Open Access

Diagnosis of Deep Venous Thrombosis by Critical Care Physicians Using Compression Ultrasonography

Christopher DiBello* and Seth Koenig*

The Long Island Jewish Medical Center, Division of Pulmonary, Critical Care and Sleep Medicine, The Albert Einstein College of Medicine, New Hyde Park, NY 11040, USA

Abstract: Lower extremity deep venous thrombosis is a common, serious, often under-recognized diagnosis in the critically ill patient. Its high association with pulmonary embolus necessitates both prompt diagnosis and constant surveillance. Point of care ultrasonography by the treating physician is gaining popularity because of its high accuracy and ease of performance coupled with an immediate response to a question often asked at the bedside. This review will highlight the advantages of compression ultrasonography compared to other diagnostic modalities and gives a practical approach in performing this simple exam by the critical care team.

Keywords: Clot, thrombosis, compression ultrasound, DVT, duplex.

INTRODUCTION

Point of care ultrasonography performed at the bedside by critical care physicians is gaining popularity. The rapid diagnosis of lower extremity deep venous thrombosis (LEDVT) and its major consequence, pulmonary embolism (PE), is critical to patient outcome. Bedside diagnosis of LEDVT using compression ultrasound (CUS) is easy, immediate, and can be acted upon by the treating physician. This article intends to discuss an approach to the diagnosis of LEDVT as used by the authors in a large tertiary care medical center. We will review briefly the incidence of LEDVT, followed by its diagnostic modalities, the anatomy of the deep venous system of the lower extremity, and how to perform a LEDVT study as done in our intensive care unit.

LEDVT is a common problem with potentially devastating consequences. It affects approximately 2 million Americans per year which makes it the third most common cardiovascular disease behind acute coronary syndrome and stroke [1, 2]. LEDVT has a strong association with pulmonary embolism. It has been shown that 90% of symptomatic PE arises from the deep veins of the lower extremity. Pulmonary emboli are detected in approximately 50% of people with documented LEDVT; while LEDVT's are found in approximately 60- 70% of patients with confirmed PE [2, 3].

Critically ill patients are at the highest risk for developing LEDVT and this risk is attributable to Virchow's triad of stasis, a hypercoaguable state, and endothelial dysfunction. Mechanical ventilation, sedation/paralysis, surgical procedures, malignancy, central venous catheters, and a prolonged hospital stay, have all been shown to increase the risk for LEDVT in ICU patients [4-6]. Diagnosis in critically ill patients is more difficult due to nonspecific signs, i.e anasarca, and the inability of many patients to relay their symptoms.

Several studies have evaluated the incidence of LEDVT in critically ill patients. The overall incidence of LEDVT has been shown to be between 12% and 33% despite prophylaxis in the majority of patients [7, 8]. Joynt *et al*. and Mian *et al*. studied the incidence of LEDVT with femoral line catheters. The incidence of LEDVT ranged between 9.6% to as high as 26.2% [9, 10]. Ibrahim *et al*. showed that despite adequate LEDVT prophylaxis, prolonged mechanical ventilation, indwelling central lines and malignancy was associated with a 23.6% incidence of LEDVT [11].

The embolic risk of a LEDVT is related to its location within the venous system. Proximal LEDVT's, those arising in the iliacs, femoral and popliteal veins have a 50% risk of PE [2]. Distal LEDVT's, those arising in the calf veins, have a much lower risk of embolization and is related to the risk of extension into the proximal venous system. Distal LEDVT's make up only 20% of all LEDVTs. When found they extend proximally with a wide variation ranging from 0 to 29% [12, 13].

Diagnosing distal LEDVT's is more complex, time consuming and is not routinely done by our critical care physicians. If a negative CUS is performed and the risk remains high a repeat CUS is performed within one week. This should pick up any missed distal LEDVT that may have extended proximally. This strategy is supported in the literature. In a recent meta-analysis by Righini, six large prospective outcome studies, comprising 5876 patients, of serial proximal CUS were reviewed. In all of these studies CUS of the proximal veins were evaluated. If negative for LEDVT they were repeated one week later. The second CUS yielded a 1 to 5.7% new proximal LEDVT, which may be related to extension of a previously undiagnosed calf DVT. The pooled three month thromboembolic risk was 0.6% [12].

*Address correspondence to these authors at the Long Island Jewish Medical Center, Division of Pulmonary, Critical Care and Sleep Medicine, The Albert Einstein College of Medicine, New Hyde Park, NY 11040, USA; Tel: (516) 465-5400; Fax: (516) 465-5489;
E-mails: cdibello@nshs.edu, skoenig@nshs.edu

DIAGNOSIS OF LEDVT

The diagnosis of LEDVT can be made by both ultrasound and non-ultrasound modalities, all of which have different sensitivities and specificities, ease of performance, and risk to the patient. Understanding their limitations is essential for the proper selection of appropriate testing. Listed below are those modalities available to the clinician in pursuit of a diagnosis of LEDVT.

Contrast Venography: It is still considered the "Gold Standard" for diagnosing LEDVT, with a high sensitivity and specificity. This modality has little utility in the critically ill patient population due to invasiveness, transportation issues, contrast nephropathy, and dye allergies.

CT Venography: Shown to have similar sensitivity and specificity to Ultrasound. It adds to the sensitivity of CT angiograms in the diagnosis of PE [14]. It has similar disadvantages to contrast venography.

Impedance Plethysmography: This method evaluates changes in blood volume by electrical impedance variation of the lower limbs. It has been shown to have inferior accuracy to ultrasound [15]. Its major limitation is that it does not detect nonoclussive thrombus, which is easily seen by compression ultrasonography [16].

MR Venography: Alternative to CT venography in patients with contrast allergy. MR should not be used in critically ill patients due to transportation issues.

ULTRASOUND FOR THE DETECTION OF LEDVT

Compression Ultrasound: Using B-mode 2-D imaging and a high frequency linear transducer the examiner locates the vessel of interest and in transverse plane performs a compression maneuver. Using the adjacent artery as a reference point, full compression of the vein with minimal deformation of the artery indicates absence of thrombus. If a vein is compressible the walls of the vessel will join together under direct pressure from the transducer resulting in the disappearance of the vessel lumen. **(Video 1 Normal Compression)**

Duplex and Triplex Ultrasound: Combines compression ultrasound with pulse-wave Doppler (duplex) and both pulse-wave and color Doppler (triplex). According to the Intersocietal Commission for the Accreditation of Vascular Laboratories (ICAVL) duplex utrasonography with color flow Doppler must be provided as Instrumentation in order for a vascular laboratory to obtain accreditation [17].

Ultrasound Strategies: Compression Ultrasound is a highly accurate and easy to use modality in the detection of LEDVT. Kearon *et al*. performed a large meta-analysis on the sensitivity and specificity of CUS, for the detection of LEDVT in symptomatic outpatients. There was an estimated overall sensitivity of 89%, specificity of 94%, and positive predictive value of 94% for the detection of both proximal and distal LEDVT. For just proximal LEDVT the sensitivity and specificity were both higher (97% and 98% respectively with a 97% PPV) [15].

What constitutes a "standard ultrasound examination" of the lower extremity venous system is still debatable. A standardized ultrasound examination performed by both vascular and radiology laboratories typically includes a combination of pulse wave and color flow analysis with CUS of the entire lower extremity venous system. There is still some controversy as to whether compression ultrasound alone is equivalent to both duplex and triplex scanning. Birdwell *et al.* studied whether anticoagulation can be withheld on the basis of a negative compression ultrasonography exam on 405 symptomatic outpatients. The common femoral vein was imaged from the inguinal line to its bifurcation into the superficial femoral vein and profunda femoris. The popliteal vein was imaged from the proximal popliteal fossa to a point 10 cm distal from the mid-patella. If the compression was normal anticoagulation was withheld and a repeat exam was done in 5 to 7 days. Of the 405 patients 70 had a LEDVT diagnosed; of the remaining, only 2 patients had a LEDVT diagnosed at 3 month follow-up. Based on these results it is reasonable to withhold anticoagulation following a normal compression ultrasonography [18].

Should One Evaluate the Whole Lower Extremity Venous System or can we Image Selectively at Certain Key Points?

A recent study by Bernardi *et al.* evaluated the equivalence of so called "two-point" CUS to standard duplex lower extremity ultrasonography. Similar to Birdwell's study, CUS was performed at the common femoral region and the popliteal fossa to the point of the calf veins. 2098 patients, who were suspected on clinical examination to have a LEDVT, were randomized to either two point compression or whole leg duplex ultrasonography. All patients randomized to the two-point strategy also received D-dimer testing. Patients with an elevated D-Dimer at baseline with a normal two-point compression study had their study repeated 5-7 days later. Anticoagulation was withheld on all negative ultrasound exams in both the two-point and whole leg ultrasonography groups. All patients then received a repeat lower extremity ultrasound exam at 3 months. The incidence of confirmed LEDVT during the follow-up at 3 months was similar with both strategies. LEDVT occurred in 0.9% of the two-point group and 1.2% of the whole leg group demonstrating that serial two point compression is equivalent to whole leg color Doppler ultrasonography [19].

How Difficult is CUS to Perform?

Two-Point ultrasonography is a rapid and efficient method to detect LEDVT. Emergency Medicine attending physicians were shown to be highly accurate and had a median scanning time of 3min and 21 seconds [20]. Emergency medicine residents were shown to be accurate in detecting LEDVT after training in a limited two site examination. They received a 90 minute training session consisting of both lecture and hands on training [21]. Compared to trained vascular technicians, these residents showed 89% sensitivity for the detection of LEDVT.

To date no studies assessing the accuracy of intensivists performing CUS for the detection of LEDVT compared to vascular or radiology technicians have been completed. Based on Emergency Medicine attending and resident data and the relatively steep learning curve in performing CUS there is no reason to believe that accuracy rates would be significantly lower compared to ultrasound technicians. Further, the bedside clinician performs the exam in real time, anytime, and can perform an appropriate follow-up exam when necessary.

Which Compression Strategy to Employ?

Published studies suggest that compression ultrasound of the lower extremity with color and pulse wave Doppler does not increase the accuracy of the examination, over CUS alone [18, 19, 21, 22]. In our ICU we employ CUS without the use of Doppler interrogation of the venous system. In cases where the patient is edematous or obese and identification of a venous segment is in question, an augmentation maneuver may be performed. This maneuver is done by manually compressing the calf, with the vascular probe over the vessel of interest. With the color Doppler on, the venous segment should fill with color.

The main question is which CUS technique to employ; a complete or limited two-point compression exam. In a complete exam you compress at approximately 2cm segments over the entire proximal venous system to the trifurcation of the popliteal veins. In the two-point compression strategy the common femoral vein is compressed at the level where the great saphenous vein enters; then the popliteal vein is compressed (Fig. **1**).

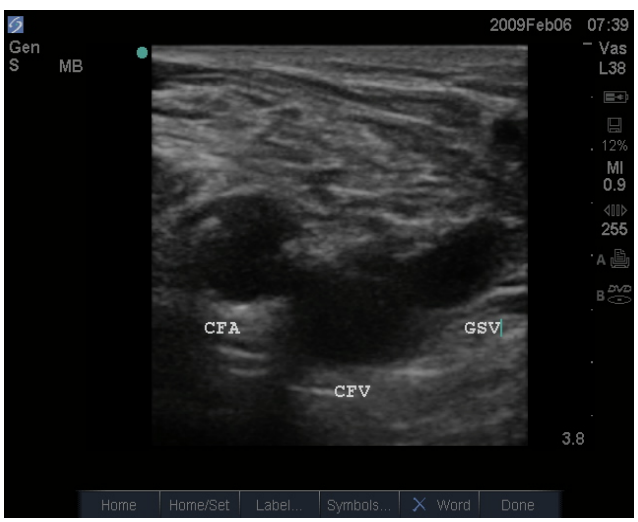

Fig. (1). Greater Saphenous Vein (GSV) and Common Femoral Vein Junction. Notice the GSV entering the CFV. This is the point where we begin our compressions.

The rational for two point CUS is that very few thrombi are isolated to the segments not visible with this two point strategy. That is to say that the ultrasonographer will pick up very few additional LEDVT's by scanning the entire venous system. In two different patient series the incidence of isolated superficial femoral vein clot was 1% [23, 24]. In contrast Maki *et al*. found the incidence of acute deep venous thrombosis isolated to the SFV to be 22.3% [25]. This study included both symptomatic and asymptomatic patients, while the other studies included only symptomatic patients. An incidence of 4.6% for isolated superficial femoral vein thrombus was observed by Fredrick *et al*. when they assessed whether the ultrasound examination can be abbreviated. The recommendation from the authors was that the exam should include scanning the entire length of the vessels [26].

Since a missed diagnosis of LEDVT in the critically ill may have devastating consequences and the data are conflicted with regards to the two point CUS strategy, we routinely scan the entire proximal venous system, from the CFV to the trifurcation of the popliteal vein.

Anatomy of the Lower Extremity Venous System

While a thorough understanding of the lower extremity venous anatomy is essential to the sonographer, this proves to be an easily and rapidly obtainable objective. Deep veins are usually paired with an artery. The common femoral artery lies laterally to the common femoral vein (CFV). The great saphenous vein (GSV) joins the common femoral vein in proximity to the inguinal ligament. This area is important sonographically because a thrombus identified at the junction between the GSV-CFV needs to be treated as a DVT. This is because of a high probability of extension into the CFV proper. Approximately 2 cm from the inguinal ligament the CFV splits into the profunda femoris vein and the superficial femoral vein (SFV). While its name, SFV, seems misleading, a thrombus identified anywhere along its length is considered a DVT and appropriate treatment should be initiated. The profunda femoris dives deep between the muscles and usually can not be seen. The SFV continues downward to Hunter's Canal (Adductor Canal) at which point it is now the popliteal vein. The popliteal vein continues caudad until its trifurcation into the calf veins.

How to Perform the Exam?

The transducer of choice to perform the examination is a 5 to 10 MHz linear array probe. Lower frequencies give you deeper penetration while higher frequencies give you better spatial resolution. Most ultrasound machines in use in ICU's today have color and pulse wave Doppler capabilities. As previously mentioned these can be used to identify vascular structures in the edematous/obese patients and to help differentiate an artery from a vein.

To maximize vessel image acquisition and compressibility the patient should be placed in the supine position, with the thigh externally rotated. To better expose the popliteal fossa the knee should be flexed at a 45 degree angle and externally rotated. Bandages and other barriers, including femoral vein catheters, make it difficult to ultrasound the lower extremity. All bandages in ultrasound field should be removed. If sterility is a concern a sterile ultrasound cover may be used.

The two sonographic findings that are diagnostic of a venous thrombosis are non-compressibility of the venous segment and/or echogenic intra-luminal material. Most acute thrombi are hypoechoic, and not well visualized. If a thrombus is identified within the vessel lumen, a compression maneuver is not essential. Excessive compression may dislodge a thrombus. If ambiguity still exists longitudinal scanning may help confirm the echogenic material as an intra-luminal thrombus (**Video 2 thrombus longitudinal**).

To begin the compression maneuver the probe is held by convention with marker to the patient's right. The vein and artery should be found in the transverse plane. With pressure, the anterior and posterior walls of the vessel should come together obliterating the vessel lumen (Fig. **2**).

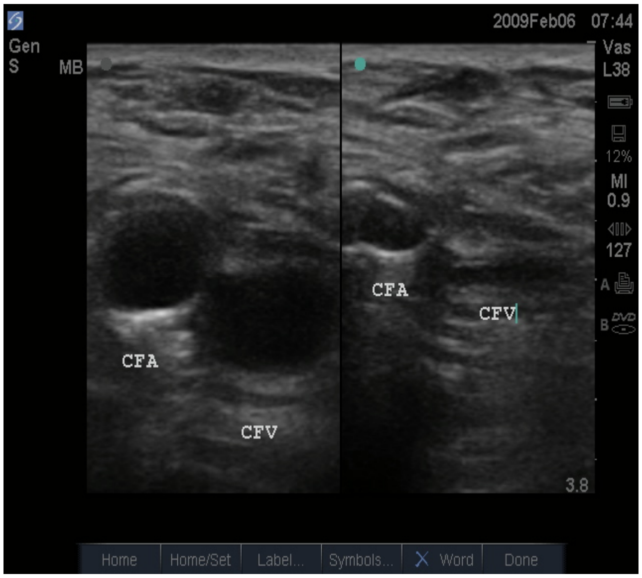

Fig. (2). Normal Compression: On the right is a compression maneuver, notice how the walls of the vein come together obliterating the lumen.

A positive exam, i.e. LEDVT, occurs when an appropriate level of pressure fails to bring apposition of the vessel walls (Fig. **3**).

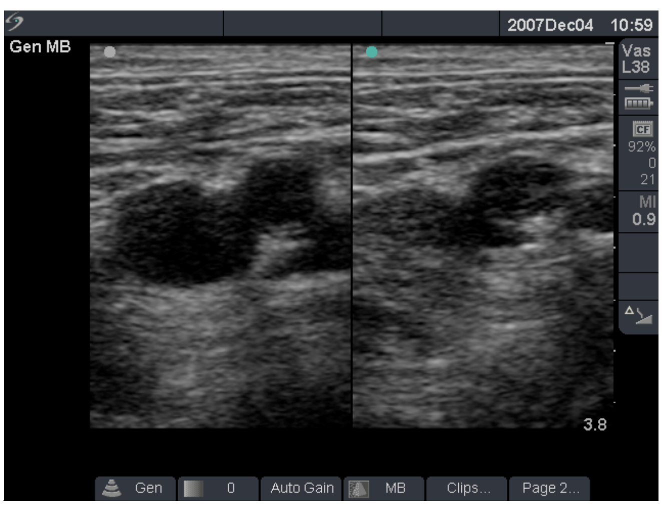

Fig. (3). Positive Compression: On the right you can see echogenic material in the vessel lumen with loss of collapsibility.

One potential pitfall in CUS is the amount of pressure exerted over the vessel. Too little and the vessel walls will not appose, misleading the sonographer into a false positive finding. The appropriate level of pressure is gauged by the deformation of the adjacent artery. If the vessel walls do not appose with enough pressure to deform the adjacent artery the vein must have a thrombus, whether visible or not. A second pitfall is the angle of the pressure exerted over the vessel walls. Pressure must be exerted perpendicular to the venous segment or even with appropriate pressure the venous segment may not collapse.

We begin our exam just above the GSV-CFV junction. At this level the examiner should locate the CFA-CFV in transverse plane. It is sometimes referred to as a "peanut sign" (Fig. **4**).

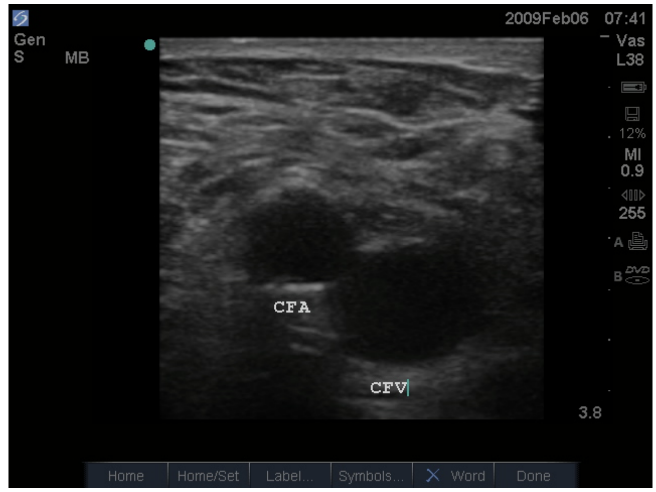

Fig. (4). Peanut Sign: The CFA lies next to the common femoral vein which looks like a "peanut."

The common femoral artery should lie laterally to the vein. A compression maneuver is done, as described. Then the CFV-GSV junction is identified and compressed. If negative we repeat compression maneuvers at 2cm increments until either the popliteal region is approached or we lose site of the vessel. The CFV will split into the SFV and Profunda or deep femoral vein (**Video 3 Splitting of CFV**). The accompanying artery will also split into the superficial femoral artery (SFA) and profunda or deep artery. It is crucial to scan back and forth "through" the bifurcations to identify the artery from vein. The SFA usually lies anterior to the SFV. We follow the SFV down to the adductor canal. Another pitfall is that compression may become challenging as it nears the adductor canal. Counter-pressure with the opposite hand to the probe may overcome this problem. Visual loss of the SFV is not uncommon as it dives deeper into the thigh. Sometimes increasing or decreasing the depth can bring the vein back into focus.

We then move on to the popliteal vein. The patient's leg should be positioned as stated above; flexed at a 45 degree angle at the knee. The transducer is placed in the popliteal fossa. The popliteal vein is easily compressed and even slight pressure may obscure it. The vein usually lies anterior to the artery. A compression maneuver is performed. We will scan this vessel with compression maneuvers until we reach the trifurcation into the calf veins. If negative, we move onto the opposite side completing the exam in the same manner.

CONCLUSION

LEDVT is a common and probably under-diagnosed condition in the critically ill. A rapid, repeatable, and easy to perform bedside modality is desirable. CUS, performed by the treating physician, in real time has obvious application. With a rapid, steep learning curve, CUS may become the "gold standard" for the diagnosis of DVT in critically ill patients.

SUPPLEMENTARY MATERIAL

This article contain 5 video files and it can be viewed at www.bentham.org/open/toccmj

REFERENCES

[1] Anand S, Wells PS, Hunt D, *et al*. Does this patient have deep venous thrombosis. JAMA 1998; 279: 1094-9.

[2] Hirsch J, Hoak J. Management of deep vein thrombosis and pulmonary embolism: a statement for healthcare professionals from the council on thrombosis (in consultation with the Council on Cardiovascular Radiology), American Heart Association. Circulation 1996; 93: 2212-45.

[3] Girard P, Sanchez O, Leroyer C, *et al*. Deep venous thrombosis in patients with acute pulmonary embolism: prevalence, risk factors and clinical significance. Chest 2005; 128: 1593-600.

[4] Attia J, Ray JG, Cook DJ, Douketis J. Deep vein thrombosis and its prevention in critically ill adults. Arch Intern Med 2001; 161: 1268-79.

[5] Geerts W, Selby R. Prevention of venous thromboembolism in the ICU. Chest 2003; 124: 357-63.

[6] Williams MT, Aravindan N, Wallace MJ, *et al*. Venous thromboembolism in the intensive care unit. Crit Care Clin 2003; 19: 185-207.

[7] Hirsch DR, Ingenito EP, Goldhaber SZ. Prevalence of deep venous thrombosis among patients in medical intensive care. JAMA 1995; 274: 335-7.

[8] Marik PE, Andrews L, Maini B. The incidence of deep venous thrombosis in ICU patients. Chest 1997; 111: 661-4.

[9] Joynt GM, Kew J, Gomersall CD, *et al*. Deep venous thrombosis caused by femoral venous catheters in critically ill adult patients. Chest 2000; 117: 178-83.

[10] Mian NZ, Bayly R, Schreck DM, Besserman ED. Incidence of deep venous thrombosis associated with femoral venous catheterization. Acad Emerg Med 1997; 4: 1118-21.

[11] Ibrahim EH, Iregui M, Prentice D, *et al*. Deep vein thrombosis during prolonged mechanical ventilation despite prophylaxis. Crit Care Med 2002; 30: 771-5.

[12] Righini M, Bounameaux H. Clinical relevance of distal deep vein thrombosis. Curr Opin Pulmon Med 2008; 14: 408-13.

[13] Righini M. Is it worth diagnosing and treating distal deep vein thrombosis? No. J Thromb Haemostasis 2007; 5: 55-9.

[14] Goodman LR, Stein PD, Matta F, *et al*. CT venography and compression ultrasonograpgy are diagnostically equivalent: Data from PIOPED II. Am J Rad 2007; 189: 1071-6.

[15] Kearon C, Julian JA, Newman TE, Ginsberg JS. Noninvasive diagnosis of deep venous thrombosis. Ann Int Med 1998; 128: 663-77.

[16] Palareti G, Cosmi B, Legnani C. Diagnosis of deep vein thrombosis. Semin Thromb Hemostasis 2006; 32: 659-72.

[17] Intersocietal Accreditation Commission. ICAVL standards for accreditation in noninvasive vascular testing. Part II. Vascular laboratory operations: peripheral venous testing 2007; pp. 1-10. Available at http://www.icavl.org

[18] Birdwell BG, Raskob GE, Whitsett TL, *et al*. The clinical validity of normal compression ultrasonography in outpatients suspected of having deep venous thrombosis. Ann Int Med 1998; 128: 1-7.

[19] Bernardi E, Camporese G, Buller HR, *et al*. Serial 2-point ultrasonography plus D-dimer *vs* whole-leg color-code Doppler ultrasonography for diagnosing suspected symptomatic deep venous thrombosis: A randomized controlled trial. JAMA 2008; 300: 1653-9.

[20] Blaivas M, Lambert MJ, Harwood RA, *et al*. Lower-extremity doppler for deep venous thrombosis—Can emergency physicians be accurate and fast? Acad Emerg Med 2000; 7: 121-6.

[21] Jacoby J, Cesta M, Axelband J, *et al*. Can emergency medicine residents detect acute deep venous thrombosis with a limited, two site ultrasound examination. J Emerg Med 2006; 32: 197-200.

[22] Lensing AW, Prandoni P, Brandjes D, *et al*. Detection of deep-vein thrombosis by real-time B-mode ultasonography. N Engl J Med 1989; 320: 342-5.

[23] Pezzullo JA, Perkins AB, Cronan JJ. Symptomatic deep venous thrombosis: diagnosis with limited compression ultrasound. Radiology 1996; 198: 67-70.

[24] Badgett DK, Comerata MC, Khan MN, *et al*. Duplex venous imaging: Role for a comprehensive lower extremity evaluation. Ann Vasc Surg 2000; 14: 73-6.

[25] Maki DD, Kumar N, Nguyen B, *et al*. Distribution of thrombi in acute lower extremity deep venous thrombosis: Implications for Sonography and CT or MR Venography. AJR Am J Roentgenol 2000; 175: 1299-301.

[26] Frederick GM, Hertzberg BS, Kliewer MA, *et al*. Can the US examination for lower extremity deep venous thrombosis be abbreviated? A prospective study of 755 examinations. Radiology 1996; 199: 45-7.

Received: April 15, 2009 Revised: May 15, 2009 Accepted: June 2, 2009