CONTINUING MEDICAL EDUCATION

Continuing Medical Education Activity in *Academic Emergency Medicine*

CME Editor: Corey Heitz, MD
Authors: Rachel A. Poley, MD, FRCP, Joseph L. Newbigging, MD, CCFP, (EM), and Marco L.A. Sivilotti, MD, FRCPC

Article Title: Estimated Effect of an Integrated Approach to Suspected Deep Venous Thrombosis Using Limited-compression Ultrasound

If you wish to receive free CME credit for this activity, please refer to the website: http://www.wileyhealthlearning.com/aem.

Accreditation and Designation Statement:
Blackwell Futura Media Services designates this journal-based CME activity for a maximum of 1 *AMA PRA Category 1 Credit*™. Physicians should only claim credit commensurate with the extent of their participation in the activity.

Blackwell Futura Media Services is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Educational Objectives
After reading the article, participants will be better able to describe the suggested workup for a patient with suspected DVT using bedside ultrasound.

Activity Disclosures
No commercial support has been accepted related to the development or publication of this activity.

Faculty Disclosures:
CME Editor: Corey Heitz, MD has no relevant financial relationships to disclose.

Authors: Rachel A. Poley, MD, FRCP discloses a grant from Physician Services Inc. Joseph L. Newbigging, MD, CCFP (EM), and Marco L.A. Sivilotti, MD, FRCPC have no relevant financial relationships to disclose.

This manuscript underwent peer review in line with the standards of editorial integrity and publication ethics maintained by Academic Emergency Medicine. The peer reviewers have no relevant financial relationships. The peer review process for Academic Emergency Medicine is double-blinded. As such, the identities of the reviewers are not disclosed in line with the standard accepted practices of medical journal peer review.

Conflicts of interest have been identified and resolved in accordance with Blackwell Futura Media Services's Policy on Activity Disclosure and Conflict of Interest.

Instructions on Receiving Free CME Credit
For information on applicability and acceptance of CME credit for this activity, please consult your professional licensing board.

This activity is designed to be completed within an hour; physicians should claim only those credits that reflect the time actually spent in the activity. To successfully earn credit, participants must complete the activity during the valid credit period, which is up to two years from initial publication.

Follow these steps to earn credit:

- Log on to http://www.wileyhealthlearning.com
- Read the target audience, educational objectives, and activity disclosures.
- Read the article in print or online format.
- Reflect on the article.
- Access the CME Exam, and choose the best answer to each question.
- Complete the required evaluation component of the activity.

This activity will be available for CME credit for twelve months following its publication date. At that time, it will be reviewed and potentially updated and extended for an additional twelve months.

CME Estimated Effect of an Integrated Approach to Suspected Deep Venous Thrombosis Using Limited-compression Ultrasound

Rachel A. Poley, MD, FRCP, Joseph L. Newbigging, MD, CCFP (EM), and Marco L.A. Sivilotti, MD, FRCPC

Abstract

Objectives: Deep vein thrombosis (DVT) is both common and serious, yet the desire to never miss the diagnosis, coupled with the low specificity of D-dimer testing, results in high imaging rates, return visits, and empirical anticoagulation. The objective of this study was to evaluate a new approach incorporating bedside limited-compression ultrasound (LC US) by emergency physicians (EPs) into the workup strategy for DVT.

Methods: This was a cross-sectional observational study of emergency department (ED) patients with suspected DVT. Patients on anticoagulants; those with chronic DVT, leg cast, or amputation; or when the results of comprehensive imaging were already known were excluded. All patients were treated in the usual fashion based on the protocol in use at the center, including comprehensive imaging based on the modified Wells score and serum D-dimer testing. Seventeen physicians were trained and performed LC US in all subjects. The authors identified a priori an alternate workup strategy in which DVT would be ruled out in “DVT unlikely” (Wells score < 2) patients if the LC US was negative and in “DVT likely” (Wells score ≥ 2) patients if both the LC US and the D-dimer were negative. The criterion standard was based on comprehensive imaging interpreted by radiologists blinded to LC US findings and by structured medical record review at 6 months in patients without comprehensive imaging.

Results: A total of 227 patients were enrolled (47% DVT likely), of whom 24 had DVT. The LC US was positive in 27 cases (21 actually DVT positive), indeterminate in 28 (one DVT positive), and negative in 172 (two DVT positive). Of 130 patients deemed DVT negative by the new strategy, one had confirmed DVT (miss rate = 0.8%; 95% confidence interval [CI] = 0.1% to 4.0%), but this patient had been misclassified by the treating physician as low risk by Wells criteria. The stand-alone sensitivity and specificity of LC US were 91% (95% CI = 70% to 98%) and 97% (95% CI = 92% to 99%), respectively. Incorporating LC US into the diagnostic approach would have reduced the rate of comprehensive imaging from 70% to 43%, D-dimer testing from 100% to 33%, and the mean time to diagnostic certainty by 5.0 hours and avoided 24 (11%) return visits for imaging and 10 (4.4%) cases of unnecessary anticoagulation. In 19% of cases, the treating and scanning physician disagreed whether the patient was DVT likely or DVT unlikely based on Wells score (κ = 0.62; 95% CI = 0.48 to 0.77).

Conclusions: Limited-compression US holds promise as one component of the diagnostic approach to DVT, but should not be used as a stand-alone test due to imperfect sensitivity. Tradeoffs in diagnostic efficiency for the sake of perfect sensitivity remain a difficult issue collectively in emergency medicine (EM), but need to be scrutinized carefully in light of the costs of overinvestigation, delays in diagnosis, and risks of empirical anticoagulation.

ACADEMIC EMERGENCY MEDICINE 2014;21:972–980

From the Department of Emergency Medicine (RAP, JLN, MLAS) and the Department of Pharmacology and Toxicology (MLAS), Queen’s University, Kingston, Ontario, Canada; and the Department of Emergency Medicine, Saint Michael’s Hospital (RAP), Toronto, Ontario, Canada.

Received September 9, 2013; revision received January 18, 2014; accepted May 6, 2014.

Presented at the Society for Academic Emergency Medicine Annual Meeting, Chicago, IL, May 2012; and the Canadian Association of Emergency Physicians Annual Scientific Assembly, Niagara Falls, Ontario, June 2012.

Supported by the physicians of Ontario through the Physicians’ Services Inc. Foundation (grant R09-47).

clinicaltrials.gov Clinical Trial Registry number NCT 01007045.

The authors have no potential conflicts of interest to disclose.

Supervising Editor: Chris Moore, MD.

Address for correspondence and reprints: Rachel A. Poley, MD, FRCP; e-mail: raply@mta.ca.

 ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/acem.12459

Deep venous thrombosis (DVT) is common, with an estimated annual incidence of 70 per 100,000 among the general population and can be fatal should it embolize to the lungs.[1] One widely accepted diagnostic approach to DVT is based on clinical suspicion, application of the modified Wells score for risk stratification, and serum D-dimer in low-risk patients to reduce unnecessary imaging.[2] While comprehensive ultrasound (US) imaging (i.e., comprehensive imaging from proximal veins to trifurcation in the calf interpreted by a radiologist) is the most accurate way to diagnose DVT, its availability is often limited to daytime hours.[3] Given the danger of a missed diagnosis, emergency physicians (EPs) may initiate anticoagulation empirically when same-day comprehensive US is unavailable, even though most comprehensive studies are ultimately negative. Moreover, the absence of a validated clinical decision instrument to forgo D-dimer testing in ultra-low-risk patients, the desire for perfect diagnostic accuracy, and the moderate specificity of D-dimer testing drive up imaging rates and render current approaches inefficient.

Portable US at the bedside by EPs has become routine for a number of conditions, usually as a component of the overall diagnostic approach rather than a standalone diagnostic test. An abbreviated US examination of the lower extremity has been proposed for the bedside diagnosis of DVT by EPs, a technique commonly referred to as limited-compression (LC) US.[4–10]

Our objective was to investigate observationally a potential alternate strategy incorporating LC US into the workup of patients with possible DVT. We were particularly interested in whether negative LC US alone might be sufficient to rule out DVT in modified Wells score "DVT unlikely" patients and whether the combination of a negative LC US and negative D-dimer would rule out DVT in modified Wells score "DVT likely" patients. We also wondered how LC US performed by EPs would be compare to comprehensive imaging and how reliably EPs classified patients as DVT likely or unlikely using the modified Wells score.

METHODS

Study Design

We performed a cross-sectional observational study. All subjects provided explicit written consent, and the study was approved by the institutional research ethics board.

Study Setting and Population

This study was performed at a tertiary care emergency department (ED; annual census 48,000 visits) and a hospital-based urgent care center (44,000 visits) between November 2009 and December 2010. We attempted to enroll consecutive patients with suspected DVT of the lower extremity, limited only to the availability of a physician trained in LC US. For inclusion in the study, the treating EP had to suspect lower-extremity DVT and order either a serum D-dimer or comprehensive US. We excluded patients younger than 16 years and those with known chronic DVT, empirical anticoagulation for greater than 48 hours prior to comprehensive imaging, inability to assess the femoral or popliteal areas (e.g., cast or above-knee amputation), or previously identified acute DVT on comprehensive imaging, if the results were known to the enrolling physician. During daytime and evening hours up to 7 days a week, on-site research staff helped identify eligible patients. In addition, an automated text message was generated by our real-time surveillance system[11] shortly after patient registration based on a standardized chief complaint (i.e. "lower extremity pain, swelling, or redness" or any chief complaint containing the phrase "deep venous thrombosis" or "DVT") and transmitted to a designated cell phone carried by one of the investigators.

Study Protocol

LC US Training and Technique. Limited compression US technique requires the identification of the common femoral vein starting near the inguinal ligament where it bifurcates from the greater saphenous vein. Starting where the greater saphenous vein bifurcates, the common femoral vein is assessed for compressibility at 1-cm intervals distally until 2 cm distal to its bifurcation into the superficial and deep femoral veins. The popliteal vein is then identified in the popliteal crease and is assessed for compressibility proximally until the vein becomes less distinct and distally until the trifurcation into calf veins. Only if all points of assessment are fully compressible is the scan considered negative for DVT.[12,13]

A total of 17 physicians (five attending EPs, 12 emergency medicine [EM] residents) agreed to participate in the study and underwent training. US experience varied widely among the trained physicians, but only three physicians had completed fellowship training in EM US. All physicians had to be considered proficient in US to participate, and each had performed a minimum of 50 bedside US scans in each of the following: aorta, pericardium, focused assessment with sonography in trauma, and obstetrics/gynecology. For this study, a 2-hour didactic training session was given by the authors (RP, JN), followed the next day by a minimum of 12 supervised scans on healthy volunteers. Throughout the study period, if physicians felt they needed refreshing of their US skills, an ad hoc training session was provided by one of the authors.

All subjects underwent bedside LC US using a 10- to 12.5-MHz linear array probe (Esoate MyLab 5, Esoate Europe B.V., Maastricht, the Netherlands). The scanning physician recorded his or her interpretation of the scan on the study form while blinded to the D-dimer or comprehensive US results and was instructed not to modify practice based on the bedside scan, nor to communicate the interpretation of the scan to the treating physician. Bedside LC US was performed after the comprehensive US in some patients, but scanning physicians were blinded to these results. All scanning physicians were instructed to exclude the subject if the comprehensive US results were known to them. Prior to beginning the study, we arbitrarily decided that each physician would not be permitted to US more than 35 subjects.

Patients were classified as either DVT unlikely or DVT likely based on the treating physician's assessment using the modified Wells criteria (score < 2 or score ≥ 2, respectively).[14] The individual elements and the total score were recorded by the treating physician on a study form prior to diagnostic testing. When the scanning physician and the treating physician were not the same individual, the scanning physician independently assessed and explicitly recorded each component of the modified Wells criteria prior to scanning to allow assessment of interrater reliability.

The study was designed to test a new diagnostic approach to DVT that incorporated LC US by the EP. We hypothesized a priori that we would consider DVT ruled out by a negative LC US alone in DVT unlikely patients and by both a negative LC US and a negative D-dimer in DVT likely patients (Figure 1A). All other patients would undergo comprehensive imaging, including those in whom LC US was deemed indeterminate. We compared how this new diagnostic strategy would perform against the protocol currently endorsed by our institution (Figure 1B), but explicitly asked physicians to continue using the current approach throughout the study.

The physician performing the ED LC US recorded the time required to perform the scan. A stopwatch was attached to the US machine and the timer was started as the US physician had the probe in hand ready to begin. The timer was stopped once the US was complete and the physician had determined whether he or she believed DVT to be present or not.

To calculate the difference in time to definitive diagnosis between our proposed strategy and the currently used strategy, we used the end time of the LC US, the time the D-dimer results were posted to the computerized laboratory information system, or the time stamp on the last image frame of the comprehensive US as appropriate for final diagnosis under the given strategy. We recognized that these time points underestimated the time the treating physician became aware of D-dimer and comprehensive imaging results, but we could not reliably estimate the finite time required for radiologist interpretation and transmission of results to

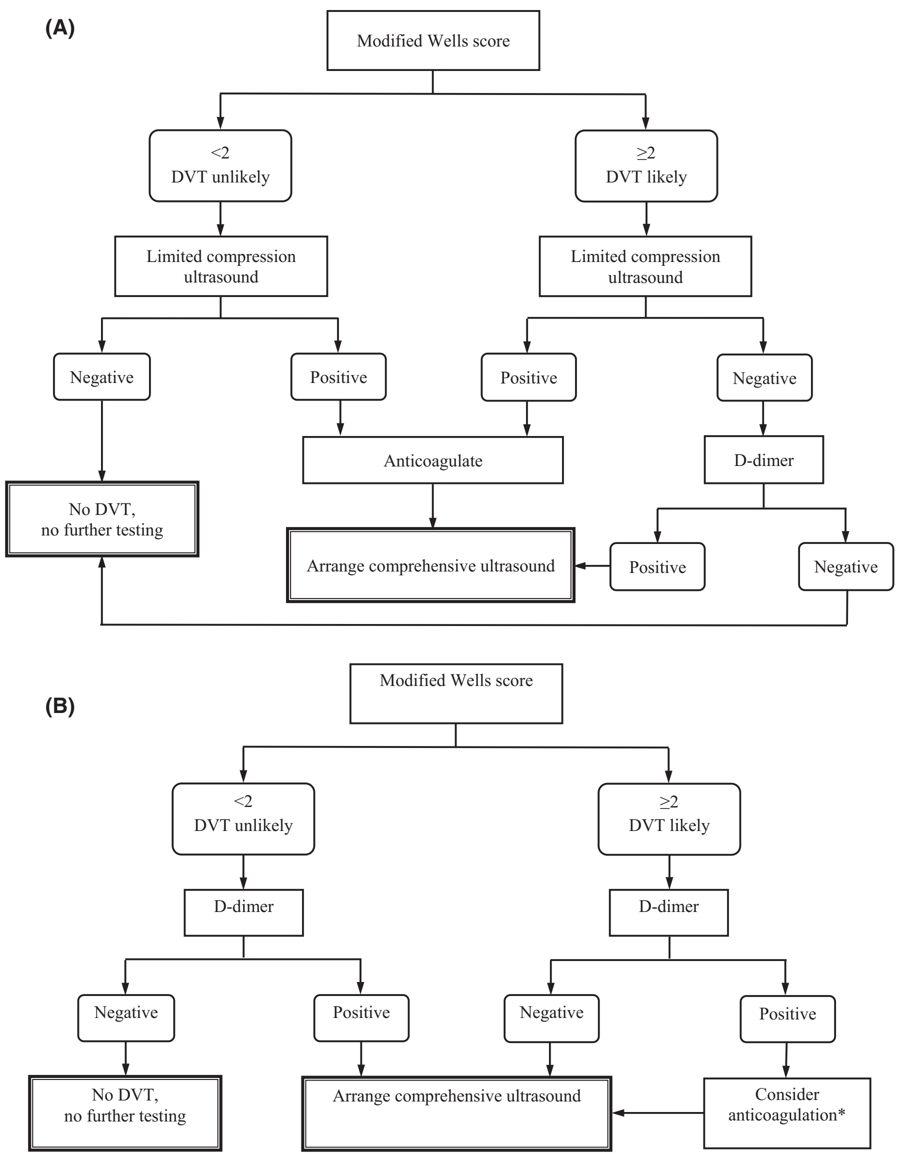

Figure 1. (A) Proposed new diagnostic approach incorporating by EP to rule out DVT. (B) Current diagnostic approach to suspected DVT. DVT = deep vein thrombosis; LC US = limited-compression ultrasound.

the treating physicians. In all cases, time intervals were calculated beginning from the time of patient registration for the initial visit when DVT was first suspected until definitive results were obtained. Specifically, when subjects were discharged home to return the next day for comprehensive imaging, the time recorded was from the first encounter until the final US results were obtained the next day.

Subjects were treated based on usual clinical care at the discretion of their treating EPs. The standard treatment approach to patients in use at our center since circa 2005 is based on the modified Wells score of DVT unlikely or DVT likely, D-dimer testing, and comprehensive US imaging. D-dimer testing was by quantitative latex immunoassay (Diagnostica Stago, Parsippany, NJ; cutoff < 0.50 μg/mL). Comprehensive US imaging was performed in the hospital's Department of Diagnostic Imaging by certified medical US technicians and interpreted by radiologists with special expertise in US imaging, blinded to the findings of the LC US. At our institution, comprehensive US is generally not available evenings or some weekends. Any arrangements for urgent outpatient imaging and decisions regarding empirical initiation of low-molecular-weight heparin prior to comprehensive imaging were left to the discretion of the treating physicians, who were instructed not to alter practice based on the study.

The criterion standard of DVT (disease positive) was based on comprehensive imaging interpreted by radiologists blinded to LC US findings and by structured medical record review at 6 months in patients without comprehensive imaging who were deemed DVT negative by the treating EP (typically DVT unlikely patients with negative serum D-dimer).

Outcome Measures

The primary outcome was the projected effect of our workup strategy on rates of missed DVT and of comprehensive imaging. The secondary outcomes were effect on return visits, empirical anticoagulation, time to definitive diagnosis, the stand-alone diagnostic accuracy of LC US, and the interobserver reliability of the modified Wells score.

Data Analysis

We performed an a priori sample size calculation based on the precision of the estimated specificity of D-dimer. Based on conservative literature estimates and our own experience, and assuming a total enrollment of 140 patients, we estimated that at least 100 (70%) would be DVT negative.[15] Assuming LC US to be at least 90% specific,[9] the exact 95% confidence band around this point estimate would be relatively narrow at ±6%. Assuming the D-dimer to be only 70% specific,[15] we would have over 80% power at a two-sided alpha of 0.05 to detect a specificity improvement of 20% using McNemar's test. McNemar's power also rises with concordance between the compared methods, such that we would have 80% power to detect a 12.5% improvement if concordance was at least 80%. Because we achieved the target enrollment faster than expected, we continued to enroll subjects into the study for 1 year to further improve the precision of our findings. Statistical analyses were performed using SAS version 9.1.

RESULTS

Based on an electronic health records search, a total of 461 patients presented during the study with chief complaints related to possible DVT. Of these potentially eligible candidates, 224 could not be enrolled for a variety of reasons, leaving 237 who agreed to participate. Of these, 10 were excluded after providing consent and did not undergo LC US. There were a total of 227 subjects enrolled (Figure 2).

A total of 184 patients (81%) underwent comprehensive imaging, of whom 24 were diagnosed with DVT. No additional cases of DVT or pulmonary embolism were identified on medical record review at 6 months in patients who did not undergo comprehensive imaging. The mean (±SD) age of study subjects was 56 (±18) years, and 137 were female (60%). A total of 121 (53%) were deemed DVT unlikely and the remaining 106 were DVT likely. LC US was positive in 27 patients (21 DVT positive), indeterminate in 28 patients (one DVT positive), and negative in 172 (two DVT positive; Data Supplement S1a, available as supporting information in the online version of this paper). Subjects with indeterminate LC US had a substantially higher body mass index (35.7 [±9.9] kg/m^2 vs. 29.5 [±6.6] kg/m^2; $p < 0.001$).

The three physicians who performed the most scans accounted for 88 (38.7%) scans. Details regarding the accuracy of each physician performing bedside US are available in Figure 3. The treating physician differed from the scanning physician in 132 (58.1%) cases. The mean (±SD) length of time for the EP to complete the LC US was 5.1 (±3.0) minutes. The median interval between the LC US and the comprehensive US was 1.3 hours (interquartile range [IQR] = 0.4 to 16.2 hours), and in 52 cases (28%) the comprehensive US had been performed first.

The stand-alone sensitivity and specificity of LC US compared to the criterion standard (either comprehensive imaging or 6-month medical chart review in patients without comprehensive imaging) were 91% (95% confidence interval [CI] = 70% to 98%) and 97% (95% CI = 92% to 99%), respectively (Table 1). The positive likelihood ratio of LC US by itself was 27, and the negative likelihood ratio was 0.090. In the subset of patients who received comprehensive imaging, the stand-alone sensitivity and specificity of LC US compared to comprehensive imaging by radiology were 91 and 96%, respectively. The specificity of the D-dimer was 52% (95% CI = 45% to 59%).

The overall interrater reliability for the modified Wells criteria was deemed good[16] ($\kappa = 0.62$, 95% CI = 0.48 to 0.77; Data Supplement S2, available as supporting information in the online version of this paper), yet 20 of 106 patients (19%) were classified into different risk groups by the two physicians. Moreover, the individual elements of the modified Wells score varied considerably in their interrater reliability. Two elements in particular, namely, the presence of deep vein tenderness and of collateral superficial veins, had poor interrater reliability, and accounted for much of the discrepant classification.

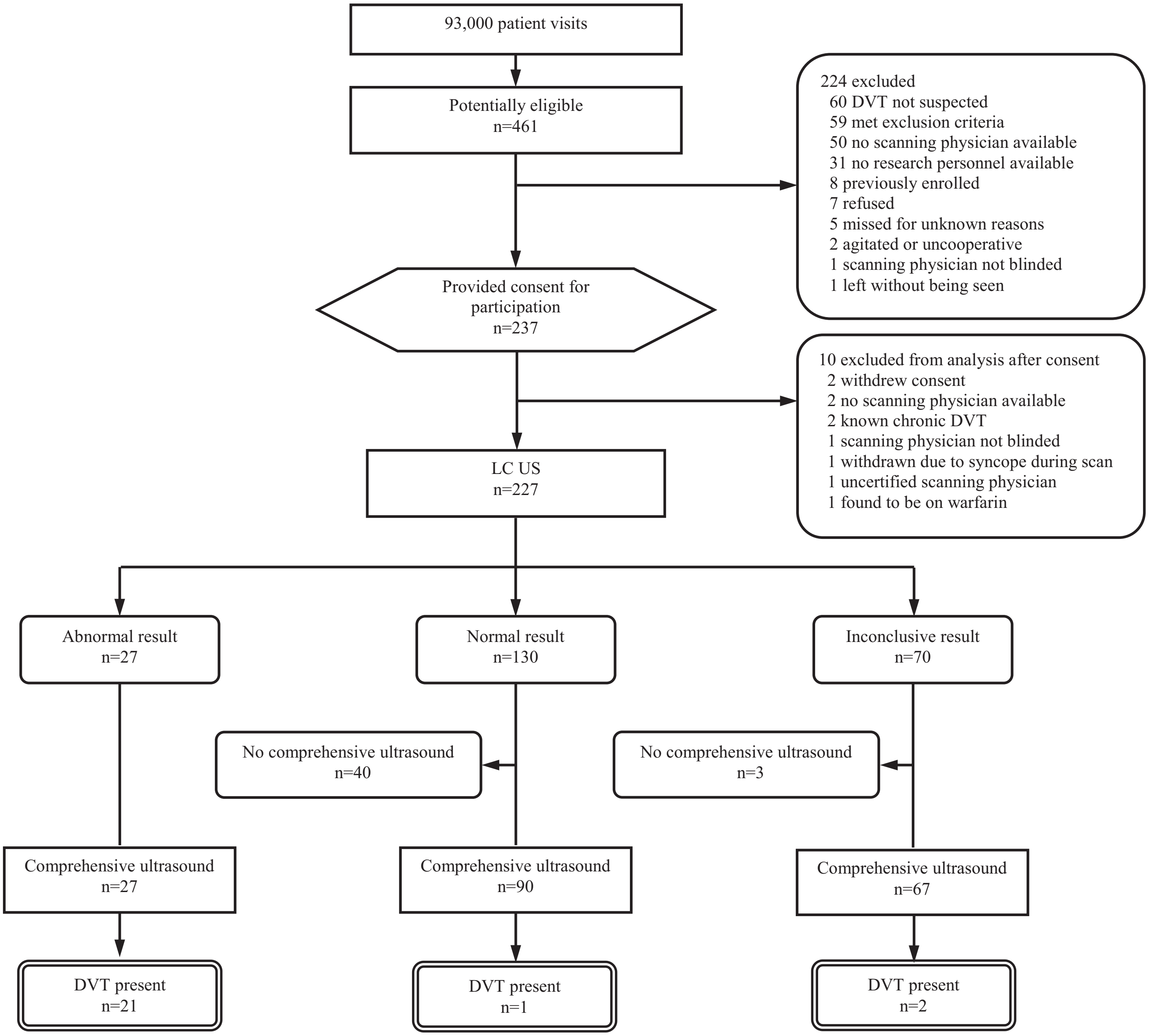

Figure 2. STARD diagram showing flow of potentially eligible, consented, and studied patients. DVT = deep vein thrombosis; LC US = limited-compression ultrasound.

Had our workup strategy been followed, the comprehensive imaging rate would have been 43% (24% of studies positive for DVT), substantially less than the actual rate of 81% (13% positive) or even the 70% rate (15% positive) had treating physicians adhered to the institutional protocol (absolute rate reduction = 27%, 95% CI = 18% to 36%; Table 2). Moreover, the mean time to definitive diagnosis would have been reduced by 5.0 hours. The new strategy would also have prevented 24 of 68 return visits for next-day imaging and 10 of 51 patients receiving unnecessary anticoagulation. There was a single false-negative patient in our approach, for an overall sensitivity of 96% (95% CI = 77% to 100%; Data Supplement S3, available as supporting information in the online version of this paper). This patient was deemed DVT unlikely by the treating physician and had a popliteal thrombus on comprehensive US 1 hour later. On retrospective review of the treating physician's own record of treatment, this patient should have been classified as DVT likely (active breast cancer with popliteal tenderness, giving a Wells score of 2). This patient did have a positive D-dimer and therefore the DVT would not have been missed had the patient been properly classified as DVT likely.

DISCUSSION

Rather than using LC US as a stand-alone test, we contemplated how it could be integrated into a diagnostic pathway for patients with suspected DVT and reduce the need for further testing. We were interested to know whether bedside US might reduce comprehensive imaging and D-dimer testing rates without compromising the ability to identify DVT. We selected one strategy

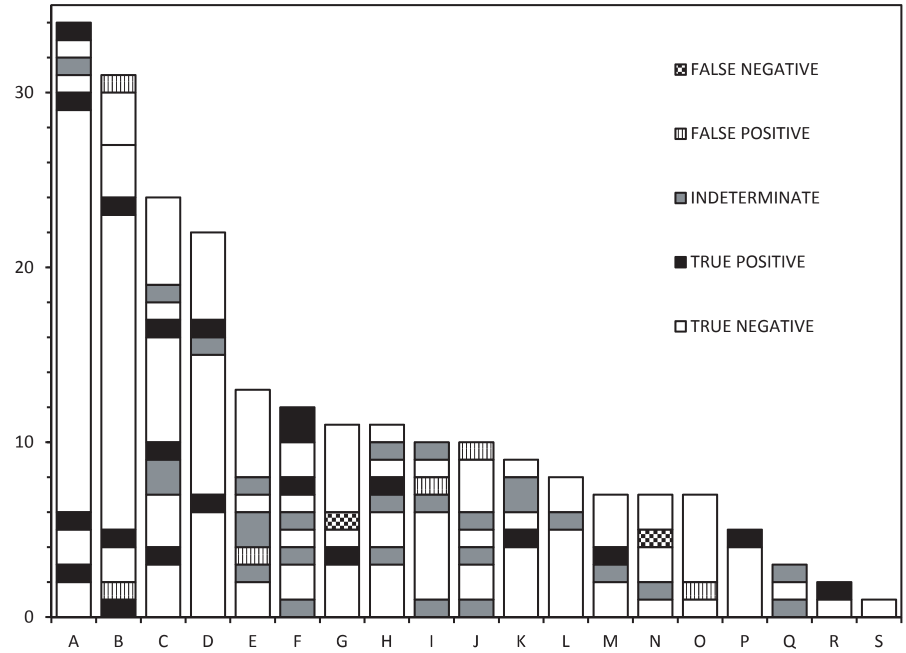

Figure 3. Diagnostic accuracy by individual EP over the course of the study. The total number of scans performed by each physician is shown as a histogram bar, with the order of scans arranged chronologically from bottom to top. For example, scanning physician O first performed a true-negative scan, then a false-positive, followed by five more true-negatives (representation adapted from Kline et al.[10]).

Table 1
Stand-alone Diagnostic Accuracy of Individual Components of Workup Strategy

Component	Positive, *n* (%)	Negative, *n* (%)	Not Done or Indeterminate, *n* (%)	Sensitivity, % (95% CI)	Specificity, % (95% CI)
Wells score (cutoff ≥ 2)	106 (46.7)	121 (53.3)	0 (0)	79 (57–92)	57 (50–64)
D-dimer (cutoff ≥ 0.50 μg/mL)	114 (50.2)	98 (43.2)	15 (6.6)	100 (82–100)	52 (45–59)
Comprehensive US	24 (10.6)	160 (70.5)	43 (18.9)	NA—criterion standard	
LC US	27 (11.9)	172 (75.8)	28 (12.3)	91 (70–98)	97 (92–99)

LC US = limited-compression ultrasound
When a component is missing, not done, or indeterminate, its effect on the sensitivity and specificity is not included. The modified Wells score shown is calculated by the treating physician. The criterion standard was comprehensive US (hence sensitivity and specificity are not shown), with medical record follow-up in patients who did not undergo imaging. As a stand-alone test, LC US had six false-positive and two false-negative tests.

a priori that incorporated both LC US and modified Wells scoring. Our results suggest that such a strategy could abbreviate time to definitive diagnosis, reduce unnecessary empirical anticoagulation, and decrease the number of return visits. These benefits came at the expense of missing one patient with DVT, who had been misclassified as DVT unlikely, and the occasional indeterminate study that would require further testing.

The benefits of ED US at the bedside by the treating physician for other serious conditions are supported by a body of literature.[17–19] Several groups have studied LC US for lower-extremity DVT. Essentially all proximal DVTs in the lower extremity involve either the common femoral or the popliteal veins.[20] In LC US, each of these two veins is examined at multiple points. Inability to fully compress the vein represents a positive study, highly suggestive of a proximal DVT. In a large study involving over 1,700 patients, this technique has been shown to be accurate when performed by radiologists.[21] Several small studies have also shown LC US to have good accuracy when performed by EPs trained in the technique, with one pooled estimate of both sensitivity and specificity between 87 and 99%.[4–8,10,22–26] Although LC US is a promising tool in the diagnosis of DVT in the ED, we must recognize that it has imperfect sensitivity. Kline et al.[10] observed an overall sensitivity of 70% (95% CI = 60% to 80%), although that sensitivity improved to 100% after individual physicians had enrolled three patients. We also found that the diagnostic sensitivity of each physician improved with time. The two false-negatives in our study were obtained in the first five to six scans performed by that physician.

We found the time needed to perform and interpret LC US to be short in comparison to the current diagnostic approach, although it requires more physician time than ordering a serum D-dimer or comprehensive

Table 2
Estimated Effect of New Versus Current Diagnostic Strategy on Comprehensive Imaging Rates and D-dimer Testing

Test Type	New Strategy	Current Strategy	Actual Approach
Comprehensive imaging			
Required*	90 + ?7	153 + ?6	184/227
Rate	0.43	0.70	0.81
(95% CI)	(0.36–0.49)	(0.64–0.76)	(0.75–0.86)
Diagnostic yield	0.24 (0.16–0.33)	0.15 (0.10–0.21)	0.13 (0.09–0.19)
D-dimer testing			
Required	76	227	212
Rate	0.33	1.00	0.93
(95% CI)	(0.28–0.40)	(0.98–1.00)	(0.89–0.96)
Diagnostic yield	0.01 (0.002–0.07)	0.11 (0.07–0.15)	0.11 (0.07–0.16)

N = 227.
"New strategy" refers to the proposed diagnostic strategy shown in Figure 1; "current strategy," the protocol in use at the institution throughout the study as shown in Figure 2; "actual approach," the strategy actually employed by the treating physician. "Diagnostic yield" represents the proportion of comprehensive imaging/D-dimer tests that were ultimately positive for a patient with DVT (not the test-positive rate).
*For seven cases (new strategy) and six cases (current strategy) the need for comprehensive imaging could not be established because D-dimer testing was not performed; these cases are shown as uncertain ("?n") but are assumed to have had positive D-dimer when calculating the imaging rate or yield.

US. Many low-risk DVT patients can have the diagnosis excluded during the same patient encounter without any test delay. In this regard, LC US is similar to other applications of bedside emergency US that have become routine in EM. While the introduction of any fast and available test encourages diagnostic creep (i.e., the threshold for performing a bedside US in a low-risk patient may be lower than the current threshold for ordering a D-dimer), the high specificity of LC US suggests that this creep will not inflate comprehensive imaging rates.

Although the kappa score for overall agreement between physicians for the modified Wells score is considered to be "good,"[16] it is not perfect, and indeed some components of the score have poor agreement. At the clinically important cut point of 2, one patient in five was classified into different risk strata depending on which physician assessment was used. As treatment algorithms for patients differ depending on their classification by the modified Wells criteria, this variability is concerning because this risk stratification scheme is in wide use to identify DVT. A recent study showed good interrater reliability of overall modified Wells score for DVT between consultant and nurse practitioner with an interrater agreement of 81% and a kappa score of 0.74.[27] Previous studies have shown variable results for the interrater reliability of modified Wells criteria for pulmonary embolism.[28,29]

It is sobering to recognize that even well-validated decision instruments remain imperfect, often limited by patient heterogeneity and operator variability. The sensitivity of any clinical decision rule, laboratory test, or imaging will also be lower in patients with less severe disease, including small or distal DVTs. The degree to which the quest for diagnostic perfection on first presentation should continue to drive imaging and laboratory testing rates upward is a difficult issue in many emergency conditions. Individual risk thresholds and comfort with using serial observation as a diagnostic strategy need also to be taken into consideration when identifying the optimal diagnostic approach to a potentially serious condition in the ED.

As a result, individual physicians may chose to incorporate LC US into their practice differently than our proposed strategy or deviate from this strategy in selected cases depending on various factors. These factors also include comfort with US imaging, pretest likelihood, clinical experience, and risk tolerance. Any proposed strategy should be formally tested in a clinical trial before it can be recommended.

LIMITATIONS

The primary limitation of this study is that we did not implement our proposed workup strategy in the actual management of patients. Thus, any inferences regarding diagnostic accuracy and improvements in imaging rates, lengths of stay, and return visits are hypothetical. We enrolled a relatively modest number of disease-positive patients, resulting in wide CIs with respect to sensitivity. We were unable to enroll consecutive patients, largely due to lack of availability of research personnel or scanning physicians. Only a subset of physicians at our center was trained to perform the technique, and some only enrolled small numbers of subjects. The physicians enrolling the most subjects likely had particular interest in bedside US and may be more accurate in its use than the average EP. The bedside LC US scans were performed after the comprehensive US in one-quarter of cases, and although scanning physicians were instructed to remain blinded to the radiologist's interpretation, we were not able to independently verify adherence with this blinding. Physicians occasionally deviated from the institutional protocol in place, mostly by ordering comprehensive imaging despite negative D-dimer testing in a DVT unlikely patient (30 cases), by ordering comprehensive imaging rather than D-dimer testing in DVT unlikely patients (six cases), by not ordering comprehensive imaging in a DVT unlikely patient with a positive D-dimer (three cases), and by not ordering D-dimer testing in DVT likely patients (seven cases).

We underestimated the time saved to definitive diagnosis to avoid having to impute delays in radiologist interpretation and communications and to avoid overstating our findings. Moreover, the time to obtaining LC US results was delayed at times due to the need to locate an available scanning physician who might be off-site. Despite these biases, LC US in the ED appears to offer substantial time saving in the diagnosis of DVT, especially in a center where comprehensive US is not readily available at all times. In centers where comprehensive US is available at night including weekends, these time savings would be expected to decrease. Several patients with negative comprehensive imaging but positive D-dimer did not have repeat imaging in 1 week as commonly recommended to rule out clot propagation. We did not search provincial death certificates or coronial records, but relied instead on medical record review at the only two hospitals in the region to identify missed venothrombotic embolism. Our estimate of savings in time, anticoagulation, and health care resource utilization may overestimate the actual benefits seen in practice, due to changes in thresholds for testing, deviation from recommended practice, and other unforeseen consequences such as reduced access to comprehensive imaging off-hours with decreased volume of studies being ordered.

CONCLUSIONS

Limited-compression ultrasound by emergency physicians holds promise as one component of the diagnostic approach to deep venous thrombosis, but should not be used as a stand-alone test due to imperfect sensitivity. Incorporating this technique has the potential to shorten ED visits, reduce return visits, and avoid unnecessary anticoagulation for a substantial number of patients suspected of lower-limb deep venous thrombosis. Tradeoffs in diagnostic efficiency for the sake of perfect sensitivity remain a difficult issue collectively in emergency medicine, but need to be scrutinized carefully in light of the cost of overinvestigation, delays in diagnosis, and risks of empirical anticoagulation.

References

1. White RH. The epidemiology of venous thromboembolism. Circulation 2003;107(Suppl 1):I4–8.
2. Scarvelis D, Wells PS. Diagnosis and treatment of deep-vein thrombosis. CMAJ 2006;175:1087–92.
3. Moore CL, Molina AA, Lin H. Ultrasonography in community emergency departments in the United States: access to ultrasonography performed by consultants and status of emergency physician-performed ultrasonography. Ann Emerg Med 2006;47:147–53.
4. Jacoby J, Cesta M, Axelband J, Melanson S, Heller M, Reed J. Can emergency medicine residents detect acute deep vein thrombosis with a limited, two-site ultrasound examination? J Emerg Med 2007;32:197–200.
5. Frazee BW, Snoey ER, Levitt MA, Wilbur LC. Negative emergency department compression ultrasound reliably excludes proximal deep venous thrombosis [abstract]. Acad Emerg Med 1998;5(Suppl):406–7.
6. Frazee BW, Snoey ER, Levitt MA. Emergency department compression ultrasound to diagnose proximal deep vein thrombosis. J Emerg Med 2001;20:107–11.
7. Blavais M, Lambert MJ, Harwood RA, Wood JP, Konicki J. Lower-extremity Doppler for deep venous thrombosis–can emergency physicians be accurate and fast? Acad Emerg Med 2000;7:120–6.
8. Jang T, Docherty M, Aubin C, Polites G. Resident-performed compression ultrasonography for the detection of proximal deep vein thrombosis: fast and accurate. Acad Emerg Med 2004;11:319–22.
9. Magazzini S, Vanni S, Toccafondi S, et al. Duplex ultrasound in the emergency department for the diagnostic management of clinically suspected deep vein thrombosis. Acad Emerg Med 2007;14:216–20.
10. Kline J, O'Malley PM, Tayal VS, Snead GR, Mitchell AM. Emergency clinician-performed compression ultrasonography for deep venous thrombosis of the lower extremity. Ann Emerg Med 2008;52:437–45.
11. Moore KM, Edgar BL, McGuinness D. Implementation of an automated, real-time public health surveillance system linking emergency departments and health units: rationale and methodology. CJEM 2008;10:114–9.
12. Pezzulo JA, Perkins AB, Cronan JJ. Symptomatic deep vein thrombosis: diagnosis with limited compression. Radiology 1996;198:67–70.
13. Cohen H, McGahan J. Standards for Performance of the Peripheral Venous Ultrasound Examination. Reston, VA: American College of Radiology, 1993.
14. Wells PS, Anderson DR, Rodger M, et al. Evaluation of D-dimer in the diagnosis of suspected deep-vein thrombosis. N Engl J Med 2003;349:1227–35.
15. Fox C, Irwin Z. Emergency and critical care imaging. Emerg Med Clin N Am 2008;26:787–812.
16. Fleiss JL. Statistical Methods for Rates and Proportions. New York, NY: John Wiley, 1981.
17. Rowland JL, Kuhn M, Bonnin RL, Davey MJ, Langlois SL. Accuracy of emergency department bedside ultrasonography. Emerg Med 2001;13:305–13.
18. American College of Emergency Physicians. ACEP emergency ultrasound guidelines–2008. Ann Emerg Med. 2009;53:550–70.
19. Socransky S; Emergency Department Targeted Ultrasound Interest Group, Canadian Association of Emergency Physicians. Emergency department targeted ultrasound: 2006 update. CJEM 2006;8:170–1.
20. Cogo A, Lensing A, 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.
21. 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.
22. Burnside PR, Brown MD, Kline JA. Systematic review of emergency physician-performed ultrasonography for lower-extremity deep vein thrombosis. Acad Emerg Med 2008;15:493–8.
23. Crisp JG, Lovato LM, Jang TB. Compression ultrasonography of the lower extremity with portable vascular ultrasonography can accurately detect deep venous thrombosis in the emergency department. Ann Emerg Med 2010;56:601–10.
24. Del Rios M, Lewiss RE, Saul T. Focus on: emergency ultrasound for deep vein thrombosis. ACEP News 2009;March.
25. Torres-Macho J, Anton-Santos J, Garcia-Gutierrez I, et al. Initial accuracy of bedside ultrasound performed by emergency physicians for multiple indications after a short training period. Am J Emerg Med 2012;30:1943–9.

26. Farahmand S, Farnia M, Shahriaran S, Khashayar P. The accuracy of limited B-mode compression technique in diagnosing deep venous thrombosis in lower extremities. Am J Emerg Med 2011;29:687–90.
27. Dewar C, Corretge M. Interrater reliability of the Wells score as part of the assessment of DVT in the emergency department: agreement between consultant and nurse practitioner. Emerg Med J 2008;25: 407–10.
28. Nordenholz KE, Naviaux NW, Stegelmeier K, Haukoos JS, Wolf SJ, McCubbin T. Pulmonary embolism risk assessment screening tools: the interrater reliability of their criteria. Am J Emerg Med 2007;25: 285–90.
29. Fesmire FM, Brown MD, Espinosa JA, et al. Critical issues in the evaluation and management of adult patients presenting to the emergency department with suspected pulmonary embolism. Ann Emerg Med 2011;57:628–52.

Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1a. DVT likely.

Data Supplement S1b. DVT unlikely.

Data Supplement S2. Interobserver agreement between treating and scanning physicians overall, and for each element of the modified Wells score.

Data Supplement S3. Diagnostic yield of proposed strategy to identify deep vein thrombosis. The document(s) is (are) in PDF format.