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ROLE OF MAGNETIC RESONANCE VENOGRAPHY IN EVALUATION OF LOWER LIMB VENOUS PATHOLOGIES

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ABSTRACT

Background: Lower-limb venous disorders encompass a wide spectrum of conditions, including deep vein thrombosis, chronic venous insufficiency, varicose veins and venous malformations. Doppler ultrasonography is commonly used for initial evaluation; however, assessment of proximal veins, disease extent and complex venous anatomy may be limited. Magnetic resonance venography (MRV) provides comprehensive non-invasive visualization of the lower-limb venous system and may provide additional anatomical information.

Aim: To evaluate the role of magnetic resonance venography in the assessment of lower-limb venous pathologies and to compare its findings with Doppler ultrasonography.

Methods: This hospital-based cross-sectional observational study included 50 patients with suspected lower-limb venous pathology who underwent Doppler ultrasonography followed by MRV. Patients were evaluated for suspected deep vein thrombosis, chronic venous insufficiency, varicose veins and venous malformations. MRV was performed using a 3-Tesla MRI system with non-contrast time-of-flight and phase-contrast sequences, covering the venous system from the pelvis to the ankles. The iliac, femoral, popliteal and calf veins were assessed for thrombosis, reflux, obstruction, collateral formation, anatomical variations, chronic venous changes and venous malformations. MRV findings were compared with Doppler ultrasonography. Diagnostic performance was assessed using sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy. Interobserver agreement was evaluated using Cohen's kappa.

Results: The mean age of the study population was 46.2 ± 12.8 years, with males comprising 56%. Limb swelling (82%) and pain (76%) were the predominant clinical presentations. Suspected deep vein thrombosis was the commonest indication (48%). MRV demonstrated acute thrombosis in 36%, chronic thrombosis in 18%, venous reflux/chronic venous insufficiency in 28%, venous malformations in 8%, and no abnormality in 10% of patients. MRV achieved 100% anatomical coverage of the iliac, femoral, popliteal and calf veins and detected more thrombotic segments than Doppler at all levels. Overall, venous abnormalities were detected in 90% by MRV compared with 74% by Doppler, with 8 additional cases identified by MRV. MRV detected venous reflux in 14 versus 10, collateral veins in 12 versus 4, and venous wall thickening in 11 versus 3 patients compared with Doppler. All four venous malformations were detected by MRV compared with two by Doppler. MRV demonstrated 95.6% sensitivity, 88.9% specificity, 93.5% PPV, 91.7% NPV and 92% overall accuracy. Interobserver agreement was high for thrombosis (κ=0.86), extent of disease (κ=0.82) and venous malformations (κ=0.90). Additional findings included pelvic venous compression in 12%, collateral venous channels in 28%, and musculoskeletal abnormalities in 10%. MRV findings resulted in treatment modification in 34%, assisted surgical planning in 24%, and reduced the need for invasive procedures in 58% of patients.

Conclusion: MRV demonstrated high diagnostic performance and provided more comprehensive anatomical assessment of lower-limb venous pathology than Doppler ultrasonography in the study population. Its ability to demonstrate additional thrombotic segments, chronic venous changes, collateral pathways, proximal venous compression and venous malformations highlights its value as a complementary problem-solving modality, particularly in patients with extensive, proximal or anatomically complex venous disease.

KEYWORDS: Magnetic resonance venography; Lower-limb venous disease; Deep vein thrombosis; Chronic venous insufficiency; Doppler ultrasonography; Venous malformation; Varicose veins.

INTRODUCTION

Lower-limb venous disorders comprise a broad spectrum of conditions ranging from superficial venous insufficiency and varicose veins to deep-vein thrombosis (DVT), chronic venous disease, venous malformations and post-thrombotic changes. These disorders represent an important cause of lower-limb morbidity and may present with pain, swelling, skin changes, venous ulceration or complications related to venous obstruction. Increasing age, obesity, prolonged standing, previous venous disease and other acquired risk factors contribute to the growing clinical burden of venous pathology. Accurate assessment of the venous system is therefore essential for appropriate diagnosis and management. [1]

Venous disease can be broadly categorized into thrombotic, obstructive, reflux-related and congenital or acquired malformative disorders. DVT refers to formation of thrombus within the deep venous system, whereas chronic venous insufficiency is characterized by impaired venous return, commonly resulting from valvular incompetence, venous obstruction or both. Chronic venous disease may progress from uncomplicated venous symptoms and varicosities to edema, skin changes, lipodermatosclerosis and venous ulceration. [2]

The clinical spectrum and management of lower-limb venous disease have expanded considerably with improved understanding of venous haemodynamics and disease progression. Deep venous obstruction and post-thrombotic changes may involve venous segments that are difficult to evaluate clinically, particularly the iliac and pelvic veins. Persistent obstruction or reflux can result in collateral formation and progressive chronic venous hypertension. Recognition of these changes is important because the anatomical extent of disease may directly influence therapeutic planning. [3]

The burden of venous disease also increases with advancing age and accumulation of risk factors. Varicose veins and chronic venous insufficiency are frequently encountered in clinical practice, while DVT remains an important cause of acute limb swelling and carries the potential for pulmonary embolism and long-term post-thrombotic morbidity. Chronic venous disease can substantially affect mobility, functional status and quality of life, particularly when edema, skin ulceration or recurrent thrombosis develops. [4]

Clinical evaluation is generally complemented by imaging to establish the presence, location and extent of venous pathology. Duplex ultrasonography (DUS) is widely used as an initial investigation because it provides information regarding venous compressibility, intraluminal thrombus, venous flow and reflux without ionizing radiation. However, assessment may be technically limited in obese patients, in the presence of extensive edema, and particularly when pathology involves the pelvic or iliac venous segments. [5]

Magnetic resonance venography (MRV) provides a non-invasive method for evaluating the venous system beyond the routinely accessible peripheral segments. It permits visualization of deep venous anatomy, venous obstruction, thrombus, collateral pathways and anatomical variations without ionizing radiation. Advances in MR techniques have improved spatial resolution and vascular assessment, increasing the potential role of MRV in patients in whom conventional imaging is inconclusive or insufficient to define the full extent of disease. [6]

MRV may be particularly valuable in chronic venous disease, where identification of proximal venous obstruction, collateralization and altered venous anatomy can contribute to treatment planning. Evaluation of the iliac and pelvic venous segments is clinically relevant because disease in these regions may be missed or incompletely characterized by routine peripheral ultrasound. Comparative studies have consequently investigated the role of MRV alongside conventional ultrasound in patients with chronic lower-extremity venous disorders. [7]

Evidence from systematic reviews has further examined the diagnostic utility of MRV for DVT. MRV can provide comprehensive visualization of the deep venous system and may be useful when ultrasound findings are equivocal, technically inadequate or discordant with clinical suspicion. Its ability to evaluate proximal and distal venous segments in a single examination is an additional advantage in selected patients. [8]

Meta-analytic evidence has also demonstrated the diagnostic potential of MRV in chronic venous disease, supporting its use as a complementary imaging modality when detailed anatomical assessment is required. Nevertheless, MRV is not intended to replace DUS in every patient; rather, its value lies in providing additional anatomical and diagnostic information when conventional evaluation does not adequately define the disease. [9]

Despite these advances, evidence describing the comprehensive application of MRV for different lower-limb venous pathologies remains comparatively limited in the Indian setting. Evaluation of thrombotic disease, chronic venous insufficiency, venous malformations and proximal venous abnormalities within the same clinical population may provide useful information regarding the additional diagnostic contribution of MRV. [10]

Therefore, the present study was undertaken to evaluate the role of magnetic resonance venography in the assessment of lower-limb venous pathologies, with particular emphasis on identifying thrombotic and non-thrombotic abnormalities, defining their anatomical extent, and assessing the diagnostic contribution of MRV in comparison with conventional Doppler ultrasonography.

METHODOLOGY

Study Design

The present study was designed as a hospital-based cross-sectional observational study to evaluate the role of magnetic resonance venography (MRV) in the assessment of lower-limb venous pathologies. The study focused on patients presenting with clinical suspicion of venous disease who had undergone Doppler ultrasonography and were subsequently referred for further evaluation with MRV. The study assessed the presence, anatomical distribution and extent of venous abnormalities and compared the findings obtained by Doppler ultrasonography with those obtained by MRV.

Study Setting

The study was conducted in the Department of Radio-Diagnosis and Imaging, Sree Balaji Medical College and Hospital, Chromepet, Chennai, Tamil Nadu. The institution is a tertiary-care teaching hospital catering to patients from Chennai and the surrounding districts and provides evaluation and management of a wide spectrum of vascular and venous disorders.

Study Period

The study was conducted over a period of 18 months following approval from the Institutional Human Ethics Committee. Patient recruitment and data collection were carried out during the approved study period.

Study Population

The study population consisted of patients referred to the Department of Radio-Diagnosis and Imaging for evaluation of suspected lower-limb venous pathology. The participants had undergone lower-limb Doppler ultrasonography for relevant clinical indications and either demonstrated venous abnormalities or had equivocal Doppler findings warranting further evaluation by MRV. The clinical spectrum included patients with suspected deep vein thrombosis, chronic venous insufficiency, varicose veins and venous malformations.

Sample Size

A total of 50 patients were included in the study. The sample size was determined based on the feasibility of recruitment, availability of eligible patients during the study period and prior institutional experience with similar imaging-based observational studies.

Sampling Technique

Purposive sampling was employed for participant recruitment. Eligible patients fulfilling the predefined inclusion criteria during the study period were recruited into the study.

Inclusion Criteria

Patients with a clinical history suggestive of varicose veins, chronic venous insufficiency or suspected deep vein thrombosis were eligible for inclusion. Patients referred for further evaluation of lower-limb venous pathology following Doppler ultrasonography were also included. Patients who were willing to participate in the study and provide informed consent were recruited.

Exclusion Criteria

Patients with contraindications to magnetic resonance imaging were excluded. These included individuals with cardiac pacemakers, cochlear implants, non-MRI-compatible metallic implants or retained metallic foreign bodies. Patients with severe claustrophobia, pregnancy, previous lower-limb venous surgery or endovascular interventions, severe systemic comorbidities, inability to provide informed consent, recent anticoagulant therapy, and active infection or inflammatory conditions involving the lower limbs were also excluded.

Ethical Considerations

Ethical approval was obtained from the Institutional Human Ethics Committee of Sree Balaji Medical College and Hospital before commencement of the study. Written informed consent was obtained from all participants in their local language. Participation was voluntary, and confidentiality of participant information was maintained throughout the study. Each participant was assigned a unique study identification number, and personal identifiers were not disclosed during data analysis or publication.

Study Tools and Data Collection

Data were collected using a structured study proforma designed specifically for the present study. Demographic information including age, sex, hospital identification number and contact details was recorded. Relevant clinical history and presenting complaints were documented. Imaging information obtained from Doppler ultrasonography and MRV was subsequently recorded in the study proforma. MRV examinations were performed using a 3 Tesla MRI system.

Doppler Ultrasonography

All participants underwent lower-limb Doppler ultrasonography before MRV. Doppler findings were documented with respect to the presence and location of venous abnormalities and were subsequently compared with MRV findings. The comparison included assessment of venous thrombosis, anatomical distribution and extent of venous disease, chronic venous insufficiency-related changes, venous reflux and other detectable abnormalities. Where clinically indicated, findings from conventional venography were also reviewed.

Magnetic Resonance Venography Protocol

Magnetic resonance venography was performed using a 3 Tesla MRI scanner. Patients were positioned in the supine position, and imaging was performed from the pelvis to the ankles to provide comprehensive assessment of the lower-limb venous system. Non-contrast MR venography techniques were employed using time-of-flight (TOF) and phase-contrast (PC) sequences. These sequences were used to assess venous anatomy, venous patency, the presence of thrombus and venous flow characteristics. Non-contrast techniques were preferred to avoid administration of gadolinium-based contrast agents and their associated risks while providing adequate diagnostic information.

The MRV examination provided assessment of both proximal and distal venous anatomy. The major venous segments evaluated included the iliac veins, femoral veins, popliteal veins and calf veins. Complete evaluation of these segments was achieved in all 50 study participants, allowing assessment of the venous system from the pelvis to the distal lower limb.

Image Interpretation

All MRV examinations were initially reviewed and interpreted by a board-certified radiologist with expertise in vascular imaging. A second independent radiologist subsequently reviewed the MRV images without access to the findings of the first observer. This independent assessment was performed to evaluate interobserver agreement. In cases of discrepancy between the two observers, the findings were resolved by consensus.

The imaging assessment focused on the presence, location and extent of venous pathology. Particular attention was given to venous thrombus, venous reflux, venous obstruction, collateral venous formation and anatomical variations. The imaging assessment also included characterization of acute and chronic thrombotic changes, chronic venous insufficiency-related abnormalities and venous malformations.

Anatomical Assessment

The lower-limb venous system was assessed systematically from the pelvis to the ankle. The iliac, femoral, popliteal and calf venous segments were evaluated for patency and abnormalities. Segment-wise assessment was performed to identify

the anatomical distribution and extent of thrombotic disease. This enabled comparison of the ability of Doppler ultrasonography and MRV to identify venous involvement at different anatomical levels.

Comparison of Doppler Ultrasonography and MRV

MRV findings were compared with the preceding Doppler ultrasonography findings to assess diagnostic concordance and the additional information obtained from MRV. The comparison included the overall detection of venous pathology, segment-wise detection of thrombosis, identification of chronic venous insufficiency features, detection of venous malformations and identification of abnormalities not demonstrated on Doppler ultrasonography.

Outcome Measures

The primary outcome measure was the diagnostic performance of MRV in detecting lower-limb venous pathologies. Secondary outcome measures included assessment of venous anatomy, determination of the extent of venous disease, identification of additional findings not detected on ultrasonography and assessment of interobserver agreement.

The diagnostic performance of MRV was assessed using sensitivity, specificity, positive predictive value, negative predictive value and overall diagnostic accuracy. The study also assessed the anatomical distribution of thrombotic involvement and the ability of MRV to identify additional venous abnormalities.

Assessment of Interobserver Agreement

Interobserver agreement between the two radiologists was assessed using Cohen's kappa coefficient. Agreement was evaluated for important MRV findings, including the presence of thrombosis, the extent of venous involvement and identification of venous malformations. Discrepant findings were reviewed and resolved by consensus after the independent assessments.

Assessment of Clinical Impact

The contribution of MRV to clinical management was documented based on the information obtained from the examination. The assessment included whether MRV findings resulted in modification of treatment decisions, assisted in surgical or procedural planning, provided additional anatomical information or helped avoid invasive conventional venography.

Follow-up

The dissertation methodology documented clinical follow-up at 1 month, 3 months and 6 months following imaging to assess disease progression, response to treatment and clinical outcomes. Repeat MRV or other imaging modalities were performed when clinically indicated.

Data Management

All collected data were entered into a pre-designed data collection sheet and subsequently transferred to a digital database for statistical analysis. Data accuracy was maintained through double-entry verification. Participant information was maintained using study identification numbers to preserve confidentiality.

Statistical Analysis

Statistical analysis was performed using standard statistical software. Descriptive statistics were used to summarize demographic characteristics and clinical variables. Continuous variables were analyzed using appropriate statistical tests according to their distribution, while categorical variables were summarized as frequencies and percentages.

For paired continuous variables, the paired t-test was used when the data followed an appropriate parametric distribution, while the Wilcoxon signed-rank test was used for non-parametric paired data. Categorical variables were analyzed using the chi-square test. Diagnostic performance was assessed by calculating sensitivity, specificity, positive predictive value, negative predictive value and overall diagnostic accuracy. Interobserver agreement was assessed using Cohen's kappa coefficient. A p-value of <0.05 was considered statistically significant.

Confidentiality and Data Protection

All study-related information was handled confidentially. Participant data were recorded using unique study identification numbers, and personal identifiers were not disclosed during statistical analysis or dissemination of study findings. The collected data were used exclusively for the purposes of the study and maintained in accordance with institutional ethical requirements.

RESULTS

TABLE 1. Baseline Demographic and Clinical Characteristics of the Study Population (n = 50)

Variable	Category	n (%) / Mean ± SD
Age (years)	Mean ± SD	46.2 ± 12.8
Sex	Male	28 (56.0)
	Female	22 (44.0)
Clinical presentation	Limb swelling	41 (82.0)
	Pain	38 (76.0)
	Varicose veins	26 (52.0)
	Skin changes	19 (38.0)
	Non-healing ulcer	11 (22.0)

Table 1. Baseline Demographic and Clinical Characteristics

The study population had a mean age of 46.2 ± 12.8 years, with males comprising 56%. Limb swelling (82%) and pain (76%) were the predominant clinical presentations, while varicose veins, skin changes, and non-healing ulcers were also observed.

TABLE 2. Clinical Indications and MR Venography Findings in the Study Population (n = 50)

Domain	Finding	n (%)
Suspected pathology at referral	Deep vein thrombosis	24 (48.0)
	Chronic venous insufficiency	14 (28.0)
	Varicose veins	8 (16.0)
	Venous malformation	4 (8.0)
Final MRV finding	Acute thrombosis	18 (36.0)
	Chronic thrombosis	9 (18.0)
	Venous reflux / chronic venous insufficiency	14 (28.0)
	Venous malformation	4 (8.0)
	No abnormality detected	5 (10.0)

Table 2. Clinical Indications and MRV Findings

DVT was the commonest clinical indication (48%). MRV demonstrated acute thrombosis in 36% and chronic thrombosis in 18% of patients, while venous reflux was identified in 28%. Venous malformations were detected in 8%, and 10% had no MRV abnormality.

TABLE 3. Anatomical Coverage and Segment-wise Detection of Deep Vein Thrombosis by Doppler Ultrasonography and MRV

A. Anatomical coverage achieved by MRV

Venous segment	Patients evaluated by MRV, n (%)
Iliac veins	50 (100.0)
Femoral veins	50 (100.0)
Popliteal veins	50 (100.0)
Calf veins	50 (100.0)

B. Segment-wise detection of thrombotic involvement

Venous segment	Doppler ultrasound, n	MRV, n	Additional segments detected by MRV
Iliac veins	6	12	+6
Femoral veins	18	22	+4
Popliteal veins	16	21	+5
Calf veins	9	17	+8

Table 3. Anatomical Coverage and Segment-wise DVT Detection

MRV achieved 100% evaluation of the iliac, femoral, popliteal, and calf veins. It identified more thrombotic segments than Doppler at every anatomical level, with the greatest differences observed in the iliac and calf veins.

TABLE 4. Comparative Detection of Venous Abnormalities by Doppler Ultrasonography and MRV

Parameter / abnormality	Doppler ultrasound	MRV	MRV additional detection
Overall detected cases	37 (74.0%)	45 (90.0%)	+8 cases
Chronic venous insufficiency features			
└ Venous reflux	10	14	+4
└ Collateral veins	4	12	+8
└ Venous wall thickening	3	11	+8
Venous malformations (n = 4)	2 (50.0%)	4 (100.0%)	+2

Table 4. Comparative Detection of Venous Abnormalities

MRV detected abnormalities in 90% of patients compared with 74% by Doppler. MRV also identified more features of chronic venous disease and detected all four venous malformations, compared with two detected by Doppler.

TABLE 5. Diagnostic Performance, Interobserver Agreement, Incidental Findings and Clinical Impact of MRV

A. Diagnostic performance

Diagnostic parameter	MRV
Sensitivity	95.6%
Specificity	88.9%
Positive predictive value	93.5%
Negative predictive value	91.7%
Overall diagnostic accuracy	92.0%

B. Interobserver agreement

MRV parameter	Cohen's κ
Presence of thrombosis	0.86
Extent of disease	0.82
Venous malformation	0.90

C. Additional/incidental findings identified on MRV

Finding	n (%)
Pelvic venous compression	6 (12.0)

Collateral venous channels	14 (28.0)
Musculoskeletal abnormalities	5 (10.0)

D. Impact on clinical management

Management consequence	**n (%)**
Treatment modification	17 (34.0)
Assistance in surgical planning	12 (24.0)
Reduced need for invasive procedures	29 (58.0)

Table 5. Diagnostic Performance, Reproducibility and Clinical Impact

MRV demonstrated sensitivity of 95.6%, specificity of 88.9%, PPV of 93.5%, NPV of 91.7%, and overall accuracy of 92%. Interobserver agreement was high (κ=0.82–0.90). MRV findings resulted in treatment modification in 34% of patients, assisted surgical planning in 24%, and reduced the need for invasive procedures in 58%.

Figure 1. Clinical Presentation of Patients with Lower-Limb Venous Disorders

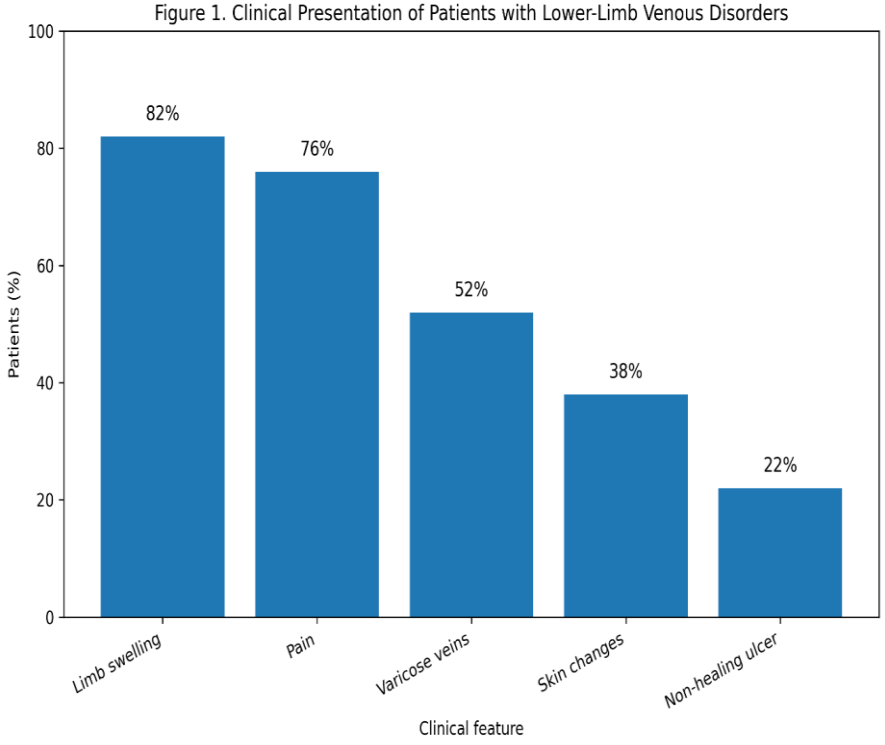


Figure 2. MR Venography Findings in Lower-Limb Venous Disorders

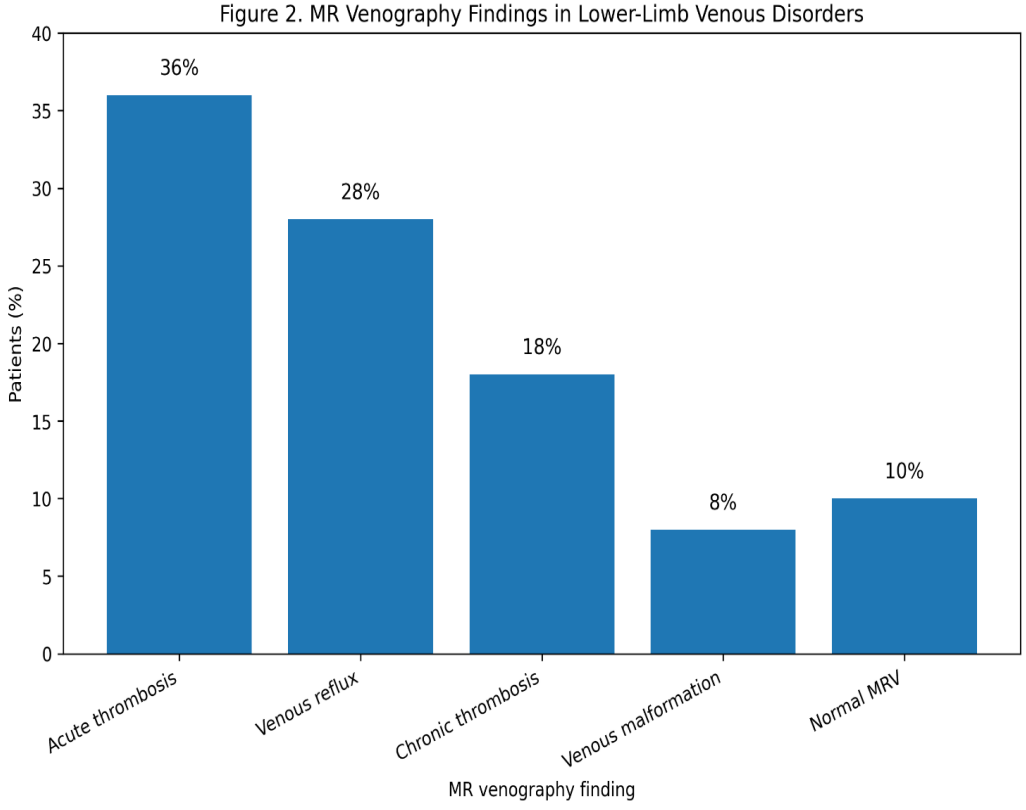
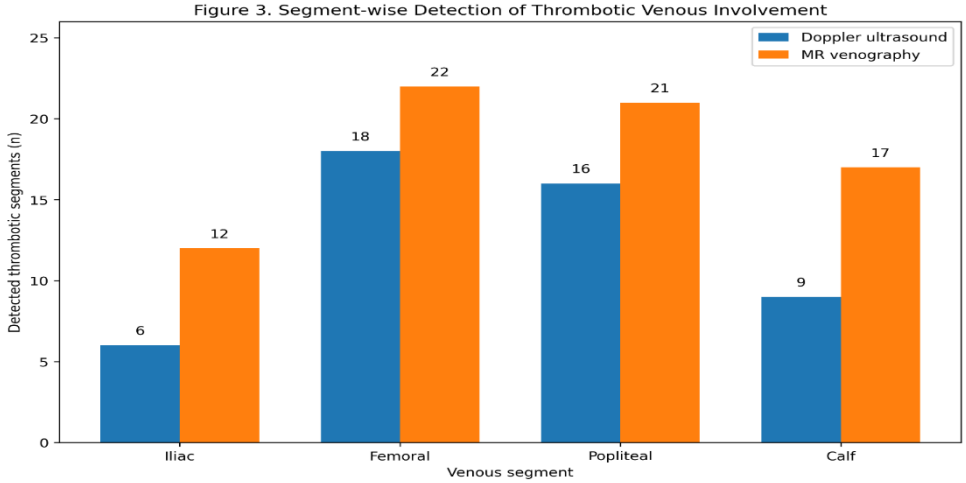


Figure 3. Segment-wise Detection of Thrombotic Venous Involvement



The present study included 50 patients with suspected lower-limb venous pathology, with a mean age of 46.2 ± 12.8 years and a slight male predominance (56%). Limb swelling (82%) and pain (76%) were the most frequent clinical presentations. Suspected DVT was the commonest referral indication (48%). On MRV, acute thrombosis was identified in 36%, chronic thrombosis in 18%, venous reflux/chronic venous insufficiency in 28%, venous malformations in 8%, while 10% had no demonstrable abnormality. MRV provided complete evaluation of the iliac, femoral, popliteal and calf veins and detected more thrombotic segments than Doppler at every level, particularly in the iliac (12 vs 6) and calf veins (17 vs 9). Overall, MRV detected venous abnormalities in 90% compared with 74% by Doppler, and detected all four venous malformations compared with two by Doppler. The diagnostic performance of MRV showed 95.6% sensitivity, 88.9% specificity, 93.5% PPV, 91.7% NPV and 92% overall accuracy. Interobserver agreement was high, with κ values ranging from 0.82 to 0.90. MRV also demonstrated pelvic venous compression in 12%, collateral channels in 28%, and musculoskeletal abnormalities in 10%; its findings resulted in treatment modification in 34%, assistance with surgical planning in 24%, and reduced need for invasive procedures in 58% of patients.

Chronic venous disease represents a clinically heterogeneous group of disorders that may manifest with edema, pain, varicosities, skin changes and ulceration. The WHO [11] has emphasized the substantial clinical burden associated with chronic venous disorders. In the present study, the predominance of limb swelling and pain reflects the symptomatic burden of venous disease, while the presence of skin changes and non-healing ulcers indicates more advanced chronic venous involvement.

The commonest clinical indication in the present study was suspected deep vein thrombosis (48%), followed by chronic venous insufficiency (28%), varicose veins (16%) and venous malformation (8%). MRV demonstrated acute thrombosis in 36%, chronic thrombosis in 18%, venous reflux/chronic venous insufficiency in 28%, venous malformations in 8%, while 10% had no demonstrable abnormality. Kumar et al. [12] describe venous pathology as including thrombotic, obstructive, reflux-related and developmental vascular abnormalities. The present findings similarly demonstrate that patients referred with suspected venous disease may have varied underlying pathologies rather than isolated DVT.

In the present study, 100% evaluation of the iliac, femoral, popliteal and calf veins was achieved with MRV. MRV detected more thrombotic segments than Doppler at every anatomical level. Iliac involvement was detected in 12 segments by MRV versus 6 by Doppler, femoral involvement in 22 versus 18, popliteal involvement in 21 versus 16, and calf involvement in 17 versus 9, with the greatest additional detection in the calf (+8) and iliac (+6) veins. Nicolaides et al. [13] emphasize the importance of identifying both reflux and obstructive components when evaluating chronic venous disease. The present findings further demonstrate the advantage of comprehensive anatomical assessment when defining the distribution and extent of venous thrombosis.

MRV detected overall venous abnormalities in 45 patients (90%), compared with 37 patients (74%) by Doppler, representing 8 additional cases. For chronic venous insufficiency, MRV demonstrated venous reflux in 14 versus 10, collateral veins in 12 versus 4, and venous wall thickening in 11 versus 3 patients. Rajendran et al. [14] reported the utility of MRV in evaluating varicose venous disease and detailed venous anatomy. The present findings support the additional value of MRV in demonstrating structural abnormalities associated with chronic venous disease, particularly collateralization and venous wall changes.

The detection of venous malformations was also higher with MRV. In the present study, MRV identified all 4 venous malformations (100%), whereas Doppler detected 2 of 4 (50%). This difference demonstrates the value of cross-sectional venous imaging in patients with complex vascular anatomy. CDC [15] recognizes DVT and other venous thromboembolic disorders as important causes of morbidity requiring appropriate diagnostic assessment. In patients with atypical presentations or suspected complex vascular abnormalities, the broader anatomical coverage of MRV may provide information not completely obtained by ultrasound.

Chronic venous insufficiency accounted for 28% of the final MRV findings. Eberhardt et al. [16] describe chronic venous insufficiency as a condition associated with edema, varicosities, skin changes and ulceration. The present study demonstrated a similar clinical spectrum, with 82% having limb swelling, 52% varicose veins, 38% skin changes and 22% non-healing ulcers. MRV additionally demonstrated reflux, collateral formation and venous wall thickening, indicating that chronic venous disease frequently involves multiple structural abnormalities rather than isolated reflux.

The Indian relevance of these findings is important because the present study was conducted in a tertiary-care population. Patel et al. [17] have discussed the burden and clinical spectrum of lower-extremity venous insufficiency in the Indian context. In the present study, the presence of advanced manifestations such as skin changes and non-healing ulcers, together with collateral venous channels in 28%, demonstrates the need for detailed evaluation of patients presenting with chronic symptoms.

According to the American College of Radiology [18], duplex ultrasonography remains an appropriate initial imaging modality for most lower-extremity venous disease, while MRV can provide additional anatomical information in selected patients. This is consistent with the present study design, in which patients underwent Doppler evaluation before MRV. Therefore, the higher detection rate with MRV should be interpreted as demonstrating its complementary and problem-solving role, particularly when Doppler does not completely define the extent or anatomy of disease, rather than suggesting replacement of Doppler as the first-line investigation.

The present study demonstrated additional thrombotic involvement at all evaluated venous levels. Gloviczki et al. [19] emphasize the importance of duplex assessment and anatomical risk stratification in lower-extremity venous disease. In the present study, the ability of MRV to evaluate the entire venous pathway from the iliac veins to the calf veins allowed more extensive mapping of thrombotic involvement. The greater detection in the iliac and calf segments is particularly relevant because these regions may be incompletely assessed or technically challenging on routine ultrasound.

MRV demonstrated 95.6% sensitivity, 88.9% specificity, 93.5% PPV, 91.7% NPV and 92% overall accuracy in the present study. Sharma et al. [20] reported the clinical utility of MRV in Indian patients with DVT, supporting its role in the assessment of thrombotic venous disease. The high sensitivity observed in the present study indicates that MRV was able to identify most patients with venous abnormalities within this selected cohort. The specificity of 88.9% and PPV of 93.5% further indicate good agreement between MRV findings and the study reference comparator.

The higher abnormality detection with MRV is clinically relevant. Mayo Clinic [21] describes duplex ultrasound as an important investigation for venous disease, with additional imaging selected when further anatomical information is required. In the present study, MRV identified abnormalities in 90% compared with 74% by Doppler and additionally demonstrated pelvic venous compression in 12%, collateral channels in 28%, and musculoskeletal abnormalities in 10%. These additional findings demonstrate the broader anatomical information available from MRV.

Rabe et al. [22] emphasize the importance of appropriate characterization of venous pathology before treatment decisions. In the present study, MRV detected all four venous malformations, compared with only two detected by Doppler, and demonstrated additional collateral pathways and proximal venous abnormalities. Such findings may be particularly relevant in patients in whom treatment depends on defining the full extent and anatomical configuration of venous disease.

The European Society for Vascular Surgery guidelines described by De Maeseneer et al. [23] emphasize anatomical and haemodynamic assessment in chronic venous disease. The present study supports this approach, as MRV identified abnormalities extending beyond the primary site of clinical suspicion. Pelvic venous compression was identified in 6 patients (12%), while collateral venous channels were identified in 14 patients (28%). These findings indicate that lower-limb symptoms may be associated with more proximal or extensive venous abnormalities requiring assessment beyond the routinely examined peripheral segments.

Gupta et al. [24] compared MRV and ultrasound in lower-limb venous insufficiency and highlighted the potential of MRV to provide additional anatomical information. The present study similarly demonstrated greater detection of reflux (14 vs 10), collateral veins (12 vs 4) and venous wall thickening (11 vs 3) with MRV. However, these additional MRV findings should be interpreted as additional abnormalities demonstrated by MRV rather than automatically considered Doppler false-negative findings, because Doppler was used as the reference comparator in the present study. This methodological distinction is important when interpreting diagnostic performance.

The reproducibility of MRV interpretation was high, with Cohen's κ of 0.86 for thrombosis, 0.82 for extent of disease and 0.90 for venous malformations. These values indicate substantial to near-perfect interobserver agreement and support the consistency of MRV interpretation in the present study.

Finally, the present study demonstrated a measurable clinical impact of MRV. MRV findings resulted in treatment modification in 34%, assisted surgical planning in 24%, and reduced the need for invasive procedures in 58% of patients. NICE [25] recommends structured diagnostic assessment of varicose veins with duplex ultrasonography and appropriate further evaluation when required. The present findings indicate that MRV may provide useful additional anatomical information in selected patients with complex thrombosis, proximal venous disease, collateralization, venous malformations or inconclusive ultrasound findings.

CONCLUSION

The present study demonstrates that magnetic resonance venography (MRV) is a valuable complementary imaging modality in the evaluation of lower-limb venous pathologies. Among 50 patients, MRV detected venous abnormalities in 90%, compared with 74% by Doppler ultrasonography, with additional thrombotic segments identified at the iliac, femoral, popliteal and calf levels. The greatest additional detection was observed in the iliac and calf veins.

MRV demonstrated 95.6% sensitivity, 88.9% specificity, 93.5% positive predictive value, 91.7% negative predictive value and 92% overall diagnostic accuracy. It also provided better characterization of chronic venous insufficiency, detecting venous reflux, collateral veins and venous wall thickening more frequently than Doppler. All four venous malformations were identified by MRV compared with two by Doppler.

The study further demonstrated the ability of MRV to provide additional anatomical information, including pelvic venous compression (12%), collateral venous channels (28%) and musculoskeletal abnormalities (10%). High interobserver

agreement was observed for thrombosis, disease extent and venous malformations, with Cohen's κ ranging from 0.82 to 0.90.

MRV findings contributed to treatment modification in 34%, assisted surgical planning in 24%, and reduced the need for invasive procedures in 58% of patients. Thus, MRV can serve as an important problem-solving and complementary investigation following Doppler ultrasonography, particularly in patients with suspected extensive, proximal, complex or anatomically difficult lower-limb venous disease.

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