Clinical and Hemodynamic Significance of the Greater Saphenous Vein Diameter in Chronic Venous Insufficiency

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Hypothesis: As the compliant greater saphenous vein (GSV) adjusts its luminal size to the level of transmural pressure, measurement of its diameter, reflecting the severity of hemodynamic compromise in limbs with GSV reflux, may simplify the hemodynamic criteria of patient selection for saphenectomy.

Objective: To evaluate the clinical significance of GSV diameter determined in the thigh and calf as a marker of global hemodynamic impairment and clinical severity in a model comprising patients with saphenofemoral junction and truncal GSV incompetence.

Design: A cohort study.

Setting: University-associated tertiary care hospitals in Brazil and England.

Patients: Eighty-five consecutive patients, aged 28 to 82 (mean, 46.2) years; 112 lower limbs with saphenofemoral junction and truncal GSV incompetence were investigated.

Interventions: Clinical examination was followed by clinical, etiological, anatomical, and pathophysiological classification (CEAP), vein duplex, and air plethysmography. The GSV diameter was measured on standing at the knee, and at 10, 20, and 30 cm above and below the knee, and in the thigh and calf, respectively, using B-mode imaging. The venous filling index (VFI), venous volume (VV), and residual volume fraction (RVF) were measured by air plethysmography.

Main Outcome Measures: The GSV diameter was correlated with the VFI, VV, RVF, and CEAP. The value of the GSV diameter for predicting the presence of critical reflux (VFI > 7 mL/s) or the absence of abnormal reflux (VFI < 2 mL/s) was determined with receiver-operator curves.

Results: The GSV diameter increased significantly overall with CEAP (P < .001) and also increased progressively with proximity to the saphenofemoral junction. The VFI, VV, and RVF increased significantly from CEAP0 through CEAP4-6; the VFI correlated well with VV, RVF, and CEAP (P < .001 for all). The GSV diameter at all 7 limb levels studied correlated well with VV (except at the distal calf), VFI, RVF, and CEAP (P < .009 for all). A GSV diameter of 5.5 mm or less predicted the absence of abnormal reflux, with a sensitivity of 78%, a specificity of 87%, positive and negative predictive values of 78%, and an accuracy of 82%. A GSV diameter of 7.3 mm or greater predicted critical reflux (VFI > 7 mL/s), with an 80% sensitivity, an 85% specificity, and an 84% accuracy.

Conclusion: The GSV diameter proved to be a relatively accurate measure of hemodynamic impairment and clinical severity in a model of saphenofemoral junction and GSV incompetence, predicting not only the absence of abnormal reflux, but also the presence of critical venous incompetence, assisting in clinical decision making before considering greater saphenectomy.

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DETERIORATION IN venous hemodynamics parallels clinical severity in patients with chronic venous insufficiency (CVI). This has been verified with plethysmographic studies,1,3 ambulatory venous pressure (AVP) measurements,4 and duplex ultrasonography.1,3 It has been proposed that the diameter of the greater saphenous vein (GSV) can provide a good estimate of the AVP in patients with superficial venous incompetence.5 Our hypothesis was that, similar to the gravitational and shear stress forces that cause the compliant vein walls to distend, hemodynamic impairment in the GSV trunk, being well correlated with the AVP, would cause a proportional readjustment of its diameter. As greater saphenectomies constitute most venous procedures in the lower extremity, stratification of reflux severity in the GSV trunk based on its diameter would allow identification of the patients with clinically relevant venous hemodynamic impairment and, thus, those in need of GSV surgery or those in whom surgery should be withheld.

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This study evaluates the clinical significance of GSV diameter, determined at different levels in the thigh and calf, as a marker of the amount of reflux, hemodynamic impairment, and clinical severity in a CVI model comprising patients with saphenofemoral junction (SFJ) and truncal GSV incompetence above and below the knee.

### METHODS

One hundred twelve lower limbs of 85 patients (mean age, 46.2 years; age range, 28-82 years) were included consecutively in the study. They were referred to the vascular laboratory for venous investigations of clinically suspected CVI by the general practitioners, internists, and surgeons within a catchment population area of 1 million people.

Clinical stratification of investigated limbs across the spectrum of CVI was determined using the clinical, etiological, anatomical, and pathophysiological classification (CEAP). Demographic features of the investigated patients and their distribution in the CEAP are depicted in Table 1. Eighty-five limbs with CVI due to SFJ and truncal GSV incompetence were included, in addition to 27 limbs without any type of reflux (control group).

Patients were subdivided into 4 groups: control group, CEAP1, CEAP2, and CEAP4. Limbs of all different grades of clinical severity of CVI were included in this study. Excluded from the study were patients with: segmental GSV reflux and a competent SFJ; segmental or axial reflux in the deep venous system; venous outflow obstruction; previous venous surgery (high tie, GSV strip, venous bypass, or reconstruction); and those with prior injection compression surgery involving segments of the GSV. Also excluded were patients with peripheral vascular disease (ankle brachial index <1.0 and absent peripheral pulses) and those taking vasoactive medication.

A lower limb venous duplex investigation was performed using color flow duplex imaging (Aspen; Acuson Corp, Mountain View, Calif), fitted with a 7- to 10-MHz linear array scan head, as previously described. Reflux was considered abnormal if its duration exceeded 0.3 second.

The diameter of the GSV was measured at 7 different levels in the lower limb: the proximal, middle, and distal thirds of the thigh; the proximal and middle thirds of the calf; and the proximal, middle, and distal thirds of the calf. Patients assumed the standing position, with the examined leg being a step forward and slightly bent, at 20° to 30° external rotation; the foot rested flat on the floor. They maintained balance by transferring their weight to the contralateral side and holding onto the frame of the duplex system. The exact level each measurement was performed at was marked on the skin with an indelible marking pen. The medial projection of the skin crease of the knee was used as a reference point. The proximal, middle, and distal measurement levels in the medial thigh were defined at 30, 20, and 10 cm above this point, respectively. The proximal, middle, and distal measurement levels in the medial calf were defined at 10, 20, and 30 cm below this point, respectively.

The GSV was insonated cross-sectionally, and its diameter was measured at opposing antidiametrical points of the intimal-luminal interfaces. Minimal pressure was applied, sufficient to enable optimal image resolution without modifying the shape of the GSV. Following a minimum standing period of 5 minutes to allow for thorough venous priming, 3 consecutive measurements (sagittally and transversely) were performed at each of the previously mentioned lower limb levels, using the standardized zoom facility for image magnification. The average of these measurements at each level was entered into the database.

Air plethysmography (model APG 1000; ACI Medical, Inc, San Marcos, Calif) was performed as previously described. The following hemodynamic parameters were determined: venous filling index (VFI) (in milliliters per second), an estimate of the amount of reflux; venous volume (VV) (in milliliters), a measure of venous capacitance; and residual volume fraction (RVF) (measured as a percentage), a well-validated noninvasive equivalent of AVP. Statistical evaluation of the data was performed by nonparametric analysis. The Kruskal-Wallis test was used to compare more than 2 sets of unrelated quantitative data. To clarify the significance of a difference between 2 sets of unrelated quantitative data, the Mann-Whitney test was applied, with a Bonferroni correction used when required. A correlational evaluation of quantitative data was performed with the Spearman rank correlation. Finally, differences in proportions were assessed using the χ² test. Comprehensive receiver-operator curves were used to determine optimal cutoff thresholds. The data are expressed as median and interquartile range unless otherwise stated.

### RESULTS

The GSV diameter measured at 7 different levels in the lower limb, across the spectrum of CVI, is depicted in Table 2 and Table 3. The GSV diameter increased significantly with clinical class, except between the con-
control group (CEAP0) and group 1 (CEAP1). The GSV diameter also increased gradually with proximity to the SFJ.

The VV, VFI, and RVF across the clinical spectrum of CVI are depicted in Table 4 and Table 5; all increased significantly from the control group (CEAP0) to group 3 (CEAP4-6), except for the RVF between the control group (CEAP0) and group 1 (CEAP1) and between the diameter, amount of reflux, and RVF compared with the control group (CEAP0) and group 1 (CEAP1). The GSV diameter increased significantly from the control group (CEAP0) to group 1 (CEAP1) and 2 (CEAP2-3).

The VV, VFI, and RVF correlated significantly with GSV diameter (Table 6) at all 7 lower limb levels investigated, except for the VV at the distal calf. Similarly, the diameter of the GSV, at all 7 limb levels, correlated significantly with the stratification of the study limbs in 4 groups (control, 1, 2, and 3) (Table 6). Equivalent correlational results (Table 6) were found between the GSV diameter, at all 7 limb levels, and the clinical class of the study limbs in the CEAP system.

The VFI of the study limbs was linearly correlated with the VV (r = .76), RVF (r = .67), and CEAP (r = .90) (P < .001 for all, Spearman rank correlation).

Finally, the diameter of the GSV in the thigh was a relatively accurate predictor of abnormal venous reflux (VV > 2 mL/s) and large amounts of reflux (VFI > 5 mL/s and VFI > 7 mL/s) (Table 7).

**Table 3. Intergroup Comparisons of the GSV Diameter**

<table>
<thead>
<tr>
<th>Group Comparisons</th>
<th>Lower Limb Level</th>
<th>PT</th>
<th>MT</th>
<th>DT</th>
<th>Knee</th>
<th>PC</th>
<th>MC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group vs group 1</td>
<td>.94</td>
<td>.43</td>
<td>.79</td>
<td>.04</td>
<td>.06</td>
<td>.18</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Control group vs group 2</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.06</td>
<td>.28</td>
<td>.32</td>
<td></td>
</tr>
<tr>
<td>Control group vs group 3</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1 vs group 2</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1 vs group 3</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 2 vs group 3</td>
<td>.002</td>
<td>.004</td>
<td>&lt;.001</td>
<td>.06</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.001</td>
<td></td>
</tr>
</tbody>
</table>

*See the “Methods” section for details on the limb level measurements. Data are given as P values (Mann-Whitney test). The clinical, etiological, anatomical, and pathophysiological classification of each group is given in Table 1. Abbreviations are explained in the first footnote to Table 2.

**Table 5. Intergroup Comparisons of Venous Hemodynamics in the Studied Limbs**

<table>
<thead>
<tr>
<th>Group Comparisons</th>
<th>VFI</th>
<th>VV</th>
<th>RVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group vs group 1</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>21</td>
</tr>
<tr>
<td>Control group vs group 2</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.004</td>
</tr>
<tr>
<td>Control group vs group 3</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Group 1 vs group 2</td>
<td>&lt;.001</td>
<td>.003</td>
<td>.17</td>
</tr>
<tr>
<td>Group 1 vs group 3</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Group 2 vs group 3</td>
<td>&lt;.001</td>
<td>.02</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*See the “Methods” section for details on the limb level measurements. Data are given as P values (Mann-Whitney test). The clinical, etiological, anatomical, and pathophysiological classification of each group is given in Table 1. Abbreviations are explained in the first footnote to Table 2.

**Table 4. Lower Limb Venous Hemodynamics of Examined Limbs Across the CVI Spectrum, Determined With APG**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 27)</th>
<th>1 (n = 28)</th>
<th>2 (n = 24)</th>
<th>3 (n = 35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VV, mL</td>
<td>78.5 (63.2-93.5)</td>
<td>109.4 (81.8-129.8)</td>
<td>132.4 (115.4-139.8)</td>
<td>148.6 (125.0-181.9)</td>
</tr>
<tr>
<td>VFI, mL/s</td>
<td>0.5 (0.3-0.8)</td>
<td>1.3 (0.7-1.8)</td>
<td>3.1 (2.8-4.5)</td>
<td>6.5 (4.0-10.1)</td>
</tr>
<tr>
<td>RVF, %</td>
<td>15.8 (11.2-23.5)</td>
<td>19.7 (11.7-28.3)</td>
<td>23.5 (20.2-32.3)</td>
<td>40.0 (33.8-46.2)</td>
</tr>
</tbody>
</table>

*CVI indicates chronic venous insufficiency; APG, air plethysmography; VV, venous volume; VFI, venous filling index; and RVF, residual volume fraction. †Data are given as median (interquartile range). All values increased significantly (P < .001, Kruskal-Wallis test). The clinical, etiological, anatomical, and pathophysiological classification of each group is given in Table 1.
in CVI. As the amount of reflux and AVP increase, there is a progressive dilatation of the vein lumens and an exponential increase in venous capacitance; this is associated with a proportional increase in the RVF, the noninvasive equivalent of AVP,10 with corresponding deterioration in the clinical severity of the CVI.

It has been proposed that, in the presence of reflux, the absence of GSV dilatation may be due to an inward course of the refluxing blood volumes through the perforating system, a condition designated as compensated venous reflux.17 The presence of reflux, in the absence of detectible GSV dilatation, is seen in limbs graded as CEAP1, and may be identified by the increase in VV. On the other hand, a dilated GSV diameter may indicate a state of decompensated venous reflux, in which the amount of refluxing blood exceeds the amount of inward blood through the perforating veins, leading to an accumulation of blood and consequently an increase of venous capacitance (CEAP2).o

The size of lower limb veins depends on the patient’s position and respiration cycle,18 increasing further with pregnancy19 and the presence of outflow obstruction.20 Our data show that, in the presence of GSV incompetence, the median diameter of the GSV in the thigh on standing increases from 4.6 mm in healthy limbs to 5.7 mm (ie, by 24%) in limbs with CEAP2,3 and to 7.8 mm (ie, by 70%) in limbs with skin changes and ulceration (CEAP4,6). We were able to demonstrate a linear

correlation between the clinical CVI severity of the limbs in the CEAP system and GSV diameter in the thigh and knee, and to a lesser extent in the calf. This deterioration, particularly in the distal calf, was not an unexpected finding. In the presence of SFJ and truncal GSV incompetence, several of the GSV's calf tributaries, such as the anterior and posterior arches and the saphenous tributaries, are also frequently incompetent,21 disseminating the orthostatic venous pressure load and the amount of reflux in the posteromedial or anterolateral aspects of the calf.

Previous studies22-24 have reported that the GSV diameter in the thigh is 4.3 mm among healthy subjects performing the Valsalva maneuver, but is significantly larger (6.7 mm) in limbs with GSV incompetence, markedly impairing VV and VFI. The present study has demonstrated that the increase in GSV diameter parallels the amount of venous reflux in the lower limb, and that in this sense the GSV diameter may be used as a marker of the severity of venous reflux. The incidence of ulceration rises with increasing VFI, being 0% for a VFI of less than 5 mL/s, 46% for a VFI of 5 to 10 mL/s, and 58% for a VFI that exceeds 10 mL/s in limbs without obstruction, regardless of the pattern of venous incompetence.25 A VFI higher than 7 mL/s, designated critical reflux, has a 73% sensitivity, a 100% specificity, and a 100% positive predictive value in identifying limbs with venous ulceration.26 Our data showed that a thigh GSV diameter of 5.5 mm or less is able to predict the absence of abnormal reflux (VFI ≤2 mL/s) with a sensitivity of 78%, a specificity of 87%, positive and negative predictive values of 78%, and an overall accuracy of 82%. We also found that a GSV diameter of 7.3 mm or greater was able to predict a VFI exceeding 7 mL/s, with a sensitivity of 80%, a specificity of 85%, a positive predictive value of 44%, a negative predictive value of 97%, and an overall accuracy of 84%. Therefore, on the basis of GSV diameter, the presence of critical venous reflux can be detected and the absence of abnormal reflux can also be safely excluded.

The practical implications of our findings are clinically relevant. Truncal incompetence of the GSV constitutes most of the indications for lower limb venous surgery. The linear relationship between the diameter of the GSV and the amount of reflux and RVF, reflecting the AVP, enables (on the basis of GSV diameter alone) clini-

### Table 6. Correlation Between GSV Diameter, Determined at 7 Lower Limb Levels, and Venous Hemodynamics, Study Group, and CEAP*

<table>
<thead>
<tr>
<th>Variable</th>
<th>PT</th>
<th>MT</th>
<th>DT</th>
<th>Knee</th>
<th>PC</th>
<th>MC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venous hemodynamics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VFI</td>
<td>0.56 (&lt;.001)</td>
<td>0.66 (&lt;.001)</td>
<td>0.48 (&lt;.001)</td>
<td>0.57 (&lt;.001)</td>
<td>0.50 (&lt;.001)</td>
<td>0.39 (&lt;.001)</td>
<td>0.26 (.006)</td>
</tr>
<tr>
<td>RVF</td>
<td>0.61 (&lt;.001)</td>
<td>0.65 (&lt;.001)</td>
<td>0.45 (&lt;.001)</td>
<td>0.48 (&lt;.001)</td>
<td>0.42 (&lt;.001)</td>
<td>92 (&lt;.001)</td>
<td>92 (&lt;.001)</td>
</tr>
<tr>
<td>RVF</td>
<td>0.56 (&lt;.001)</td>
<td>0.66 (&lt;.001)</td>
<td>0.48 (&lt;.001)</td>
<td>0.45 (&lt;.001)</td>
<td>0.45 (&lt;.001)</td>
<td>0.29 (&lt;.001)</td>
<td>45 (&lt;.001)</td>
</tr>
<tr>
<td>Study group</td>
<td>0.64 (&lt;.001)</td>
<td>0.65 (&lt;.001)</td>
<td>0.68 (&lt;.001)</td>
<td>0.60 (&lt;.001)</td>
<td>0.53 (&lt;.001)</td>
<td>48 (&lt;.001)</td>
<td>31 (&lt;.001)</td>
</tr>
<tr>
<td>CEAP</td>
<td>0.60 (&lt;.001)</td>
<td>0.62 (&lt;.001)</td>
<td>0.66 (&lt;.001)</td>
<td>0.60 (&lt;.001)</td>
<td>0.55 (&lt;.001)</td>
<td>49 (&lt;.001)</td>
<td>33 (&lt;.001)</td>
</tr>
</tbody>
</table>

*See the “Methods” section for details on the limb level measurements. Data are given as correlation coefficient (r) value, using the Spearman rank correlation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>PT</th>
<th>MT</th>
<th>DT</th>
<th>Knee</th>
<th>PC</th>
<th>MC</th>
<th>DC</th>
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<tbody>
<tr>
<td>Venous Filling Index, mL/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>GSV diameter, mm</td>
<td>5.5</td>
<td>5.0</td>
<td>4.7</td>
<td>7.2</td>
<td>5.6</td>
<td>5.2</td>
<td>7.3</td>
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<tr>
<td>Sensitivity, %</td>
<td>78</td>
<td>81</td>
<td>85</td>
<td>70</td>
<td>74</td>
<td>74</td>
<td>80</td>
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<tr>
<td>Specificity, %</td>
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<td>89</td>
<td>88</td>
<td>86</td>
<td>74</td>
<td>85</td>
<td>73</td>
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<td>PPV, %</td>
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<td>89</td>
<td>82</td>
<td>45</td>
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<td>44</td>
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<tr>
<td>NPV, %</td>
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<td>81</td>
<td>83</td>
<td>92</td>
<td>92</td>
<td>92</td>
<td>97</td>
</tr>
<tr>
<td>Accuracy, %</td>
<td>82</td>
<td>85</td>
<td>84</td>
<td>84</td>
<td>76</td>
<td>76</td>
<td>84</td>
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</tbody>
</table>

*GSV indicates greater saphenous vein; PT, proximal thigh; MT, middle thigh; DT, distal thigh; PC, proximal calf; MC, middle calf; DC, distal calf; VFI, venous filling index; RVF, residual volume fraction; and VV, venous volume.
cal decisions to be made as to whether a patient with documented GSV and SFJ incompetence has such a hemodynamic impairment as to warrant a saphenectomy. If the diameter of the GSV is small, reflux within its trunk is also small and, thus, hemodynamically insignificant. According to our data, patients with a GSV diameter in the thigh of 5.5 mm or less could be spared surgery, as this diameter indicates a low amount of venous reflux. On the other hand, a GSV diameter of 7.3 mm or greater indicates a substantial amount of reflux within the GSV trunk, so that surgery should be performed if the clinical indications exist and the patient fulfills the criteria of physical fitness. Therefore, further to the confirmation of the sites and extent of venous reflux identified initially on clinical examination, the use of duplex imaging based on the GSV diameter data of the present article in patients with primary truncal GSV and SFJ reflux can be expanded to afford a safe quantification of global venous hemodynamic impairment, obviating the use of further functional tests.

The need for further hemodynamic investigation depends on the individual case. If deep vein incompetence in the major axial vein trunks can be safely excluded clinically with the help of a handheld Doppler system, the significance of GSV reflux can be assessed as previously mentioned, without further venous investigations required for reaching a clinical decision. In the presence of deep vein incompetence, air plethysmography will provide quantification of the amount of reflux and its repeat measurement with simultaneous superficial occlusion will aid in estimating the relative contribution of each system. If reflux is predominantly superficial, determination of the GSV diameter may provide an answer to the question of the clinical significance of its reflux. Limbs with varicose vein recurrence and postthrombotic sequelae with deep vein incompetence are indications for more comprehensive noninvasive investigation before the shaping of clinical decisions.

In conclusion, the GSV diameter has been proved to be a relatively accurate measure of the degree of venous impairment within its trunk. The GSV diameter is in linear correlation with the amount of reflux, the venous capacitance, and the RVF, measured by air plethysmography; and with the clinical severity, in a CVI model defined by the SFJ and truncal GSV incompetence. On this basis, patients with a GSV diameter of 5.5 mm or less should be spared saphenectomy. On the other hand, those with a GSV diameter of 7.3 mm or greater, an indicator of clinically significant venous reflux, and provided that the clinical indications for a saphenectomy are present, should be considered for surgery following clarification of their surgical risk. Patients with an intermediate GSV diameter should be considered individually, with emphasis on the presenting symptoms and signs.

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