

# Three-Dimensional CT Venography of Varicose Veins of the Lower Extremity: Image Quality and Comparison with Doppler Sonography

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**OBJECTIVE.** The purpose of this study was to verify the imaging quality of CT venography in the clinical evaluation of the lower extremity superficial venous system and to correlate the CT and duplex sonographic findings about varicose veins.

**SUBJECTS AND METHODS.** One hundred consecutively registered patients with varicose veins underwent CT venography. The image quality of overall 3D volume rendering was rated, and the absolute attenuation of each component at the level of the knee was measured. Factors that affected visualization of varicose veins were identified. For comparison analysis, 50 of the 100 patients also underwent Doppler sonography, and saphenous vein size and morphologic features on CT were compared with the functional information from Doppler sonography.

**RESULTS.** The overall quality of 3D volume-rendered images in the visualization of varicose veins was excellent in 76% of patients, fair in 21%, and poor in 3%. The entire length of the great saphenous vein (GSV) was visualized with CT venography in 99.5% of 200 GSVs. The quality of 3D volume-rendered images was better when a thick subcutaneous layer, no skin changes, and no subcutaneous edema were present. Size of the GSV determined whether findings at CT venography and Doppler sonography correlated well, the linear regression coefficient being 0.72. At CT venography, the mean diameter of GSVs exhibiting insufficiency on duplex sonography was 7.0 mm, and the mean diameter of GSVs exhibiting competence on duplex sonography was 4.9 mm ( $p < 0.001$ ). Prediction of GSV insufficiency with CT venography had a sensitivity of 98.2% and a specificity of 83.3%.

**CONCLUSION.** CT venography has adequate image quality for evaluation of the venous system of the lower extremities.

**Keywords:** 3D image, CT, CT venography, varicose veins

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**V**aricose veins are one of the most common diseases in the world. It is estimated that 30–60% of adults have some form of true lower extremity varicose veins [1]. The introduction of less-invasive treatments, such as laser ablation and radiofrequency thermal ablation, has led to increased interest in this disease. Various methods are used in the preoperative evaluation of varicose veins, such as ascending venography and handheld Doppler and duplex sonography [2]. Because of the ability to evaluate hemodynamic information and its convenience and availability, duplex sonography is considered the reference standard for noninvasive anatomic and functional assessment of venous reflux [3–6]. Preoperative evaluation of varicose veins must reveal the primary cause of varicosity, the secondary reflux, and the distribution of varicosity, including perforating veins. The

concern, however, is the possibility that because of the limited field of view of duplex sonography, deep-seated varicose vein pathways and major perforators will be missed. Missing an important perforating vein associated with insufficiency during preoperative detection is a leading cause of recurrence after surgical therapy for varicose veins [7].

CT of the entire lower extremity vascular system and volume-rendered reconstruction have become feasible [8]. In addition, MDCT has sufficient spatial resolution to show superficial veins 2 mm in diameter and smaller, thus 3D visualization of the entire superficial venous system is possible. Three-dimensional CT venographic images also can be used as complementary road maps for preoperative mapping of varicose veins. In this study, we evaluated the imaging quality of CT venography for clinical evaluation of the lower extremity superficial venous system.

## CT Venography of Varicose Veins

We also compared CT and duplex sonographic findings about varicose veins.

### Subjects and Methods

#### Patient Population

One hundred patients (55 women, 45 men; mean age, 54.9 years; range, 18–84 years) consecutively referred to our department for the evaluation of varicose veins over a 3-month period were included in this study. All patients had visible varicose veins. Fifty-one patients had bilateral varicose veins, and 49 patients had varicose veins in only one limb. The study protocol was approved by our institutional review board, and informed consent was obtained.

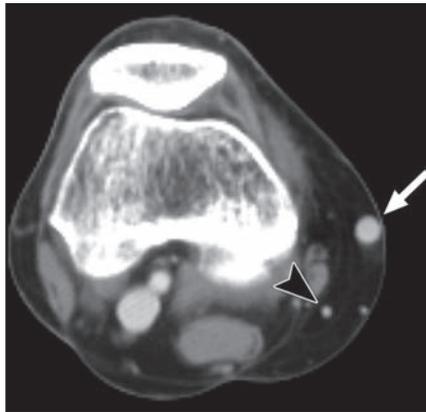
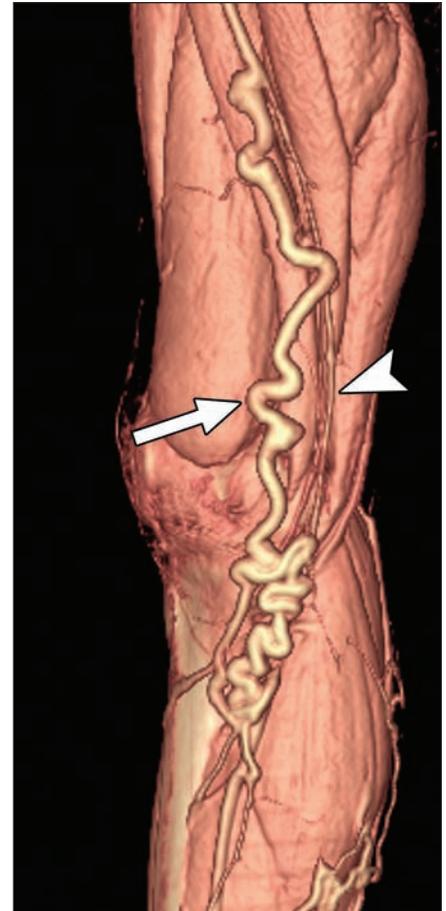
#### MDCT Venography Technique

Immediately before CT, patients were asked to remove their underwear, stockings, and socks, which might have compressed superficial veins. On the CT table, extra support was provided for the buttocks and heels to prevent direct contact between the lower extremities and the CT table. CT examinations were performed with an 8-MDCT (LightSpeed Ultra, GE Healthcare) or 16-MDCT (Sensation 16, Siemens Medical Solutions) scanner. An 18- or 20-gauge catheter was placed into an antecubital vein, and 2 mL/kg of nonionic contrast material (iopromide, Ultravist 370, Bayer HealthCare) was injected with a power injector (Envision CT, Medrad) at a rate of 2.5 mL/s. We used a scan delay time of 3 minutes after initiating injection of the contrast material for CT venography to enhance deep and superficial veins, including varicose veins and perforating veins.

The scanning parameters for CT venography were as follows. For the 8-MDCT scanner, the values were collimation, 1.25 × 8 mm; pitch, 1.35; slice thickness, 1.25 mm; reconstruction interval, 1 mm; x-ray tube voltage, 120 kVp; effective tube current, 150 mAs. For the 16-MDCT scanner, the values were detector collimation, 0.75 × 16 mm; pitch, 1.5; slice thickness, 1 mm; reconstruction interval, 0.7 mm; x-ray tube voltage, 120 kVp; effective tube current, 150 mAs. The scan range was the iliac crest to the end of the feet.

#### Postprocessing of Volume Data

All thin-section axial images were transferred to a workstation running PC-based 3D reconstruction software (Rapidia, Infinitt). Individual volume data were loaded into the 3D program, and two experienced radiologists performed the 3D reconstruction (Fig. 1). The techniques used for 3D reconstruction of the superficial venous system were smoothing of axial images for noise reduction and interactive volume rendering to display



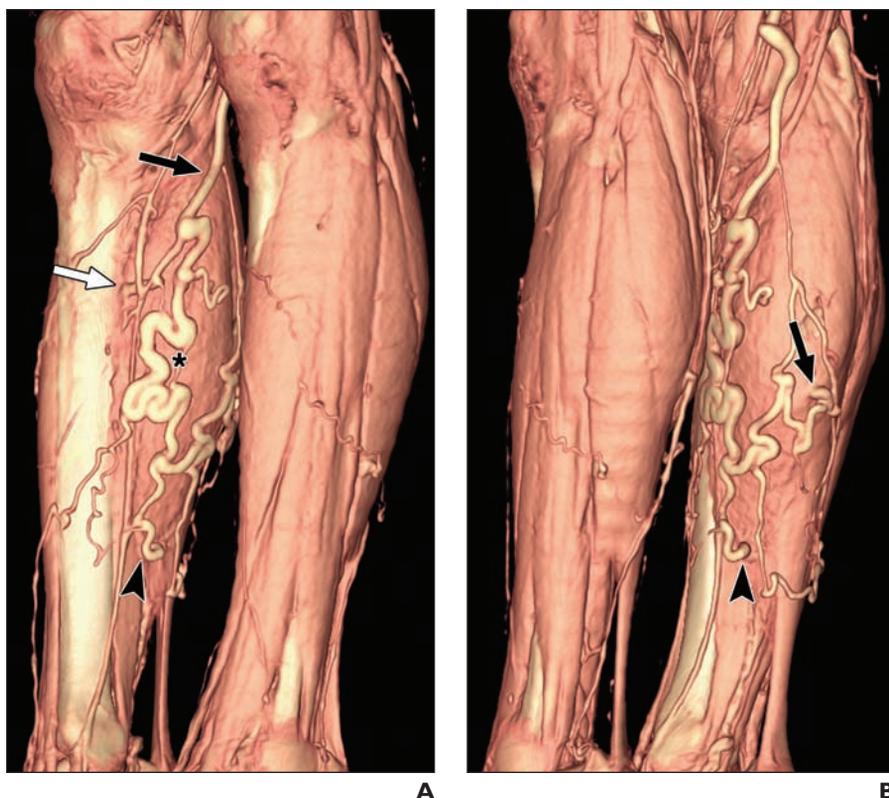
**Fig. 1**—43-year-old woman with varicose veins. **A**, Three-dimensional volume-rendered image produced at opacity–transparency function setting for superficial visualization shows enlarged right great saphenous vein in medial aspect of thigh and calf. Varicose vein pathway is situated along superficial duplication of right great saphenous vein. **B**, Volume-rendered image shows enlarged superficial duplication (arrow) and unenlarged midsegment of main great saphenous vein in its original location (arrowhead). **C**, Axial CT scan at level of patella shows unenlarged segment of right great saphenous vein in its original location in saphenous vein space (arrowhead) and enlarged superficial duplication pathway (arrow) of right great saphenous vein.

surface venous channels and varicose veins with muscle planes (Fig. 2). For the perforator survey, we used interactively rotating volume-rendered images and corresponding axial, sagittal, and coronal images. To evaluate the saphenofemoral and saphenopopliteal junctions, we used axial images and maximum intensity projection and multiplanar reformatted images in the interactive image plane.

#### Image Analysis

Evaluation of overall image quality was followed by analysis of the factors believed to affect image quality.

*Assessment of overall quality of 3D volume-rendered images*—Two radiologists evaluated the quality of volume-rendered images using a three-level grading system (excellent, fair, or poor), and grades were reached by consensus. Excellent



**Fig. 2**—51-year-old woman with varicose veins.

**A**, Three-dimensional volume-rendered image obtained at opacity–transparency function setting for muscle planes shows enlarged left great saphenous vein (*black arrow*) and tortuous varicose veins (*asterisk*). Perforating veins are vividly shown, and paratibial (*white arrow*) as well as posterior tibial (*arrowhead*) perforating veins are evident.

**B**, Left posterior oblique 3D volume-rendered image shows medial gastrocnemius perforating veins (*arrow*) and posterior tibial perforating vein (*arrowhead*).

meant volume-rendered images vividly showed all varicose vein channels and perforators. Fair meant some of the channels and perforators were not clear on volume-rendered images but that the quality of volume-rendered images was sufficient for detection of channels and perforators. Poor quality meant the volume-rendered images were unsuitable for detection of channels and perforators and that axial images were needed to conduct the evaluation.

**Enhancement of deep and superficial veins and varicose veins**—To quantify vein enhancement and attenuation differences in relation to surrounding tissue, we measured the mean attenuation of each component at the level of the knee. The mean attenuation of the great saphenous vein (GSV), small saphenous vein, popliteal vein, and varicose veins was measured within a circular region of interest. The attenuation of muscle and the popliteal artery was measured for comparative purposes. Venous enhancement was assessed for homogeneity (homogeneous vs heterogeneous), layering, thrombi, obliteration, filling defect, and absence of segmental opacification.

**Factors affecting visualization of varicose veins**—An analysis was performed to identify factors affecting image quality. The factors examined included severity of varicosity and presence of abnormal skin thickening, subcutaneous edema, and thickening of the subcutaneous layer. The severity of a varicose vein was divided into three categories. Varicosities involving the calf and thigh were ranked severe; varicosities involving more than one half of the surface of the calf were ranked moderate; and varicosities involving less than one half of the surface of the calf were ranked mild. Abnormal skin thickening was defined as skin thickening of more than 1 mm. Subcutaneous edema was defined as subcutaneous attenuation greater than that of the normal subcutaneous fat layer. Thickening of the subcutaneous layer was measured on axial CT images at the level of the knee at the medial aspect of the calf.

Other factors used for statistical analysis were mean attenuation of the GSV, homogeneous or inhomogeneous enhancement pattern of the GSV, mean attenuation of the popliteal artery, mean

attenuation of the popliteal vein, mean attenuation of muscle, mean attenuation of the varicose vein, and the difference between the maximum and minimum attenuations of the varicose vein. Multiple regression testing was performed with the GraphPad InStat program (version 3.05, GraphPad Software).

#### *Correlation Between CT Venography and Duplex Sonography*

Among 100 patients who underwent consecutive CT venographic examinations, 50 patients (22 men, 28 women; mean age, 56.5 years; range, 17–83 years) also underwent Doppler sonography. Doppler sonography was requested by vascular surgeons for preoperative evaluation of varicose veins. These 50 patients were included in the comparative analysis. One radiologist performed all duplex sonographic studies using a color Doppler sonograph (Accuvix XG, Medison) and a 7.5-MHz linear probe. The average time between CT venography and Doppler sonography was 0.6 days. Instead of adopting the classic standing position, patients were positioned on a tilt table 10–20° from vertical and were asked to support the upper body on the table but were requested to rest the leg being examined on the table. The GSV was measured at the most proximal segment of the GSV that was tubular under minimum pressure to avoid underestimation of the diameter due to compression by the ultrasound probe. The GSV and small saphenous vein were measured with CT at the site evaluated with duplex sonography. Sizes measured with CT venography and duplex sonography were compared, and the sizes of insufficient and competent saphenous veins were analyzed.

The presence of valvar insufficiency in GSVs and small saphenous veins was evaluated primarily. Reflux flow for more than 500 milliseconds after the Valsalva maneuver or distal manual compression and release was considered to indicate the presence of saphenofemoral or saphenopopliteal insufficiency [9]. All CT findings, such as focal ectasia, diffuse dilatation more than 6 mm, asymmetry, and tortuosity, directly connected to varicosity of GSVs and small saphenous veins that were confirmed insufficient at Doppler sonography were analyzed on volume-rendered images. The incidence of these CT finding in cases of GSV insufficiency was calculated. Using these CT findings, two radiologists separately predicted the presence of GSV or small saphenous vein insufficiency. With duplex sonography as the reference standard, the sensitivity and specificity of CT venography in the prediction of insufficiency of the GSV and small saphenous vein were calculated.

## CT Venography of Varicose Veins

### Results

#### Assessment of Overall Quality of 3D Volume-Rendered Images

The overall quality of 3D volume-rendered images was excellent in 76 cases, fair in 21 cases, and poor in three cases.

#### Enhancement of Deep and Superficial Veins and Varicose Veins

The mean attenuation of vessels and muscle is summarized in Table 1; enhancement homogeneities are summarized in Table 2. In the 151 limbs with varicose veins, 111 varicose veins had homogeneous enhancement throughout varicosities, 14 had heterogeneously enhanced segments, 11 exhibited layering of opacified and unopacified blood in dilated varicose veins, four had a filling defect with varicose veins, and 11 had no segmental opacification.

#### Factors Affecting Varicose Vein Visualization

Varicosity was ranked severe in 17 limbs, moderate in 63, and mild in 68; the other 51 limbs did not have varicosities. Abnormal skin thickening was found in 18 limbs and subcutaneous edema in 18 limbs. Three-dimensional volume-rendered images of excellent overall quality showed that limbs with varicose veins had a thicker subcutaneous layer ( $p < 0.0036$ ), no skin changes ( $p < 0.026$ ), and no subcutaneous edema ( $p < 0.0001$ ) compared with limbs with varicose veins depicted on 3D volume-rendered images of fair or poor overall quality. Severity of varicosity, degree of enhancement, and homogeneity were found to have no significant correlation with overall image quality.

#### Correlation with Doppler Sonographic Findings

CT venography was performed with the patient in the supine position, and sonography was performed with the patient in a 10–20° from vertical semierect position. Nevertheless, the sizes of the GSV determined with the two techniques correlated well, having a linear regression coefficient of 0.72 without any statistically significant discrepancy (Fig. 3). On CT venography, the mean diameter of GSVs found insufficient at Doppler sonography was 7.0 mm and the mean diameter of GSVs found competent was 4.9 mm ( $p < 0.001$ ).

Insufficiency of 61 GSVs was confirmed with Doppler sonography, and 57 of the 61 veins were varicose; four insufficient GSVs were not affected by varicosity. The morphologic findings of the insufficient GSVs

**TABLE 1: Average Absolute Attenuation at Level of Knee 3 Minutes After Injection of Contrast Medium**

Vessel	Attenuation (HU)
Great saphenous vein	150.8
Small saphenous vein	139.9
Popliteal vein	156.4
Varicose vein	143.7
Muscle	71.3
Popliteal artery	198.4

with varicosity were focal ectasia, diffuse dilatation of more than 6 mm, asymmetry, tortuosity, and direct connection to varicosity. The prevalence of these findings is listed in Table 3. One of the 57 varicose veins related to insufficiency of the GSV had normal morphologic features. The sensitivity of CT venography in the prediction of GSV insufficiency was 98.2% (56 of 57 cases), and the specificity was 83.3% (14 of 17 cases).

There were 15 insufficient small saphenous veins. Focal ectasia (62.3%) and diffuse dilatation (54.1%) were found in insufficient small saphenous veins, but tortuosity was not, probably because of the smaller interfascial spaces in which these veins are located. Seven of the 15 insufficient small saphenous veins had normal morphologic features. CT venography had a sensitivity of 53.3% (eight of 15 cases) and a specificity of 94.9% (56 of 59 cases) in prediction of insufficiency of the small saphenous vein.

### Discussion

CT of the lower extremity is used to evaluate the deep venous system, especially in cases of deep venous thrombosis [10, 11]. However, to our knowledge, no evaluation of

the CT findings on the superficial system of the lower extremity has been conducted. There are potential pitfalls in evaluation of the superficial venous system of the lower extremities. Compression of the superficial vein that occurs when patients lie on the CT table is one. For this study, we constructed buttock and heel pads to support the affected limb on the CT table, preventing contact between the CT table and the limb other than at the high aspect of the buttock and at the heel. Another important requirement in imaging superficial veins is removal of clothing (stockings, socks, and underwear) covering the lower extremity. When these precautions are taken, almost all varicose veins can be imaged without collapse. In all of our cases, CT venography showed nearly the entire length (99.5%) of the GSV. Another important factor in imaging superficial veins is the size of the veins. However, varicose veins are usually more than 2 mm in diameter and are easily visualized with CT. Furthermore, newer CT machines have submillimeter spatial resolution, and imaging of vessels 1 mm and larger is possible.

The degree of venous enhancement on CT venography is an important consideration. The bolus-tracking method is preferred for CT during peak enhancement of the arterial system. In the case of the venous system, however, determining the period to peak enhancement is difficult owing to the different circulation times in the venous system. Venous return of contrast medium from some veins may not have started before return from other veins is effectively complete. On occasion, direct CT venography has been performed with direct injection of diluted contrast medium into a targeted vein [12]. This direct CT venographic method may work for central veins, but we have found that in many cases not all venous channels in

**TABLE 2: Pattern of Vein Enhancement on Lower Extremity CT Venography (n = 200)**

Vessel	Homogeneous Enhancement	Heterogeneous Enhancement	Layering	Filling Defect	Absence of Segmental Opacification
Great saphenous vein	194	6	0	0	0
Femoral vein	180	20	0	0	0
Small saphenous vein	181	7	2	0	7
Popliteal vein	169	27	2	0	2
Calf vein	170	27	0	0	3
Varicose vein	111	14	11	4	11

Note—Values are numbers of veins.

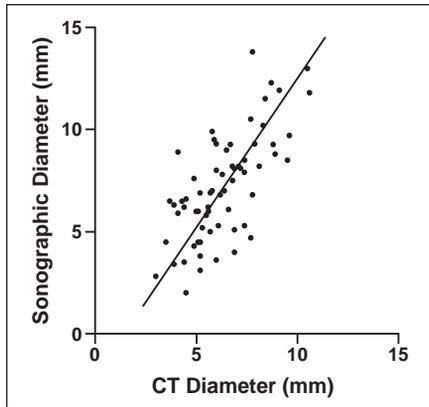


Fig. 3—Scatterplot shows great saphenous vein dimensions obtained with CT and Doppler sonography.

the lower extremity are filled, especially varicose veins.

Yankelevitz et al. [13] drew time–density curves of the common femoral veins of 20 patients after CT pulmonary angiography and reported that peak enhancement of the common femoral vein occurred a mean of approximately 2 minutes after administration of the contrast medium. In our study, for CT venography we used a 3-minute delay to obtain homogeneous enhancement of deep and varicose veins. We found that at 3 minutes, the circulation was in equilibrium and all veins were almost equally enhanced. However, degrees of enhancement were not as high as those achieved at CT arteriography, for which attenuation is usually more than 300 HU. Nevertheless, at CT venography, the average attenuation of enhanced veins in the lower extremity was 140–150 HU. This attenuation was sufficient to allow us to differentiate targeted veins from surrounding muscle and subcutaneous fatty tissue, which have an attenuation of 70 HU and less than 0 HU, respectively. In the case of a patient with severely dilated varicose veins, some segments of the varicose vein remained in an unopacified state 3 minutes after contrast injection (Table 3). In cases such as this, compression on or rubbing of the varicose vein after contrast injection and before the start of CT acquisition is helpful for opacifying the entire varicose vein.

Varicose veins are located in the subcutaneous layer, and surrounding fatty tissue contrasts against blood-filled veins. Three-dimensional volume-rendered images obtained without contrast enhancement can be used to visualize varicose veins [14]; the deep venous system and perforators can be visualized on CT only after contrast en-

hancement. Even though evaluation of the deep venous system was not one of the objectives of this study, CT venography is an excellent means of evaluating this system. Calf veins especially have many tributaries at both superficial and deep locations. Imaging of a deep calf vein with Doppler sonography is not easy because of the deep location and small caliber of the vein and the sheer number of vessels. Ascending venography can show both the superficial and deep venous systems in the calf, but it is difficult to differentiate the vessels and to detect abnormal veins among abundant dilated varicose veins, especially in severe cases of varicose veins, because ascending venography has the intrinsic limitation of projectional imaging.

Contrast-enhanced CT venography can show the calf veins with clear anatomic landmarks such as muscle and bone, and use of this technique facilitates detection of abnormalities of the deep calf veins. The presence of deep venous thrombosis is an important consideration during the preoperative evaluation of patients with varicose veins, and the diagnostic accuracy of CT in the detection of deep venous thrombosis has been established [11, 15]. CT venography is sensitive in the depiction of deep venous thrombosis, and one of its strong points is that it can show chronic changes. For example, after reorganization and recanalization in cases of deep venous thrombosis, affected veins are narrowed and contain fibrotic bands and organized thrombi, which disturb venous flow and cause development of superficial collateral vessels with and without varicose vein formation [16].

The development of duplex sonography has made possible the precise functional evaluation of varicose veins and has led to determination of the primary cause of varicose veins. Nevertheless, surveying all significant perforators during the evaluation of varicose veins remains difficult and time-consuming. The survey should be thoroughly conducted, however, because recurrence rates largely depend on the management of insufficient perforators [7, 17, 18]. Although it has good resolution and is useful for evaluating venous insufficiency, duplex sonography does not show an overview of the situation and is operator dependent. Because of these shortcomings, duplex sonography is limited for finding all perforators. In contrast, CT venography can show all perforators but does not yield functional information. Thus CT venography and duplex sonography complement

TABLE 3: CT Findings in Great Saphenous Veins Insufficient Due to Varicosity (n = 57)

Finding	Prevalence <sup>a</sup>
Focal ectasia	37 (64.9)
Diffuse dilatation (> 6 mm)	33 (57.9)
Asymmetry	14 (24.6)
Tortuosity	13 (22.8)
Directly connected to varicosity	55 (96.5)
Normal morphology	1 (1.8)

Note—Values in parentheses are percentages. Insufficiency was confirmed with duplex sonography.

<sup>a</sup>Veins could have more than one finding.

each other. CT venography also can be used to obtain an excellent road map of perforator vessels. Three-dimensional imaging of varicose veins not only yields a road map of the superficial venous system for the sonographic evaluation of functional anatomy but also improves the performance of Doppler sonography. The improvement is achieved through shortening of the examination time and increasing the rate of detection of perforators because perforator veins can be identified on 2D CT images and marked on 3D images. In addition, contrast-enhanced CT depicts both the deep venous and superficial venous systems better than does Doppler sonography.

Varicose vein evaluations with Doppler sonography usually are performed with the patient standing or sitting. In this study, we used a tilt table and performed Doppler sonography with the patient in a 70–80° semierect position. The advantage of using a tilt table is that patients can lean on the table and thus feel more comfortable during examinations, which can take 40–60 minutes. CT was performed with the patient in the supine position; thus hydrostatic dilation due to hydrostatic pressure in the lower-extremity veins was not an issue. Nevertheless, GSV diameters on CT images correlated well with diameters measured at sonography. Veins collapsed easily during sonographic examinations in the supine position, and diameters measured in the standing and supine positions at sonography differed. However, no significant difference was observed between diameters determined with CT and sonography when the techniques were performed in the supine and semierect positions, respectively. We presume that the relaxed leg position and minimal pressure applied to the superficial venous system during this study

## CT Venography of Varicose Veins

explains how we obtained good correlation between venous diameters measured with CT in the supine position and those measured with sonography in the semierect position.

CT images are an excellent 3D overview of varicose veins but contain no functional information on reflux or valvar insufficiency. Nevertheless, functional information can be derived from the morphologic information. In our study, CT-based predictions of the primary causes of varicose veins agreed well with the duplex sonographic findings. Determining the primary cause of venous insufficiency is the most important aspect of planning the management of varicose veins. In particular, GSV insufficiency, which is the main cause of varicose veins, can be predicted with high accuracy on the basis of CT venographic findings alone.

CT venography has disadvantages in relation to duplex sonography: the need for contrast medium and ionizing radiation and the lack of utility in the study of venous valve function. The radiation dose administered to the lower extremities during CT venography is in the range of 1.6–3.9 mSv, determined by direct measurement and calculation [19], and most of this dose is delivered to the pelvic region. Pelvic scanning yields information about the pelvic vasculature, such as the status of pelvic varices and the iliac vein. However, if the purpose of CT venography is superficial venous mapping, the range of acquisition can be decreased from the femoral head or great trochanter to the feet, substantially reducing radiation exposure. In terms of radiation dose, MR venography can be considered an alternative technique, but there have been few studies of MR venography in the evaluation of varicose veins.

CT venography was found to have sufficient image quality for evaluation of varicose veins. In addition, CT venographic evalua-

tion of the superficial venous system yields comprehensive anatomic information, leading to avoidance of anatomic pitfalls and increasing surgeon confidence in the surgical approach. Three-dimensional images can be considered a complementary road map for surgical planning.

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