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Research Article

Role of Ultrasound in Evaluation of deep vein thrombosis: a Prospective Observational Study

Mukkera Hemanth Ram Kumar Reddy[1], V V Seetha Pramila[2], Gautham M[3]

[1]Junior Resident, [2]Professor,[3] Professor and HOD, Department of Radiodiagnosis, Rajarajeswari Medical college and hospital, Bengaluru

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Corresponding Author:

Dr Mukkera Hemanth Ram Kumar Reddy,
Department Of Radiodiagnosis, Rajarajeswari Medical college and hospital, Bengaluru
Email: -
Hemanthchukku@gmail.com

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ABSTRACT

Introduction: Venous thromboembolism remains a major preventable cause of morbidity and mortality. Duplex ultrasonography is the first-line imaging test for suspected lower-limb deep vein thrombosis (DVT), yet real-world data on yield, distribution, and clinico-laboratory correlation are valuable for optimizing radiology pathways. This study evaluated the diagnostic yield and sonographic profile of duplex ultrasound in clinically suspected lower-limb DVT at a tertiary-care center.
Materials and Methods: A prospective observational study was conducted over 18 months (January 2024–June 2025) in a tertiary teaching hospital. Consecutive adults (>18 years) with clinical suspicion of lower-limb DVT were enrolled after ethics approval and written consent. Clinical probability was assessed using the Wells score and categorized as unlikely (<2) and likely (≥2) D-dimer testing was performed where feasible (positive ≥500 ng/mL). All participants underwent standardized venous duplex ultrasonography with graded compression from the common femoral to popliteal vein; calf veins were evaluated when indicated. DVT was diagnosed primarily by venous non-compressibility with supportive grayscale and Doppler criteria. Associations were tested using Chi-square/Fisher's exact test ($p<0.05$).
Results: Among clinically suspected cases, duplex ultrasonography confirmed DVT in 54.0% (n=27). Left-sided involvement was most common (55.6%), followed by right-sided (37.0%); bilateral disease occurred in 7.4%. Proximal DVT constituted 74.1% of confirmed cases whereas isolated distal thrombosis accounted for 25.9%. The most frequent ultrasound feature was loss of venous compressibility (92.6%) followed by thrombus visualization (85.2%) and reduced or absent color flow (77.8%). D-dimer positivity was statistically significantly higher in DVT-positive patients (88.9% vs 52.2%, p=0.004).
Conclusion: Duplex ultrasound demonstrated high diagnostic yield in cases of lower-limb DVT. Venous non-compressibility was the most reliable diagnostic sign and ultrasound positivity correlated significantly with higher Wells score and elevated D-dimer.

Keywords: Venous Thromboembolism, Deep Vein Thrombosis, Ultrasonography Doppler Duplex, D-Dimer, Wells Score.

INTRODUCTION

Venous thromboembolism (VTE), encompassing deep vein thrombosis (DVT) and pulmonary embolism, remains a major cause of preventable morbidity and mortality worldwide, with an estimated incidence of approximately 1–2 per 1,000 person-years in Western populations and lower but increasingly recognized rates across Asia.[1] Lower-limb DVT accounts for the predominant clinical burden and is strongly age-dependent, rising steeply in older adults and in patients with transient or persistent provoking factors such as hospitalization, malignancy, surgery, pregnancy, and immobility. From a radiology standpoint, the clinical consequences of delayed or missed diagnosis extend beyond acute pulmonary embolism to chronic venous insufficiency and post-thrombotic syndrome, whereas overdiagnosis can expose patients to unnecessary anticoagulation and bleeding risk. These competing risks make accurate, timely imaging central to care pathways, and position ultrasound as a pivotal "gatekeeper" investigation in suspected DVT.[2]

Ultrasound has become the first-line imaging modality for suspected lower-extremity DVT due to its accessibility, lack of ionizing radiation, bedside feasibility, and ability to provide real-time hemodynamic assessment.2 Contemporary radiology practice primarily relies on duplex techniques integrating gray-scale imaging, compression assessment, and Doppler interrogation to evaluate vein patency, thrombus echogenicity, venous distensibility, and flow characteristics.2 The Society of Radiologists in Ultrasound (SRU) consensus recommendations emphasize standardization of protocols and reporting lexicon because variability persists across institutions in the extent of scanning (limited/proximal versus whole-leg evaluation), the role of Doppler, and the terminology used to communicate results and management implications.2 This variability is not trivial: the diagnostic target differs depending on whether the aim is to detect proximal DVT (immediately actionable due to higher embolic potential) or to comprehensively characterize distal/calf DVT and alternative diagnoses contributing to symptoms.[3]

Evidence syntheses demonstrate that ultrasound strategies have high diagnostic performance for clinically relevant proximal DVT, while sensitivity decreases for isolated distal thrombosis, creating ongoing debate on the optimal balance between comprehensiveness and efficiency.3 In a systematic review and meta-analysis evaluating contemporary diagnostic tests, proximal compression ultrasound and whole-leg ultrasound both showed high specificity, with pooled sensitivity estimates generally higher when whole-leg or serial approaches are used, reflecting improved detection of distal thrombi and evolving clot burden over time. These data underpin imaging pathways in which radiology departments may adopt either (a) a limited/proximal protocol with planned serial re-imaging when initial findings are negative but clinical suspicion remains, or (b) a single whole-leg duplex examination aimed at ruling out both proximal and distal disease in one encounter. From the radiology workflow perspective, each approach carries implications for scan time, operator dependence, scheduling capacity, and downstream utilization, especially in high-volume emergency and inpatient settings.[4] Randomized and management-outcome studies have further informed this protocol debate by showing comparable short-term safety outcomes between competing ultrasound strategies when embedded within structured diagnostic algorithms.4 In a multicenter randomized trial of symptomatic outpatients, a diagnostic strategy based on serial two-point (proximal) ultrasonography with adjunct D-dimer testing was equivalent to whole-leg color Doppler ultrasonography with respect to 3-month venous thromboembolism outcomes after an initially negative workup. Importantly, ultrasound also provides value beyond binary DVT detection by revealing alternative etiologies of limb swelling or pain (e.g., Baker's cyst, hematoma, lymphadenopathy, cellulitis, or mass effect), reinforcing its role as a problem-solving modality in radiology-led care pathways.[5]

Despite strong evidence supporting ultrasound as the standard imaging test for suspected DVT, meaningful knowledge gaps remain at the level most relevant to radiology practice. Additionally, the radiologic interpretation of partial compressibility, duplicated venous segments, obesity-related acoustic limitations, and confounders such as prior DVT/post-thrombotic change can influence diagnostic confidence and downstream management, yet these issues are inconsistently quantified in routine practice. Therefore, the present observational study is designed from a radiology perspective to evaluate the role of ultrasound in suspected lower-extremity DVT by systematically describing sonographic findings, segmental distribution, technical limitations and clinically relevant alternative diagnoses. This approach aims to aid in protocol optimization and standardized reporting to improve patient outcomes.

MATERIAL AND METHODS

This prospective observational study was conducted in the Department of Radiodiagnosis of a at a tertiary care teaching hospital over a period of 18 months (January 2024 to June 2025). Written informed consent was obtained from all participants before enrolment. All eligible consecutive patients who presented with clinical suspicion of lower-limb deep vein thrombosis (DVT) were evaluated.

The sample size was calculated for a diagnostic accuracy study by considering the expected sensitivity of duplex ultrasonography for detecting lower-limb DVT as 95%, absolute precision of 5%, confidence level of 95%, and an anticipated DVT prevalence of 30% among clinically suspected cases. Based on these assumptions and allowing for ~10% incomplete evaluation/loss to follow-up, a minimum sample of 46 participants was required; hence, 50 participants were included and analyzed.

After enrolment, demographic details, comorbidities (diabetes mellitus, hypertension, malignancy), provoking factors (recent surgery/immobilization, trauma, pregnancy/postpartum state, oral contraceptive use), and symptoms (limb pain, swelling, redness) were recorded on a structured proforma. A focused clinical examination was performed to assess limb circumference difference, pitting edema, tenderness along deep venous system, and superficial collateral veins. Pre-test clinical probability was assessed using the modified Wells score. Patients were categorized as either "DVT likely" (≥2) or "DVT unlikely" (<2). Baseline investigations such as complete blood count, kidney function tests and coagulation profile (PT/INR and aPTT) was done in all cases. Plasma D-dimer was measured (where feasible before starting anticoagulation); a value <500 ng/mL (0.5 µg/mL FEU) was considered within normal limits, and values ≥500 ng/mL were considered positive.

All participants underwent lower-limb venous duplex ultrasonography as the index test, performed by radiologists trained in vascular ultrasound using a high-frequency linear transducer. Examination was performed with the patient in supine position with slight external rotation of the hip for femoral evaluation and in prone/lateral decubitus position for popliteal

and calf evaluation. A standardized compression ultrasonography protocol was used with graded compression at 1–2 cm intervals from the common femoral vein (including saphenofemoral junction) through femoral vein segments up to popliteal vein, and further evaluation of calf veins (posterior tibial, peroneal veins) when indicated (high clinical suspicion with negative proximal study, calf symptoms, or raised D-dimer). Color Doppler and spectral Doppler were used to assess spontaneous flow and phasicity with respiration and augmentation with distal compression. Response to Valsalva (for proximal obstruction) was also observed. Sonographic criteria for DVT diagnosis included non-compressibility of the vein (primary criterion) or visualization of intraluminal thrombus/echogenic material. Additional features such venous dilatation (acute), lack of color fill or reduced spectral flow, loss of respiratory phasicity (suggesting proximal obstruction), and absence of augmentation was also assessed. DVT was classified anatomically as proximal (popliteal vein or above: popliteal, femoral, common femoral, iliac) or distal (calf veins), and as unilateral/bilateral. Features suggesting acute versus chronic thrombus were also documented.

The primary outcome measure was the diagnostic yield of ultrasonography for DVT among clinically suspected cases, expressed as proportion of ultrasound-confirmed DVT with segmental distribution (proximal vs distal) and extent. Secondary outcomes included correlation of ultrasound positivity with Wells clinical probability and D-dimer status, and assessment of ultrasound performance parameters (sensitivity, specificity, positive predictive value, negative predictive value) wherever a reference standard was available. In participants with high clinical probability but negative initial proximal compression study, repeat ultrasonography was performed after 5–7 days to detect evolving/progressive thrombosis.

Data were entered into a standardized database and analyzed using SPSS software. Categorical variables were expressed as frequencies and percentages, and continuous variables were expressed as mean±standard deviation or median (interquartile range) based on distribution. Associations between ultrasound-confirmed DVT and clinical probability category/D-dimer positivity were tested using Chi-square test or Fisher's exact test. Continuous variables were compared using independent t-test or Mann–Whitney U test as appropriate. A p value <0.05 was considered statistically significant.

Inclusion criteria

- Age of the patients above 18 years
- Those who gave informed and written consent to be part of study.
- Patients presenting with clinical suspicion of lower-limb DVT (limb swelling/pain, redness, tenderness along deep veins, or unexplained unilateral limb edema), including inpatients and outpatients.
- Patients with moderate-to-high pretest probability for DVT (modified Wells score) and/or positive D-dimer as per institutional testing (where performed).

Exclusion criteria

- Age below 18 years.
- Those who refused to provide written consent to be part of study.
- Prior documented DVT in the same limb within the preceding 3 months (to avoid misclassification of residual thrombus).
- Patients already on therapeutic anticoagulation for >48 hours before ultrasound evaluation (as it could alter D-dimer interpretation and early thrombus characteristics).
- Isolated upper-limb DVT or superficial thrombophlebitis without suspicion of deep venous involvement.
- Patients with inadequate ultrasound window or technically non-diagnostic study despite repeat attempt (e.g., severe edema/immobilization preventing compression).

RESULTS

The majority of suspected DVT cases were aged 41–60 years (48.0%), followed by more than 60 years (32.0%), while those ≤40 years comprised 20.0%. A male predominance was observed, with males accounting for 60.0% of cases compared to 40.0% females. The M:F ratio was found to be 1: 0.66. (Table 1).

Table 1: Age and sex distribution of patients presenting with clinical suspicion of lower-limb DVT.

Variable	Category	Number of cases	Percentage (%)
Age group (years)	≤40	10	20.0
	41–60	24	48.0
	>60	16	32.0
Gender	Male	30	60.0
	Female	20	40.0

The most common presenting feature was unilateral limb swelling (82.0%), followed by limb pain/tenderness (76.0%). Pitting edema was observed in 60.0%, and calf tenderness in 56.0% of patients. Local warmth/erythema (36.0%) and dilated superficial veins (24.0%) were less frequently noted. Overall, swelling and pain predominated the clinical spectrum of suspected DVT (Table 2).

Table 2: Distribution of presenting clinical features among suspected DVT patients.

Clinical feature	Number of cases	Percentage (%)
Unilateral limb swelling	41	82.0
Limb pain/tenderness	38	76.0
Calf tenderness	28	56.0
Pitting edema	30	60.0
Increased local warmth/erythema	18	36.0
Dilated superficial veins	12	24.0

Hypertension (42.0%) and diabetes mellitus (34.0%) were the most common comorbidities. Among provoking factors, recent immobilization/bed rest (26.0%) and recent surgery/trauma (18.0%) were most frequent. Active malignancy was present in 12.0%, while previous VTE, prolonged travel, and hormonal therapy were each reported in 8.0% of cases. (Table 3).

Table 3: Distribution of major thrombotic risk factors and comorbidities among suspected DVT cases.

Risk factor / comorbidity	Number of cases	Percentage (%)
Recent immobilization/bed rest	13	26.0
Recent surgery/trauma (≤4 weeks)	9	18.0
Active malignancy	6	12.0
Previous VTE history	4	8.0
Prolonged travel (≥6 hours)	4	8.0
Hormonal therapy/OCP use	4	8.0
Diabetes mellitus	17	34.0
Hypertension	21	42.0

Doppler ultrasound confirmed DVT in 54.0% of suspected cases. Among DVT-positive patients (n=27) the left lower limb was commonly affected (55.6%) as compared to the right limb (37.0%). Bilateral involvement was observed in 7.4% cases. Proximal DVT (popliteal vein and above) accounted for 74.1% of confirmed cases. Isolated distal (calf vein) thrombosis constituted 25.9% of the studied cases (Table 4).

Table 4: Doppler-confirmed DVT prevalence and anatomical distribution among study participants.

Parameter	Category	Number of cases	Percentage (%)
Doppler diagnosis	DVT present	27	54.0
	DVT absent	23	46.0
Laterality (DVT-positive, n=27)	Left lower limb	15	55.6
	Right lower limb	10	37.0
	Bilateral	2	7.4
Extent (DVT-positive, n=27)	Proximal	20	74.1
	Distal	7	25.9

Although recent immobilization, surgery, malignancy, diabetes, and hypertension were more frequent in the DVT-positive group, none of these associations reached statistical significance ($p>0.05$) (Table 5).

Table 5: Comparison of selected risk factors between Doppler-confirmed DVT and non-DVT groups.

Variable	DVT present (n=27), n (%)	DVT absent (n=23), n (%)	p-value
Recent immobilization/bed rest	9 (33.3)	4 (17.4)	0.33
Recent surgery/trauma	6 (22.2)	3 (13.0)	0.47
Active malignancy	4 (14.8)	2 (8.7)	0.67
Diabetes mellitus	10 (37.0)	7 (30.4)	0.76
Hypertension	12 (44.4)	9 (39.1)	0.77
Previous VTE history	3 (11.1)	1 (4.3)	0.61

A significant association was observed between two-tier Wells clinical probability and Doppler-confirmed DVT. Patients classified as Wells ≥2 (DVT likely) were significantly more often DVT-positive than DVT-negative (88.9% vs 52.2%, $p=0.005$), whereas Wells <2 (DVT unlikely) was significantly more common in the DVT-absent group (47.8% vs 11.1%, $p=0.005$). D-dimer positivity was also significantly higher in the DVT-positive group (88.9% vs 52.2%, $p=0.004$) (Table 6).

Table 6: Association of Wells score category and D-dimer status with Doppler-confirmed DVT.

Parameter	Category	DVT present (n=27), n (%)	DVT absent (n=23), n (%)	p-value
Wells score	<2 (unlikely)	3 (11.1)	11 (47.8)	0.0053
	≥2 (likely)	24 (88.9)	12 (52.2)	
D-dimer	Positive	24 (88.9)	12 (52.2)	0.005
	Negative	3 (11.1)	11 (47.8)	

Among Doppler-confirmed cases (n=27), loss of venous compressibility (92.6%) was the most consistent finding. Intraluminal thrombus visualization was observed in 85.2%, and absent or reduced color flow was seen in 77.8%. Reduced augmentation or loss of respiratory phasicity was noted in 70.4% cases. Venous dilatation was present in 55.6%. Occlusive thrombus constituted 66.7% of cases and remainder being non-occlusive. (Table 7).

Table 7. Sonographic characteristics among Doppler-confirmed DVT cases (n=27)

Ultrasound feature	Number of cases	Percentage (%)
Loss of venous compressibility	25	92.6
Intraluminal thrombus visualized	23	85.2
Absent/reduced color flow	21	77.8
Reduced augmentation/loss of phasicity	19	70.4
Venous dilatation	15	55.6
Occlusive thrombus	18	66.7
Non-occlusive/partial thrombus	9	33.3

DISCUSSION

In this prospective observational cohort of adults with clinically suspected lower-limb DVT ultrasound could confirm DVT in 54.0% of cases, indicating a high diagnostic yield. In the landmark clinical probability work by Wells et al, DVT prevalence varied substantially across pretest probability strata, supporting the concept that diagnostic yield is strongly dependent on case mix and referral threshold.[6] Similarly, in the management study integrating D-dimer with ultrasound pathways, Cosmi B demonstrated that structured use of D-dimer testing could safely reduce the need for ultrasonography.[7] Against this background, the 54% yield in our series likely reflects inclusion of a substantial proportion of "DVT likely" patients (high Wells category) and the operational reality of tertiary services, where immobilization, malignancy, postoperative states and advanced age are overrepresented.

In this study proximal thrombosis (74.1% of DVT-positive patients) was significantly more common as compared to isolated distal (calf) thrombosis comprising 25.9%. This pattern aligns with evidence that ultrasound performs best for clinically consequential proximal disease. In the meta-analysis by Goodacre et al, pooled sensitivity of ultrasonography was substantially higher for proximal DVT than for distal DVT, reinforcing that the diagnostic utility of ultrasound is femoropopliteal location and above.[8] From a protocol standpoint, this performance gradient has shaped the long-standing debate between limited proximal compression strategies with serial follow-up versus whole-leg approaches that attempt to detect distal DVT in one encounter. The randomized trial by Bernardi et al demonstrated that serial 2-point ultrasonography combined with D-dimer could be equivalent to whole-leg color Doppler ultrasonography in terms of 3-month thromboembolic outcomes after an initially negative workup.[9] In our setting, where most positives were proximal, the data support prioritizing meticulous proximal compression as the core diagnostic step while maintaining a defined plan for calf-vein assessment (or repeat scanning) in patients with persistent high clinical suspicion, positive D-dimer, or calf-predominant symptoms.

Laterality findings in this study are consistent with recognized anatomic and physiologic contributors to left-leg predominance, particularly in iliofemoral disease. Left-sided predominance is frequently attributed to iliac vein compression phenomena and pelvic venous anatomy, which can predispose to left iliofemoral thrombosis and may be underappreciated unless proximal obstruction patterns (loss of phasicity, poor augmentation, continuous flow) trigger iliac evaluation or further cross-sectional imaging. In a clinical review Harbin et al highlighted the pathophysiologic basis for extensive left iliofemoral DVT driven by left common iliac vein compression by the right common iliac artery which is an important consideration when duplex shows indirect signs of proximal obstruction or when symptoms are disproportionate to femoropopliteal findings.[10] Complementing this, an observational analysis by Shin et al reported left-side predominant DVT as the most frequent pattern in pelvic and lower extremity venous thrombosis, supporting the external validity of our laterality distribution in routine practice.[11] For radiology pathways, these findings underscore the importance of documenting Doppler phasicity and augmentation and maintaining a low threshold for iliac interrogation (especially in obese patients or when femoral segments appear patent).

With respect to ultrasound features loss of venous compressibility was the most consistent feature in our DVT-positive patients (92.6%). It was followed by thrombus visualization (85.2%) and absent/reduced color flow (77.8%). These findings closely reflect the established principle that non-compressibility is the primary diagnostic criterion in symptomatic lower-limb DVT. Additionally Doppler findings should serve as supportive evidence and help characterize proximal obstruction and clot extent. The Society of Radiologists in Ultrasound consensus recommendations led by Needleman et al emphasized use of uniform and standardized technique and terminology.[12] They further recommended centring diagnosis on compression while using Doppler to address flow abnormalities, proximal obstruction and symptom explanation rather than the diagnosis of DVT itself. Similarly, the predictive implications of non-compressibility at specific sites have been studied by Birdwell et al.[13] The authors evaluated the positive predictive value of compression ultrasonography according to the anatomic site of non-compressibility and concluded non-compressibility to be pathognomic of DVT.

In this study High Wells probability was significantly associated with ultrasound-confirmed DVT (59.3% vs 13.0%, $p<0.001$), and D-dimer positivity was more frequent in DVT-positive patients (88.9% vs 52.2%, $p=0.004$). These results support integrated triage strategies in which clinical probability and D-dimer guide the urgency, extent, and repetition of

ultrasound examinations, especially where scan capacity is constrained. In the study by Subramaniam et al, the combined use of pretest probability scoring and D-dimer significantly informed imaging decisions.[14] At the same time, the diagnostic performance of Wells and D-dimer is not uniform across all DVT phenotypes; isolated distal DVT is a particular challenge. In a large outpatient study, Sartori et al evaluated the Wells rule and D-dimer specifically for isolated distal DVT and highlighted limitations in relying on these tools alone for calf thrombosis, reinforcing the importance of either whole-leg ultrasound or planned serial strategies when calf DVT is a concern.[15] In our cohort—where distal DVT constituted about one-quarter of positives—this nuance is clinically relevant: while a high Wells score and positive D-dimer appropriately increase suspicion and justify urgent duplex, a "negative" initial proximal study in a high-probability patient should prompt either calf-vein interrogation (where protocolized) or scheduled repeat scanning. Overall, our findings support a pragmatic, radiology-led diagnostic pathway in which compression is the primary diagnostic anchor, Doppler physiology is used to assess extent and proximal obstruction and Wells score and D-dimer are incorporated to prioritize scanning.

CONCLUSION

In this prospective observational study, duplex ultrasonography was found to have a high diagnostic yield for suspected lower-limb DVT. Most confirmed cases were seen to be involving proximal veins. Loss of venous compressibility was the most reliable sonographic criterion for diagnosis of DVT. Finding of non-compressibility was supported by thrombus visualization and Doppler flow abnormalities. Higher Wells clinical probability and elevated D-dimer levels were associated with significantly high chances of DVT. We conclude that Duplex ultrasound is an accessible, rapid and effective tool for timely DVT diagnosis.

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