Preoperative Detection of Inadequate Saphenous Vein by Noncontrast Three-dimensional Computed Tomography

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Objective: The saphenous vein (SV) is a commonly used graft; however, sometimes, it cannot be used due to small diameter or abnormal morphology. Although ultrasonography has been widely used to evaluate SV preoperatively, it has difficulty in capturing the entire image of the SV. We conducted this study to clarify the usefulness of noncontrast computed tomography (CT) and to elucidate the incidence of inadequate SV as a graft. Materials and methods: All patients routinely underwent preoperative thoracoabdominal CT. The scanning range was extended to the ankles and the exposure increased by approximately 5-6 mGy. Three-dimensional (3D) CT images were reconstructed from noncontrast CT images. From October 2017 to February 2019, 54 patients’ SVs were evaluated by preoperative 3D-CT. We generally harvested the SV from the lower leg, but if the SV of the lower leg had any morphological abnormality, we harvested from the thigh. Results: Of the 54 patients, the proportion of patient with inadequate SVs was approximately 20%. Adequate SV was 76.9% in the lower legs and 88.0% in the thighs. Forty-seven SVs were harvested from the lower legs, and 15 SVs were switched to harvest from the thighs. Conclusion: Noncontrast 3D-CT can provide accurate, objective, and reproducible high-resolution images of the SVs with a slight increase in radiation exposure. The proportion of adequate SV was not high, and nearly 40% of the patients had an inadequate SV as a graft. KEY WORDS: coronary artery bypass grafting, saphenous vein graft, noncontrast three-dimensional computed tomography, preoperative evaluation.

I. Introduction

Despite the widespread use and superior patency of the arterial graft for coronary artery bypass grafting (CABG), the saphenous vein (SV) continues to be the most commonly used graft. The SVs, however, sometimes have anatomical problems such as varicose veins, small or large diameter, and duplication. Ultrasonography has been the main modality for preoperative SV evaluation because of its simplicity and low invasiveness; however, it has drawbacks, such as a lack of objectiveness, poor reproducibility, and difficulty in capturing the entire image of SV. Meanwhile, computed tomography (CT) can clearly visualize the SV without contrast. Although CT is performed as a standard preoperative examination for CABG in Japan, it is only used for evaluating the thoracoabdominal area in most facilities. To evaluate graft suitability of the SV preoperatively, we extended the CT scanning range to the lower extremities. The present study was conducted to clarify the usefulness of CT in the preoperative evaluation of the SV and to elucidate the incidence of inadequate SV as a graft.

II. Materials and methods

From October 2017 to February 2019, preoperative noncontrast three-dimensional (3D) CT of the lower extremities was performed in 54 patients undergoing CABG. CT examinations were performed using a 320-multidetector CT system (Aquilion 1; Canon Medical Systems Corp., Otawara, Japan) or a 128-multidetector CT system (Somatom Definition Flash; Siemens Medical Solutions, Forchheim, Germany). All thin-section axial images were reconstructed with the volume-rendering method using a Synapse Vincent workstation (Fujifilm Medical Co., Ltd, Tokyo, Japan). The CT scanning range was extended to the lower extremities in addition to the contrast enhanced thoracoabdominal CT which performed as a standard preoperative examination, thoracoabdominal area was contrasted and the pelvis to the ankles was noncontrast. The patient was in the supine position and legs mildly supinated. Imaging took approximately 5
seconds longer than a usual thoracoabdominal CT. The required radiation exposure dose was approximately 5 to 6 mGy, which is one-third to one-half of the usual thoracoabdominal CT dose. Cardiovascular surgeons performed the 3D reconstruction, which took approximately 3 minutes. The SV of both the thighs and lower legs were counted one by one, with four SV segments per case. We evaluated the presence of morphological abnormalities such as duplication, reticulation, small diameter, or varicose vein.

The diameter of the SV was measured by CT axial imaging at the average point of the vein at the middle of the thigh and middle of the lower leg. We defined small-diameter SVs as less than 3 mm, and the diameter was measured at the narrowest part of the vein at the thigh and lower leg. SVs with sufficient diameter that had duplication were determined as adequate.

All patients underwent an ultrasound evaluation of the SV under general anesthesia just before the start of surgery. The patient was placed in supine and slight reverse Trendelenburg position, with the legs mildly supinated and the hip and knee joints slightly flexed. The SV was evaluated with B-mode duplex ultrasonography using a Sonosite S-Nerve (SonoSite Inc., Bothell, WA, USA) with an HFL38x 13–6 MHz linear transducer probe (SonoSite Inc.).

We harvested all SVs using the no-touch (NT) harvesting technique under skip incisions.

### III. Results

The patients’ characteristics are summarized in Table 1, and the characteristics of the SVs are shown in Table 2. Of the 54 patients, 22 SVs had morphological abnormalities. In the lower legs, 13 SVs had an abnormal morphology (including duplication, reticulation, and varicose veins) and 18 SVs had small diameters. The proportion of adequate SV was 76.9%. In the thighs, the proportion of adequate SV was 88.0%. Forty-seven SVs were harvested from the lower legs, and 15 SVs were harvested from the thighs. The average diameter of harvested SV grafts was 3.8 mm in the thigh and 3.7 mm in the lower leg.

Preoperative ultrasonography showed that the actual position of SVs and the side branches were consistent with the CT findings in all cases. All branches depicted with 3D-CT were also detected with ultrasonography. Meanwhile, there were no branches that were detected by only ultrasonography but not visualized by CT. It was very easy to scan SV with ultrasound while viewing 3D-CT images on a monitor.

The graft patency rate for SV was confirmed by angiography or CT-angiography before discharge. The patency rate was 96.8% (60/62 grafts).

We present four representative cases in which preoperative noncontrast 3D-CT was particularly useful.

### Table 1  Patient characteristics (n=54)

| Characteristics            | Total | Thigh | Lower leg |
|---------------------------|-------|-------|-----------|
| Age (years)               | 68.0 ± 9.7       |       |           |
| Gender (male/female)      | 40/14 |       |           |
| Body mass index (kg/m²)   | 24.9 ± 3.4       |       |           |
| Hypertension              | 51 (94.4)        |       |           |
| Diabetes mellitus         | 28 (51.9)        |       |           |
| Dyslipidemia              | 54 (100)         |       |           |
| Chronic kidney disease    | 21 (38.9)        |       |           |
| LV dysfunction (EF <35%)  | 8 (14.8)         |       |           |
| No. of diseased vessels   |                   |       |           |
| One vessel                | 3 (5.6)          |       |           |
| Two vessels               | 6 (11.1)         |       |           |
| Three vessels             | 25 (46.3)        |       |           |
| Left main trunk disease   | 20 (37.0)        |       |           |
| Off pump surgery          | 46 (85.2)        |       |           |

Variables are expressed as mean ± standard deviation or number (%). LV: left ventricle, EF: ejection fraction.

### Table 2  Characteristics of the saphenous vein

| Characteristics                  | Total | Thigh | Lower leg |
|----------------------------------|-------|-------|-----------|
| Number                           | 216   | 95 (88.0) | 83 (76.9) |
| Adequate SVs                     | 178 (82.4) |       |           |
| Harvested grafts                 | 62    | 15    | 47        |
| Inadequate SVs                   | 38 (17.6) | 13 (12.0) | 25 (23.1) |
| Diameter <3 mm                   | 27 (12.5) | 9 (8.3)    | 18 (16.7) |
| Abnormal morphology              | 22 (10.2) | 9 (8.3)   | 13 (12.0) |
| Duplication                      | 16 (7.2) | 7 (6.5)    | 9 (8.3)   |
| Reticulation                     | 2 (0.9)  | 0 (0)     | 2 (1.9)   |
| Varicose veins                   | 4 (1.9)  | 2 (1.9)   | 2 (1.9)   |

Variables are expressed as mean ± standard deviation or number (%). SVs: saphenous veins.
1. Case 1

A 70-year-old woman with three-vessel disease was referred to our institute. Preoperative noncontrast 3D-CT showed duplicated SV of the left thigh and reticulated SV of the left lower leg; however, the right-side SV (*) was evaluated to have sufficient diameter without abnormal morphology. LAO: left anterior oblique position, RAO: right anterior oblique position.

2. Case 2

A 76-year-old man with three-vessel disease and aortic stenosis was referred to our institute. Preoperative noncontrast 3D-CT showed varicose veins (white star) of the SVs of the right thigh and the right lower leg and small aneurysmal deformity (black star) of the SV of the right thigh. The left SVs (*) of both the thigh and the lower leg were evaluated to be adequate. LAO: left anterior oblique position, RAO: right anterior oblique position.

3. Case 3

A 75-year-old man with severe left main trunk stenosis and aortic stenosis was referred to our institute. Preoperative noncontrast 3D-CT showed that the diameter of right-side SV (†) was small; however, the left-side SV (*) was evaluated to have sufficient diameter without abnormal morphology. LAO: left anterior oblique position, RAO: right anterior oblique position.
placement and multivessel on-pump beating heart CABG; the left IMA was anastomosed to the LAD, the right IMA to the circumflex artery, and the SV to the PD.

4. Case 4

A 47-year-old man with three-vessel disease was referred to our institute. Preoperative noncontrast 3D-CT showed reticulation of the SV of the right lower leg and duplication of the left-side SV (Fig. 4). The use of SV was abandoned, and OPCAB using bilateral IMA and gastroepiploic artery was performed.

IV. Discussion

The SV is the most commonly used graft in CABG because of its ready availability and ease of use. Moreover, the development of a device that enables proximal anastomosis of grafts without aorta clamping as well as the development of the NT-SV harvesting technique, which harvests the SV as a pedicled graft with a pedicle of surrounding perivascular tissue and avoids direct contact with the vein or excessive high-pressure expansion, has further established the usefulness of SV grafts. As the use of the NT-SV harvesting technique permits long-term graft patency similar to that of IMA graft2,3; we used this technique from October 2016.

Although the usefulness of SV graft is without doubt, approximately 30% of SVs have anatomical problems such as varicose veins, small or large diameter, duplication, and reticulation, which render them unsuitable for grafting9. Although ultrasonography is the main modality for preoperative SV evaluation1), it has poor reproducibility, is time-consuming, and has other limitations such as operator-dependent variable results. Furthermore, because its visual range is limited, it is hard to capture the entire SV image. Since acquiring an objective and accurate image of the entire SV before surgery is essential for harvesting SV grafts, we preoperatively assessed the SV properties and chose the graft harvesting site using noncontrast multidetector 3D-CT of the lower extremities.

Caggiati et al. first reported the usability of noncontrast 3D-CT for morphological assessment of varicose veins5). Noncontrast 3D-CT uses the difference in CT value between the vein (30 HU) and its surrounding fat tissue (-100 HU) and reconstructs the images by volume-rendering method, with skin and subcutaneous fat removed. One of the advantages of noncontrast 3D-CT is the absence of adverse reactions to contrast media or risk to patients with renal dysfunction.

Additionally, noncontrast 3D-CT is superior to ultrasonography in detecting malformations or morphological abnormalities such as varicose vein, duplicated SV, and variations of the side branches of the SV more accurately and objectively6). Because it is difficult to capture the exact position of the side branches using the NT technique, there is a possibility of injuring the branches under the skin skip.

In the case of duplicated SVs, determining which one is the main trunk is difficult. In the present study, 17.6% of the SVs (12% of the thigh and 23% of the lower leg) were judged as inadequate for SV grafting because of an abnormal morphology such as small diameter, duplication, reticulation, or varicose vein. Using preoperative noncontrast 3D-CT rather than ultrasonography, the SV can be evaluated in more detail and harvested more easily, with a reduced possibility of graft injury. Furthermore, 3D-CT imaging can comprehensively display a detailed 3D map of the SV on the monitor. Thus, anyone can understand the overall properties of the SVs objectively and immediately before surgery, allowing one to determine the site of the skin incision based on an objective assessment.

Recently, Na et al. reported the usefulness of preoperative thoracoabdominal CT angiography in patients undergoing CABG7). They reported that incidental findings affecting the preoperative management were found in half of the patients and highlighted the usefulness of the preoperative evaluation of the IMAs and iliofemoral arteries in one-third of the patients undergoing CABG.

In patients undergoing CABG using the SV, we obtained highly useful information by expanding the CT scanning range from the thoracoabdominal area to the lower limbs.

However, CT has the disadvantages of radiation exposure and increased severity of artifact in patients with joint prosthesis. Moreover, hospital reimbursement remains the same if the lower extremities CT is added to a usual thoracoabdominal CT, but additional CT scan itself costs about 10,000 yen, and the hospital would lose the amount of the medical resource such as working...
fee of doctors, radiologists, radiology technicians, and other paramedical staffs. Despite these disadvantages, we consider 3D-CT to have great advantages in elucidating the overall properties of the SVs accurately, objectively and reproducibility, less time-consuming, with little invasiveness and low cost; in evaluating whether the SV can be used as a graft in terms of detecting malformations, morphological abnormalities or variations of the side branches of the SV; and in determining the graft harvest or skin incision site more easily with a reduced possibility of graft injury.

The present study has several limitations. First, the study was retrospective and observational in nature and was conducted at a single center. Second, the number of patients was small. Third, because the ultrasound evaluation was performed just before surgery, SV diameter measurements were not made. Whether there is a discrepancy in diameter between CT and ultrasound measurements has not been confirmed. However, it has been reported that the diameter measurement results were consistent between CT and ultrasonic evaluations. Fourth, it is not possible to show the difference of outcomes between pre and post induction of CT evaluation in our clinical series because SV was only evaluated by ultrasonography and no images were stored before induction of non-contrast 3D CT evaluation in October 2017.

The usefulness of noncontrast 3D-CT has been previously reported; however, this study describes both the usefulness of noncontrast 3D-CT and its ability to diagnose an inadequate SVs. In addition, this is the first paper that examined the frequency of inappropriate SV by preoperative noncontrast 3D-CT. We believe that this simple evaluation modality is beneficial for both the patient and the surgeon, as a considerable amount of information can be obtained with acceptably less invasiveness.

V. Conclusion

Noncontrast 3D-CT can provide accurate, objective, and reproducible high-resolution images of the SVs, but the radiation exposure is slightly increased. Furthermore, 3D-CT is a useful modality for determining the graft harvest site. Using noncontrast 3D-CT, we found that the proportion of SVs that were adequate as a graft was not high and even lower than 80% for the lower legs. Additionally, nearly 40% of the patients had an inadequate SV as a graft in one or both of the thighs and lower legs.

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Disclosure statement

No conflict of interest.

References

1) Soo A, Noel D, MacGowan S: Ultrasound mapping of the long saphenous vein in coronary artery bypass graft surgery. Interact Cardiovasc Thorac Surg 2013; 16: 886–887
2) Samano N, Geijer H, Liden M, et al: The no-touch saphenous vein for coronary artery bypass grafting maintains a patency, after 16 years, comparable to the left internal thoracic artery: a randomized trial. J Thorac Cardiovasc Surg 2015; 150: 880–888
3) Souza D: A new no-touch preparation technique. Technical notes. Scand J Thorac Cardiovasc Surg 1996; 30: 41–44
4) Kupinski AM, Evans SM, Khan AM, et al: Ultrasonic characterization of the saphenous vein. Cardiovasc Surg 1993; 1: 513–517
5) Caggiati A, Ricci S, Laghi A, et al: Three-dimensional contrastless varicography by spiral computed tomography. Eur J Vasc Endovasc Surg 2001; 21: 374–376
6) Maruyama Y, Imura H, Shiraka M, et al: Preoperative evaluation of the saphenous vein by 3-D contrastless computed tomography. Interact Cardiovasc Thorac Surg 2013; 16: 550–552
7) Na KJ, Choi JW, Hwang HY, et al: Usefulness of thoraco-abdominal computed tomography angiography in coronary artery bypass patients. Eur J Cardiothorac Surg 2018; 54: 1110–1115
8) Johnston WF, West JK, LaPar DJ, et al: Greater saphenous vein evaluation from computed tomography angiography as a potential alternative to conventional ultrasonography. J Vasc Surg 2012; 56: 1331–1337. e1