

# Evaluation of Calf Elastography & Thrombus Elastography in Deep Venous Thrombosis: A Cross-Sectional Study in a Tertiary Care Institute in South India

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## ABSTRACT

**Background** Deep venous thrombosis (DVT) is a significant cause of morbidity and mortality, with complications such as pulmonary embolism and post-thrombotic syndrome. Although duplex ultrasonography is highly sensitive for diagnosis, it has limitations in differentiating acute from chronic thrombi. Ultrasound elastography, which evaluates tissue stiffness, offers a potential solution by providing quantitative assessment of thrombus characteristics.

**Objectives** To evaluate the role of thrombus elastography and calf muscle elastography in patients with lower limb DVT and to determine their utility in differentiating thrombus stages.

**Methods** This hospital-based cross-sectional study was conducted in a tertiary care centre in South India over six months. A total of 100 participants were included, comprising 50 DVT cases and 50 controls. All subjects underwent Doppler ultrasonography followed by elastography assessment using shear wave elastography. Thrombi were categorized based on duration into acute (0–3 days), subacute (3–7 days), early chronic (7–28 days), and chronic (>28 days). Mean elasticity values were measured in kilopascals (kPa) for both thrombus and calf muscles. Statistical analysis was performed using Student's t-test.

**Results** Mean thrombus elasticity values increased progressively from  $17.3 \pm 4.5$  kPa in acute thrombi to  $28.5 \pm 4.5$  kPa in chronic thrombi. Calf muscle elasticity was significantly higher in DVT patients ( $15.8 \pm 4.0$  kPa) compared to controls ( $12.5 \pm 3.4$  kPa) ( $p < 0.01$ ). A statistically significant difference was observed between acute and chronic thrombi ( $p < 0.01$ ), indicating the ability of elastography to differentiate thrombus stages.

**Conclusion** Ultrasound elastography provides a reliable and quantitative method for assessing thrombus age and associated tissue changes in DVT. Its integration into routine imaging protocols may enhance diagnostic accuracy and guide clinical management.

**Keywords:** Deep venous thrombosis, Elastography, Shear wave elastography, Thrombus aging, Calf muscle elasticity, Doppler ultrasound, Venous thromboembolism, Imaging biomarkers.

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## INTRODUCTION

Deep venous thrombosis (DVT) is a significant global health problem, with an estimated annual incidence of approximately 1 per 1,000 adults and substantial associated morbidity and mortality due to complications such as pulmonary embolism and post-thrombotic syndrome. Autopsy-based evidence suggests that pulmonary embolism is frequently underdiagnosed during life, indicating that a considerable proportion of DVT cases remain clinically unrecognized [3]. Early diagnosis and accurate characterization of thrombus are therefore essential to improve clinical outcomes.

The pathogenesis of DVT is multifactorial and explained by Virchow's triad—venous stasis, endothelial injury, and hypercoagulability—which together contribute to thrombus formation and propagation. Initially, thrombi are composed of loosely organized platelets and fibrin; however, over time they undergo structural remodelling, including fibrin cross-linking, collagen deposition, and neovascularization, resulting in progressive stiffening and loss of elasticity [2]. These temporal changes in biomechanical properties form the basis for differentiating acute from chronic thrombi.

Accurate assessment of thrombus age has important therapeutic implications. Acute thrombi are more responsive to anticoagulation and catheter-directed thrombolysis, whereas chronic thrombi are less amenable to such interventions due to fibrosis and organization. Hence, determining thrombus chronicity is critical in guiding treatment strategies and preventing complications [4]. However, despite advances in imaging, reliable differentiation between acute and chronic thrombi remains a clinical challenge. Duplex ultrasonography is currently the first-line imaging modality for DVT, offering high sensitivity and specificity exceeding 95% [5]. It evaluates vein compressibility, intraluminal echogenicity, and flow characteristics. Nevertheless, conventional ultrasound has limitations in staging thrombus age. Features such as echogenicity, vein diameter, and collateral formation are often subjective and exhibit significant interobserver variability, reducing their reliability in distinguishing acute from chronic thrombi [6]. This diagnostic gap necessitates the exploration of more objective imaging techniques.

Ultrasound elastography has emerged as a promising non-invasive modality for assessing the mechanical

properties of biological tissues. First described by Ophir et al., elastography enables quantitative and qualitative evaluation of tissue stiffness by measuring deformation in response to applied force [7]. The concept of "sonoelasticity," introduced by Lerner et al., further demonstrated the feasibility of generating elasticity images from ultrasound signals [8]. These advancements have expanded the application of elastography across multiple clinical domains.

In the context of DVT, elastography is particularly relevant because thrombus composition and stiffness change predictably over time. Experimental and early clinical studies have shown that elasticity imaging can differentiate thrombi based on their age, with acute thrombi appearing softer and chronic thrombi demonstrating increased stiffness [9]. Rubin et al. further validated the clinical application of sonographic elasticity imaging in human DVT, demonstrating significant differences in elasticity between acute and chronic thrombi [10]. These findings highlight the potential of elastography as an objective tool for thrombus characterization.

Recent technological advancements have enabled real-time elastographic assessment, including strain and shear wave elastography, which provide reproducible quantitative measurements of tissue stiffness. These techniques can be seamlessly integrated into routine ultrasonography without additional radiation exposure or significant increase in examination time [1]. Despite these advantages, the clinical application of elastography in DVT remains underutilized, particularly in developing countries.

An additional area of interest is the evaluation of surrounding calf musculature. Changes in calf muscle elasticity may reflect underlying venous congestion, edema, or inflammatory changes associated with DVT. However, normative data for calf muscle elasticity in the Indian population are limited, and its potential role in DVT assessment remains largely unexplored.

Therefore, there is a clear need for studies evaluating both thrombus and calf muscle elastography in patients with DVT, particularly in the Indian context. The present study aims to assess the mean elasticity values of venous thrombi and calf muscles and to determine their utility in differentiating acute and chronic thrombi.

**Novelty of the study** lies in the combined evaluation of thrombus elastography and calf muscle elastography, along with the attempt to establish

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baseline elasticity values in an Indian population. This dual approach may enhance diagnostic accuracy and provide a more comprehensive understanding of the pathophysiological changes in DVT.

In conclusion, by addressing the limitations of conventional ultrasonography and introducing an objective, quantitative imaging modality, this study seeks to contribute to improved diagnostic precision and better clinical decision-making in the management of deep venous thrombosis.

### METHODOLOGY

This study was designed as a hospital-based cross-sectional analytical study conducted in the Department of Radio-diagnosis at Sree Balaji Medical College and Hospital, Chennai, a tertiary care institute in South India. The study was carried out over a period of six months, from October 2025 to March 2026, after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to inclusion in the study.

#### Study Population and Sampling

The study population consisted of patients aged between 20 and 50 years who were referred to the radiology department for lower limb venous Doppler evaluation. A purposive sampling method was adopted. The study included two groups: (1) patients diagnosed with lower limb deep venous thrombosis (DVT) and (2) control subjects without evidence of venous thrombosis or venous insufficiency. A total sample size of 100 participants was considered, comprising 50 cases and 50 controls, based on feasibility and availability during the study period.

#### Inclusion and Exclusion Criteria

Patients with confirmed venous thrombosis on Doppler ultrasonography were included in the case group. Control subjects included individuals undergoing Doppler evaluation without evidence of thrombosis, venous incompetence, or sarcopenia. Patients who were hemodynamically unstable, those with known myopathies, and individuals unwilling to participate were excluded from the study.

#### Ultrasound and Elastography Protocol

All examinations were performed using a GE LOGIQ P10 ultrasound system equipped with a high-frequency linear transducer (ML6–15 MHz). Initially, gray-scale and Doppler ultrasonography were performed to identify the presence, location, and extent of thrombus. The common femoral vein and superficial femoral vein were examined with the patient in the supine position, while the popliteal vein was assessed in the prone or lateral decubitus position. Compression

ultrasonography was performed in transverse sections to evaluate vein compressibility. Once a thrombus was identified, its extent and characteristics were documented.

Subsequently, elastographic assessment was carried out using shear wave elastography technique. A color-coded elastogram was generated, where red indicated stiff tissue, green indicated intermediate stiffness, and blue represented soft tissue. The elastogram was displayed simultaneously with the grayscale image in dual mode.

For thrombus assessment, regions of interest (ROI) measuring 5–10 mm were placed over the thrombus, ensuring exclusion of the vessel wall. Measurements were obtained from the stiffest region within the thrombus, and mean elasticity values were recorded in kilopascals (kPa). Each measurement was repeated three times, and the average value was used for analysis.

In addition, calf muscle elastography was performed in all participants to assess associated soft tissue changes. The examination was conducted with the patient in a relaxed supine or prone position to minimize muscle contraction. The gastrocnemius (medial head) and soleus muscles were evaluated in the longitudinal plane. ROI of 5–10 mm was placed within the muscle belly, carefully avoiding fascia, vascular structures, and artifacts. Minimal transducer pressure was applied to prevent artificial elevation of stiffness values.

Three consecutive measurements were obtained from the same region, and the mean elasticity value was calculated to improve reproducibility. In DVT cases, measurements were taken from the affected limb, while in control subjects, measurements were obtained from a corresponding anatomical location. The calf muscle elasticity values were recorded in kilopascals (kPa) and compared between cases and controls.

#### Classification of Thrombus

Based on clinical history and imaging findings, thrombi were categorized into different stages according to duration: acute (0–3 days), subacute (3–7 days), early chronic (7–28 days), and chronic (>28 days). Elasticity values were compared across these groups to evaluate differences in stiffness.

#### Statistical Analysis

Data were entered and analysed using Statistical Package for Social Sciences (SPSS) software version 21.0. Continuous variables such as elasticity values were expressed as mean  $\pm$  standard deviation. Comparisons between groups (acute vs chronic thrombi and cases vs controls) were performed using

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Student's t-test. A p-value of less than 0.05 was considered statistically significant.

### RESULTS

A total of 100 participants were included in the present study, comprising 50 patients diagnosed with deep venous thrombosis (DVT) and 50 control subjects without evidence of thrombosis. Among the cases, thrombi were categorized based on duration into acute (0–3 days), subacute (3–7 days), early chronic (7–28 days), and chronic (>28 days) groups.

The distribution of thrombus duration showed that the majority of cases were in the acute phase, followed by chronic cases, with fewer patients in intermediate stages. Quantitative elastography assessment demonstrated a progressive increase in thrombus stiffness with increasing duration, indicating gradual organization and fibrosis of the clot.

Similarly, calf muscle elasticity values were found to be higher in patients with DVT compared to controls, suggesting associated changes in surrounding soft tissues. A statistically significant difference was observed between acute and chronic thrombi with respect to both thrombus elasticity and calf muscle elasticity ( $p < 0.01$ ), highlighting the potential role of elastography in differentiating thrombus stages.

**TABLE 1: Study Population Distribution**

Group	Number of Participants	Percentage (%)
Cases (DVT)	50	50%
Controls	50	50%
<b>Total</b>	<b>100</b>	<b>100%</b>

**TABLE 2: Duration-wise Distribution of Thrombus**

Duration of Thrombus	Number of Cases	Percentage (%)
0–3 days	30	38.5%
3–7 days	15	19.2%
7–28 days	8	10.3%
>28 days	25	32.1%

**TABLE 3: Elasticity Values of Thrombus and Calf Muscle**

Duration	Thrombus Elasticity (kPa) Mean $\pm$ SD	Calf Muscle Elasticity (kPa) Mean $\pm$ SD
0–3 days	17.3 $\pm$ 4.5	13.7 $\pm$ 1.9
3–7 days	21.2 $\pm$ 4.3	15.7 $\pm$ 5.5
7–28 days	23.3 $\pm$ 2.2	16.0 $\pm$ 3.2

>28 days	28.5 $\pm$ 4.5	16.3 $\pm$ 4.6
Controls	—	12.5 $\pm$ 3.4

**TABLE 4: Comparison Between Acute and Chronic Thrombi**

Parameter	Acute (0–3 days)	Chronic (>28 days)	p-value
Thrombus Elasticity (kPa)	17.3 $\pm$ 4.5	28.5 $\pm$ 4.5	<0.01
Calf Muscle Elasticity (kPa)	13.7 $\pm$ 1.9	16.3 $\pm$ 4.6	<0.01

**TABLE 5: Summary of Statistical Findings**

Variable Compared	Mean Values (kPa)	Statistical Test	Test Statistic (t-value)*	p-value	Significance
Thrombus elasticity (Acute vs Chronic)	17.3 $\pm$ 4.5 vs 28.5 $\pm$ 4.5	Student's t-test	—	<0.01	Significant
Calf muscle elasticity (Cases vs Controls)	15.8 $\pm$ 4.0* vs 12.5 $\pm$ 3.4	Student's t-test	—	<0.01	Significant

### Discussion :

The present study demonstrates a clear and statistically significant relationship between thrombus age and increasing stiffness on elastography, with mean thrombus elasticity values rising from **17.3  $\pm$  4.5 kPa in acute thrombi (0–3 days) to 28.5  $\pm$  4.5 kPa in chronic thrombi (>28 days)**. This progressive increase reflects the biological evolution of thrombus from a soft, fibrin-rich structure to a more organized and collagen-dense entity. A similar trend was reported by Rubin et al., who observed that chronic thrombi exhibit significantly greater stiffness compared to acute thrombi using sonographic elasticity imaging, although their study did not provide absolute quantitative values

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[11]. In contrast, our study provides measurable kPa-based differentiation, thereby improving clinical objectivity and reproducibility.

The gradual rise in elasticity observed across intermediate stages in our study (**17.3 → 21.2 → 23.3 → 28.5 kPa**) closely parallels experimental findings by Xie et al., who demonstrated progressive increases in elasticity parameters with thrombus maturation in an animal model [13]. Likewise, Geier et al. showed that elastography could reliably determine thrombus age, with older thrombi demonstrating significantly higher stiffness, although their measurements were semi-quantitative [12]. Compared to these studies, our results offer a more refined stage-wise quantification, which may be useful in real-time clinical decision-making.

The magnitude of stiffness increase observed in our study, approximately **11 kPa between acute and chronic thrombi**, is consistent with the concept of time-dependent clot hardening. Mfoumou et al. reported similar findings using shear wave elastography, demonstrating a continuous increase in clot stiffness over time due to fibrin cross-linking and structural reorganization [14]. However, Liu et al. highlighted that pathological heterogeneity within thrombi may lead to variability in elasticity measurements and potential overlap between stages [15]. Despite this, our findings showed a statistically significant difference ( $p < 0.01$ ), indicating that the overall trend remains robust even in the presence of heterogeneity.

Our results also align with clinical elastography studies. Yi et al. reported significantly lower elasticity indices in acute thrombi compared to chronic thrombi, supporting the role of elastography in staging [16]. Similarly, Pan et al. demonstrated that shear wave elastography provides added value over conventional ultrasound, with chronic thrombi showing higher stiffness values [17]. In comparison, our study not only confirms these observations but also provides absolute elasticity values across multiple time intervals, thereby enhancing clinical applicability.

In a larger cohort, Mumoli et al. evaluated 215 thrombi and found that acute thrombi exhibited higher elasticity indices compared to chronic thrombi using strain elastography, with highly significant differences ( $p < 0.0001$ ) [18]. While their study used semi-quantitative strain ratios, our findings using shear wave elastography demonstrate a comparable pattern, with chronic thrombi showing significantly higher stiffness (28.5 kPa) compared to acute thrombi (17.3 kPa). Similarly, Durmaz et al. reported that shear wave

elastography could effectively differentiate acute from subacute thrombi, with statistically significant differences ( $p < 0.05$ ) [19], whereas our study demonstrates even stronger statistical significance ( $p < 0.01$ ), likely due to clearer stratification of chronic stages.

Recent advances have positioned elastography as a potential imaging biomarker. Bosio et al. described shear wave elastography as a reliable quantitative tool for thrombus characterization, reporting progressive increases in stiffness with thrombus age [20]. The elasticity range observed in our study (17.3–28.5 kPa) is comparable to their findings, reinforcing the validity of our measurements. Furthermore, a systematic review by Santini et al. concluded that elastography is a promising modality for thrombus aging, though standardization remains a challenge [21]. Our study contributes to this domain by providing structured, stage-wise quantitative data in a defined population, thereby addressing the need for standard reference values.

In addition to thrombus characterization, the present study uniquely evaluated calf muscle elasticity, demonstrating significantly higher values in DVT patients ( **$15.8 \pm 4.0$  kPa**) compared to controls ( **$12.5 \pm 3.4$  kPa**,  $p < 0.01$ ). This finding suggests secondary changes in surrounding soft tissues, possibly due to venous congestion, interstitial edema, or inflammatory processes. While most previous studies have focused solely on thrombus stiffness, Yusof et al. emphasized the importance of non-invasive imaging in assessing both thrombus and surrounding tissue characteristics [22]. Our findings extend this concept by providing quantitative evidence of calf muscle involvement, representing a novel contribution to the literature.

The clinical relevance of these findings is underscored by the significant difference observed between acute and chronic thrombi in our study. Czaplicki et al. highlighted that thrombus age plays a crucial role in determining treatment strategies, particularly the effectiveness of thrombolytic therapy [23]. The ability to identify chronic thrombi based on higher stiffness values (~28.5 kPa) may therefore aid in selecting appropriate therapeutic approaches and avoiding ineffective interventions.

From a technical perspective, the use of shear wave elastography in the present study ensured objective and reproducible measurements. Ozturk et al. described elastography as a technique that provides quantitative assessment of tissue stiffness, improving diagnostic accuracy compared to conventional ultrasound [24]. Similarly, the EFSUMB guidelines recommend the use

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of elastography as an adjunct imaging modality for tissue characterization [25]. Our study supports these recommendations and demonstrates the feasibility of integrating elastography into routine Doppler evaluation in a tertiary care setting.

Overall, the findings of the present study are consistent with existing literature and further strengthen the evidence supporting elastography as a reliable tool for thrombus characterization. The demonstration of a progressive increase in thrombus stiffness from **17.3 kPa in acute stages to 28.5 kPa in chronic stages**, along with significant alterations in calf muscle elasticity, highlights the potential of this modality for both thrombus staging and assessment of associated tissue changes. By providing quantitative, stage-wise data and incorporating evaluation of surrounding musculature, this study adds a novel dimension to current research and supports the broader clinical application of elastography in the management of deep venous thrombosis.

### CONCLUSION

The present study demonstrates that ultrasound elastography is a valuable, non-invasive imaging modality for the characterization and staging of deep venous thrombosis (DVT). A significant and progressive increase in thrombus elasticity was observed from acute to chronic stages, with mean values rising from 17.3 kPa to 28.5 kPa, reflecting thrombus organization and fibrosis. Elastography also revealed significantly higher calf muscle elasticity in DVT patients compared to controls, indicating associated soft tissue changes such as edema and venous congestion. These findings highlight the ability of elastography to provide objective, quantitative assessment beyond conventional ultrasonography, which is limited in differentiating thrombus age. The combined evaluation of thrombus and calf muscle elasticity represents a novel approach that enhances diagnostic accuracy. Incorporation of elastography into routine Doppler protocols may improve clinical decision-making, particularly in guiding therapeutic strategies based on thrombus chronicity.

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