Could Non-contrast 3DCT-Venography Be the First-Choice Diagnostic Imaging Modality for the Treatment of Varicose Vein?

Yoshifumi Takahashi, Masaki Kokubo, MD, and Tetsuya Nozaka

We investigated whether non-contrast three-dimensional computed tomography-venography (3DCTV) using 128-row multidetector computed tomography (MDCT) could be the first-choice diagnostic imaging modality for the treatment of varicose veins. Its utility was assessed in terms of estimation of the venous function, ability to visualize incompetent perforators, association with deep venous diseases, and determination of surgical procedures in 1348 patients with 2696 limbs who underwent non-contrast 3DCTV between September 2009 and August 2013.

A positive correlation was observed between the diameter of the great saphenous vein and the venous filling index \( r = 0.539 \). The detection rate of incompetent perforators was 86.7%. In deep venous incompetence and deep venous thrombosis, a characteristic finding showing a wide net-like spread of varicose veins from a branch not communicating with the saphenous vein was observed. Non-contrast 3DCTV facilitated an objective understanding of the overall three-dimensional images of varices and was useful for determining surgical strategies. Although the concomitant use of duplex scan is necessary for assessment depending on the situation, it appears that non-contrast 3DCTV could be the first-choice diagnostic imaging modality. (This article is a translation of Jpn J Phlebol 2014; 25: 332-9.)

**Keyword:** varicose vein, non-contrast 3DCT-venography, 128-row MDCT

**Introduction**

In the treatment of varicose veins, air plethysmography (APG), Doppler imaging, intravenous venography, duplex scan, three-dimensional computed tomography-venography (3DCTV), magnetic resonance-venography and other imaging studies are performed in addition to examination of subjective symptoms and physical findings. Among the imaging studies, duplex scan is the mainstay modality in many institutions.

At our department, to examine patients presenting with a chief complaint of varicose veins, we measure the venous filling index (VFI) with APG, perform non-contrast 3DCTV using 128-row multidetector computed tomography (MDCT), and confirm the presence or absence of saphenous vein reflux with Doppler imaging. Although the duplex scan is performed in patients who are suspected of having incompetent perforators and deep venous abnormalities by physical examination or non-contrast 3DCTV, there are also many patients in whom non-contrast 3DCTV alone is determined to be sufficient.

We assessed whether non-contrast 3DCTV could substitute for duplex scan as the first-choice diagnostic imaging modality for the treatment of varicose veins in terms of (1) correlation between findings of venodilation obtained by non-contrast 3DCTV and venous function, (2) ability to visualize perforators, and (3) utility for determining surgical strategies and so forth. The results are reported herein.

**Subjects and Methods**

Of patients with varicose veins treated between September 2009 and August 2013, 1348 patients with 2696 limbs who underwent non-contrast 3DCTV, Doppler imaging, and APG were included.

(1) To assess the correlation between findings of venodilation obtained by non-contrast 3DCTV and the venous function, the correlation between the diameter of the saphena magna (SM) calculated on cross-sectional images of non-contrast 3DCTV (defined as the mean of the largest and smallest diameters of SM between the saphenous junction and the site 10 cm peripheral from the junction) and VFI (used as an indicator of the severity of varices) was assessed in patients with SM varices between January and September 2013, excluding patients with recurrence or varices originating from incompetent perforators.
(2) The ability of non-contrast 3DCTV to visualize incompetent perforators was assessed between January 2012 and September 2013 in patients who were suspected by physical examination or non-contrast 3DCTV to have incompetent perforators, which were confirmed by duplex scan and ligated during surgery. An incompetent perforator was defined as a perforator detected by preoperative duplex scan to demonstrate reflux for 0.5 s or more under the milking test. During surgery, milking was performed on the lower limbs, and veins showing reflux from deep veins were diagnosed as incompetent perforators. To detect incompetent perforators with non-contrast 3DCTV, communication with deep veins was examined on cross-sectional images, and the diameters of perforators were measured at the sites of fascial perforation.

(3) Cases in which non-contrast 3DCTV appeared to be useful for determining a diagnosis and surgical strategies were investigated.

**Table 1** List of identified and not identified incompetent perforating vein on non-contrast 3DCTV

| Number of identified perforating vein on 3DCTV (%) | 26 (86.7%) |
| Type (number) | Dodd 3, Boyd 8, Cockett 15 |
| Caliber (mm) | Mean ± SD 5.5 ± 1.5, Range 3.3–10 |
| Number of not identified perforating vein on 3DCTV (%) | 4 (13.3%) |
| Details | Varicose concentrate on narrow area 1, Lipodermatosclerosis 2, Varicose have thrombosis 1 |

3DCTV: three-dimensional computed tomography-venography; SD: standard deviation

---

**Procedure of Non-contrast 3DCTV**

This section describes the procedure employed at our hospital to produce non-contrast 3DCTV images. A Siemens SOMATOM Definition AS+ is used to perform 128-row MDCT, and images are reconstructed by the volume rendering method with Synapse Vincent, an imaging workstation produced by Fujifilm Medical Co., Ltd. The imaging range is set from the pelvis to the tips of the feet, and imaging is performed with the patient in the supine position with the knees slightly bent (approximately 120°) to avoid exclusion and tension of the saphena parva (SP) (Fig. 1).
(2) During the study period, 30 incompetent perforators were included in the analyses. In 26 of the 30 incompetent perforators, perforators were clearly visualized by non-contrast 3DCTV. The diameter (mean ± standard deviation [SD]) of these perforators calculated on 3DCTV images was 5.5 ± 1.5 mm. Perforators could not be identified by 3DCTV in the remaining 4 cases with densely packed varices, severe lipodermatosclerosis, or intravascular thrombi adjacent to perforators (Table 1).

(3) Non-contrast 3DCTV was extremely useful for determining surgical strategies. Typical cases are presented in this section. Figure 3 shows a case of deep vein incompetence (DVI) in both lower limbs. Many varices arising in a net-like pattern from branches not communicating with the saphenous veins are observed in both lower limbs. As with this case, a net-like spread of varices arising from branches not communicating with the saphenous veins is common in cases of deep venous abnormalities including deep vein thrombosis (DVT).

Figure 4 shows a case of an incompetent perforator. By non-contrast 3DCTV, the presence of a perforator is

The imaging parameters are X-ray tube voltage of 120 kV, auto-exposure control (AEC), 0.6 × 128 slices, image reconstruction thickness of 1 mm, and image reconstruction interval of 1 mm.

Imaging takes approximately 30 s. The number of images taken varies with the length of the lower limbs but is approximately 1100. Processing of images is completed within several minutes from the start of imaging. The exposure dose ranges from 4 to 7 mSv. In the outpatient examination rooms, three-dimensional images are reconstructed. They are rotated in any direction, enlarged, or used in conjunction with cross-sectional images to make a diagnosis.

Results

(1) VFI was measured in 169 limbs in the surgical patients. After excluding limbs with recurrence or the condition originating from an incompetent perforator, there were 126 limbs with SM varices and 31 with SP varices. The association between SM diameter and VFI in the limbs with SM varices is shown in Fig. 2. The correlation coefficient was 0.539 (p < 0.0001). Although non-contrast 3DCTV was performed with patients in a decubitus position, which does not elevate venous pressure, a positive correlation was observed between SM diameter and VFI.

(2) During the study period, 30 incompetent perforators were included in the analyses. In 26 of the 30 incompetent perforators, perforators were clearly visualized by non-contrast 3DCTV. The diameter (mean ± standard deviation [SD]) of these perforators calculated on 3DCTV images was 5.5 ± 1.5 mm. Perforators could not be identified by 3DCTV in the remaining 4 cases with densely packed varices, severe lipodermatosclerosis, or intravascular thrombi adjacent to perforators (Table 1).

(3) Non-contrast 3DCTV was extremely useful for determining surgical strategies. Typical cases are presented in this section. Figure 3 shows a case of deep vein incompetence (DVI) in both lower limbs. Many varices arising in a net-like pattern from branches not communicating with the saphenous veins are observed in both lower limbs. As with this case, a net-like spread of varices arising from branches not communicating with the saphenous veins is common in cases of deep venous abnormalities including deep vein thrombosis (DVT).

Figure 4 shows a case of an incompetent perforator. By non-contrast 3DCTV, the presence of a perforator is
suspected at the site with an arrow (Fig. 4A). On a cross-sectional image obtained with this perforator at the center, the perforator is confirmed to communicate with deep veins (Fig. 4B). Because the diameter of the perforator is 6.3 mm showing dilation, it is assumed to be an incompetent perforator. Duplex scan visualized a perforator with a diameter of 6.8 mm and revealed reflux from deep veins (Fig. 4C).

Figure 5A presents a case that is likely to be misdiagnosed as varices attributed to only SM because of reflux observed in SM and varices located in the SM area in the anterior aspect of the leg. By rotating and examining non-contrast 3DCTV images, it can be easily determined that not only SM but also SP is dilated (Fig. 5B). Because reflux in SP is often overlooked, caution is required. However, non-contrast 3DCTV facilitates detection of a dilated SP.

Next, Fig. 6 shows a case of a duplicated saphenous vein, which is difficult to detect with duplex scan, and Fig. 7 shows a case of a Giacomini vein. Because these veins are located under the superficial fascia, they are often impalpable and overlooked on physical examination. However,
non-contrast 3DCTV, which allows understanding of the three-dimensional overall image, facilitates diagnosis and prevents the veins from being overlooked. In addition, regarding variations in influx from SP to deep veins and localized varices (Fig. 8), this modality in conjunction with cross-sectional images clearly visualized influx routes and was useful for determining an appropriate site of high ligation. Moreover, in a case of an obese patient weighing over 100 kg, the modality in conjunction with cross-sectional images also clearly visualized the saphenofemoral junction (Fig. 9) and was extremely useful for reliably performing high ligation regardless of body constitution.

**Discussion**

In the treatment of varicose veins, intravenous venography was the gold standard imaging study in the past. At present, duplex scan is performed as a standard imaging study at many institutions because it allows accurate assessment of not only the morphology but also function of varices. Meanwhile, Ciaggiati et al. first reported the use of MDCT for varicose veins, using non-contrast 3DCTV with 4-row MDCT. They indicated that the function of superficial veins cannot be assessed with MDCT, and that perforators and deep veins are also difficult to assess. However, non-contrast 3DCTV using MDCT is superior for morphological assessment and has the great advantage of allowing anyone to objectively and easily understand the overall image of varices in a short period of time. The usefulness of this modality is also reported by researchers in Japan.

In this study, we attempted to estimate venous function by employing the noteworthy ability of non-contrast 3DCTV to assess morphology in combination with improved resolution due to higher slice MDCT (128-row MDCT). First, because non-contrast 3DCTV was performed with patients in a decubitus position, which does not elevate venous pressure, we assessed the correlation...
between SM diameter and VFI, which is an indicator of the severity of varices. Because reflux in SP could not be assessed with VFI, patients with SP varices were excluded from the analyses. The results revealed that the degree of SM dilation determined by non-contrast 3DCTV correlated with venous function.

Next, we assessed incompetent perforators, which had been considered to be difficult to assess with non-contrast 3DCTV. After 4 patients with severe inflammation caused by lipodermatosclerosis, thrombi, and so forth were excluded from 30 patients with incompetent perforators, incompetent perforators were clearly visualized in the remaining 26 patients. Although it can be assumed that incompetent perforators can be assessed with certainty in patients without inflammation, it seems that the improved resolution due to higher slice computed tomography (CT) and the use of cross-sectional images might have greatly contributed to this result. The diameters of 24 of the 26 perforators (92%) visualized by non-contrast 3DCTV were 4 mm or more. Because a report of a study using duplex scan describes that perforators with a diameter of 4 mm or more are diagnosed as incompetent perforators with a sensitivity of 88%, we consider that perforators visualized by non-contrast 3DCTV can be determined to be incompetent in principle. At our department, for patients who are suspected to have incompetent perforators by physical examination or 3DCTV, duplex scan is performed to make a definitive diagnosis, and perforators are ligated during surgery. Because duplex scan is not performed in all patients, there may be, strictly speaking, overlooked cases of incompetent perforators. However, reflux often disappears after stripping of incompetent perforators. Thus, we consider that there is no problem with ignoring perforators with a diameter of 4 mm or less.

Although non-contrast 3DCTV does not directly provide information on deep veins, “a wide net-like spread of varices arising from branches that do not communicate with the saphenous vein” is often observed in patients with deep venous abnormalities. We consider that, when this finding is observed, deep venous diseases should be actively suspected, and that duplex scan should be performed. We believe that deep venous function can be estimated to some extent from indirect but characteristic findings of non-contrast 3DCTV.

Our basic strategies for the treatment of saphenous varicose veins consist of selective stripping, high ligation of the saphenous vein, and varicosectomy by stab avulsion. According to a study on long-term prognosis of stripping, the causes of recurrence include incomplete high ligation, residual duplicated saphenous vein, incompetent perforators, and reflux in a variant saphenous vein. Because non-contrast 3DCTV could reliably visualize these anatomical features of veins, this modality appeared to facilitate selection of appropriate surgical procedures and to be extremely useful for preventing recurrence. In particular, this modality was greatly effective for high ligation of SP varices. Although it has been reported that there is a risk of concomitant development of pulmonary embolism resulting from DVT when localized varices 20 mm or more in diameter proximal to the saphenopopliteal junction (SPJ) are left, treatment of such varices has been considered to be difficult because of problems associated with neuropathy and variations, as well as difficulty in determining appropriate sites of ligation. Using cross-sectional images obtained from 3DCTV, we can accurately and three-dimensionally assess the diameter of SPJ, the number of branches, and their positional relationship and determine whether varicectomy is applicable. When we decide that varices have to be left, we intraoperatively administer heparin to attempt prevention of DVT.

It is assumed that duplex scans are performed by laboratory technicians at many institutions. When an operation and scans are performed by different persons, information needed by surgeons for the operation may not always be provided in test reports from technicians. In that regard, we share images among all members of a surgical team immediately before surgery and reaffirm the appropriate surgical procedures and the sites of skin incisions on the basis of objective assessment. Because images obtained by duplex scan are difficult to use in this setting, we consider that 3DCTV has greater advantages.

The advantages of non-contrast 3DCTV include the absence of adverse reactions to contrast media or risk to patients with renal dysfunction, as well as the omission of punctures and other procedures. Furthermore, this modality allows physicians to explain disease conditions to patients in daily clinical practice while rotating or enlarging actual 3DCTV images and showing cross-sectional images to the patient. Thus, other advantages include helping patients to understand the severity of their diseases and the need for operation.

The disadvantages of non-contrast 3DCTV include the inability to provide direct information on deep veins or data on thrombi, difficulty in visualization of superficial veins in patients with severe inflammation such as lipodermatosclerosis, severe artifacts in patients with joint prosthesis, and radiation exposure.

**Conclusion**

Non-contrast 3DCTV was superior for morphological assessment, facilitated understanding of the overall image of varices, and was extremely useful for planning surgical strategies. The venous function could also be estimated by examining the degree of venodilation. Furthermore, improved resolution due to higher slice CT and the use of...
cross-sectional images allowed assessment of incompetent perforators, which could previously only be assessed using contrast media. Deep venous diseases could also be estimated by determining the presence or absence of characteristic findings. In comparison with duplex scan, the results and duration of non-contrast 3DCTV do not vary among operators, and its results are objective and can be shared among the surgical team. Although the concomitant use of duplex scan may be necessary depending on the situation, we consider, on the basis of our experience with 1348 cases of non-contrast 3DCTV (128-slice MDCT), that this modality can be the first-choice diagnostic imaging modality in the treatment of varicose vein.

**Disclosure Statement**

There is no conflict of interest in this report.

**References**

1) Caggiati A, Ricci S, Laghi A, et al. Three-dimensional contrastless varicography by spiral computed tomography. Eur J Vasc Endovasc Surg 2001; 21: 374-6.

2) Yamada T, Ohta T, Ishibashi H, et al. Evaluation of varicose vein of lower extremities by three-dimensional CT scanning without use of contrast media. Jpn J Phlebol 2004; 15: 19-23. (in Japanese)

3) Miyazami Y, Nishimoto S, Ishii H, et al. Threedimensional contrast-less computed tomography for varicose vein examination. Jpn J Plast Surg 2013; 56: 313-6. (in Japanese)

4) Sugiyama S, Shimizu Y. The correlation between air plethysmography and CEAP classification in patients with varicose veins. Jpn J Phlebol 2003; 14: 361-6. (in Japanese)

5) Ogi S, Kanaoka Y, Mori T. Diagnosis of incomplete perforators in primary varicose veins by high resolution ultrasonography. J Jpn Surg Soc 1994; 95: 34-9. (in Japanese)

6) van Rij AM, Jiang P, Solomon C, et al. Recurrence after varicose vein surgery: a prospective long-term clinical study with duplex ultrasound scanning and air plethysmography. J Vasc Surg 2003; 38: 935-43.

7) Sakata M, Wakita N, Matsumoto R, et al. Massive acute pulmonary embolism after venous ligation for varicose veins. Jpn J Phlebol 2003; 14: 297-301. (in Japanese)

8) Kokubo M, Nozaka T, Shiroyama S. A case of short saphenous type varicose veins considered to be a source of pulmonary embolism. Hokkaido J Surg 2013; 58: 22-6. (in Japanese)