Bangladesh Journal of Radiology and Imaging

ORIGINAL ARTICLE

2026; Vol. 34, No. 1, PP. 1-5

ISSN 1726-961X eISSN 2708-7506

Duplex Ultrasound Evaluation of Chronic Venous Disease According to CEAP Classification: A Prospective Hemodynamic Study

Mahmud Hasan Mostofa Kamal[1] Md. Nazrul Islam[1] ASM Shahidul Hossain[1] Mohammad Ali Kabir[1] Morshida Begum[1] Jeenat Sabah[2]

[1]Department of Radiology and Imaging, Bangladesh Medical University, Dhaka, Bangladesh
[2]Rupganj Upazilla Health Complex, Narayanganj, Bangladesh

Publication history
Accepted: 25 Mar 2026
Published online: 7 June 2026

Correspondence
ASM Shahidul Hossain
asmshahidul74@bsmmu.edu.bd

Conflict of interest
We do not have any conflict of interest

Keywords
Chronic venous disease, Doppler ultrasound, Hemodynamic parameters, Retrograde flow, Spectral Doppler, Venous reflux

Abstract

Background: Chronic venous disease (CVD) is a progressive disorder characterized by venous reflux, valvular incompetence, and venous hypertension. The CEAP (Clinical–Etiological–Anatomical–Pathophysiological) classification system, updated by the Society for Vascular Surgery and American Venous Forum, provides standardized staging. Duplex ultrasound remains the gold standard for hemodynamic assessment.

Objective: To evaluate venous reflux patterns using duplex Doppler ultrasound and correlate imaging findings with CEAP clinical classification.

Methods: This prospective observational study included 86 patients with clinically suspected CVD. Patients were categorized according to CEAP clinical class (C2–C6). B-mode, color, and spectral Doppler ultrasound were performed to assess reflux duration, reflux velocity, venous diameter, valvular competence, and presence of deep vein thrombosis (DVT). Statistical analysis included Chi-square test, ANOVA, and Pearson correlation.

Results: Great saphenous vein (GSV) reflux was detected in 72.1% of patients. Prolonged reflux (>0.5 sec) was significantly associated with higher CEAP classes (C4–C6) ($P < 0.05$). Mean reflux duration increased progressively with disease severity. Venous diameter positively correlated with CEAP class ($r = 0.62$). DVT was identified in 18.6%, predominantly in advanced CEAP stages.

Conclusion: Integration of duplex ultrasound findings with CEAP classification enhances disease stratification and prognostic evaluation in CVD. Reflux duration and venous diameter may serve as imaging biomarkers of advanced venous disease.

Introduction

Chronic venous disease (CVD) is a common vascular disorder characterized by impaired venous return, leading to lower extremity edema, skin changes, and venous ulcers [1]. It encompasses a spectrum of venous abnormalities resulting from sustained venous hypertension. Progressive valvular incompetence leads to reflux, venous dilation, inflammatory changes, and ulceration. The CEAP classification provides standardized staging. Objective hemodynamic quantification using duplex ultrasound enhances disease characterization. This study aims to analyze reflux patterns and correlate hemodynamic parameters with CEAP clinical staging (C0 - No visible or palpable signs, C1 - Telangiectasias or

reticular veins, C2 - Varicose veins, C3 – Edema, C4a - Pigmentation or eczema, C4b - Lipodermatosclerosis or atrophie blanche, C5 - Healed venous ulcer, C6 - Active venous ulcer). According to CEAP classification CVD includes entire spectrum (C0-C6) and chronic venous insufficiency (CVI) is the advanced stage of CVD (C3-C6) with chronic venous hypertension leads to oedema, skin changes or ulceration. CVD primarily results from valvular incompetence or venous obstruction, affecting deep, superficial, or perforating veins [2]. The prevalence of CVD varies globally, with studies estimating that up to 40% of the adult population experiences some form of venous reflux, particularly among the elderly, obese individuals, and those with a sedentary lifestyle [3, 4]. If left untreated, CVD can progress to severe complications, including venous stasis ulcers and deep vein thrombosis (DVT), significantly impacting the quality of life [5]. Doppler ultrasound is widely regarded as the gold standard for assessing venous disease due to its non-invasive nature, cost-effectiveness, and high sensitivity in detecting valvular incompetence and venous reflux [6]. It provides real-time evaluation of hemodynamic parameters, including retrograde flow (reflux) and duration of reflux, which are crucial in diagnosing venous dysfunction [7, 8]. The use of color and spectral Doppler imaging allows for a detailed assessment of the great saphenous vein, small saphenous vein, and deep venous system, aiding in treatment planning and prognosis [9]. The pathophysiology of CVD is primarily attributed to venous hypertension resulting from reflux or obstruction, which leads to endothelial damage and inflammation [10]. Persistent venous hypertension promotes capillary leakage, tissue hypoxia, and inflammatory cytokine release, ultimately causing skin changes and ulceration [11,12]. Doppler ultrasound plays a crucial role in identifying reflux patterns, measuring reflux duration, and assessing venous wall abnormalities, enabling early intervention and management [13]. Management of CVD typically involves conservative approaches such as compression therapy, pharmacological agents, and lifestyle modifications, with surgical or minimally invasive procedures reserved for severe cases [14]. Endovenous techniques, including radiofrequency ablation (RFA) and endovenous laser therapy (EVLT), have gained popularity due to their efficacy in reducing reflux and symptom burden [15,16]. Doppler ultrasound is essential not only in diagnosis but also in guiding interventional procedures and monitoring post-treatment outcomes [17]. Despite its clinical significance, CVD remains underdiagnosed and undertreated, particularly in low-resource settings where access to vascular imaging is limited [18]. This study aims to evaluate the role of Doppler ultrasound in assessing CVD at an institutional level, documenting its effectiveness in detecting venous reflux, valvular incompetence, and associated complications. The findings of this study will contribute to improving diagnostic accuracy, guiding appropriate treatment strategies, and enhancing patient outcomes.

Methods

This prospective observational study was conducted at the Department of Radiology and Imaging, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from January 2015 to December 2015. A total of 86 patients diagnosed with CVD were enrolled using a purposive sampling technique. Patients were categorized as: C2 – varicose veins, C3 – edema, C4 – skin changes, C5 – healed ulcer, C6 – active ulcer. All patients underwent Doppler ultrasound evaluation by high-frequency linear probe (7 – 12 MHz) in stranding position with distal compression-release maneuver as well as Valsalva maneuver to assess venous reflux, valve incompetence, and associated complications. B-mode ultrasound was used to examine venous anatomy, wall thickness, luminal diameter, and thrombotic changes. Color and spectral Doppler imaging were performed to evaluate venous flow patterns, detect reflux, and measure hemodynamic parameters, including retrograde flow (reflux) and duration of reflux. The great saphenous, small saphenous, deep, and perforator veins were assessed for reflux and segmental incompetence. Venous reflux was defined as retrograde flow lasting more than 0.5 seconds after distal compression release. Complications such as deep vein thrombosis, post-thrombotic changes, and venous ulcers were documented. Data were analyzed using appropriate statistical methods. The Chi-square test was applied to evaluate the association between the presence of venous reflux and different CEAP

clinical classes. One-way analysis of variance (ANOVA) was performed to compare reflux duration among the various CEAP groups. Additionally, Pearson correlation analysis was used to determine the relationship between venous diameter and CEAP classification. A *P* value of less than 0.05 was considered statistically significant. Findings were interpreted to guide treatment strategies and monitor disease progression.

Results

A total of 86 patients diagnosed with chronic venous disease were evaluated using Doppler ultrasound. The mean age of the study population was 42.6 ± 9.8 years, with a male predominance (67.4%) compared to females (32.6%). According to CEAP distribution 46.5% patients are C2 – C3 category, 25.6% patient are C4 category and 18.6% patients are C5 - C6 category. The common underlying causes identified were chronic venous hypertension (37.2%), post-thrombotic syndrome (27.9%), varicose veins (16.3%), and venous valve dysfunction (12.6%). On B-mode ultrasound, venous wall thickening and valvular incompetence were observed in 30.2% of patients. Doppler ultrasound revealed abnormal venous reflux in 37.2% of cases, primarily affecting the great saphenous vein (GSV) and small saphenous vein (SSV). Retrograde flow (reflux) and duration of reflux in affected veins were 95.2 ± 18.3 cm/sec. Increased venous diameter, a key indicator of venous hypertension, was noted in 27.9% of patients. The study categorized complications based on severity. Immediate complications included acute venous thrombosis (4.7%) and superficial phlebitis (2.3%). Early complications, such as chronic venous inflammation (20.9%) and skin changes, were noted in 25.6% of cases. Advanced-stage complications included venous ulcers (11.6%) and recurrent varicosities (9.3%). Doppler ultrasound was instrumental in detecting venous reflux, thrombosis, and hemodynamic alterations, making it a valuable tool for assessing CVD severity and guiding treatment strategies.

Table 1 Baseline characteristics of patients with chronic venous disease

Characteristic	Value (n = 86) n (%)
Mean age (years)	42.6 ± 9.8
Male	67.4 (58.0)
Female	32.6 (28.0)
Underlying causes	
Chronic venous hypertension	37.2 (32.0)
Post-thrombotic syndrome	27.9 (24.0)
Varicose veins	16.3 (14.0)
Venous valve dysfunction	12.6 (10.0)
Idiopathic	7.0 (6.0)

Discussion

Chronic venous disease is a disorder characterized by various pathological changes, such as lower limb swelling, skin alterations, and discomfort, resulting from venous hypertension; it is a widely prevalent condition globally [19]. Doppler ultrasound is crucial in diagnosing and evaluating CVD by assessing venous reflux, valve function, and hemodynamic parameters [20, 21]. This study aimed to assess the utility of Doppler ultrasound in detecting venous abnormalities in patients with CVD at our institution. The findings of our study indicate that great saphenous vein reflux was a predominant feature in patients with CVD, which aligns with previous studies highlighting the involvement of superficial veins in venous disease [21].

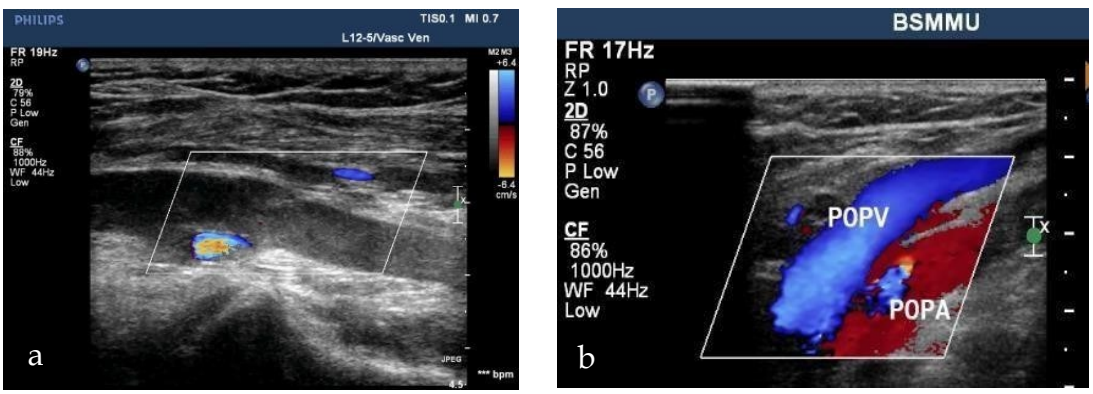

Figure 1 Normal venous valves with color flow

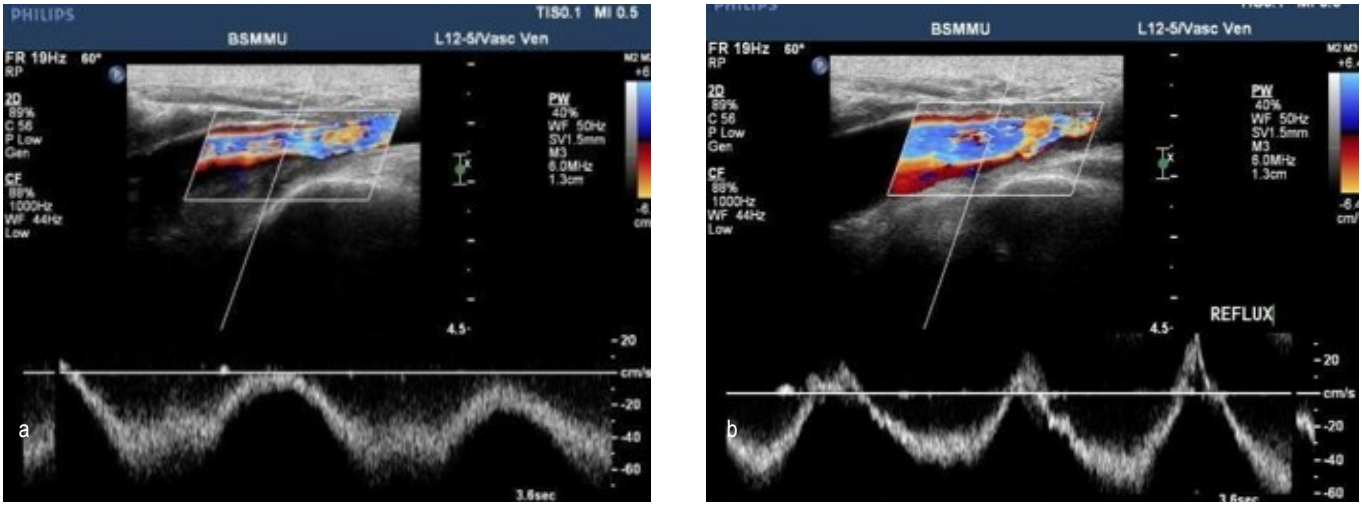

Figure 2 a) Spectral doppler waveform showing normal venous spectrum, b) venous valve dysfunction with retrograde flow (>10 cm/ s) indicating venous incompetence

Increased venous diameter and wall thickening were also commonly observed, consistent with chronic venous hypertension and venous wall remodeling seen in long-standing CVD cases [22]. These changes contribute to the progression of venous disease and may increase the risk of complications such as venous ulcers [23]. Venous valve dysfunction emerged as a significant finding, with a notable proportion of patients exhibiting absent valve function and retrograde blood flow. Research indicates that valvular incompetence is the main factor contributing to venous reflux and chronic venous hypertension. Extended reflux time detected on spectral Doppler ultrasound is a key marker of venous dysfunction, with reflux lasting more than 0.5 seconds being a diagnostic criterion for CVD. Deep vein thrombosis (DVT) was identified in certain patients, characterized by echogenic thrombus and non-compressible veins, which are hallmark features of thrombotic occlusion [24]. The presence of deep vein thrombosis (DVT) in patients with CVD is clinically significant, as it increases the risk of developing post-thrombotic syndrome (PTS) and exacerbates venous hypertension [25]. Additionally, Color Doppler imaging is instrumental in evaluating CVD, revealing venous congestion and reduced flow velocity, which indicate compromised venous return and stasis—factors contributing to the chronic nature of CVD [26]. Compared to previous studies, our findings support the role of Doppler ultrasound as a reliable, non-invasive tool for evaluating CVD [27]. Its ability to assess venous reflux, valve function, and hemodynamic abnormalities makes it

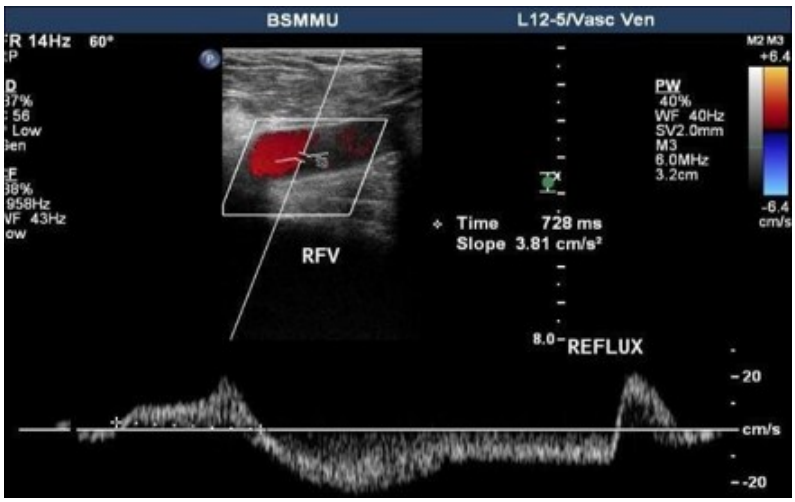

Figure 3 Spectral doppler waveform showing prolonged duration of reflux (>0.5 sec) indicating venous incompetence

Table 2 Doppler ultrasound findings in chronic venous disease

Parameter	Mean ± SD n (%)
Venous wall thickening	30.2 (26.0)
Venous reflux present	37.2 (32.0)
Affected veins	
Great saphenous vein	27.9 (24.0)
Small saphenous vein	9.3 (8.0)

Table 3 Complications of chronic venous disease

Complication	n (%)
Immediate complications	
Acute venous thrombosis	4.7 (4.0)
Superficial phlebitis	2.3 (2.0)
Early complications	
Chronic venous inflammation	20.9 (18.0)
Skin change (pigmentation, edema)	25.6 (22.0)
Advanced complications	
Venous ulcers	11.6 (10.0)
Recurrent varicosities	9.3 (8.0)

indispensable in the diagnostic workup of venous disease. Moreover, early detection of venous pathology through Doppler ultrasound can facilitate timely intervention and prevent disease progression [28].

Limitations

This study was conducted in a single institution with a relatively small sample size, limiting the generalizability of the findings. The absence of long-term follow-up data restricts the assessment of disease progression.

Conclusion

Duplex ultrasound integrated with CEAP classification provides reliable stratification of chronic venous disease severity. Reflux duration and venous diameter demonstrate significant correlation with advanced clinical stages and may serve as predictive imaging biomarkers. Multicenter studies with larger cohorts are recommended.

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