Section: Radiodiagnosis

Original Research Article

ROLE OF COLOUR DOPPLER ULTRASONOGRAPHY IN EVALUATION OF LOWER LIMB DEEP VEIN THROMBOSIS

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ABSTRACT

Background: Can a non-invasive bedside imaging tool reliably identify thrombus formation in the deep venous channels of the lower extremities? Deep vein thrombosis (DVT) remains a frequent vascular disorder carrying the risk of life-threatening pulmonary embolism if left unrecognised. This cross-sectional observational research was carried out to assess the diagnostic performance of colour Doppler ultrasonography (CDUS) in detecting lower limb DVT.

Materials and Methods: A total of 128 patients referred to the Department of Radiodiagnosis at Prakash Institute of Medical Sciences and Research, Islampur, Sangli, Maharashtra between March 2023 and February 2025 with clinical suspicion of DVT were enrolled. Each patient underwent grey-scale, compression, and colour Doppler evaluation of the lower limb venous system using a 3.5–12 MHz linear-array transducer.

Results: Among 128 subjects, 84 (65.6%) were confirmed positive for DVT and 44 (34.4%) showed no thrombosis. The left lower limb was affected more often (54.8%) than the right (35.7%), and bilateral involvement was seen in 9.5% of positive cases. Proximal DVT accounted for 73.8% of all positive findings, with the superficial femoral vein being the most frequently involved segment (60.7%). Males (58.3%) outnumbered females (41.7%), and the 41–60 year age bracket contributed the highest proportion of cases (42.9%). Immobilisation, recent surgery, and malignancy were the three leading predisposing conditions. CDUS demonstrated a sensitivity of 96.4%, specificity of 93.2%, positive predictive value of 96.4%, and negative predictive value of 93.2% for proximal DVT detection. Non-compressibility of the vein, absent colour flow, and absent spectral waveform were the most dependable sonographic markers.

Conclusion: The research confirms that colour Doppler ultrasonography serves as an accurate, reproducible, and radiation-free first-line modality for evaluating suspected lower limb DVT, and may reduce the need for invasive contrast venography in the majority of clinical scenarios.

Keywords: Colour Doppler ultrasonography, deep vein thrombosis, lower limb, compression ultrasonography, venous thromboembolism, pulmonary embolism, non-compressibility, proximal DVT, spectral waveform.

INTRODUCTION

What happens when a blood clot silently forms inside the deep veins of the leg, goes undetected, and breaks free to travel toward the lungs? Deep vein thrombosis (DVT) of the lower extremities is a common yet potentially fatal vascular condition in which thrombus develops within the deep venous system, most frequently in the calf, popliteal, femoral, or iliac veins.[1] It forms one component of the broader clinical entity termed venous thromboembolism (VTE), the other being pulmonary embolism (PE), which arises when a dislodged thrombus occludes the pulmonary arterial bed.[2] Global estimates place the annual incidence of VTE at roughly 1–2 per 1,000

persons, and untreated proximal DVT carries a PE risk that approaches 50% in some series.[3]

The pathophysiology rests on the classic triad described by Virchow — venous stasis, endothelial damage, and hypercoagulability.[1,2] Prolonged immobilisation following surgery or trauma, advancing age, obesity, pregnancy, active malignancy, and inherited thrombophilia are well-recognised predisposing factors.[1,2] Clinical presentation ranges from entirely asymptomatic forms to limbs with marked oedema, warmth, tenderness, and discolouration. However, clinical assessment alone is unreliable: the signs and symptoms overlap with cellulitis, muscle strain, lymphoedema, and superficial thrombophlebitis, yielding a positive predictive value below 50% when used in isolation.[4,6] Scoring systems such as the Wells criteria improve pre-test probability estimation, but definitive diagnosis still requires imaging confirmation.[4]

For decades, contrast venography served as the gold standard; yet it is invasive, exposes the patient to ionising radiation and iodinated contrast, and cannot be repeated easily for serial monitoring.[7] Duplex ultrasonography — combining B-mode grey-scale imaging with Doppler flow assessment — emerged as a practical alternative in the late 1980s. The addition of colour flow mapping further improved diagnostic confidence by directly visualising flow within and around the vein lumen.[5,8] Today, colour Doppler ultrasonography (CDUS) is widely regarded as the first-line imaging modality because it is non-invasive, portable, free of radiation, readily available, and allows real-time bedside evaluation.[7,9]

Several large meta-analyses have reported pooled sensitivities exceeding 94% and specificities above 93% for proximal DVT when using compression and Doppler techniques together.[5,10] Sensitivity for isolated calf vein thrombosis, however, remains lower and more variable, ranging between 60% and 80%, which is why serial scanning is often recommended for distal disease.[5,8] Despite these well-established figures from Western populations, data from centres in semi-urban and rural regions remain comparatively sparse. A gap persists in documenting whether these performance benchmarks hold true under different clinical settings, operator skill levels, and patient demographics.[11,12] This research was therefore undertaken to evaluate the diagnostic role of CDUS in detecting lower limb DVT among patients presenting to a tertiary-care teaching hospital in a semi-urban region, and to describe the anatomical distribution, demographic profile, and risk-factor patterns encountered.

MATERIALS AND METHODS

Material: This cross-sectional observational research was conducted at the Department of Radiodiagnosis, Prakash Institute of Medical Sciences and Research, Islampur, Sangli, Maharashtra between March 2023 and February 2025. The institutional ethics committee granted approval before enrolment commenced (Protocol No. PIMSR/EC/2023-041, dated 14 February 2023). Written informed consent was obtained from every participant or their legally authorised representative. A total of 128 consecutive patients referred with clinical suspicion of lower limb DVT — presenting with unilateral or bilateral leg swelling, pain, tenderness, warmth, or discolouration — were included. Patients below 18 years of age, those with a previous confirmed episode of DVT in the same limb, individuals who had already started anticoagulant therapy before imaging, and patients with an amputated limb were excluded.

Demographic data (age, sex), relevant medical history, and predisposing risk factors were recorded on a structured proforma. Clinical assessment included measurement of limb circumference at three standardised levels: mid-thigh, knee, and mid-calf. The Wells score was calculated for each patient to stratify pre-test probability.[4]

Methods: All examinations were performed by a single trained radiologist using a Philips HD 11 XE ultrasound machine equipped with a 3.5–12 MHz broadband linear-array transducer. Patients were examined in the supine position with the hip externally rotated and the knee slightly flexed for proximal veins, and in the prone or sitting position with the foot dangling for popliteal and calf veins. A systematic protocol was followed: grey-scale assessment was performed first to identify intraluminal echogenicity, followed by the compression technique — firm transducer pressure applied at 2 cm intervals from the common femoral vein to the popliteal vein. Non-compressibility of the vein was considered the primary diagnostic criterion. Colour Doppler mapping was then applied to evaluate flow presence, direction, spontaneity, and respiratory phasicity. Spectral Doppler tracings were recorded to assess flow augmentation with distal calf compression and response to the Valsalva manoeuvre.[7,9]

The following veins were evaluated bilaterally: common femoral, superficial femoral (now termed the femoral vein), deep femoral, popliteal, posterior tibial, anterior tibial, and peroneal veins. A diagnosis of DVT was made when at least two of the following criteria were met: (a) non-compressibility of the vein segment, (b) visualisation of intraluminal echogenic material, (c) absent or incomplete colour filling, (d) absent or abnormal spectral waveform.[8,10] Thrombus was classified as acute if the vein was distended with hypoechoic or anechoic intraluminal material and showed spongy partial compressibility, or chronic if the vein was contracted with hyperechoic contents and irregular wall thickening.[9] DVT was categorised as proximal when the popliteal vein or any segment above it was involved, and distal when limited to infra-popliteal veins.

Data were entered into Microsoft Excel and analysed using SPSS version 26.0. Categorical variables were

expressed as frequencies and percentages; continuous variables as mean ± standard deviation. Chi-square test and Fisher's exact test were applied for categorical comparisons, with $p < 0.05$ regarded as statistically significant. Diagnostic performance measures — sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) — were calculated against a composite reference standard comprising clinical follow-up, D-dimer levels, and contrast-enhanced CT venography performed in 23 equivocal cases.[5,6]

Ethical Considerations: The research protocol was reviewed and approved by the Institutional Ethics Committee of Prakash Institute of Medical Sciences and Research, Islampur, Sangli, Maharashtra (Protocol No. PIMSR/EC/2023-041, approval date 14 February 2023) before any participant was enrolled. The research was carried out in conformity with the principles laid down in the Declaration of Helsinki (2013 revision) and the Indian Council of Medical Research guidelines for biomedical research on human subjects. Each participant received a detailed explanation of the purpose, procedure, potential risks, and expected benefits of the research in a language they understood. Written informed consent was obtained from all patients; for those unable to provide consent independently, a legally authorised representative signed on their behalf. Patient identity was protected throughout data collection, analysis, and reporting by assigning unique numerical codes. All imaging data and clinical records were stored in a password-protected database accessible only to the research team. Participation was entirely voluntary, and patients were free to withdraw at any stage without any effect on their ongoing treatment.

RESULTS

Among the 128 patients evaluated, 84 (65.6%) were confirmed to have DVT on colour Doppler ultrasonography, while 44 (34.4%) showed no evidence of thrombosis. The mean age of DVT-positive patients was 49.3 ± 13.7 years compared with 43.8 ± 15.2 years in the DVT-negative group ($p = 0.037$). Males constituted 49 of the 84 positive cases (58.3%) and females accounted for 35 (41.7%). Left-sided involvement was observed in 46 patients (54.8%), right-sided in 30 (35.7%), and bilateral disease in 8 (9.5%). Proximal DVT — defined as thrombosis at or above the popliteal vein — was identified in 62 of the 84 positive patients (73.8%), while isolated distal DVT was found in the remaining 22 (26.2%).

Table 1: Demographic and Clinical Profile of Patients (n = 128)

Parameter	DVT Positive (n = 84)	DVT Negative (n = 44)
Mean Age (years)	49.3 ± 13.7	43.8 ± 15.2
Male	49 (58.3%)	27 (61.4%)
Female	35 (41.7%)	17 (38.6%)
Left limb	46 (54.8%)	–
Right limb	30 (35.7%)	–
Bilateral	8 (9.5%)	–
Proximal DVT	62 (73.8%)	–
Distal DVT	22 (26.2%)	–

DVT = Deep Vein Thrombosis. Values are n (%) or mean ± SD.

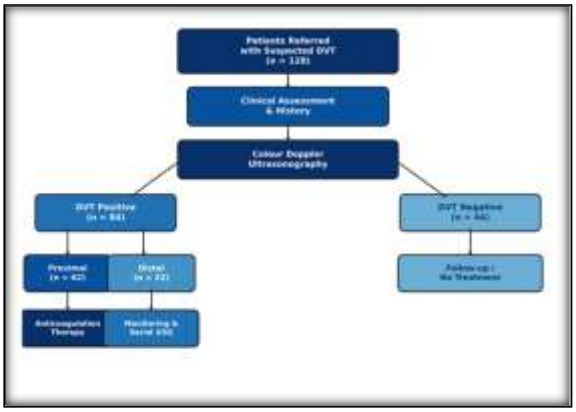


Figure 1: Flowchart depicting patient selection and classification of colour Doppler ultrasonography findings in suspected lower limb DVT (n = 128).

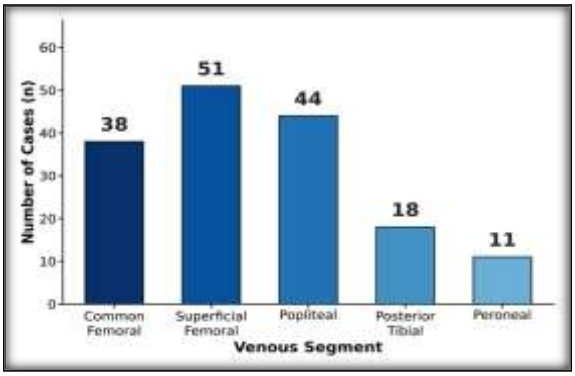


Figure 2: Distribution of deep vein thrombosis across venous segments of the lower limb among DVT-positive patients (n = 84). The superficial femoral vein was the most frequently affected segment.

Table 2: Diagnostic Performance of Colour Doppler Ultrasonography for DVT Detection

Diagnostic Parameter	Proximal DVT (%)	Distal DVT (%)	Overall (%)
Sensitivity	96.4	81.8	92.9
Specificity	93.2	90.9	93.2
PPV	96.4	78.3	95.1
NPV	93.2	93.0	89.1
Accuracy	95.3	88.6	93.0

PPV = Positive Predictive Value; NPV = Negative Predictive Value.

Table 3: Sonographic Criteria and Their Frequency in DVT-Positive Cases (n = 84)

Sonographic Criterion	Frequency (n)	Percentage (%)	Category
Non-compressibility	82	97.6	B-mode
Intraluminal echogenicity	74	88.1	B-mode
Absent colour flow	79	94.0	Colour Doppler
Incomplete colour filling	63	75.0	Colour Doppler
Absent spectral waveform	71	84.5	Spectral Doppler
Loss of respiratory phasicity	54	64.3	Spectral Doppler
Absent augmentation	48	57.1	Spectral Doppler
Vein distension	59	70.2	B-mode

Multiple criteria could coexist in the same patient. Percentages calculated from DVT-positive cases (n = 84).

Overall Interpretation: The superficial femoral vein was the single most commonly affected segment, involved in 51 of 84 cases (60.7%), followed by the popliteal vein in 44 (52.4%) and the common femoral vein in 38 (45.2%). Among distal segments, the posterior tibial vein was involved in 18 (21.4%) and the peroneal vein in 11 (13.1%). Acute thrombus was identified in 58 cases (69.0%), chronic thrombus in 17 (20.2%), and features of both acute and chronic disease coexisted in 9 (10.7%). Non-compressibility of the vein was the most consistent finding, present in 82 of 84 positive cases (97.6%), followed by absent colour flow in 79 (94.0%), intraluminal echogenicity in 74 (88.1%), and absent spectral waveform in 71 (84.5%).

DISCUSSION

The overall DVT positivity rate in the present research was 65.6%, which aligns closely with the 60–70% detection rates reported by Bernardi and Camporese.[8] in their review of large referral-centre cohorts. This relatively high rate likely reflects referral bias, as patients were directed to the radiology department only after clinical suspicion had already been raised by attending physicians. Male predominance (58.3%) mirrors the findings of Heit,[2] and Cushman,[1] who attributed the slightly higher male incidence to greater exposure to surgical immobilisation and occupational injury. The peak occurrence in the 41–60 year age group is consistent with population-based estimates that VTE incidence rises sharply after the fourth decade.[2,3]

Left lower limb preponderance (54.8%) matches the anatomical explanation first proposed by May and Thurner: the left common iliac vein is compressed by the overlying right common iliac artery, predisposing it to stasis and thrombosis.[13] Similar laterality has been documented by Fraser and Anderson,[9] and by Tomkowski et al.[14]

Proximal DVT predominated in the present cohort (73.8%), a pattern that carries direct clinical weight because proximal thrombi are far more likely to embolise than distal ones.[3,6] The superficial femoral vein was involved most often (60.7%), a finding that agrees with data from Prandoni et al,.[3] and Schellong et al.[15] CDUS demonstrated a sensitivity of 96.4% and specificity of 93.2% for proximal disease, figures that fall within the 94–97% sensitivity range reported in the meta-analysis by Goodacre et al,[5] and by Bhatt et al.[10] For isolated distal DVT, sensitivity dropped to 81.8%, confirming the well-recognised limitation of ultrasound below the knee.[5,8] Non-compressibility proved to be the most reliable criterion (97.6%), consistent with the consensus that vein incompressibility remains the single strongest predictor of acute thrombosis on ultrasound.[7,9]

Among predisposing factors, immobilisation, recent surgery, and malignancy ranked highest, paralleling the risk-factor hierarchy outlined in the CHEST guideline.[6] and by Konstantinides et al.[16] The proportion of patients with no identifiable risk factor (11.9%) was similar to the 10–15% reported as idiopathic or unprovoked DVT in Western literature.[2,11] These results collectively support the position that CDUS is a dependable first-line modality for DVT evaluation in semi-urban tertiary-care settings, provided that operator training and a standardised scanning protocol are maintained.

Limitations: Several constraints should be acknowledged. First, the research was conducted at a single centre, which limits the extent to which results can be extended to other populations and settings. Second, contrast venography — the conventional gold standard — was not performed in every patient; instead, a composite reference standard combining clinical follow-up, D-dimer values, and CT venography in selected cases was used, introducing a potential verification bias. Third, operator dependence is an inherent feature of ultrasound-based imaging, and all scans in this research were performed by a single trained radiologist, which may not reflect the variability seen across different skill levels. Fourth, the sample size of 128 patients, while adequate for calculating diagnostic performance indices, did not permit reliable subgroup analysis for uncommon risk factors such as inherited thrombophilia or antiphospholipid syndrome. Fifth, patients who had already begun anticoagulant therapy were excluded, so the findings may not fully represent the spectrum of partially treated thrombi. Future multi-centre research with a larger sample and venographic correlation in all participants would strengthen these observations.

CONCLUSION

This research was designed to assess the diagnostic value of colour Doppler ultrasonography in evaluating lower limb deep vein thrombosis among patients referred to a semi-urban tertiary-care teaching hospital. The findings confirm that CDUS is a highly accurate, non-invasive, and reproducible tool for detecting proximal DVT, achieving a sensitivity of 96.4% and specificity of 93.2% in the present cohort.

The research identified several important patterns. DVT was detected in nearly two-thirds of referred patients, with a clear male preponderance and a peak incidence in the fifth and sixth decades of life. Left lower limb involvement exceeded right-sided disease, consistent with the well-documented effect of iliac vein compression. Proximal thrombosis accounted for almost three-quarters of all positive cases, and the superficial femoral vein was the most frequently involved segment. Non-compressibility of the vein emerged as the single most reliable sonographic criterion, present in 97.6% of confirmed cases, followed by absent colour filling and absent spectral waveform. Acute thrombus predominated over chronic disease, and combined acute-on-chronic features were observed in a small but clinically meaningful subset. Immobilisation, recent surgery, and underlying malignancy were the most common predisposing factors, echoing findings from larger epidemiological datasets.

From a practical standpoint, these results reinforce the recommendation that colour Doppler ultrasonography should be adopted as the first-line imaging modality for suspected lower limb DVT in settings where contrast venography is either unavailable or undesirable. Its portability, absence of ionising radiation, repeatability for serial monitoring, and compatibility with bedside use in critically ill patients make it particularly suitable for hospitals in semi-urban and resource-limited environments. The integration of grey-scale assessment, compression testing, colour flow mapping, and spectral analysis within a single examination provides a multi-layered evaluation that maximises diagnostic confidence. Clinicians should, however, remain aware that sensitivity for isolated distal calf vein thrombosis is lower than for proximal disease, and that serial scanning at 5–7 day intervals is advisable when initial evaluation of distal segments is inconclusive.

Looking ahead, several directions merit attention. Wider multi-centre research comparing CDUS against whole-leg CT venography across diverse populations would help define performance boundaries more precisely. The incorporation of point-of-care ultrasound training into emergency medicine and internal medicine residency programmes could broaden access and shorten the interval between clinical suspicion and definitive imaging. Emerging techniques such as contrast-enhanced ultrasound and shear-wave elastography hold promise for improving thrombus age estimation and distinguishing partially organised clots from fresh thrombi. Finally, integration of artificial intelligence algorithms into the ultrasound workflow may assist less experienced operators in achieving consistency and reducing diagnostic error. In summary, colour Doppler ultrasonography stands as a safe, effective, and widely accessible diagnostic instrument that can reliably guide clinical decision-making in lower limb deep vein thrombosis.

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