



## ANATOMICAL AND PATHOPHYSIOLOGICAL FEATURES OF VARICOSE VEINS: USING DUPLEX ULTRASOUND

Dr. Shaziya Afzal<sup>1</sup>, Dr. Sabia Nazir<sup>2</sup>, Dr. Ghulam Mohammad Bhat<sup>3</sup>, Dr. Gulzar Ahmad Haji<sup>4</sup>

<sup>1</sup>Senior Resident, Department of Anatomy, GMC, Srinagar

<sup>2</sup>Associate Professor, Department of Anatomy, GMC, Srinagar

<sup>3</sup>Professor and Head, Department of Anatomy, GMC, Srinagar

<sup>4</sup>Radiologist, Director and owner of Haji Diagnostic and Imaging Centre shopian, J&K

**\*Corresponding Author:** Dr. Shaziya Afzal

**\*Resident,** Department of Anatomy, Government Medical College Srinagar Email: shaziyaliba3456@gmail.com

### Abstract

**Background:** Varicose veins are a common manifestation of chronic venous insufficiency, often associated with incompetence at key venous junctions and perforator veins. Duplex ultrasonography is the diagnostic modality of choice for evaluating both the anatomical and functional aspects of venous abnormalities. This study aimed to assess the anatomical patterns and distribution of saphenous and perforator incompetence among patients with varicose veins using duplex ultrasound. **Methods:** A six-month prospective study was conducted in the Departments of Anatomy and Radiodiagnosis, Government Medical College, Srinagar. Of 400 patients presenting with lower limb venous symptoms, 262 (65.5%) diagnosed with varicose veins were included for detailed assessment. Duplex ultrasonography (Philips Affiniti 50/70) with Valsalva and distal compression maneuvers was used to evaluate junctional and perforator incompetence. Data were analyzed using SPSS v20.0, with p-values <0.05 considered statistically significant. **Results:** Out of 262 patients with varicose vein, 168 (64.1%) demonstrated junction incompetence. Of these, 106 (63.1%) had saphenofemoral junction (SFJ) incompetence, 14 (8.3%) had saphenopopliteal junction (SPJ) incompetence, and 48 (28.6%) had incompetence at both SFJ and SPJ. Perforator incompetence was noted in 213 patients (81.3%), while 49 (18.7%) had competent perforators. The most commonly affected site was the medial mid-third below the knee (70.9%), followed by the medial lower third below the knee (64.3%). Incompetence in the calf (6.1%) and ankle (4.2%) was less frequent. **Conclusion:** A high prevalence of junctional and perforator incompetence was observed in varicose vein patients, emphasizing the critical role of duplex ultrasonography in diagnosis and treatment planning.

**Keywords:** Varicose veins; Saphenofemoral junction; Saphenopopliteal junction; Perforator incompetence; Duplex ultrasonography; Chronic venous insufficiency; Lower limb venous disorders

### Introduction

Varicose veins are dilated, tortuous superficial veins that most commonly affect the lower limbs and are among the earliest and most visible signs of chronic venous insufficiency (CVI). They result

from structural and functional abnormalities within the venous system, particularly the failure of one-way valves in the superficial, perforator, or deep veins.<sup>1</sup> This incompetence allows retrograde blood flow (venous reflux), leading to venous hypertension, venous wall dilation, and eventual varicosity formation. The condition is highly prevalent, affecting up to 25–30% of the adult population worldwide, with increased incidence among older adults, women, and individuals with prolonged standing occupations, obesity, or a family history of venous disease.<sup>2,3</sup> Anatomically, the lower limb venous system is divided into three components: the superficial veins (e.g., great and small saphenous veins), the deep veins (e.g., femoral and popliteal veins), and the perforator veins that connect the superficial and deep systems.<sup>4</sup> Varicosities most often originate in the superficial system, particularly at the saphenofemoral junction (SFJ) or saphenopopliteal junction (SPJ), where valve failure allows reflux from the deep system into the superficial system. Perforator vein incompetence further exacerbates this reflux, facilitating transmission of high pressures from deep to superficial veins, particularly in the lower leg and ankle regions. The pathophysiology of varicose veins involves both mechanical and biochemical changes. Prolonged venous hypertension leads to endothelial dysfunction, leukocyte activation, and increased inflammatory mediators, which together degrade the extracellular matrix and weaken the venous wall and valves.<sup>5</sup> This cyclic deterioration results in further valve failure and venous dilation. Histologically, varicose veins show reduced smooth muscle content, fragmentation of elastic fibers, and increased collagen deposition, all of which contribute to the loss of vein wall tone and competence.

Duplex ultrasonography has become the diagnostic gold standard for CVI, combining B-mode imaging to visualize anatomical structures with Doppler spectral assessment of blood flow; use of maneuvers such as Valsalva and distal compression enhances sensitivity for detecting reflux. It enables precise mapping of valvular incompetence and reflux at key junctions such as the saphenofemoral (SFJ) and saphenopopliteal (SPJ), as well as perforator veins connecting superficial and deep systems.<sup>6</sup> Perforator vein incompetence is particularly important, as up to 45% of legs with varicose veins exhibit reflux and may contribute to recurrent disease post-treatment.<sup>7</sup> Iliac and Adductor perforators especially below-knee are commonly involved and often overlooked during clinical examination, underscoring the value of duplex ultrasonography.<sup>8</sup> Despite the widespread use of duplex ultrasound in CVI assessment, few studies have characterized the anatomical distribution of junctional and perforator incompetence in South Asian populations. This study aims to fill that gap by examining Kashmiri patients with varicose veins, mapping the prevalence of SFJ, SPJ, and perforator reflux, and evaluating the diagnostic utility of duplex ultrasonography. By establishing anatomically specific patterns, we aim to improve preoperative planning, reduce recurrence, and guide optimal treatment strategies.

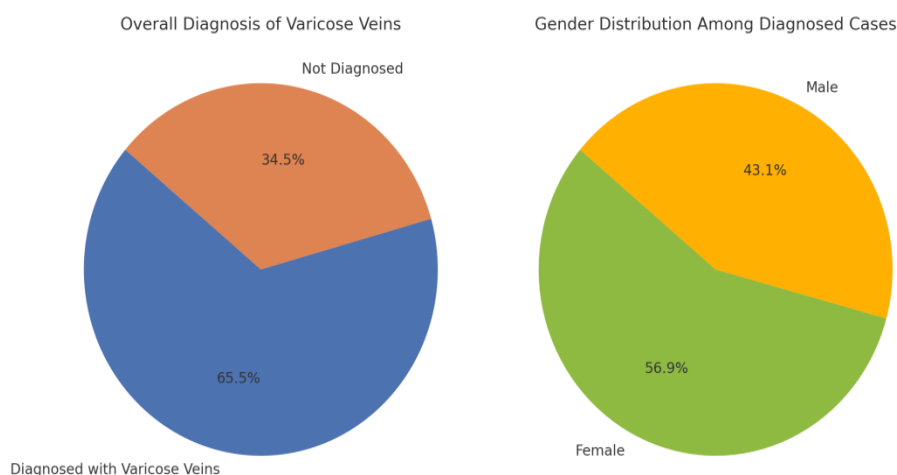
## **Material and methods**

This prospective cohort study was conducted over a six-month period in the Postgraduate Department of Anatomy at Government Medical College (GMC), Srinagar, in collaboration with the Department of Radiodiagnosis. The study aimed to evaluate the anatomical distribution and patterns of junctional and perforator vein incompetence in patients with clinically suspected varicose veins, using duplex ultrasonography as the primary diagnostic modality. Ethical clearance was obtained prior to initiation from the Institutional Ethics Committee (Reference No. IRBGMC-SGR/Anat/504), and informed written consent was obtained from all participants after explaining the study purpose and procedures. Of the 400 patients presenting with lower limb venous symptoms during the study period, 262 patients (65.5%) who were diagnosed with varicose veins were included for detailed evaluation. The inclusion criteria comprised ethnic Kashmiri men and women aged between 17 and 80 years, who exhibited cardinal symptoms of lower limb venous insufficiency and had not undergone any previous treatment for varicose veins or deep vein thrombosis (DVT). Exclusion criteria included non-Kashmiri patients referred for venous Doppler examination, individuals with peripheral arterial disease of the lower limbs, patients younger than 25 years, and those with documented venous malformations or recent DVT.

All enrolled patients underwent duplex ultrasonographic assessment using the Philips Affiniti 50/70 ultrasound system, equipped with a high-frequency linear probe (5–12 MHz). The evaluation was performed by experienced radiologists, with patients positioned standing or in a reverse Trendelenburg position to optimize venous visualization. Both longitudinal and transverse scans were used to assess the great and small saphenous veins, saphenofemoral and saphenopopliteal junctions, and relevant perforator veins. Reflux testing was conducted using standardized Valsalva maneuvers and distal limb compression techniques. Venous incompetence was defined as retrograde flow lasting more than 0.5 seconds, as detected on spectral Doppler tracing. The location, laterality, and severity of junctional and perforator incompetence were documented systematically. Clinical and sonographic data were recorded in structured data forms and entered into Microsoft Excel before being transferred to SPSS software, version 20.0 (SPSS Inc., Chicago, IL, USA) for statistical analysis. Continuous variables, such as age and symptom duration, were expressed as mean  $\pm$  standard deviation (SD), while categorical variables, such as site and frequency of venous incompetence, were presented as counts and percentages. Comparative analysis of continuous data was carried out using the Student's t-test or the Mann–Whitney U-test, depending on the distribution of data. The Chi-square test or Fisher's exact test was applied for analyzing categorical variables. A p-value of less than 0.05 was considered statistically significant, and all statistical tests were two-tailed. Graphical representations such as bar and line diagrams were used to illustrate major findings.

## Results

Of the 400 patients presenting with lower limb venous symptoms during the study period, 262 individuals (65.5%) were diagnosed with varicose veins and subsequently included for detailed evaluation. Among these, 149 (56.8%) were female and 113 (43.2%) were male, reflecting a higher prevalence of varicose veins in women.



**Table 1: Junction incompetence among patients with varicose vein abnormality**

Junction incompetence	Number	Percentage
Present	168	64.1
Absent	94	35.9
<b>Total</b>	<b>262</b>	<b>100</b>

Table 1 presents the distribution of junctional incompetence among patients diagnosed with varicose vein abnormalities. Out of a total of 262 patients assessed, junctional incompetence was identified in 168 individuals, accounting for 64.1% of the cohort. The remaining 94 patients (35.9%) did not exhibit incompetence at any major venous junctions.

**Table 2: Type of junction incompetence among patients with varicose vein abnormality**

Junction incompetence	Number	Percentage
Saphenofemoral Junction (SFJ)	106	63.1
Saphenopopliteal Junction (SPJ)	14	8.3
Both SFJ and SPJ	48	28.6
<b>Total</b>	<b>168</b>	<b>100</b>

Table 2 outlines the distribution of the types of junctional incompetence among the 168 patients who exhibited junctional reflux in the present study. The most common site of incompetence was the saphenofemoral junction (SFJ), observed in 106 patients, accounting for 63.1% of cases. Incompetence at the saphenopopliteal junction (SPJ) was detected in 14 patients (8.3%), while combined incompetence at both SFJ and SPJ was noted in 48 patients (28.6%). These findings highlight the predominance of SFJ incompetence in the pathogenesis of varicose veins, a trend consistently reported in the literature.

**Table 3: Perforator incompetence among patients with varicose vein abnormality**

Perforator incompetence	Number	Percentage
Present	213	81.3
Absent	49	18.7
<b>Total</b>	<b>262</b>	<b>100</b>

Table 3 presents the distribution of perforator incompetence among patients diagnosed with varicose vein abnormalities. Out of the 262 individuals included in the study, perforator incompetence was identified in 213 patients, representing a significant majority of 81.3%. In contrast, 49 patients (18.7%) showed no evidence of incompetence in the perforator veins. These findings underscore the prominent role of perforator vein dysfunction in the pathophysiology of varicose veins.

**Table 4: Level of perforator incompetence among patients with varicose vein abnormality**

Level of perforator incompetence	Number	Percentage
Below knee (medial mid 1/3 <sup>rd</sup> )	151	70.9
Below knee (medial lower 1/3 <sup>rd</sup> )	137	64.3
Calf	13	6.1
Ankle	9	4.2

Table 4 illustrates the anatomical distribution of perforator incompetence among patients with varicose vein abnormalities. The most frequently affected site was the medial mid-third below the knee, observed in 151 patients (70.9%). This was followed closely by incompetence in the medial lower third below the knee, seen in 137 patients (64.3%). In comparison, involvement of the calf and ankle regions was considerably less common, recorded in only 13 (6.1%) and 9 (4.2%) patients, respectively.

## Discussion

Among the 400 patients presenting with lower limb venous symptoms in our study, 262 individuals (65.5%) were clinically and sonographically diagnosed with varicose veins and subsequently included for detailed evaluation. Of these, 149 (56.8%) were female and 113 (43.2%) were male, indicating a higher prevalence of varicose veins among women. This finding is consistent with several large-scale epidemiological studies that have consistently demonstrated a female predominance in the occurrence of varicose veins. For instance, Clark et al., in a UK population-based study, reported a prevalence of 63.2% in women compared to 56.4% in men, highlighting a similar gender disparity. Likewise, the Framingham cohort study also observed a higher incidence of varicose veins among women and attributed this difference to multiple factors including

pregnancy, hormonal fluctuations, and prolonged sedentary or standing occupations.<sup>10</sup> A U.S.-based review further supported this trend, indicating that up to 30% of women develop varicose veins compared to 10–20% of men.<sup>11</sup> Beebe-Dimmer et al. provided a broader range in prevalence estimates, noting that varicose veins affect less than 1% to 73% of women and 2% to 56% of men, reinforcing the pattern of higher prevalence among females.<sup>12</sup> The reasons for this gender discrepancy are multifactorial. Hormonal influences, particularly the effects of estrogen and progesterone, are known to reduce venous wall tone and weaken venous valves, promoting venous dilation and reflux. Additionally, pregnancy-induced hemodynamic changes, such as increased blood volume and pressure on pelvic veins, contribute significantly to venous insufficiency in women. Occupational factors, especially jobs requiring prolonged standing or static posture, may further exacerbate venous pressure and valve incompetence. Thus, the predominance of females among patients with varicose veins in our study reflects a well-documented global trend and underscores the need to consider gender-specific risk factors when developing prevention and management strategies.

In the present study, Duplex ultrasonography revealed that among 262 patients diagnosed with varicose vein abnormalities, junctional incompetence was present in 64.1% of cases. Within this subset, incompetence of the saphenofemoral junction (SFJ) was most prevalent, seen in 63.1% of patients, followed by combined SFJ and saphenopopliteal junction (SPJ) incompetence in 28.6%, and isolated SPJ incompetence in 8.3%. These findings not only emphasize the dominant role of the SFJ in the pathophysiology of varicose veins but also highlight the importance of carefully evaluating both major junctions for comprehensive diagnosis. This pattern of distribution is in close agreement with several previous studies. Bashir et al. reported SFJ incompetence in 41.7% of cases and combined SFJ-SPJ incompetence in 63.88%, which aligns well with our observations.<sup>13</sup> Similarly, Sharma et al. noted a predominance of SFJ incompetence (60.9%) over SPJ (10%), with a significant proportion (30%) showing incompetence at both junctions.<sup>14</sup> Additionally, Arumugam et al.'s work reinforced the clinical relevance of SFJ incompetence, documenting reflux in 63% of examined limbs due to valve dysfunction at this site.<sup>15</sup> They also noted a relatively higher rate of SPJ incompetence (30%) compared to other reports, a figure that still compares closely with the combined incompetence rate (28.6%) observed in our research.<sup>15</sup> The high prevalence of SFJ incompetence in both our study and prior literature can be explained by the anatomical configuration and hemodynamic significance of the SFJ. This junction serves as a critical conduit for venous return from the great saphenous vein into the deep venous system, making it highly susceptible to valvular dysfunction and reflux under conditions of elevated venous pressure. SPJ incompetence, although less common, still plays an important role in disease progression, especially when it occurs concurrently with SFJ incompetence, as such cases may indicate more extensive venous system failure. The presence of combined junctional incompetence is particularly noteworthy as it suggests a more advanced stage of venous insufficiency. These patients may present with more severe clinical symptoms and are likely to benefit from a more aggressive or multimodal treatment approach. Hence, the detailed characterization of junctional involvement via Duplex ultrasound is critical for tailoring management strategies and improving clinical outcomes. Perforator vein incompetence is a major contributor to saphenous reflux and varicose vein development. Perforators connect the superficial and deep venous systems and are classified as thigh or leg perforators, with leg perforators further divided into medial, posterior, and lateral groups. Normally, perforator valves direct blood from superficial to deep veins. When incompetent, these valves allow retrograde flow, increasing superficial venous pressure and leading to venous dilation and reflux. Additionally, failure of check valves in perforators permits pressure from deep veins, especially during muscle contraction, to be transmitted into superficial veins. Given the anatomical variability and subtle nature of early perforator dysfunction, duplex ultrasonography is vital for accurate assessment. In our study, perforator incompetence emerged as a highly prevalent finding among patients with varicose vein abnormalities. Duplex ultrasonography revealed that 81.3% of the 262 patients exhibited incompetence of one or more perforator veins. The most frequently involved sites were the medial mid-third (70.9%) and medial lower third (64.3%) regions

below the knee—locations that are anatomically vulnerable due to their dependence on competent perforators for effective venous drainage. Comparatively fewer patients exhibited perforator incompetence in the calf (6.1%) and ankle (4.2%), suggesting that these distal segments may be less prone to significant hemodynamic disruption or may manifest reflux later in the disease course. These observations are consistent with a growing body of literature emphasizing the vulnerability of these anatomical regions. Sharma et al. reported that among 65 patients with varicose veins, 54 exhibited perforator incompetence, with the highest prevalence in the medial mid-third (72%) and medial lower third (62.9%) below the knee, closely aligning with our findings of 70.9% and 64.3%, respectively.<sup>14</sup> Similarly, Azhar et al. observed incompetence in the medial mid-third (69.5%) and medial lower-third (67.4%), again supporting the pattern documented in our cohort.<sup>16</sup> Delis et al. also corroborated the medial predominance of incompetent perforating veins, highlighting the middle third of the calf as the most affected zone, followed by the lower third and the medial thigh.<sup>17</sup> Their findings, which emphasize the medial distribution of incompetent perforators across different stages of disease, reinforce the anatomical consistency observed in our study. Similarly, Townsend et al., using interosseous venography, found that the medial middle third of the calf accounted for 44% of incompetent perforators, while 20% were located in the medial lower third.<sup>18</sup> Pierik et al. further supported this distribution, noting the highest incidence of incompetent perforators in the medial middle and lower calf segments.<sup>19</sup> These concordant results highlight a well-established anatomical predilection for perforator incompetence in the medial zones of the lower limb, particularly the mid- and lower-thirds below the knee. This reinforces the need for targeted diagnostic evaluation of these regions during duplex scanning and supports focused therapeutic interventions for effective management of varicose vein disease.

## Conclusion

This study underscored the indispensable role of duplex ultrasonography in the evaluation of varicose veins, providing detailed anatomical and functional insights into the venous system. As a non-invasive and dynamic imaging modality, it allows accurate detection of valvular incompetence, identification of reflux at major junctions, and precise localization of incompetent perforator veins. The findings revealed that a significant proportion of patients with varicose veins exhibit incompetence at both junctional and perforator levels, with the medial perforators below the knee being the most commonly involved. Given the complex interplay between superficial, perforator, and deep venous systems, clinical assessment alone is often insufficient to guide treatment decisions. Duplex ultrasonography not only confirms the diagnosis but also plays a vital role in planning targeted interventions, such as surgical ligation or endovenous ablation. Its incorporation into routine vascular assessment significantly improves diagnostic precision and informs effective patient management.

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