Limited B-mode venous imaging versus complete color-flow duplex venous scanning for detection of proximal deep venous thrombosis

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Purpose: **The purpose of this study was to compare the accuracy of a limited B-mode compression technique (BMCT) with a complete color-flow duplex venous examination (CDVE) for the detection of proximal deep vein thrombosis (DVT).**
Methods: **We prospectively studied 72 patients (20 men and 52 women) for DVT. Two technologists blinded to each other performed either BMCT or CDVE independently. The BMCT is an abbreviated technique compressing two sites per limb. One site was the saphenofemoral junction including the superficial femoral and deep femoral vein confluence; the other was the saphenopopliteal junction including tibial vein confluence. Total limbs studied were 144. CDVE was considered the gold standard for purposes of sensitivity, specificity, and accuracy.**
Results: **The technical failure rate of BMCT was three of 144. In all technically satisfactory examinations, the BMCT result was positive in 15 of 141 limbs, and the CDVE result was positive in 13. Sensitivity of BMCT was 100%, specificity was 98%, and overall accuracy was 99%. There were two false-positive results with BMCT; both were cases of popliteal veins deep to the artery leading to difficulty in compression. The BMCT was able to detect chronic thrombus, floating thrombus, and small thrombus behind femoral vein valve cusps.**
Conclusion: **These data suggest that BMCT is a rapid, acceptable, alternative technique for detecting proximal DVT. In cases of equivocal or positive findings, the spectral and color-flow Doppler examination should be used to confirm the results. (J VASC SURG 1995;22:553-7.)**

Since Talbot[1] first described ultrasonic venous imaging as a tool for the detection of venous thrombi, the ability to directly view thrombus and determine the location, extent, and composition has revolutionized the diagnostic algorithm for lower extremity deep venous thrombosis (DVT). Presently, two different approaches are used for the noninvasive diagnosis of DVT. One technique, developed by the vascular surgery community, relies on venous Doppler assessment as described by Barnes et al.[2] and uses color-flow Doppler scanning routinely. The entire leg, including calf veins, is evaluated, and an attempt is made to differentiate acute from chronic thrombus.[3,4] This technique is valuable for studying progression of the pathologic process in patients with and without symptoms and anatomic propagation of DVT over time.[5,6]

A second approach focuses primarily on the detection of a proximal DVT. This technique neglects Doppler technology and focuses on use of B-mode images and compressibility for diagnosis. It has the inherent advantages of brevity and minimal technologic requirements. The reported sensitivity and specificity of this method approaches 100%.[7-9]

The claimed accuracy of the B-mode compression technique (BMCT) raises the question whether a more technically demanding and time-consuming complete color-flow duplex venous evaluation (CDVE) is absolutely necessary to diagnose a proxi-

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Presented at the Seventh Annual Meeting of the American Venous Forum, Fort Lauderdale, Fla., Feb. 23-25, 1995.
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0741-5214/95/$5.00 + 0 **24/6/67553**

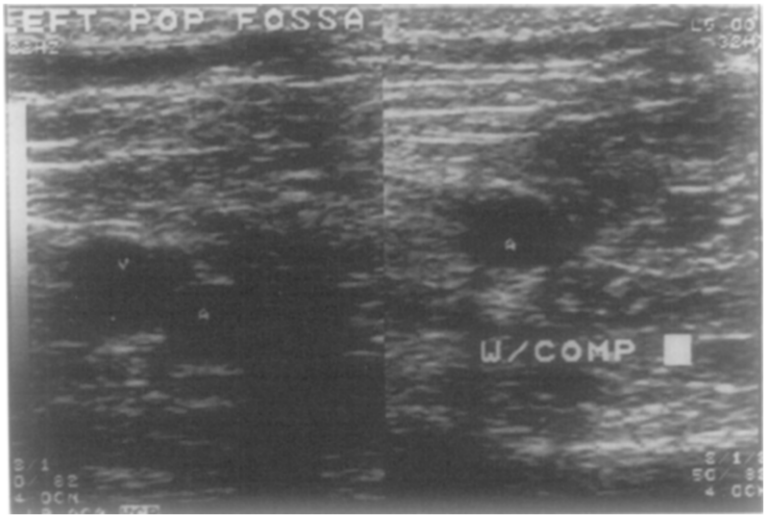

Fig. 1. Normal anatomic pattern; popliteal vein is superficial to popliteal artery.

mal DVT. The purpose of this study was to prospectively compare the accuracy of BMCT to CDVE for diagnosis of proximal DVT. The hypothesis advanced is that a BMCT examination is as accurate for detection of proximal DVT as a complete CDVE.

PATIENTS AND METHODS

During a 6-month period patients referred to the University of Southern California University Hospital vascular laboratory for a venous duplex examination were entered into a prospective protocol to determine the accuracy of BMCT versus CDVE for proximal DVT of the lower extremity. Only patients with symptoms referred to evaluate the presence or absence of an acute DVT were entered. Symptom-free patients undergoing screening for venous thrombosis were not included.

Each patient first underwent a BMCT followed by a CDVE. Scans were obtained independently by two registered vascular technologists who were blinded to the results of the other. Both lower extremities were evaluated. The examinations were performed within 1.5 hours of each other. Studies were performed with either the Toshiba 140 High Pace color-flow scanner (Toshiba America Medical Systems, Inc., South San Francisco, Calif.) or the high-definition imaging Ultramark 9 color-flow system (Advanced Technology Laboratories, Bothell, Wash.). A 5 MHz linear array transducer was used with each system.

Techniques

BMCT. BMCT entailed black-and-white real-time B-mode imaging only. Only two vein segments were included: the iliofemoral and the popliteal. First, the iliofemoral veins 1 to 2 cm above and below the saphenofemoral junction, including the deep and superficial femoral vein confluences, were assessed. As much of the iliac veins was incorporated into this technique as was included in the complete technique. Second, the popliteal veins 1 to 2 cm above and below the saphenopopliteal junction, including the tibial vein confluences, were assessed. All vein confluences were compressed. Hard copy of the veins with and without compression and real-time video recordings of the compressions were made. Each venous site was reported as positive or negative for DVT on the basis of compressibility alone. A third category, classified as *indeterminate*, was used when B-mode ultrasonography alone was insufficient for DVT determination, for example, when the vein could not be identified as a vascular structure without the aid of Doppler scanning.

CDVE. CDVE consisted of B-mode imaging, spectral Doppler scanning, and color-flow duplex scanning,[10] beginning with the most proximal deep vein segment visible. The distal lilac vein/common femoral vein (CFV) and proceeding caudad through the superficial femoral vein, popliteal vein, proximal tibial vein, posterior tibial vein, and peroneal vein were examined in a transverse plane. Special attention was paid to the venous confluences: the saphenofemoral, deep/superficial femoral, saphenopopliteal, gastrocnemius, and tibial vein confluences. The veins were assessed for full color filling by color-flow Doppler scanning, as well as full compressibility with extrinsic probe pressure. The extrinsic compressions were performed in a transverse plane at all vein confluences observed and every 2 cm along the venous segment. Spectral Doppler scanning was performed at the traditional sites of CFV, superficial

Table I. Results of BMCT versus CDVE

	CDVE				
	Norm	*CFV*	*CFV/POP*	*POP*	*Total*
BMCT					
Norm	126	0	0	0	126
CFV	0	4	0	0	4
CFV/POP	0	0	8	0	8
POP	2	0	0	1	3
Total	128	4	8	1	141

POP, Popliteal vein.

femoral vein at mid thigh, popliteal vein, and posterior tibial vein at the medial malleolus.[11] Signals were assessed for spontaneity, respiratory variation augmentation with a distal compression, and reflux with proximal compression or Valsalva's maneuver. Calf and lower leg veins were routinely included, with the exception of the anterior tibial veins. With the exception of the venous confluences, the greater and lesser saphenous systems were not routinely studied except in patients with physical signs suggestive of superficial venous thrombosis such as palpable cord, redness, or pain in the medial or posterior aspect of the extremity.

All results of both the BMCT and the CDVE were reviewed and compared by a third independent observer. The third observer was a vascular surgeon with registered vascular technologist credentials and experienced in reading noninvasive venous examinations. The full color-flow duplex study (CDVE) was considered the gold standard when calculating sensitivity, specificity, positive predictive value, negative predictive value, and accuracy.

Seventy-two patients (20 men and 52 women), ages 21 to 87 years (average age 63 years) were entered into the study. Indications for referral to the vascular laboratory included 61 patients (85%) with pain or swelling of the lower extremity and 11 (15%) with a possible pulmonary embolism as evidenced by tachypnea, hypoxemia, or chest pain. All studies were performed within 12 hours of request. Eighty-eight percent of referrals were from surgical specialties, whereas 12% were from internists and family practitioners.

RESULTS

A complete BMCT evaluation was possible in 141 limbs. Indeterminate findings occurred in three limbs as a result of the inability to localize the CFV in both limbs of an obese individual and to assess the popliteal vein in a patient with an above-knee plaster cast. This left 141 limbs available for a comparison between BMCT and CDVE. The average time to perform the BMCT was 5.5 minutes, range 2 to 11 minutes. The average time to perform the CDVE was 37 minutes, range 25 to 47 minutes.

The BMCT identified 15 of 141 limbs as positive for a proximal DVT (Table I). Sites positive by BMCT were CFV and popliteal vein ($n = 8$), CFV only ($n = 4$), popliteal vein only ($n = 2$), and popliteal vein with extension into calf ($n = 1$). Additionally, the BMCT also identified two small thrombi located behind valve cusps in the CFV, a floating thrombus and chronic thrombi, as well as two popliteal cysts.

CDVE confirmed all BMCT findings with the exception of two popliteal vein thrombi. In both cases the popliteal veins were deep to the artery and difficult to compress (Figs. 1 and 2). In retrospect, once the anatomic variant was recognized by color-flow Doppler scanning, rescanning provided full compression of the vein with more forceful pressure of the popliteal fossa. CDVE also identified additional findings of six limbs with reflux at the saphenofemoral junction, two mid calf DVTs, two limbs with calf vein reflux and one superficial thrombus in the distal greater saphenous vein. No additional proximal DVTs were diagnosed by CDVE.

In detection of a proximal DVT, the BMCT was found to be 100% sensitive and 98% specific, with a positive predictive value of 87%, a negative predictive value of 100%, and an overall accuracy of 99% when compared with a complete CDVE.

DISCUSSION

Lensing[12] compared B-mode ultrasonography with venography for the detection of DVT in 220 consecutive patients. With femoral and popliteal sites only and the single criterion of compressibility, a sensitivity of 100% and specificity of 91% were reported. At our institution, CDVE has replaced venography as the primary diagnostic test for a proximal DVT. Because most vascular laboratories have made this transition, we considered it important to evaluate BMCT prospectively against the most commonly used examination to detect a proximal DVT, the CDVE.

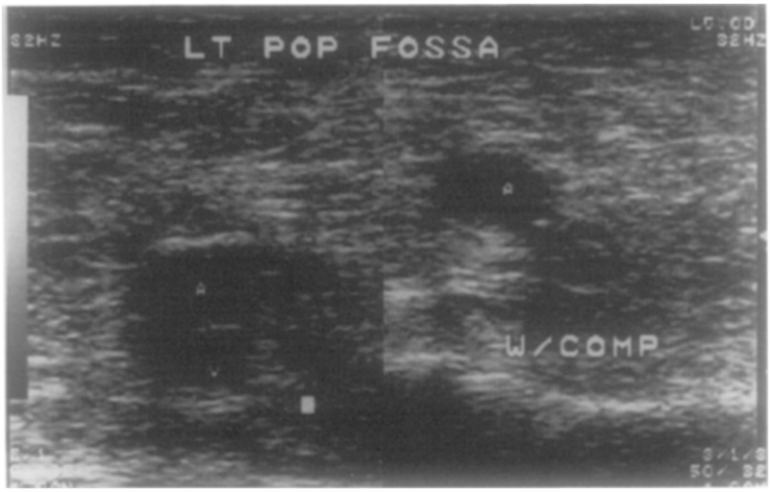

Fig. 2. Anatomic variant, popliteal vein is deep to popliteal artery and requires more forceful pressure to collapse walls.

As our data demonstrate, BMCT appears to be equivalent to CDVE for the diagnosis of proximal venous thrombosis. The absence of the Doppler component and more limited B-mode examination of venous segments does not appear to compromise the diagnostic utility of BMCT. This is contrary to the finding of Killewich et al.[13] that vein compression alone is less sensitive than the phasicity of the Doppler signal for the diagnosis of a DVT. However, significant refinements in B-mode resolution have occurred since Killewich's[13] report, thus improving the image detection of small thrombi. In addition, the correct interpretation of phasicity is very technician dependent, and this finding from a laboratory well schooled in Doppler interpretation may not apply to other diagnostic laboratories.

One obvious concern when omitting the Doppler component of a venous examination is the failure to detect an isolated lilac thrombus. Such thrombi are quite rare. Lund et al.[14] described a striking rarity of isolated thrombi in avalvular vein segments such as the inferior vena cava and the common iliac vein, as well as in veins supplied with one or very few valves such as the external iliac and the popliteal veins. Sarpa[15] reported that 1% of patients with a DVT had an isolated iliac vein thrombus. In that same report, Sarpa also reported that a complete evaluation of the iliac veins by CDVE was only possible in 60%. Moreover, proximal nonocclusive thrombi may not appreciably alter Doppler phasic flow patterns and may be missed when Doppler scanning is used alone. Furthermore, the BMCT as described in our report does not ignore the iliac vessels entirely, because compression of the distal external iliac is routinely performed. Both techniques therefore have potential limitations. Our study suggests that both techniques are equally capable of detecting a proximal DVT, but the rarity of an isolated iliac thrombosis mandates that a larger clinical experience is needed to confirm this finding.

Another major concern of BMCT is that it fails to examine the infrapopliteal venous tree. Philbrick[16] after a review of the literature of the past 46 years, opined that most research concerning the natural history of calf vein thrombosis was not "methodologically sound." What has been widely accepted, however, is that propagation into the popliteal vein invariably occurs before embolization. Krupski et al.[6] found that this occurred in two of 24 patients. Heijboer[17] reported a 1.5% rate of more proximal venous thrombosis within 6 months after normal venous screening study results in 985 consecutive outpatients. None of these documented episodes were followed by significant pulmonary embolism with thrombosis confined to the legs only. The BMCT used in our study examines the popliteal-tibial confluence, the portion of the tibial veins that conceptually are at highest risk for thrombus propagation. The clinical relevance of missing a mid to distal calf vein thrombosis remains unknown, but our approach therapeutically has been not to give anticoagulants and to repeat scanning only when symptoms persist.

Finally, chronicity of thrombi, visualization of collateral vessels, and assessment of superficial venous disease is not addressed by BMCT. Thus patients with complicated venous disease should be evaluated initially by CDVE rather than BMCT. Furthermore,

if the result of BMCT is equivocal or positive, color-flow scanning should be used to characterize more fully what abnormality if any is present. The two false-positive results were the only major discrepancy between BMCT and CDVE. Both were due to an anatomic transposition of the popliteal artery and vein. A combined technique that selectively uses color-flow Doppler scanning and compression would have detected the anatomic anomaly. The addition of color-flow Doppler scanning would also have eliminated the two technical failures as well.

Thus it appears that BMCT is a reasonable alternative to CDVE when attempting to exclude a proximal DVT. A sensitivity of 100% for proximal vein thrombosis makes this technique ideal for patients with abrupt onset of extremity swelling or in whom the suspicion that the lower extremity is the source of a pulmonary embolus must be ruled out. Compared with CDVE, the BMCT technique has the advantages of brevity and simplicity of technology, while reducing interobserver variability and training of staff. BMCT is especially suitable for emergency department and critical care settings. Furthermore the option to perform a more extensive study on a selected basis when a high index of suspicion exists and the result of BMCT is negative remains.

In this era of financial limitations, the impact of BMCT on the noninvasive vascular laboratory is also important to consider. Technical costs for personnel time are fixed at 37% to 46% of laboratory expenses. Reimbursement, in many instances, is below actual operating expenses.[18] The current rate of reimbursement by Medicare in our institution is approximately 42% of charges. Medicaid reimburses at approximately 10%. With venous imaging being the most frequently ordered test in most vascular laboratories, the routine use of a shorter test such as BMCT has the potential of improving the financial viability of many vascular laboratories.

This report confirms the accuracy of BMCT when compared with CDVE for the diagnosis of proximal DVT and supports the contention that BMCT is an acceptable technique for the evaluation of patients with symptoms. Nevertheless, further study is needed to clarify possible limitations in the detection of the isolated lilac thrombus and to determine what clinical settings will optimally maximize the technical advantages and brevity of BMCT.

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Submitted March 17, 1995; accepted June 30, 1995.