results of comprehensive duplex US examination.^{11–13} However, all of these studies were performed in a vascular laboratory by an experienced staff of technologists and physician interpreters. Our data demonstrate high accuracy for an EDUS examination performed by EPs in comparison with a formal duplex US examination; only 3 of 399 patients (0.8%) showed a distal DVT at the formal duplex US examination. These results compare favorably with studies conducted by dedicated operators.^{11–13}

One caveat for a duplex US examination performed by the EP is that it takes time, especially if the need to be accurate leads us to perform articulated US evaluations. The mean (\pm SD) time for examination in our study was 13 (\pm 3) minutes, similar to the time (10 minutes) reported in a study of focused proximal vein US examinations by uncredentialed emergency medicine residents.³ Although others have reported that the focused US compression of proximal veins required only 3 to 4 minutes,⁴ an examination time within 15 minutes may be reasonable even in a busy ED if the results promptly lead the EP to a correct diagnosis and disposition without the need for other tests, such as D-dimer or repeat US examination. Another potential problem is that patients' habitus, especially obesity, has been reported to interfere with successful images of the leg veins, especially of the calf.^{6,17} Recent studies have suggested that imaging of the calf is sensitive enough to exclude clinically significant thrombosis, except a small number of patients in whom acceptable images cannot be obtained.^{12,13} In our experience, uncertain findings at the EDUS examination are relatively uncommon (8 of 399 patients; 2%) and were all related to the distal venous system of the calf, where previous literature also demonstrates lower accuracy.

Of clinical importance, we found that it is safe to hold anticoagulation of symptomatic patients after one negative examination with EDUS. No patient with negative findings on EDUS examination died or showed major venous thromboembolic events (symptomatic proximal DVT or pulmonary embolism, or both) at one-month follow-up. If patients with uncertain findings at EDUS are also considered, venous thrombosis occurred in

Table 2
Diagnostic Accuracy of EDUS Examination

	EDUS Positive	EDUS Negative	Percent	95% CI
All venous thrombosis				
Formal duplex positive	93	—		
Formal duplex negative	5	301		
Sensitivity			100	97, 100
Specificity			98.4	97.4, 98.7
Positive predictive value			94.9	92.1, 94.9
Negative predictive value			100	99.1, 100
All deep vein thrombosis				
Formal duplex positive	72	—		
Formal duplex negative	5	322		
Sensitivity			100	96.2, 100
Specificity			98.5	97.6, 98.5
Positive predictive value			93.5	89.9, 93.5
Negative predictive value			100	99.1, 100
Isolated distal deep vein thrombosis				
Formal duplex positive	19	—		
Formal duplex negative	5	375		
Sensitivity			100	86.5, 100
Specificity			98.7	98.0, 98.7
Positive predictive value			79.2	68.5, 79.2
Negative predictive value			100	99.3, 100

EDUS = emergency duplex ultrasonography.

0.8% of patients during follow-up. These data compare favorably with those shown for normal venograms¹⁸ and for other noninvasive approaches, as a combined CUS plus D-dimer test strategy,¹⁹ or one or two repeated CUSs.^{4,19} The advantage of our approach in comparison with the others is that a single test performed in the ED by the EP allowed immediate discharge from the ED without treatment in the majority of patients with suspected DVT (about 75%). Testing also allowed treatment of those with positive findings and rapid recognition of a very small proportion of patients (2%) who required treatment until other confirmatory tests were performed. This approach may increase patient convenience and reduce costs.

LIMITATIONS

In this study, no predefined clinical criteria were used to risk stratify patients for DVT. This precludes the possibility of investigating the negative and positive predictive values of EDUS examination in patients with clinically low, intermediate, or high risk of DVT. This was a single-center study, and applicability to other settings may be limited. All EDUS studies were performed by only two physicians out of the staff of 15, so these findings may not be applicable to all EPs. Further, the training undertaken by the two researchers was significantly more intensive than that previously described in studies regarding emergency US of lower extremity DVTs. Not all EPs may have the capability to undergo such in-depth and time-consuming training. No comparison was made with the focused US approach, which calls for repeat US examinations, to ascertain actual differences in cost or convenience to patients or the health system. Similarly, many centers now practice performing focused US examinations with a follow-up examination only in patients with moderate and high risk for DVT and do not follow

up lower-risk patients. It is unclear how much effort or money would be saved when compared with such a scenario. However, we believe that ours is an efficient approach. We also do not know how the mean (\pm SD) performance time of 13 (\pm 3) minutes for each examination time would affect patient flow in busier departments. Another limitation is that the use of duplex US of the entire leg vein system may lead to overdiagnosis and overtreatment of distal DVT.²⁰ This is crucial, because many patients (we found 26% of all patients with DVT, 4.8% of all patients with suspected DVT) had isolated distal DVT and may receive anticoagulation unnecessarily (without treatment, only one fourth of these DVTs are believed to progress in the proximal vein system). This therapeutic dilemma is especially vexing because so little evidence exists about appropriate treatment of distal DVTs based on clinical outcome measures.

CONCLUSIONS

Our findings have important clinical implications, showing that duplex US of the entire venous system of the leg performed by an EP has a sensitivity and specificity sufficiently high to be used as a stand-alone diagnostic test in the vast majority of patients presenting to the ED (>95%), promptly leading to correct diagnosis and disposition without the need for a repeated US examination or any other test.

References

1. Zeirler BK. Ultrasonography and diagnosis of venous thromboembolism. *Circulation*. 2004; 109(Suppl 1): I9-14.

2. Frazee BM, Snoey ER, Levitt A. Emergency department compression ultrasound to diagnose proximal deep vein thrombosis. *J Emerg Med.* 2001; 20:107–11.
3. Jang T, Docherty M, Aubin C, et al. Resident-performed compression ultrasonography for the detection of proximal deep vein thrombosis: fast and accurate. *Acad Emerg Med.* 2004; 11:319–22.
4. Blaivas M, Lambert MJ, Harwood RC, et al. Lower extremity Doppler for deep venous thrombosis: can emergency physicians be accurate and fast? *Acad Emerg Med.* 2004; 7:120–6.
5. Theodoro D, Blaivas M, Duggal S, et al. Real-time B-mode ultrasound in the ED saves time in the diagnosis of deep vein thrombosis (DVT). *Am J Emerg Med.* 2004; 22:197–200.
6. Birdwell BG, Gary E, Raskob MSc, et al. The clinical validity of normal compression ultrasonography in outpatients suspected of having a deep venous thrombosis. *Ann Intern Med.* 1998; 128:1–7.
7. Bernardi E, Prandoni P, Lensing AWA, et al. D-dimer testing as an adjunct to ultrasonography in patients with clinically suspected deep vein thrombosis: prospective cohort study. *BMJ.* 1998; 317:1037–40.
8. Kearon C. Natural history of venous thromboembolism. *Circulation.* 2003; 107(Suppl 1):I22–30.
9. Cogo A, Lensing AW, Koopman MM, et al. Compression ultrasonography for diagnostic management of patients with clinically suspected deep vein thrombosis: prospective cohort study. *BMJ.* 1998; 316:17–20.
10. Wells PS, Owen C, Doucette S, Fergusson D, Tran H. Does this patient have deep vein thrombosis? *JAMA.* 2006; 295:199–207.
11. Shellong SM, Schwarz T, Hallbritter K, et al. Complete compression ultrasonography of the leg veins as a single test for the diagnosis of deep vein thrombosis. *Thromb Haemost.* 2003; 89:228–34.
12. Elias A, Mallard L, Elias M, et al. A single complete ultrasound investigation of the venous network for the diagnostic management of patients with a clinically suspected first episode of deep venous thrombosis of the lower limbs. *Thromb Haemost.* 2003; 89:221–7.
13. Stevens SM, Elliott CG, Chan KJ, Egger MJ, Ahmed KM. Withholding anticoagulation after a negative result on duplex ultrasonography for suspected symptomatic deep venous thrombosis. *Ann Intern Med.* 2004; 140:985–91.
14. Buller HR, Agnelli G, Hull RD, Hyers TM, Prins MH, Raskob GE. Antithrombotic therapy for venous thromboembolic disease: the Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest.* 2004; 126(3 Suppl):401S–28S.
15. Intersocietal Accreditation Commission. ICAVL: essentials and standards for accreditation in non-invasive vascular testing. Part II. Vascular laboratory operations-peripheral venous testing, 2000:1–8. Available at: www.intersocietal.org/intersocietal.htm. Accessed Jul 27, 2006.
16. Grifoni S, Olivotto I, Cecchini P, et al. Short-term clinical outcome of patients with acute pulmonary embolism, normal blood pressure, and echocardiographic right ventricular dysfunction. *Circulation.* 2000; 101:2817–22.
17. Cogo A, Lensing AW, Prandoni P, Hirsh J. Distribution of thrombosis in patients with symptomatic deep vein thrombosis. Implications for simplifying the diagnostic process with compression ultrasound. *Arch Intern Med.* 1993; 153:2777–80.
18. Hull R, Hirsh J, Sacket DL, et al. Clinical validity of a negative venogram in patients with clinically suspected venous thrombosis [abstract]. *Circulation.* 1981; 64:622–5.
19. Tick LW, Ton E, van Voorthuizen T, et al. Practical diagnostic management of patients with clinically suspected deep vein thrombosis by clinical probability test, compression ultrasound, and D-dimer test. *Am J Med.* 2002; 113:630–5.
20. El Kheir D, Buller H. One-time comprehensive ultrasonography to diagnose deep venous thrombosis: is that the solution? *Ann Intern Med.* 2004; 140:1052–3.