Section: General Surgery

Original Research Article

CLINICAL EXAMINATION VERSUS COLOUR DOPPLER ULTRASONOGRAPHY IN THE DIAGNOSIS OF SUPERFICIAL VENOUS AND PERFORATOR DISEASE OF THE LOWER LIMB: A PROSPECTIVE CORRELATIVE STUDY WITH INTRA-OPERATIVE FINDINGS

Received : 07/05/2026
Received in revised form : 20/06/2026
Accepted : 04/07/2026

Keywords:
Chronic venous disease, colour Doppler ultrasonography, saphenofemoral junction, saphenopopliteal junction, perforator incompetence, varicose veins, diagnostic accuracy, kappa statistic.

Corresponding Author:
Dr. Kartikay Mohan,
Email: kartikay.mohan1@gmail.com

DOI: 10.47009/jamp.2026.8.4.130

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (4); 750-761

Kartikay Mohan[1], N.K. Singh[1], Rajul Rastogi[2], Ashok Kumar Singh[1]

[1]Department of General Surgery, Teerthanker Mahaveer Medical College & Research Centre, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India
[2]Department of Radiology, Teerthanker Mahaveer Medical College & Research Centre, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India.

ABSTRACT

Background: Chronic venous disease of the lower limb is a highly prevalent vascular disorder whose surgical management depends on accurate localisation of the site of reflux. Clinical examination remains the first step in most resource-constrained settings, but its accuracy relative to colour Doppler ultrasonography and to actual intra-operative anatomy is incompletely defined for individual anatomical sites (saphenofemoral junction [SFJ], saphenopopliteal junction [SPJ], and perforators). The objective is to determine the sensitivity of clinical evaluation and of colour Doppler ultrasonography in diagnosing venous disease of the lower limb, to compare the two modalities with each other, and to correlate both with intra-operative findings. **Materials and Methods:** This prospective observational study was conducted in the Department of General Surgery, Teerthanker Mahaveer Medical College & Research Centre, Moradabad, over 18 months. Fifty-seven patients with clinical features suggestive of lower-limb venous disease were evaluated by clinical examination (tourniquet tests) and colour Doppler ultrasonography; findings in operated patients were correlated with intra-operative observations. Agreement was quantified using Cohen's kappa (κ), and diagnostic accuracy (sensitivity, specificity, positive and negative predictive value) was calculated for SFJ, SPJ, and perforator incompetence using intra-operative findings as the reference standard. **Results:** The mean age of the 57 participants was 41.58 ± 11.19 years (range 18–75 years), with a male predominance (73.7%). Agreement between clinical diagnosis and colour Doppler was moderate ($\kappa = 0.604$, $p < 0.0001$); agreement between clinical diagnosis and intra-operative findings was similarly moderate ($\kappa = 0.625$, $p < 0.0001$); agreement between colour Doppler and intra-operative findings was near-perfect ($\kappa = 0.905$, $p < 0.0001$). Against the intra-operative reference standard, colour Doppler outperformed clinical examination for SFJ (sensitivity 86.7% vs 66.7%; specificity 97.6% vs 85.7%) and, most strikingly, for perforator incompetence (sensitivity 100.0% vs 46.7%; specificity 95.2% for both). For SPJ, clinical examination showed higher sensitivity (100.0% vs 90.0%) but colour Doppler showed higher specificity (97.9% vs 89.4%) and positive predictive value (90.0% vs 66.7%). **Conclusion:** Colour Doppler ultrasonography correlates far more closely with intra-operative anatomy than clinical examination, particularly for perforator incompetence, which clinical examination misses in more than half of cases. Clinical examination retains value as an inexpensive screening step, but colour Doppler should be considered mandatory before any definitive surgical intervention for lower-limb venous disease.

INTRODUCTION

Venous disease of the lower limb is one of the most frequently encountered vascular disorders in general surgical practice, disproportionately affecting adults engaged in occupations that involve prolonged standing, heavy physical exertion, or, conversely, extended periods of sedentary immobility. Efficient venous return from the lower limb against gravity depends on the coordinated function of unidirectional venous valves, the calf-muscle pump, and respiration-induced pressure changes in the thoracic and abdominal cavities.[1] Failure of any one of these components precipitates venous hypertension, venous reflux, and progressive structural deterioration of the venous wall and valves, culminating in the clinical syndrome broadly termed chronic venous disease (CVD).[2]

CVD is a progressive disorder whose manifestations range from cosmetically troubling telangiectasia and varicose veins to advanced complications such as lipodermatosclerosis, chronic venous ulceration, and recurrent cellulitis. These features compromise mobility and occupational productivity, and, if unrecognised at an early stage, predispose to chronic pain, disfigurement, work disability, and a substantial economic burden, making CVD an important public-health problem rather than a purely cosmetic concern.[3]

Historically, the diagnosis of lower-limb venous disease has relied on bedside clinical manoeuvres — the Trendelenburg test, Perthes test, Schwartz (tap) test, and tourniquet occlusion tests — which provide indirect information about venous reflux, valvular incompetence, and the level of superficial venous involvement. These tests remain clinically useful as an initial screen, but they cannot reliably identify the precise anatomical origin of reflux, differentiate superficial from deep venous involvement, or localise incompetent perforators.[4] This limitation frequently translates into diagnostic inaccuracy, suboptimal surgical planning, incomplete intervention, and disease recurrence.

The introduction of colour Doppler ultrasonography transformed the diagnostic landscape for venous disease. By combining B-mode grey-scale imaging with colour-flow and spectral Doppler analysis, this technique permits real-time, non-invasive assessment of venous anatomy, valvular competence, direction of blood flow, and the presence or absence of pathological reflux. Colour Doppler has consequently become the reference imaging investigation for mapping incompetent perforators and planning interventions such as saphenous vein stripping, endovenous laser therapy (EVLT), radiofrequency ablation (RFA), and perforator ligation.[5]

In resource-constrained settings such as India, where access to Doppler ultrasonography may be limited by cost, availability, or trained personnel, clinical assessment continues to guide a substantial proportion of surgical decision-making. Many surgeons rely predominantly on clinical findings because of convenience and expense, yet inaccurate localisation of reflux, missed perforator incompetence, or unrecognised deep venous pathology may result in inappropriate or incomplete surgery and high recurrence rates.

A rigorous comparative evaluation of clinical assessment against colour Doppler ultrasonography — and, wherever feasible, against intra-operative anatomy as the ultimate arbiter of truth — is therefore essential to establish an evidence-based diagnostic pathway, guide appropriate surgical planning, and minimise recurrence in lower-limb venous disease.[6]

The present study was designed to address this need by comparing the diagnostic performance of clinical evaluation and colour Doppler ultrasonography in patients with disease of the superficial venous system and perforators, correlating both modalities with intra-operative findings whenever surgery was performed.

Epidemiology: Venous disorders are among the most prevalent vascular conditions worldwide. It is estimated that between 20% and 40% of adults globally have some form of chronic venous disorder, and approximately 25–30% will develop varicose veins at some point in their lives.[3] Chronic venous insufficiency affects nearly 10–15% of adults and is one of the leading causes of chronic leg pain and ulceration.

Women are affected more often than men, largely because of hormonal influences, pregnancy, and genetic predisposition, with some population studies reporting a prevalence of varicose veins in women roughly double that in men.[7] Men, however, more often present with advanced disease, possibly reflecting delayed health-seeking behaviour or reduced awareness. Prevalence rises sharply after the fourth decade of life as a consequence of progressive valvular degeneration.

Within India, reported prevalence of varicose veins ranges from 6% to 30% depending on geography and the population studied, with a disproportionate burden among individuals in occupations requiring prolonged standing — teaching, policing, retail, and factory work. Rising urbanisation, sedentary office-based employment, and increasing obesity are together expected to raise the burden of venous disease further.[8]

Chronic venous ulceration, although affecting only 0.3–1% of the population globally, is associated with disproportionate morbidity because of its tendency to recur, its protracted healing course, and the mobility restriction and economic cost it imposes on patients and health systems alike.[9] Given this high prevalence, progressive natural history, and considerable socio-economic burden, early and accurate diagnosis using a reliable modality such as colour Doppler ultrasonography is critical to forestalling long-term complications.

Anatomy and Physiology of the Lower-Limb Venous System

The venous drainage of the lower limb is organised into three interconnected compartments: the superficial venous system, the deep venous system, and the perforator veins that connect the two.

Superficial system. The superficial compartment comprises the great saphenous vein (GSV), the small saphenous vein (SSV), and their tributaries. The GSV ascends along the medial aspect of the limb to join the common femoral vein at the saphenofemoral

International Journal of Academic Medicine and Pharmacy (www.academicmed.org)
ISSN (O): 2687-5365; ISSN (P): 2753-6556

junction (SFJ), whereas the SSV runs along the posterior calf and drains into the popliteal vein at the saphenopopliteal junction (SPJ).[10]

Deep system. The deep venous system — comprising the tibial, peroneal, popliteal, and femoral veins — carries approximately 85–90% of total venous return from the limb.[1]

Perforator veins. Perforator veins pierce the deep fascia to connect the superficial and deep systems. Competent unidirectional valves normally permit flow only from superficial to deep veins; failure of these valves allows retrograde, deep-to-superficial flow that is a major contributor to skin changes and ulceration.[11]

Venous return against gravity depends on three physiological mechanisms operating in concert: the venous valves, which prevent retrograde flow; the calf-muscle pump, which propels blood centrally during ambulation; and the respiratory pump, which generates cyclical pressure gradients between the thoracic and abdominal cavities.[12] Failure of any of these mechanisms produces venous hypertension, the final common pathway that drives the clinical progression of chronic venous insufficiency. A sound understanding of this anatomy and physiology is essential, since structural or functional failure at any level directly determines the clinical phenotype of disease encountered.

Pathophysiology

The central pathophysiological event in venous disease is venous hypertension arising from valvular incompetence, venous obstruction, or a combination of the two. When venous valves fail, retrograde (reflux) flow occurs, producing venous dilatation and sustained elevation of pressure within the superficial system. Chronic venous hypertension triggers an inflammatory cascade of endothelial dysfunction, leukocyte activation, and microcirculatory derangement that ultimately manifests as hyperpigmentation, lipodermatosclerosis, eczema, and, in advanced cases, ulceration.[3]

Superficial venous reflux results from incompetence of the GSV or SSV valves; the resulting pressure overload in the superficial compartment manifests clinically as varicose veins, oedema, and skin change.

Perforator incompetence permits transmission of deep venous pressure directly into the superficial system. This reversed flow disproportionately affects the gaiter area, particularly around the medial malleolus, and is strongly implicated in the pathogenesis of venous ulceration.[13]

Deep venous reflux or obstruction, whether primary or secondary to post-thrombotic syndrome, further compounds venous hypertension and complicates management.

Because partial correction of only some of these anatomical contributors predisposes to disease recurrence, accurate localisation of the exact site of reflux — superficial, perforator, or deep — is a prerequisite for definitive treatment. Clinical examination alone is indicative rather than precise in this regard, which is the principal justification for the routine use of colour Doppler ultrasonography.[14]

Clinical Features of Venous Disease of the Lower Limb

Chronic venous disease presents along a spectrum of severity that is conventionally divided into early and advanced clinical features, a distinction that both aids diagnosis and reflects the severity of the underlying pathophysiology.[15]

Telangiectasia. Dilated intradermal venules less than 1 mm in diameter, appearing as fine red, blue, or purple thread-like lines, most often on the thigh, leg, and ankle. Although principally a cosmetic concern, telangiectasia may herald early venous hypertension.[16]

Reticular veins. Blue subdermal veins 1–3 mm in diameter forming an interconnected network, typically on the posterior thigh or lateral calf, reflecting early superficial venous reflux and occasionally associated with a dull ache or heaviness.[17]

Varicose veins. Dilated, tortuous superficial veins exceeding 3 mm in diameter arising from valvular incompetence, predominantly of the GSV or SSV, and presenting with discomfort, heaviness, swelling, itching, or a visible bulge.[3]

Oedema. Peri-malleolar swelling from excessive capillary filtration and impaired interstitial fluid resorption secondary to venous hypertension; typically worsens through the day and improves with leg elevation, but persistent oedema signals more advanced disease.[18]

Hyperpigmentation. Dermal deposition of haemosiderin following chronic extravasation and macrophage breakdown of erythrocytes, producing characteristic dark-brown discoloration of the gaiter region and indicating chronicity of disease.

Venous eczema (stasis dermatitis). Erythematous, pruritic, scaly patches resulting from chronic inflammation and impaired skin barrier function, which may progress to erosion, secondary infection, or ulceration if untreated.[3]

Lipodermatosclerosis. Chronic inflammatory fibrosis and tissue scarring producing skin thickening and the characteristic 'inverted champagne bottle' contour of the lower leg, with significant impact on mobility.[19]

Atrophie blanche. Smooth, ivory-white atrophic plaques studded with hyperpigmentation and dilated capillaries, a site prone to recurrent, painful ulceration secondary to ischaemic skin injury from venous congestion.

Venous ulceration represents the most severe consequence of chronic venous disease. Typically located in the gaiter region, especially over the medial malleolus, venous ulcers have irregular margins, moderate exudate, and surrounding hyperpigmentation; their pathogenesis involves venous hypertension, microvascular injury, leukocyte activation, and tissue hypoxia, and they carry substantial impact on quality of life.[20]

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Because these clinical features arise from varying degrees and combinations of superficial, perforator, and deep venous hypertension, precise diagnosis of the exact source of reflux is essential — a requirement that clinical examination alone cannot reliably satisfy.

Diagnostic Methods

A systematic diagnostic approach is required to differentiate superficial from deep venous disease, identify incompetent perforators, and guide management.

Clinical evaluation. Clinical assessment remains the first and most accessible diagnostic step, comprising history-taking and bedside examination — inspection, palpation, and provocative manoeuvres such as the Trendelenburg and Perthes tests. Symptoms such as limb heaviness, evening oedema, and standing-induced discomfort suggest venous hypertension. However, such subjective bedside tests lack objectivity and reproducibility, particularly in obese or oedematous patients, and cannot localise the precise origin of reflux or reliably assess deep venous or perforator involvement. Multiple studies have reported poor correlation between clinical findings and the haemodynamic abnormalities demonstrated by colour Doppler.[4]

Colour Doppler ultrasonography. Colour Doppler ultrasound is now the benchmark investigation for lower-limb venous disease, providing a comprehensive real-time assessment of anatomy, haemodynamics, and valvular competence. By combining B-mode imaging, colour-flow Doppler, and spectral waveform analysis, it accurately delineates vessel-wall integrity, luminal patency, thrombus, and flow dynamics. Its principal advantages include:

- **Detailed anatomical mapping** of the course, calibre, and branching pattern of the GSV, SSV, accessory veins, and perforators;
- **Valve competency assessment** using provocative manoeuvres such as distal compression-release or the Valsalva technique to detect retrograde flow;
- **Reflux quantification** against standardised diagnostic thresholds — reflux duration greater than 0.5 seconds in superficial veins, 0.35 seconds in perforators, and 1.0 second in deep veins — allowing objective grading of disease severity.[21]
- **Detection of thrombosis or obstruction,** including acute and chronic thrombus, wall thickening, and partial recanalisation; and
- **Surgical and interventional planning,** by precisely mapping incompetent segments, perforator location, and junctional reflux before saphenofemoral ligation, saphenopopliteal disconnection, endovenous laser ablation, radiofrequency ablation, or foam sclerotherapy.

Doppler ultrasonography is equally valuable for postoperative surveillance, confirming successful ablation, excluding deep vein thrombosis, and identifying residual or recurrent reflux. Owing to its non-invasive nature, repeatability, and high diagnostic accuracy, colour Doppler has supplanted most invasive investigations and now forms the cornerstone of evidence-based venous disease management.

Invasive methods (rarely used). Conventional venography, once regarded as the reference standard, involves fluoroscopic imaging after injection of radiopaque contrast into the superficial veins; it delineates anatomy and obstruction precisely but carries risk of allergic reaction, contrast nephropathy, and radiation exposure, and is now reserved chiefly for suspected iliac vein obstruction, post-thrombotic syndrome, and complex recurrent varicosities.[22] Plethysmography (air or strain-gauge) provides global information on venous capacitance and refill time but cannot localise the site of reflux, limiting its clinical utility. Intravascular ultrasound (IVUS), a catheter-based technique offering high-resolution images of the venous wall and lumen, is mainly reserved for iliac vein compression syndrome and venous stenting, and its invasiveness and cost preclude routine use.

Limitations of Clinical Evaluation

Although clinical evaluation remains foundational and is invariably the first step in assessment, it carries several important limitations that materially reduce its diagnostic accuracy:

1. **Poor sensitivity for perforator reflux —** up to 40–50% of incompetent perforators, situated deep to the fascia, may be missed on clinical examination alone.[23]
2. **Inability to assess the deep venous system —** the femoral, popliteal, and tibial veins cannot be visualised or palpated, precluding clinical detection of deep reflux, thrombosis, or obstruction.
3. **Reduced accuracy in obese or oedematous patients —** thick adipose tissue and extensive swelling obscure varicosities and perforators, compromising physical detection.
4. **Operator dependency —** tests such as the Trendelenburg, Perthes, and calf compression tests require considerable skill and experience; inconsistent technique produces false positives and false negatives.
5. **Inability to quantify disease severity —** clinical examination cannot measure reflux duration, flow velocity, venous luminal diameter, or junctional incompetence, precluding objective haemodynamic assessment.
6. **Poor correlation with intra-operative findings —** clinical diagnosis frequently misidentifies the origin of reflux and fails to detect accessory saphenous vein reflux or segmental incompetence, with the risk of inappropriate treatment if surgery is planned on clinical grounds alone.[24]

These constraints collectively justify objective imaging as an adjunct — or, arguably, as a prerequisite — to clinical assessment, and underpin the rationale for the comparative evaluation reported here. [summarised in Table 1]

Importance of Colour Doppler Ultrasonography

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Colour Doppler ultrasound provides a multi-dimensional evaluation of venous disease encompassing anatomical, physiological, and pathological information.

1. **High diagnostic accuracy:** sensitivity and specificity exceeding 90% for venous reflux, valve incompetence, and thrombosis, detecting abnormalities not apparent on inspection or palpation.[25]
2. **Comprehensive venous mapping** of the superficial system, deep system, perforators, junctional anatomy (SFJ, SPJ), and collateral channels, providing a three-dimensional anatomical framework essential before intervention.
3. **Essential preoperative planning,** ensuring all incompetent segments and accessory reflux pathways are identified, perforators precisely localised, and junctional incompetence correctly addressed — without which surgical outcomes are significantly compromised.
4. **Key postoperative role,** confirming closure of treated segments, detecting residual or recurrent reflux, and excluding thrombus extension or recanalisation.
5. **Differentiation of superficial from deep disease,** a distinction clinical examination cannot reliably make, but which determines whether surgery, compression therapy, or conservative management is appropriate.
6. **Reduction of recurrence** through Doppler-guided identification and complete treatment of all incompetent segments.
7. **A robust evidence base:** multiple studies consistently demonstrate the superiority of Doppler over clinical examination alone, with the combination of both methods representing best practice for the investigation of venous disease.[26]

Rationale and Aim of the Study

Colour Doppler ultrasonography therefore not only surpasses clinical examination in diagnostic accuracy but is indispensable to contemporary venous disease management: it underpins appropriate treatment selection, minimises recurrence, and improves outcomes. Given the rising burden of venous disorders, the well-documented limitations of clinical examination, and the established reliability of colour Doppler, an empirical assessment of the comparative performance of the two modalities — validated wherever possible against intra-operative anatomy — is both timely and clinically important.

Aim: To compare clinico-radiological findings with intra-operative findings in patients with venous disease (superficial venous system and perforators) of the lower limb.

Objectives:

1. To determine the sensitivity of clinical evaluation in diagnosing venous disease of the lower limb.
2. To determine the sensitivity of colour Doppler ultrasonography in diagnosing venous disease of the lower limb.
3. To compare clinical evaluation with colour Doppler ultrasonography in venous disease of the lower limb.
4. To compare clinical evaluation and colour Doppler findings with intra-operative findings, wherever applicable.

MATERIALS AND METHODS

Study Setting and Duration: This study was conducted in the Department of General Surgery, Teerthanker Mahaveer Medical College & Research Centre (TMMC&RC), a tertiary-care teaching hospital serving a large urban and rural catchment population, providing a suitable environment for clinical research on lower-limb venous disease. The study spanned 18 months, commencing after approval from the Institutional Ethics Committee (IEC) and College Research Committee (CRC).

Study Design: This was a prospective observational study designed to assess the correlation between clinical signs and symptoms, colour Doppler imaging findings, and intra-operative findings in patients presenting with venous disease of the lower limb.

Sample Size: The required sample size was calculated using the standard formula for prevalence-based studies, $n = Z^2 \times P \times (100-P)/E^2$, with $Z = 1.96$ (95% confidence interval) and an allowable error (E) of 13%, using a reference prevalence of 52%. This yielded a calculated sample size of approximately 57 patients, which was adopted for the study.

Materials and Equipment: Standard clinical and diagnostic tools available at the institution were used, comprising a tourniquet for bedside clinical examination of venous insufficiency, and colour Doppler ultrasonography for non-invasive evaluation of venous flow, valvular competence, and reflux or obstruction. These tools were selected on the basis of feasibility, availability, and their established role in the diagnostic work-up of venous disorders.

Selection of Study Participants

Inclusion criteria:

- Patients admitted with clinical features suggestive of venous disease of the lower limb, including varicose veins and chronic venous insufficiency.
- Patients who provided written informed consent to participate.

Exclusion criteria:

- Patients with deep vein thrombosis (DVT) diagnosed at the time of clinical evaluation.
- Patients with lower-limb oedema attributable to causes other than venous insufficiency.
- Patients with a prior history of surgical intervention for varicose veins, to avoid bias in outcome assessment.

Study Procedure: Following approval from the CRC and IEC, eligible patients were enrolled according to the pre-specified inclusion and exclusion criteria. After informed consent, demographic data, medical history, and presenting

ISSN (O): 2687-5365; ISSN (P): 2753-6556

complaints were recorded, followed by a thorough clinical examination for signs of venous insufficiency (including tourniquet testing). All enrolled patients subsequently underwent colour Doppler ultrasonography as the primary radiological investigation to assess venous reflux, obstruction, and valvular incompetence. Patients undergoing surgical intervention were further assessed intra-operatively, permitting a three-way comparative analysis between clinical findings, Doppler findings, and intra-operative findings, which was used to determine the accuracy and reliability of the pre-operative assessments.

Statistical Analysis

Descriptive statistics (frequencies, percentages, mean, and standard deviation) were used to summarise demographic and diagnostic data. Agreement between diagnostic modalities (clinical diagnosis, colour Doppler, and intra-operative findings) was assessed using Cohen's kappa (κ) statistic, interpreted according to conventional benchmarks (≤0.20 slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1.00 almost perfect agreement). Diagnostic accuracy — sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) — was calculated for clinical examination and colour Doppler against intra-operative findings as the reference standard, separately for SFJ, SPJ, and perforator incompetence. A p-value < 0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants. Patient confidentiality was strictly maintained throughout; personal identifiers were not disclosed, and all data were used exclusively for academic and research purposes.

RESULTS

A total of 57 patients meeting the inclusion criteria were enrolled and evaluated by clinical examination and colour Doppler ultrasonography; findings were further correlated with intra-operative observations in patients who underwent surgery. The record-level data underlying every table and figure in this section were cross-verified against the study's original case-record ('master chart') dataset; the pairwise concordance and kappa statistics derived independently from that record-level dataset reproduced the tabulated results below exactly, confirming internal consistency of the reported findings.

Table 1: Demographic Profile

Variable	Category	Number (n=57)	Percentage (%)
Age group (years)	11–20	1	1.8
	21–30	7	12.3
	31–40	25	43.9
	41–50	11	19.3
	51–60	12	21.1
	>60	1	1.8
Mean ± SD (years)	—	41.58 ± 11.19	—
Gender	Male	42	73.7
	Female	15	26.3

The predominant age group was 31–40 years (43.9%), followed by 51–60 years (21.1%) and 41–50 years (19.3%); a smaller proportion of patients were aged 21–30 years (12.3%), while only 1.8% each were aged 11–20 years and above 60 years. The mean age of participants was 41.58 ± 11.19 years. Males comprised the majority of the study cohort (73.7%), with females accounting for 26.3% — a pattern consistent with occupational and lifestyle exposure to venous disease risk factors in the economically productive age group. [Figure 1]

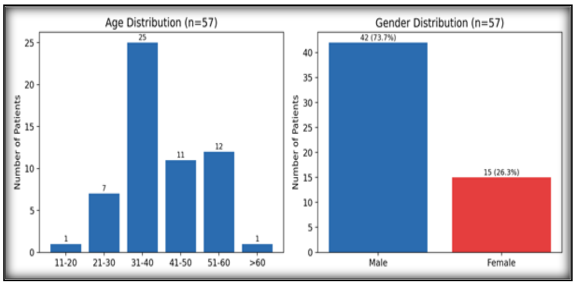

Figure 1: Age and gender distribution of study participants (n=57).

Table 2: Distribution of Diagnoses Across Modalities

Diagnostic Modality	Finding	Number (n=57)	Percentage (%)
Clinical diagnosis	SFJ	16	28.1
	SPJ	15	26.3
	Perforator	9	15.8
	None	17	29.8
Colour Doppler	SFJ	14	24.6
	SPJ	10	17.5
	Perforator	17	29.8
	None	16	28.1
Intra-operative	SFJ	15	26.3
	SPJ	10	17.5

ISSN (O): 2687-5365; ISSN (P): 2753-6556

	Perforator	15	26.3
	None	17	29.8

On clinical examination, absence of identifiable pathology was the most frequent finding (29.8%), followed by SFJ involvement (28.1%) and SPJ involvement (26.3%), with perforator involvement identified least often (15.8%). Colour Doppler, by contrast, identified perforator incompetence as the single most common abnormality (29.8%), followed by SFJ (24.6%) and SPJ (17.5%), with 28.1% showing no abnormality. Intra-operatively, SFJ and perforator involvement were equally represented (26.3% each), with SPJ noted in 17.5% and no pathology in 29.8% — a distribution that mirrors the Doppler findings far more closely than the clinical findings, foreshadowing the concordance analyses that follow. [Figure 2]

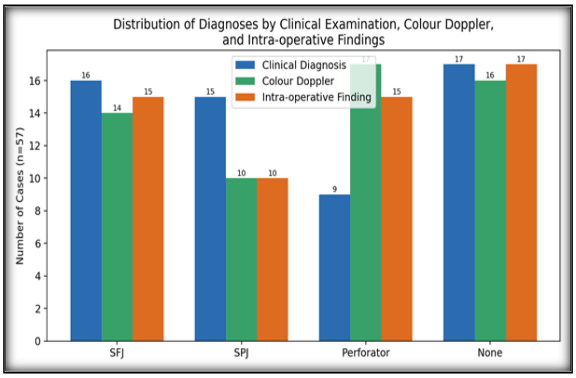

Figure 2: Distribution of diagnoses by clinical examination, colour Doppler, and intra-operative findings

Table 3: ***Agreement Between Clinical Diagnosis and Colour Doppler***

Clinical Diagnosis	SFJ	SPJ	Perforator	None	Total
SFJ	10 (71.4%)	0 (0.0%)	4 (23.5%)	2 (12.5%)	16
SPJ	2 (14.3%)	10 (100.0%)	3 (17.6%)	0 (0.0%)	15
Perforator	1 (7.1%)	0 (0.0%)	7 (41.2%)	1 (6.3%)	9
None	1 (7.1%)	0 (0.0%)	3 (17.6%)	13 (81.3%)	17
Total (Colour Doppler)	14	10	17	16	57

Among patients clinically diagnosed with SFJ involvement, 71.4% were confirmed on colour Doppler, while 23.5% were re-classified as perforator incompetence and 12.5% showed no Doppler abnormality. All clinically diagnosed SPJ cases (100%) were confirmed on Doppler, although some were additionally identified as SFJ (14.3%) or perforator (17.6%) involvement. Of clinically diagnosed perforator cases, only 41.2% were confirmed on Doppler. Among patients with no clinical diagnosis, 81.3% were also Doppler-negative. Overall agreement between clinical diagnosis and colour Doppler was statistically significant but only moderate ($\kappa = 0.604$, $p < 0.0001$).

Table 4: Agreement Between Clinical Diagnosis and Intra-Operative Findings

Clinical Diagnosis	SFJ	SPJ	Perforator	None	Total
SFJ	10 (66.7%)	0 (0.0%)	4 (26.7%)	2 (11.8%)	16
SPJ	4 (26.7%)	10 (100.0%)	1 (6.7%)	0 (0.0%)	15
Perforator	1 (6.7%)	0 (0.0%)	7 (46.7%)	1 (5.9%)	9
None	0 (0.0%)	0 (0.0%)	3 (20.0%)	14 (82.4%)	17
Total (Intra-operative)	15	10	15	17	57

Of patients clinically diagnosed with SFJ involvement, 66.7% were confirmed intra-operatively, while 26.7% proved to be perforator incompetence and 11.8% showed no abnormality at surgery. All clinically diagnosed SPJ cases were confirmed intra-operatively (100%). Only 46.7% of clinically diagnosed perforator cases were verified at surgery. Among patients with no clinical diagnosis, 82.4% also had no intra-operative abnormality, but 20.0% proved to have perforator disease. This corresponded to a statistically significant, moderate level of agreement ($\kappa = 0.625$, $p < 0.0001$).

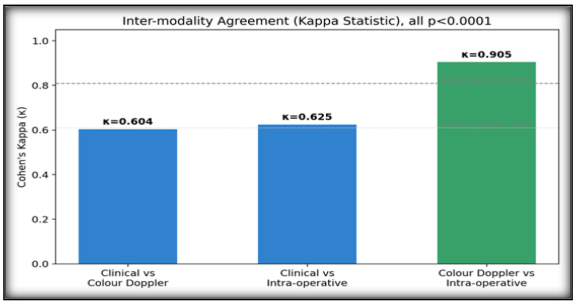

Figure 3: Summary of inter-modality agreement (Cohen's kappa) across the three pairwise comparisons

Table 5: Agreement Between Colour Doppler and Intra-Operative Findings

Colour Doppler	SFJ	SPJ	Perforator	None	Total
SFJ	13 (86.7%)	0 (0.0%)	0 (0.0%)	1 (5.9%)	14
SPJ	1 (6.7%)	9 (90.0%)	0 (0.0%)	0 (0.0%)	10
Perforator	1 (6.7%)	1 (10.0%)	15 (100.0%)	0 (0.0%)	17
None	0 (0.0%)	0 (0.0%)	0 (0.0%)	16 (94.1%)	16
Total (Intra-operative)	15	10	15	17	57

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Colour Doppler showed markedly higher concordance with intra-operative findings than clinical examination did. Among Doppler-diagnosed SFJ cases, 86.7% were confirmed at surgery; among Doppler-diagnosed SPJ cases, 90.0% were confirmed; and among Doppler-diagnosed perforator cases, all (100%) were confirmed intra-operatively. Among Doppler-negative cases, 94.1% were also negative at surgery. This corresponded to a near-perfect level of agreement ($\kappa = 0.905$, $p < 0.0001$), substantially exceeding the agreement achieved by clinical examination against the same intra-operative reference

Table 6: Diagnostic Accuracy for SFJ Involvement

Diagnostic Parameter	Clinical Diagnosis	Colour Doppler
Sensitivity	66.7%	86.7%
Specificity	85.7%	97.6%
PPV	62.5%	92.9%
NPV	87.8%	95.3%

Colour Doppler demonstrated higher sensitivity (86.7% vs 66.7%), specificity (97.6% vs 85.7%), PPV (92.9% vs 62.5%), and NPV (95.3% vs 87.8%) than clinical examination for detecting SFJ involvement, confirming its superior ability both to detect and to exclude SFJ incompetence.

Table 7: Diagnostic Accuracy for SPJ Involvement

Diagnostic Parameter	Clinical Diagnosis	Colour Doppler
Sensitivity	100.0%	90.0%
Specificity	89.4%	97.9%
PPV	66.7%	90.0%
NPV	100.0%	97.9%

For SPJ involvement, clinical examination achieved higher sensitivity (100.0% vs 90.0%) — reflecting the relatively superficial and readily palpable location of the SPJ region in many patients — whereas colour Doppler achieved higher specificity (97.9% vs 89.4%) and PPV (90.0% vs 66.7%), indicating that a positive clinical finding at the SPJ is considerably less likely to be a true positive than a positive Doppler finding. NPV was comparably high for both modalities (100.0% vs 97.9%).

The starkest difference between the two modalities was observed for perforator incompetence. Clinical examination demonstrated markedly low sensitivity (46.7%), missing more than half of all perforator disease subsequently confirmed at surgery, whereas colour Doppler achieved 100.0% sensitivity, correctly identifying every case. Specificity was identical for both modalities (95.2%), but colour Doppler achieved a higher PPV (88.2% vs 77.8%) and, critically, a perfect NPV (100.0% vs 83.3%), meaning a Doppler-negative result reliably excluded perforator incompetence, whereas a clinically negative examination did not.

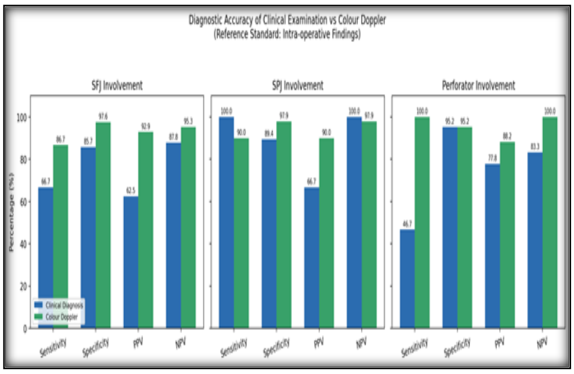

Figure 4. Comparative diagnostic accuracy (sensitivity, specificity, PPV, NPV) of clinical examination versus colour Doppler for SFJ, SPJ, and perforator involvement, using intra-operative findings as the reference standard.

Table 8: Diagnostic Accuracy for Perforator Incompetence

Diagnostic Parameter	Clinical Diagnosis	Colour Doppler
Sensitivity	46.7%	100.0%
Specificity	95.2%	95.2%
PPV	77.8%	88.2%
NPV	83.3%	100.0%

DISCUSSION

This study set out to evaluate the diagnostic accuracy of clinical examination and colour Doppler ultrasonography in patients with lower-limb venous disease, using intra-operative findings as the reference standard. The findings are discussed below in relation to the relevant published literature.

Demographic Profile

The predominant age group in this cohort was 31–40 years (43.9%), followed by 51–60 years (21.1%) and 41–50 years (19.3%), with a mean age of 41.58 ± 11.19 years, and a marked male predominance (73.7%). These findings suggest that venous disease principally affects individuals in the economically productive age group, likely reflecting cumulative occupational exposure to risk factors such as prolonged standing, heavy physical activity, and sustained venous pressure.

This age distribution is consistent with that reported by Sridhar et al,[33] and by Azhar et al,[38] both of whom found the highest incidence in the fifth decade of life. The male predominance observed here is similarly corroborated by Uddesh et al,[39] and by Panwar et al,[28] who attributed the higher male burden to occupational factors and delayed health-seeking behaviour — a pattern plausibly extending to the present cohort as well.

Distribution of Diagnoses Across Modalities

A notable divergence was observed in the distribution of pathology across the three diagnostic modalities. Clinically, absence of pathology was the most frequent finding (29.8%), followed by SFJ (28.1%) and SPJ (26.3%) involvement, with perforator incompetence detected least often (15.8%). Colour Doppler, in contrast, identified perforator incompetence as the single most common finding (29.8%), and intra-operative findings placed SFJ and perforator involvement in equal proportion (26.3% each) — corresponding far more closely to the Doppler distribution than to the clinical one.

This pattern reflects the well-recognised insensitivity of clinical examination to perforator disease, given the deeper anatomical location of perforating veins. Panwar et al,[28] similarly found combined superficial and perforator involvement to be the most prevalent disease pattern, while Arumugam et al,[10] reported a high burden of perforator incompetence, particularly at the medial calf, that is frequently overlooked on clinical assessment. Taken together, these observations confirm that clinical examination systematically under-diagnoses perforator disease, whereas colour Doppler provides a substantially more accurate representation of the true burden of pathology.

Agreement Between Clinical Examination and Colour Doppler

Agreement between clinical examination and colour Doppler in this study was statistically significant but only moderate ($\kappa = 0.604$, $p < 0.0001$). While clinical examination performed reasonably in identifying SFJ and SPJ involvement, its performance for perforator incompetence was markedly limited, with a substantial proportion of clinically diagnosed cases not confirmed on Doppler.

This moderate level of agreement indicates that clinical palpation alone lacks sufficient precision, particularly for deeper venous structures, a conclusion consistent with Ummer et al,[34] who reported lower sensitivity of clinical examination relative to Doppler for perforator incompetence. Similarly, Prabhu et al,[37] demonstrated superior accuracy of Doppler ultrasonography in localising venous reflux and incompetent segments, while Antani et al,[29] emphasised that clinical evaluation alone cannot adequately characterise venous haemodynamics and should routinely be supplemented by Doppler imaging. The present findings reinforce that clinical examination, although a useful initial screening tool, is insufficient as a stand-alone diagnostic modality.

Correlation Between Clinical Diagnosis and Intra-Operative Findings

Agreement between clinical diagnosis and intra-operative findings was likewise moderate ($\kappa = 0.625$, $p < 0.0001$), indicating only partial concordance. Clinical examination performed well for SPJ involvement but was markedly less accurate for SFJ involvement and, in particular, for perforator incompetence.

A substantial proportion of cases clinically classified as SFJ involvement were found intra-operatively to represent perforator pathology, suggesting frequent misclassification on clinical grounds. These results parallel those of Sureshkumar et al,[14] who reported that reliance on clinical examination alone led to inaccurate perforator identification and increased unnecessary surgical exploration, and Mehmood et al,[36] who similarly found lower concordance between clinical findings and intra-operative observations than between Doppler and intra-operative findings. This underscores that clinical examination alone lacks the precision required for definitive surgical planning and, if used in isolation, may result in incomplete or inappropriate treatment.

Agreement Between Colour Doppler and Intra-Operative Findings

The single most important finding of this study is the near-perfect concordance between colour Doppler and intra-operative findings ($\kappa = 0.905$, $p < 0.0001$). Colour Doppler correctly identified the great majority of SFJ, SPJ, and perforator involvement, with particularly high accuracy for perforator incompetence.[40]

This exceptionally high level of agreement indicates that colour Doppler provides an accurate and reliable representation of venous anatomy and pathology, supporting its role as an essential pre-operative investigation. This finding is strongly consistent with Sharma et al,[21] who demonstrated excellent diagnostic accuracy of Doppler in venous disease; with Azhar et al,[38] who similarly reported high consistency between Doppler and intra-operative findings; and with Meyer et al,[41] who confirmed that duplex ultrasonography is as effective as venography in identifying incompetent perforators (Cockett veins).

Diagnostic Accuracy for SFJ Involvement

Colour Doppler demonstrated superior sensitivity (86.7% vs 66.7%) and specificity (97.6% vs 85.7%) relative to clinical examination for SFJ involvement, with correspondingly higher predictive values, indicating that Doppler is more reliable both for confirming and for excluding SFJ disease. These findings mirror those of Singh et al,[32] who reported that Doppler ultrasonography accurately identifies SFJ reflux and plays a pivotal role in pre-operative mapping. The present study reinforces the conclusion that Doppler provides a substantially more precise assessment of SFJ involvement than clinical examination alone.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Diagnostic Accuracy for SPJ Involvement

For SPJ involvement, clinical examination showed higher sensitivity (100.0%), reflecting its ability to detect overt cases, whereas colour Doppler showed higher specificity (97.9%) and PPV (90.0%), reflecting greater accuracy in confirming true disease and minimising false-positive diagnoses. This pattern suggests that clinical assessment may be adequate for initial identification of SPJ pathology, but Doppler remains superior for confirmatory diagnosis — a conclusion consistent with the broader literature emphasising the role of Doppler in venous disease evaluation.

Diagnostic Accuracy for Perforator Incompetence

The most clinically significant finding of this study relates to perforator incompetence. Clinical examination demonstrated markedly low sensitivity (46.7%), missing a substantial number of cases, whereas colour Doppler achieved 100.0% sensitivity, correctly identifying every case of perforator incompetence.

This large disparity illustrates the fundamental limitation of clinical examination for perforator disease, which plays a central role both in the pathogenesis and in the recurrence of venous insufficiency. This observation is consistent with Ummer et al,[34] and Prabhu et al,[37] both of whom demonstrated superior Doppler sensitivity relative to clinical examination for incompetent perforators. The present study provides strong corroborating evidence for the routine use of Doppler in the diagnosis of perforator disease.

Clinical Implications

These findings underscore the critical importance of integrating colour Doppler ultrasonography with clinical examination in the assessment of lower-limb venous pathology. While clinical assessment remains the appropriate first step in diagnosis, its limited sensitivity — particularly for perforator incompetence — substantially reduces its reliability as a stand-alone diagnostic tool. The present results indicate unequivocally that colour Doppler affords markedly greater diagnostic precision, particularly for venous reflux, perforator involvement, and junctional incompetence.

Given the near-perfect concordance observed between colour Doppler and intra-operative findings, Doppler ultrasonography can reasonably be regarded as an indispensable pre-operative investigation for accurate mapping and surgical planning. Its ability to detect clinically silent lesions — most notably incompetent perforators — is invaluable in preventing under-treatment and minimising the risk of disease recurrence. Its non-invasive nature, relative affordability, and wide availability further support its routine incorporation into standard clinical practice. The combined use of clinical examination and colour Doppler, rather than either modality alone, enables the most comprehensive characterisation of disease and is therefore advocated for all patients undergoing evaluation for lower-limb venous disease.

Limitations and Future Scope

This study has several limitations that merit consideration. First, it was conducted at a single tertiary-care centre with a comparatively modest sample size, which may limit the generalisability of the findings; larger, multicentric studies with more diverse populations would strengthen external validity. Second, colour Doppler ultrasonography is inherently operator-dependent, and variability in radiologist expertise and technique may have introduced inter-observer variability; standardisation of imaging protocols and formal assessment of inter-observer agreement would improve reproducibility. Third, intra-operative findings were used as the reference standard, but not all enrolled patients underwent surgery, which may have introduced selection effects into the sub-group used for diagnostic accuracy calculations. Finally, more advanced imaging modalities and longitudinal follow-up were beyond the scope of this study, limiting assessment of disease progression, recurrence, and long-term outcomes.

Future research should prioritise multicentric studies with larger sample sizes and standardised protocols to validate these findings, together with longitudinal follow-up to assess disease progression, recurrence rates, and the impact of imaging-guided intervention on clinical outcomes. Integration of advanced imaging modalities alongside conventional diagnostic approaches may further refine diagnostic precision. The incorporation of artificial intelligence (AI)- and machine-learning-based image analysis represents a particularly promising direction, with the potential to reduce operator dependency, enhance diagnostic accuracy, and detect subtle imaging patterns that may elude the human eye; development of automated or semi-automated Doppler interpretation systems and predictive models could substantially improve clinical decision-making and standardise diagnostic workflows going forward.

CONCLUSION

Lower-limb venous disease remains a significant clinical problem affecting the adult population, particularly individuals exposed to occupational and lifestyle-related risk factors. Early and accurate diagnosis is essential to guide appropriate management and to prevent disease progression and recurrence. This study evaluated the relationship between clinical examination, colour Doppler ultrasonography, and intra-operative findings in patients with lower-limb venous disease.

Clinical examination identified SFJ and SPJ involvement in a considerable number of cases but showed limited accuracy in detecting perforator incompetence, with substantial overlap and misclassification between categories, highlighting its limitations in precisely identifying the anatomical site and extent of venous reflux. Colour Doppler ultrasonography demonstrated superior diagnostic

ISSN (O): 2687-5365; ISSN (P): 2753-6556

performance overall, with high sensitivity, specificity, and predictive values, and near-perfect agreement with intra-operative findings. It was particularly effective in detecting perforator incompetence — the category most frequently missed on clinical examination — underscoring its central role in comprehensive venous evaluation.

These findings indicate that, while clinical examination remains an indispensable initial screening step, it cannot be relied upon as the sole basis for diagnosis or surgical decision-making. Colour Doppler ultrasonography provides detailed anatomical and physiological information that permits accurate localisation of reflux and should be regarded as a dependable, non-invasive, and highly accurate imaging modality that meaningfully enhances diagnostic precision. Its routine use in clinical practice is recommended to improve diagnostic accuracy, guide surgical planning, and reduce the risk of recurrence in patients with lower-limb venous disease.

Future Perspective

Future prospective research should adopt multicentric and large-scale designs to validate and generalise the present findings across more diverse populations, with larger sample sizes providing stronger evidence on the comparative diagnostic accuracy of clinical examination and colour Doppler ultrasonography. Standardisation of Doppler protocols and structured technician training would reduce inter-observer variability and improve the reliability of results. Studies incorporating more advanced imaging modalities together with longitudinal data collection would help evaluate treatment efficacy and long-term outcomes. Further work should also examine the role of colour Doppler in monitoring disease progression and postoperative outcomes, its integration into standardised diagnostic and treatment algorithms, and its cost-effectiveness and applicability in resource-limited settings, further consolidating its position as a primary imaging modality in the evaluation and management of lower-limb venous disease.

Declarations

Ethical approval: Obtained from the Institutional Ethics Committee and College Research Committee, Teerthanker Mahaveer Medical College & Research Centre, Moradabad. All participants provided written informed consent.

REFERENCES

1. Meissner MH, Moneta G, Burnand K, Gloviczki P, Lohr JM, Lurie F, et al. The hemodynamics and diagnosis of venous disease. J Vasc Surg. 2007;46(6):S4–24. doi:10.1016/j.jvs.2007.09.043.
2. Ortega MA, Fraile-Martínez O, García-Montero C, Álvarez-Mon MA, Chaowen C, Ruiz-Grande F, et al. Understanding Chronic Venous Disease: A Critical Overview of Its Pathophysiology and Medical Management. J Clin Med. 2021;10(15):3239. doi:10.3390/jcm10153239
3. Eberhardt RT, Raffetto JD. Chronic Venous Insufficiency. Circulation. 2014;130(4):333–46. doi:10.1161/CIRCULATIONAHA.113.006898
4. Krishnan S, Nicholls SC. Chronic venous insufficiency: clinical assessment and patient selection. Semin Intervent Radiol. 2005;22(3):169–77. doi:10.1055/s-2005-921961
5. Necas M. Duplex ultrasound in the assessment of lower extremity venous insufficiency. Australas J Ultrasound Med. 2010;13(4):37–45. doi:10.1002/j.2205-0140.2010.tb00178.x
6. Ghauri ASK, Nyamekye I, Grabs AJ, Farndon JR, Whyman MR, Poskitt KR. Influence of a specialised leg ulcer service and venous surgery on the outcome of venous leg ulcers. Eur J Vasc Endovasc Surg. 1998;16(3):238–44. doi:10.1016/S1078-5884(98)80226-8
7. Evans CJ, Fowkes FG, Ruckley CV, Lee AJ. Prevalence of varicose veins and chronic venous insufficiency in men and women in the general population: Edinburgh Vein Study. J Epidemiol Community Health. 1999;53(3):149–53. doi:10.1136/jech.53.3.149
8. Khanna AK, Kumar S. Venous Scenario in India. Indian J Surg. 2023;85(S1):1–6. doi:10.1007/s12262-021-02949-1
9. Stanek A, Mosti G, Nematillaevich T, Valesky E, Planinšek Ručigaj T, Boucelma M, et al. No More Venous Ulcers—What More Can We Do? J Clin Med. 2023;12(19):6153. doi:10.3390/jcm12196153
10. Arumugam S, Manaswini DP, Reddy PA, Ghoshal JA, Subbiah NK. A Study of Valvular Incompetencies in the Lower Limb Veins Using Doppler Ultrasound Findings. Cureus. 2024;16(2):e53765. doi:10.7759/cureus.53765
11. Kuyumcu G, Salazar GM, Prabhakar AM, Ganguli S. Minimally invasive treatments for perforator vein insufficiency. Cardiovasc Diagn Ther. 2016;6(6):593–8. doi:10.21037/cdt.2016.11.12
12. Tauraginskii RA, Lurie F, Simakov S, Agalarov R, Khramtsov P, Babushkin M, et al. The human lower leg muscle pump functions as a flow diverter pump, maintaining low ambulatory venous pressures during locomotion. J Vasc Surg Venous Lymphat Disord. 2025;13(1):101996. doi:10.1016/j.jvsv.2024.101996
13. Caprini JA, Partsch H, Simman R. Venous Ulcers. J Am Coll Clin Wound Spec. 2012;4(3):54–60. doi:10.1016/j.jccw.2013.11.001
14. Sureshkumar S, Vignesh N, Venkatachalam J, Vijayakumar C, Sudharsanan S. Clinical Tests Combined with Color Doppler Versus Color Doppler Alone in Identifying Incompetent Perforator Veins of the Lower Limb: A Prospective Analytical Study. Cureus. 2018;10(1):e2026. doi:10.7759/cureus.2026
15. Yun S. Chronic Venous Disease is a Progressive Disease that Requires Early Intervention. Ann Phlebol. 2023;21(2):80–4. doi:10.37923/phle.2023.21.2.80
16. Sandean DP, Syed HA, Winters R. Spider Veins. StatPearls. 2025.
17. Chung JH, Heo S. Varicose Veins and the Diagnosis of Chronic Venous Disease in the Lower Extremities. J Chest Surg. 2024;57(2):109–19. doi:10.5090/jcs.23.110
18. Bergan JJ, Schmid-Schönbein GW, Smith PDC, Nicolaides AN, Boisseau MR, Eklof B. Chronic Venous Disease. N Engl J Med. 2006;355(5):488–98. doi:10.1056/NEJMra055289
19. Miteva M, Romanelli P, Kirsner RS. Lipodermatosclerosis. Dermatol Ther. 2010;23(4):375–88. doi:10.1111/j.1529-8019.2010.01338.x
20. Grey JE, Harding KG, Enoch S. Venous and arterial leg ulcers. BMJ. 2006;332(7537):347–50. doi:10.1136/bmj.332.7537.347
21. Sharma D, D'Souza J, Joshi P. Role of colour Doppler in evaluation of venous abnormalities of lower limb. Int Surg J. 2019;7(1):163. doi:10.18203/2349-2902.isj20195963
22. Gagne PJ, Tahara RW, Fastabend CP, Dzieciuchowicz L, Marston W, Vedantham S, et al. Venography versus intravascular ultrasound for diagnosing and treating iliofemoral vein obstruction. J Vasc Surg Venous Lymphat Disord. 2017;5(5):678–87. doi:10.1016/j.jvsv.2017.04.007
23. Almeida JI. Treatment of Perforating Veins. In: Atlas of Endovascular Venous Surgery. 2nd ed. 2018:265–84. doi:10.1016/B978-0-323-51139-1.00009-7
24. Yilmaz S, Cakir Pekoz B, Dincer N, Deniz S, Oguzkurt L. Classification of reflux patterns in patients with great saphenous vein insufficiency and correlation with clinical

severity. Diagn Interv Radiol. 2021;27(2):219–24. doi:10.5152/dir.2021.19580
25. Raju S. Evaluation of Methods for Detecting Venous Reflux. Arch Surg. 1990;125(11):1463. doi:10.1001/archsurg.1990.01410230057010
26. Nicolaides AN. Investigation of Chronic Venous Insufficiency. Circulation. 2000;102(20):e126. doi:10.1161/01.CIR.102.20.e126
27. Harathi MS, Mohanty SS, Mohapatra CKR, Mohapatra M, Swain BM, Reddy MR, et al. Association between the venous reflux and diameter of great saphenous vein on colour Doppler in patients with varicose veins. Eur J Cardiovasc Med. 2025;15(6):408–14. doi:10.5083/ejcm/25-06-74
28. Meghwal SL, Kharadi AL, Panwar S. A clinical, radiological and operative study of varicose veins of lower limb. Int J Life Sci Biotechnol Pharma Res. 2024. doi:10.69605/ijlbpr_13.11.2024.114
29. Antani MR, Dattilo JB. Varicose Veins. StatPearls. 2025.
30. Nasra K, Negussie E. Sonography Vascular Peripheral Vein Assessment, Protocols, and Interpretation. StatPearls. 2025.
31. Hong KP. Correlation of Clinical Class with Duplex Ultrasound Findings in Lower Limb Chronic Venous Disease. J Chest Surg. 2022;55(3):233–8. doi:10.5090/jcs.22.010
32. Singh AK, Karmacharya RM, Vaidya S, Thapa P, Bhatta G. Ultrasound Color Duplex Parameters of Patients Presenting with Lower Limb Varicose Veins at Outpatient Department of University Hospital of Nepal. Indian J Vasc Endovasc Surg. 2021;8(1):29–34. doi:10.4103/ijves.ijves_11_20
33. Sridhar AS, Mamtha G, Ravi Shankar M, Rashmi BV, Basti BD. Role of Duplex Color Doppler Ultrasonography for Evaluation of Lower Limb Venous Disease in Patients Presenting with Varicose Veins. Eur J Cardiovasc Med. 2019;9(4):118–23. doi:10.61336/ejcm
34. Ummer SB, Kanchana B. A study to compare the usefulness of a careful clinical examination with venous Doppler studies in patients with varicose veins. Int Surg J. 2018;5(6):2107. doi:10.18203/2349-2902.isj20181841
35. Narra RK, Vuyyuru S, Baba Rao P, Putcha A. Role of colour flow duplex sonography in evaluation of varicose veins of lower limbs. J Evid Based Med Healthc. 2018;5(49):3358–62. doi:10.18410/jebmh/2018/684
36. Mehmood H, Murtaza M, Aslam U, Sarwar A, Waqar A, Gohar A. Concordance of Clinical Examination and Duplex Scan Findings for Prediction of Surgery in Patients Presenting with Varicose Vein. Ann Pak Inst Med Sci. 2018;14(2):100–5. doi:10.48036/apims.v14i2.100
37. Prabhu MA, Natarajan K, Smile SR. Comparison of clinical tests and Doppler ultrasound in the preoperative assessment of lower extremity varicose veins. Indian J Vasc Endovasc Surg. 2017;4(2):51. doi:10.4103/ijves.ijves_5_17
38. Azhar MA. Role of colour flow duplex sonography in evaluation of chronic venous insufficiency in lower limbs. Int J Chronic Venous Insuff Radiol. 2017;2(3):80–4.
39. Uddesh S, Singh K, Meshram S. Colour Doppler evaluation of varicose veins. Int J Res Med Sci. 2016;67–73. doi:10.18203/2320-6012.ijrms20160006
40. Khilnani NM. Duplex Ultrasound Evaluation of Patients with Chronic Venous Disease of the Lower Extremities. AJR Am J Roentgenol. 2014;202(3):633–42. doi:10.2214/AJR.13.11465
41. Meyer T, Cavallaro A, Lang W. Duplex ultrasonography in the diagnosis of incompetent Cockett veins. Eur J Ultrasound. 2000;11(3):175–80. doi:10.1016/S0929-8266(00)00085-9.