

Impact of the no-touch harvesting technique on the vessel diameter of saphenous vein grafts for coronary artery bypass grafting



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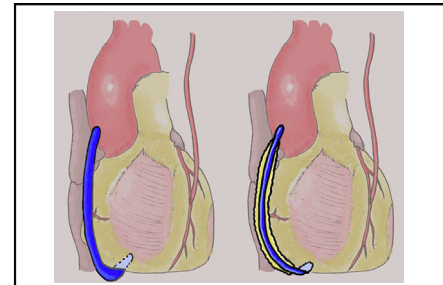
ABSTRACT

Objectives: To explore the impact of the no-touch harvesting technique on the vessel diameter of saphenous vein grafts.

Methods: This retrospective, single-center study enrolled 166 patients who underwent isolated coronary artery bypass grafting using saphenous vein grafts. Saphenous vein grafts were harvested conventionally in 83 patients (conventional group) and using the no-touch technique in 83 patients (no-touch group). We analyzed graft patency and the vessel diameters of saphenous vein grafts in the pre- and postoperative states. The diameter mismatch between the saphenous vein grafts and the coronary artery at the anastomotic site was also measured; preoperative diameter was measured using ultrasound imaging, and the postoperative diameter was measured using electrocardiogram-gated enhanced computed tomography.

Results: A total of 135 saphenous vein grafts (66 and 69 grafts in the conventional and no-touch groups, respectively) were evaluated for postoperative patency. Graft patency was equivalent in the 2 groups (conventional, 96.9% vs no-touch, 100%; $P = .24$). A detailed evaluation was performed in 109 saphenous vein grafts (52 and 57 grafts in the conventional and no-touch groups, respectively). Saphenous vein graft diameter was significantly distended in the conventional group (preoperative, 2.6 ± 0.7 mm vs postoperative, 3.4 ± 0.5 mm; $P < .0001$). However, saphenous vein graft diameter did not change in the no-touch group (preoperative, 2.9 ± 0.4 mm vs postoperative 2.8 ± 0.4 mm, $P = .33$). The diameter mismatch was significantly smaller in the no-touch group (conventional 1.4 ± 0.6 mm vs no-touch 1.0 ± 0.4 mm, $P < .0001$).

Conclusions: The no-touch technique avoids the expansion of graft diameter and diameter mismatch between the saphenous vein grafts and coronary artery. (JTCVS Techniques 2022;15:87-94)



No-touch harvesting avoids expansion of the vessel diameter of saphenous vein grafts.

CENTRAL MESSAGE

The no-touch harvesting technique avoids expansion of the vessel diameter of saphenous vein grafts, which may improve graft patency.

PERSPECTIVE

The no-touch harvesting technique is expected to resolve the issue of long-term graft patency. The vessel diameter of grafts affects patency; however, the impact of the no-touch harvesting technique on vessel diameter remains unclear. This study investigated whether the no-touch harvesting technique causes differences in the vessel diameter of saphenous vein grafts.

Coronary artery disease remains one of the major causes of death worldwide.¹ In many clinical guidelines, coronary artery bypass grafting (CABG) is recommended as the gold standard revascularization for various coronary stenotic lesions.^{2,3} Despite the inferior long-term patency compared with that of arterial grafts, saphenous vein grafts (SVGs) have been widely used for CABG because of their ease of use. In 2015,

Samano and colleagues⁴ reported excellent long-term patency of SVGs harvested using the no-touch technique. Subsequently, an increasing number of reports attempted to elucidate the mechanism underlying these superior outcomes of the no-touch harvesting technique. In this study, we focused on the impact of the no-touch technique on vessel diameter changes in SVGs.

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Read at the 26th Annual Meeting of the Japanese Association for Coronary Artery Surgery, Yamaguchi, Japan, July 15, 2021.

The data that support the findings of this study are available from the corresponding author, R.S., upon reasonable request.

Received for publication Jan 20, 2022; revisions received June 16, 2022; accepted for publication July 1, 2022; available ahead of print July 12, 2022.

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<https://doi.org/10.1016/j.xjtc.2022.07.005>

Abbreviations and Acronyms

- CABG = coronary artery bypass grafting
- CT = computed tomography
- NO = nitric oxide
- PVAT = perivascular adipose tissue
- RCA = right coronary artery
- SVG = saphenous vein graft

METHODS

This retrospective, single-center study was approved by the institutional review board of Yamaguchi University Hospital (Study ID: H2020-149, approved on March 24, 2021). The center used an opt-out consent process, and all procedures complied with the Declaration of Helsinki.

Conventional and No-Touch Harvesting Techniques

In both techniques, SVGs were mainly harvested from the lower legs of the skipped longitudinal leg skin incision. SVGs with venous reflux or varicose were excluded as grafts except in one patient. Fourteen patients did not undergo preoperative ultrasound vein mapping, and 152 patients completed vein mapping (Figure 1). No SVGs were excluded as CABG grafts based on intraoperative findings of SVGs. In total, 152 patients, 29 patients (23 male and 6 female patients) had venous reflux in their lower limbs. Six patients among these 29 patients had varicose veins, whereas 28 patients had venous reflux in only 1 leg; hence the SVGs were harvested from the other healthy leg. Only 1 patient had venous reflux in both legs, but did not have varicose veins; hence, SVG was harvested from the patient's thigh.

In the conventional technique, SVGs were stripped of the surrounding tissue gently, and the side branches were ligated using 4-0 braided silk. The harvested SVGs, syringes, and pressure monitoring line were connected to a T-shaped stopcock. They were manually distended using a syringe with a blood-mixed solution (30 mL of blood, 30 mg of papaverine hydrochloride, and 3000 U of heparin sodium) before grafting at <300 mm Hg. The lumen of the harvested SVGs were fulfilled with a blood-mixed solution that included papaverine and heparin to avoid impairment of endothelial cells. They were stored in gauze wetted with saline until use.

In the no-touch technique, SVGs were harvested along with 5 mm of surrounding fat tissue. Side branches were sealed using an ultrasonic energy device (HARMNIC FOCUS+ scissors handle; Ethicon). After

removal from the legs, SVGs were connected to the side tube of a 4-Fr sheath, which was inserted into the femoral artery and dilated with a blood-mixed solution by arterial pressure for 10 minutes (Video Abstract). The SVGs were neither distended nor manually flushed. The harvested SVGs were stored in the same manner as in the conventional methods.

Study Enrollment

The outline of the study enrollment process is shown in Figure 1. A total of 166 consecutive patients who underwent isolated CABG with at least 1 SVG, between April 2011 and December 2020, were enrolled in this study. During this period, 183 SVGs were harvested from 166 patients. We implemented a no-touch harvesting technique in 2016. Before 2016, 94 SVGs were harvested using the conventional technique from 83 patients (conventional group, CV group). After 2016, a total of 89 SVGs were harvested using the no-touch harvesting technique from 83 patients (no-touch group, NT group).

First, we evaluated early and mid-term graft patency (left arm of Figure 1) to confirm that the induction of the no-touch harvesting technique in our institution did not deteriorate graft patency. A total of 48 patients were excluded because postoperative angiography or enhanced computed tomography (CT) scan to evaluate graft patency was not performed due to chronic kidney disease or the patients' decisions. Regarding evaluation of mid-term grafts, patients underwent an annual examination of chest radiograph, electrocardiogram, and echocardiography. Additional angiography or enhanced CT scans were performed to confirm graft patency if patients had any chest symptoms or abnormal findings on annual examination.

Second, we analyzed vessel diameter (right arm of Figure 1); 74 patients were excluded because they did not have enough image data for vessel diameter analysis. For example, the patients did not have preoperative SVG measurement or high-resolution images of postoperative CT scans, which require evaluation. Details of how vessel diameter was measured are explained below. We measured the diameter of the preoperative SVG, postoperative SVGs, and coronary arteries at the anastomotic site.

The primary end points of this study were as follows: (1) early- and mid-term graft patency, (2) preoperative and postoperative SVGs diameter, and (3) diameter mismatch between the SVGs and coronary arteries at the anastomotic site.

Measurement of Vessel Diameter

In the preoperative state, a total of 6 points of SVG diameter (3 points in the lower legs and 3 points in the thigh) were measured by ultrasound

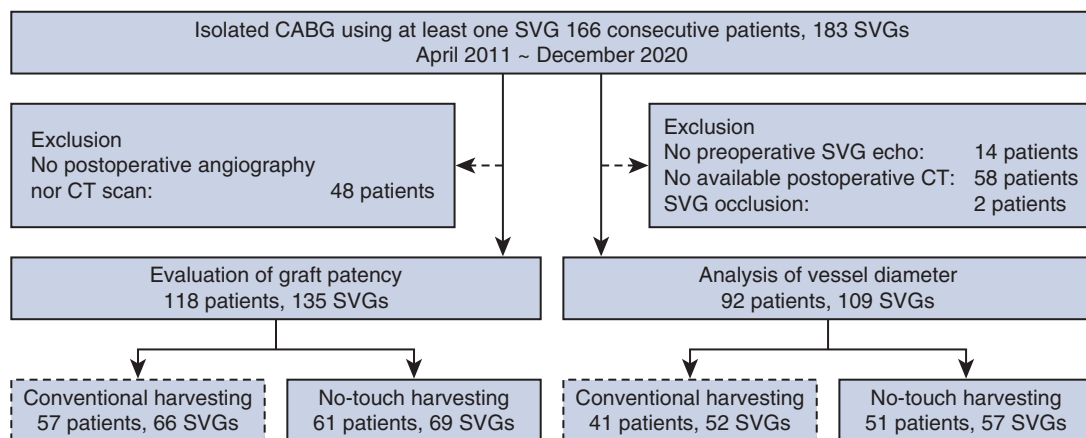


FIGURE 1. Study enrollment. The patency evaluation was performed in 118 patients with 135 grafts (left arm). The vessel diameter analysis was performed in 92 patients with 109 grafts (right arm). CABG, Coronary artery bypass grafting; SVG, saphenous vein graft; CT, computed tomography.

imaging. Two of these 6 measured diameters, which were closest to the harvested area, were averaged and identified as the preoperative SVG diameter (Figure 2, A).

A schematic drawing of how to measure the vessel diameter postoperatively is shown in Figure 2, B. Postoperative electrocardiogram-gated enhanced CT scans were performed using a 192-slice CT scanner (Somatom Force; Siemens Healthcare). SVG diameters at 3 points, proximal, mid-, and distal portion of the SVG, were measured by image analysis software named Ziostation (Ziosoft Inc). The mean value of these 3 points was identified as the postoperative SVG diameter. The coronary artery diameter at 2 points, just proximal and distal sites of anastomosis, was measured. The mean value of these 2 points was identified as the postoperative diameter of the coronary artery. The vessel diameters were measured in a blinded manner. Postoperative CT scans were reviewed by blinded physicians.

Statistical Analysis

Continuous data are expressed as mean \pm standard deviation and were evaluated using paired or unpaired Student *t* tests. Time-to-event curves are presented as Kaplan–Meier estimates and were compared between groups using the log-rank test. Statistical analyses were performed using the StatView software (version 5.0; SAS Institute).

RESULTS

In this study, in-hospital mortality was observed in 1 patient in the no-touch group (1/166, 0.6%) due to pulmonary embolism. A total of 135 patients underwent postoperative

angiography or enhanced CT within 1 month after CABG (Figure 1, left arm). Early graft patency was 98.5% (133/135) overall, 96.9% (64/66) in the CV group, and 100% (69/69) in the NT group. Early graft patency was not significantly different between the 2 groups ($P = .24$). Mid-term graft patency is shown in Figure 3. Graft patency at 4 years was 87.5% overall, 82.7% in the CV group, and 97.4% in the NT group, and the mid-term graft patency was not significantly different between the 2 groups ($P = .11$, log-rank).

More detailed evaluations were performed in 92 patients, 109 SVGs (Figure 2, right arm), because they completed preoperative SVG diameter measurement and had postoperative high-resolution CT scan images for vessel diameter analysis. The clinical characteristics for the analysis of vessel diameters are shown in Table 1. The mean age was 68.2 years in the CV group and 69.8 years in the NT group ($P = .39$). Preoperative comorbidity was not significantly different between the 2 groups. In the CV group, 48% (25/41) of the SVGs were grafted to the RCA territory, and 40% (21/41) were grafted to the circumflex territory. In the NT group, 64% (34/51) of SVGs were grafted to RCA and 26% (15/51) were grafted to circumflex territory.

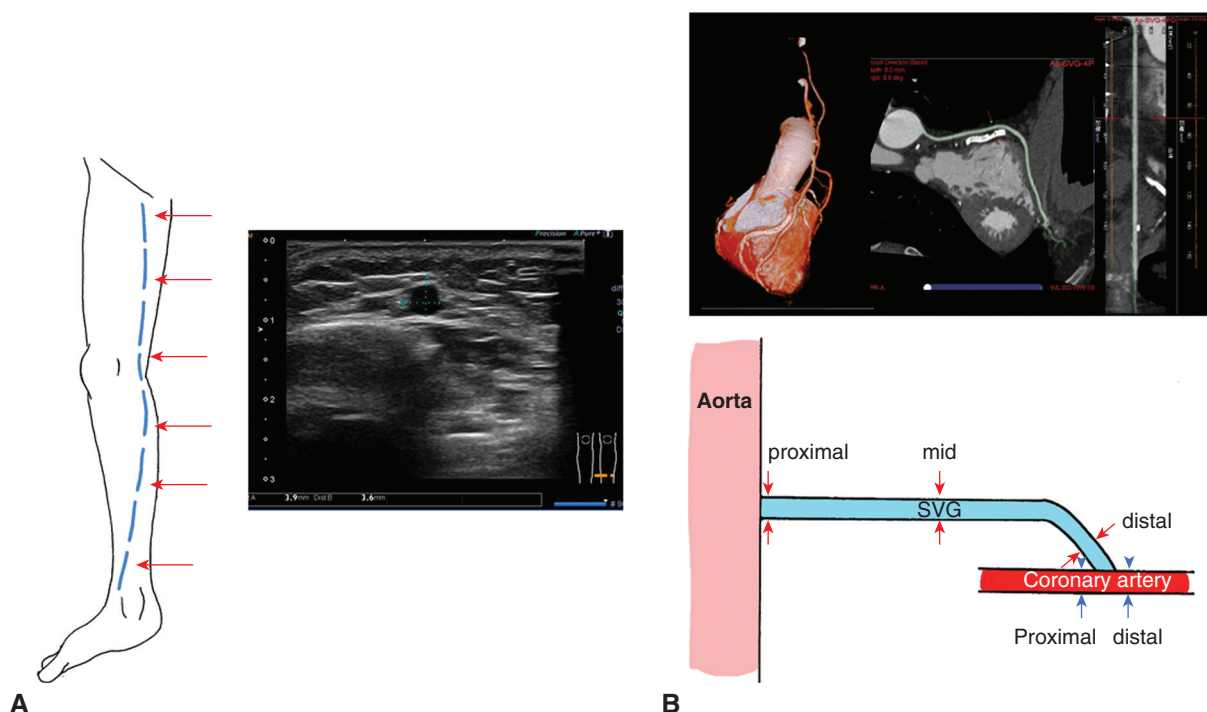


FIGURE 2. Vessel diameter measurement. A, Preoperative measurement of the SVG using ultrasound. A total of 6 points of SVG diameter were measured. Two of these 6 measured diameters, which were closest to the harvested area, were averaged and identified as the preoperative SVG diameter. B, Postoperative measurement of the SVG and coronary artery using enhanced CT. SVG diameters at 3 points, proximal, mid-, and distal portion of the SVG, were measured. The mean value of these 3 points was identified as the postoperative SVG diameter. The coronary artery diameter at 2 points, just proximal and distal sites of anastomosis, was measured. The mean value of these 2 points was identified as the postoperative coronary artery diameter. SVG, Saphenous vein graft.

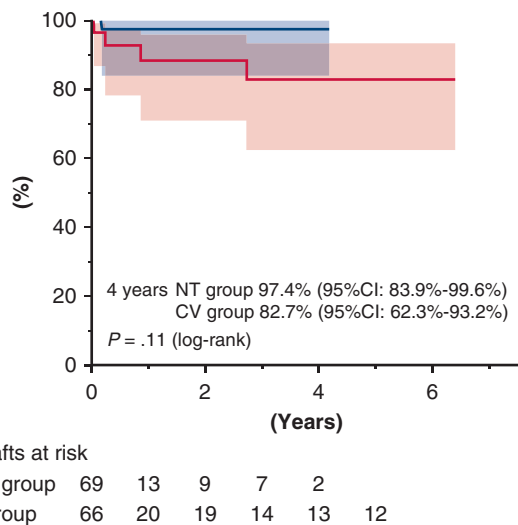


FIGURE 3. Freedom from graft occlusion. The curve for the CV group is represented by a red line and that for the NT group is represented by a blue line. The 95% confidence interval for each group is shaded. NT, No-touch; CV, conventional; CI, confidence interval

The results of the vessel diameter analysis are shown in Figure 4. SVGs in the CV group tended to be distended; contrastingly, SVGs in the NT group tended to maintain preoperative vessel diameter (Figure 4, A). The average diameter of each vessel and its graph are shown in Figure 4, B. The preoperative SVG diameter was 2.6 ± 0.7 mm in the CV group and 2.9 ± 0.4 mm in the NT group. There was no statistically significant difference between the 2 groups ($P = .07$, unpaired *t*-test). In the postoperative state, SVGs in the CV group were distended up to 3.4 ± 0.5 mm. However, SVGs in the NT group remained at 2.8 ± 0.4 mm, which was almost the same as the

preoperative diameter. SVGs in the CV group were significantly distended in the postoperative state ($P < .0001$, paired *t*-test). In contrast, SVGs in the NT group were not distended ($P = .33$, paired *t*-test).

The coronary artery diameters at the anastomotic site were 2.0 ± 0.3 mm in the CV group and 1.8 ± 0.2 mm in the NT group. Diameter mismatch between SVGs and the coronary artery was 1.4 ± 0.6 mm in the CV group and 1.0 ± 0.4 mm in the NT group; therefore, the diameter mismatch was significantly smaller in the NT group ($P < .0001$).

DISCUSSION

Several trials have tried to elucidate the clinical efficacy and mechanism of the no-touch technique. Some of these trials showed improved graft patency, while some failed to demonstrate improved graft patency.⁵ More studies have tried to elucidate the precise mechanism of the no-touch technique on graft patency. In this study, both early- and mid-term graft patency rates were excellent in both groups. In the no-touch group (the late period of this study), SVGs were much more anastomosed to the right coronary artery (RCA) territory because most of the left coronary artery territory was covered by the internal thoracic artery bilaterally in our hospital. Therefore, 64% of NT-SVGs were anastomosed to the RCA system (Table 1). In a previous study, early SVG patency anastomosed to the circumflex and anastomosed to the RCA were not different.⁶ We think the difference of anastomotic site between the 2 groups does not have a major impact on graft patency. Furthermore, we found that the postoperative vessel diameter of SVGs was significantly smaller when SVGs were harvested using the no-touch technique (Figure 5 and Video Abstract). To the best of our knowledge, this is the first report to focus on the impact of the no-touch technique on vessel diameter change in SVGs.

Ischemic heart disease is the leading cause of death globally,¹ with CABG and percutaneous coronary intervention being the current gold standard therapies for ischemic heart disease.^{2,3} SVGs are one of the most common grafts for CABG because of their availability and ease of use. According to the annual report 2020 from the Japanese Association for Coronary Artery Surgery, SVGs were the second most-used grafts—after left internal thoracic artery.⁷ SVGs are indispensable conduits for CABG; however, the inferior long-term patency is a major issue. The no-touch harvesting technique is expected to resolve this issue of long-term patency and has thus attracted much attention. In the 2018 European Society of Cardiology/European Association for Cardio-Thoracic Surgery guidelines on myocardial revascularization, no-touch vein harvesting was a class IIa recommendation, because of its superior patency compared to conventional harvesting.² However, the precise mechanism of this improved

TABLE 1. Clinical characteristics for the analysis of vessel diameter

	Conventional (n = 41)	No-touch (n = 51)	P value
Age, y	68.2 ± 9.0	69.8 ± 8.5	.39
Male, n (%)	29 (70.7)	38 (74.5)	.81
Hypertension, n (%)	32 (78.0)	42 (82.3)	.60
Dyslipidemia, n (%)	27 (65.8)	37 (72.5)	.50
Diabetes mellitus, n (%)	23 (56.0)	30 (58.8)	.83
Hemodialysis, n (%)	4 (9.7)	6 (11.7)	1.00
Number of used SVGs	52	57	
Target			.20
RCA (%)	25 (48.1)	37 (64.9)	
Cx (%)	21 (40.4)	15 (26.3)	
Dx (%)	6 (11.5)	5 (8.8)	
LAD (%)	0	0	

SVG, Saphenous vein graft; RCA, right coronary artery; Cx, circumflex branch; Dx, diagonal branch; LAD, left anterior descending artery.

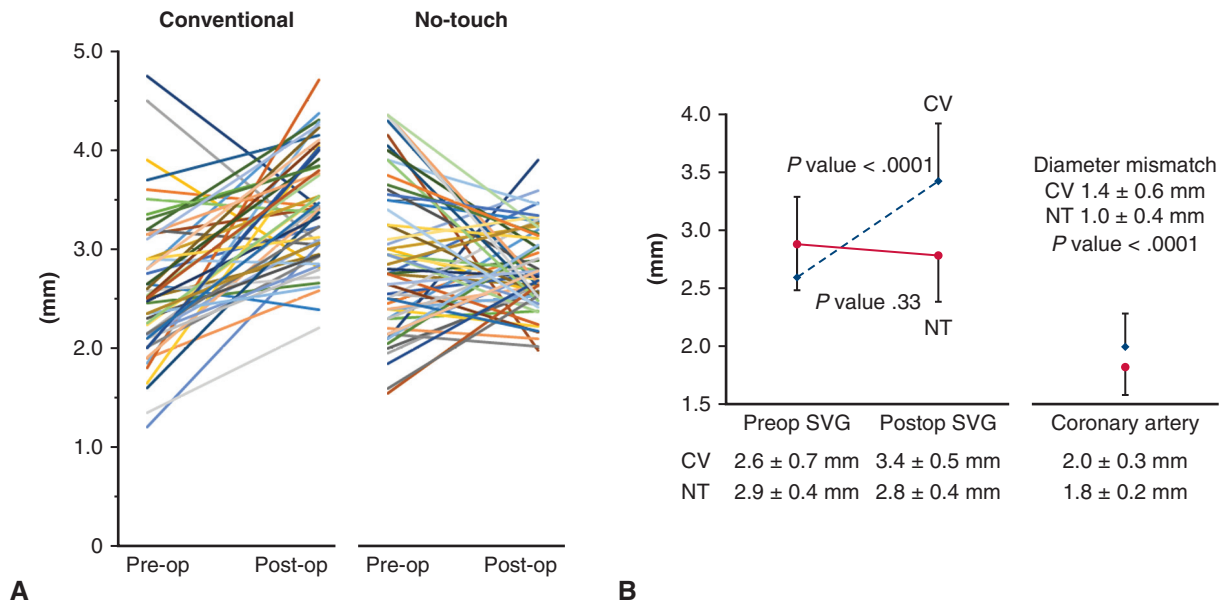


FIGURE 4. Diameter of the SVG and coronary artery. A, Diameter change of the SVG for all individuals. B, Averaged diameter of the SVG and coronary artery. The curve for the CV group is represented by a dashed line, and that for the NT group is represented by a solid line. CV, Conventional; NT, no-touch; SVG, saphenous vein graft.

patency remains unclear. We failed to demonstrate improved graft patency in the mid-term, although data on long-term patency were not available in this study.

There are many potential factors that can contribute to the long-term patency of no-touch SVGs. Stigler and colleagues⁸ reported that endothelial SVGs are exposed to more than 300 mm Hg when manually distended, which can induce loss of endothelial cells and histological deterioration. The no-touch SVG maintains normal vascular structures, including endothelial, medial, and adventitial

cells.^{9,10} Furthermore, no-touch SVGs preserve intact vasa vasorum. The luminal flow to the vein graft wall is supplied by a double pathway: intrinsic, provided directly from blood flow, and extrinsic, ensured by the vasa vasorum.¹¹ No-touch SVGs maintain rich blood flow of the vasa vasorum after their implantation in CABG, which can prevent ischemia of the SVG wall.¹² Perivascular adipose tissues (PVATs) are also preserved by no-touch harvesting. The saphenous vein has muscular layers, and vasospasm of the saphenous vein has been reported both intraoperatively

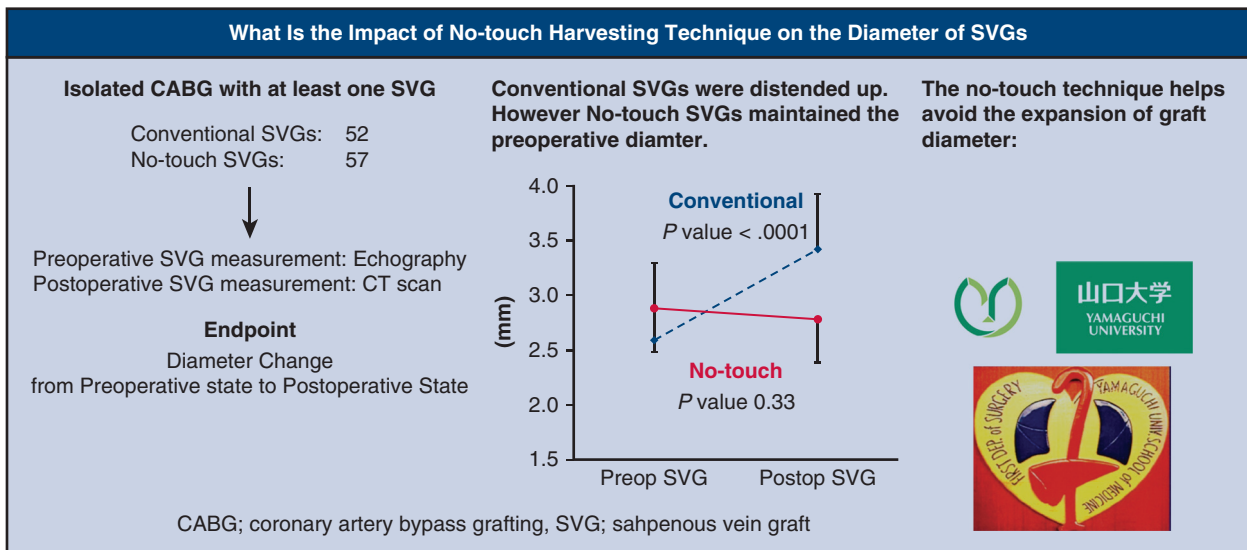


FIGURE 5. Summary of this study. SVG, Saphenous vein graft; CABG, coronary artery bypass grafting; CT, computed tomography.

and postoperatively. Arterial and venous graft have pharmacologic reactions to vasodilators (acetylcholine, papaverine, etc).¹³ PVAT can release vasodilators including nitric oxide (NO) or leptin,^{14,15} and Gür and colleagues¹⁶ reported that a no-touch SVG is less likely to cause vasospasm. It has been reported that PVATs in no-touch SVG play the important role of the producing NO. In addition, the NO produced from ITA can regulate vascular homeostasis through multiple factors (eg, inhibition of atherosclerosis and thrombosis, regulation of vascular tone, etc).¹⁷ This may affect the conduit (internal thoracic artery or SVG) and the vascular bed it perfuses. We speculated that the NO produced by PVAT might regulate vascular homeostasis as well as ITA.¹⁸ We believe the mechanism behind the vasodilation of conventional SVGs is not related to NO production but due to other reasons. For example, excessive manual distention of the SVG may cause structural deterioration of vessel wall integrity. PVAT in no-touch SVG can act as an external stent of SVG, resulting in less vasodilation of SVGs.

Although data on long-term patency were not available in this study, graft patency in the CV group was comparable with that in the NT group. We previously reported that SVGs in our institute maintain almost-normal endothelial cells in both groups.¹⁹ In our practice, SVGs in the CV group were distended by moderately high pressure (less than 300 mm Hg). Weiss and colleagues²⁰ reported that endothelial cell damage linearly increases as distension pressure becomes greater. Avoiding dilation is the best way to preserve endothelial cells. When we dilated SVGs manually and monitored the pressure through a T-shaped stopcock, its pressure easily reached up to 500 mm Hg or 700 mm Hg. We speculate that moderate distension pressure may contribute to the preservation of endothelial cells and satisfactory patency in the CV group. Avoiding dilation is the best way to preserve endothelial cells. However, after anastomosis, SVGs are permanently and unavoidably exposed to systemic blood pressure. We think dilation by systemic pressure is inevitable in the clinical setting. Further investigations of long-term patency in our institute are warranted.

In this study, we elucidated a no-touch harvesting technique associated with a small diameter of the SVG. There are several reports on the relationship between vessel diameter and graft patency. Shah and colleagues²¹ reported that the conduit diameter of the SVG significantly affects graft patency. Larger-diameter SVGs were associated with worse patency, for instance 2- to 2.4-mm conduits, which is the smallest category of conduit size in Shah and colleagues' study, have the best graft patency.²¹ Une and colleagues²² also reported that larger-diameter SVGs were associated with more intimal hyperplasia and graft occlusion risk. Yamane and colleagues²³ reported the impact of the size mismatch between SVGs and coronary arteries on graft patency. They focused on the SVG/target coronary ratio,

and the resulting cutoff value was more than 2.8. The SVG/target coronary ratio of their report seems to be much greater than that in our study because the coronary artery diameter was smaller in the report of Yamane and colleagues²³ (1.57 mm in the report of Yamane and colleagues²³ vs 2.0 mm in our conventional SVG). However, they also reported a relationship between SVG diameter and SVG occlusion. Their report also showed a negative linear relationship between SVG diameters and patency. Thus, larger SVGs were associated with decreased graft patency.

Implanted vein grafts are exposed to shear stress and radial and circumferential stretch. Low shear stress induces intimal hyperplasia. Large diameter induces low shear stress, and the site of low shear stress is thought to increase leukocyte and platelet adhesion, resulting in high local concentration of growth factor and cytokines, which induce intimal hyperplasia.²⁴ The small diameter of conduits may affect the superior patency of no-touch SVGs. The no-touch technique has 2 major features that differentiates it from the conventional technique. First, SVGs are harvested gently and not distended manually. Second, SVGs have a layer of PVAT. Avoiding manual dilation may help in maintaining the vessel's diameter because the integrity of the SVGs is preserved. Furthermore, PVAT can act as an external support of the SVG, which may avoid graft expansion.²⁵ Further investigations are required to elucidate the most important factor of the no-touch harvesting technique.

We also elucidated that the no-touch harvesting technique resulted in less mismatch in the diameter between the SVG and coronary artery. We speculate that a smaller mismatch can lead to several advantages. In terms of intraoperative periods, the anastomosis between less-diameter mismatched vessels is generally easy to sew for surgeons. In terms of the postoperative state, a large diameter mismatch of the conduit generally leads to a more turbulent flow. Previous *in vitro* studies revealed that the turbulent shear stress stimulates substantial endothelial DNA synthesis, which increase endothelial cell turnover and results in intimal hyperplasia and atherosclerotic lesions.²⁶ Less mismatch of conduits may also affect the superior patency of no-touch harvested SVGs.

The no-touch harvesting technique has several advantages. Intraoperative gentle dissection of SVGs preserves vascular structures (endothelium, vasa vasorum, and perivascular fat), and preserved perivascular adipose tissue releases a vasodilator.^{8-10,14,15} The no-touch technique avoids distention of the SVG. Small-sized SVGs achieve better hemodynamic forces (avoid low shear stress and turbulent flow).^{24,26}

In the middle of the SVG, blood flow is steady and induces laminar shear stress. In contrast, at the anastomotic site of the SVG, blood flow is more unstable and provides turbulent shear stress. We believe SVG, which provides

high laminar shear stress and low turbulent shear stress, is the better conduit. These multiple factors may affect the superiority of the long-term patency of no-touch harvested SVGs.

SVGs harvesting in an endoscopic manner is also performed worldwide. Endoscopic harvesting is less invasive and more cosmetic. Conversely, no-touch harvesting is expected to incur long-term patency. However, no-touch SVG's long-term patency remains controversial, and future studies will need to provide evidence to support this. The choice between endoscopic harvesting and no-touch harvesting may depend on a trade-off between cosmetic superiority and patency.

This study has some limitations. First, this was a single-center, nonrandomized study. Second, 72 patients (43.3%) did not have available data for the analysis of vessel diameter. Third, data on long-term patency and vessel diameter were not available. In this study, how the difference in diameter between the conventional and no-touch harvesting technique affects long-term patency was not assessed. Fourth, in this historical study, the surgeons, techniques, perioperative care, discharge medications changed gradually during the study period. Fifth, the mid-term graft patency was relatively high in each group, compared to that in a previous report. However, this study could not detect asymptomatic graft failure, and these results may be overestimated.

CONCLUSIONS

The no-touch technique avoids the expansion of the graft diameter and the diameter mismatch between the SVG and coronary artery. These aspects may contribute to the superior patency of SVGs harvested using the no-touch technique. Further investigation of the precise mechanism underlying the superiority of no-touch SVG is warranted.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: saphenous vein graft, no-touch harvesting technique, coronary artery bypass grafting, vessel diameter