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Original

Pilot Study of the Composite Graft Constructed from Two Saphenous Veins with a Single Inflow Source in Coronary Artery Bypass Grafting with Atherosclerotic Ascending Aorta

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Background: This pilot study aimed to evaluate early outcomes of a composite graft constructed from two saphenous veins (SVs) with a single inflow source in coronary artery bypass grafting (CABG) for patients with an atherosclerotic ascending aorta. The analysis focused on prevention of embolic events and early graft patency.

Methods: The analysis included 17 patients who underwent CABG using the left internal thoracic artery (LITA) to the left anterior descending artery (LAD), combined with a composite graft constructed from two saphenous veins (SVs) with a single inflow source. The SV composite graft was anastomosed to non-LAD coronary territories.

Results: Intraoperative flow and pulsatility index values of the SV grafts were satisfactory. No major complications, including new cerebrovascular embolic events, were observed. The early patency rate of SV anastomoses was 90%; all four occlusions among the total 40 anastomoses occurred in the Y-shaped composite graft.

Conclusions: A composite graft constructed from two SVs with a single inflow source appears to reduce the risk of embolic events by minimizing manipulation of the atherosclerotic ascending aorta. However, the configuration of the proximal SV anastomoses may affect early graft patency. Specifically, the risk of early failure appears to be higher in the Y-shaped configuration than in the V-shaped configuration.

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Keywords: coronary artery bypass grafting, saphenous vein, composite graft, embolic event, graft patency

Introduction

The left internal thoracic artery (LITA) anastomosis to the left anterior descending coronary artery (LAD) is the gold standard in coronary artery bypass grafting (CABG)[1]. However, the optimal revascularization strategy for non-LAD territories is unclear. Because of its availability, the saphenous vein (SV) often becomes the second graft for non-LAD territories[2].

Traditionally, the SV has been anastomosed to the ascending aorta as an inflow source. However, repeated manipulation of the ascending aorta for proximal anastomosis of SV increases the risk of embolic events, especially in patients with an atherosclerotic ascending aorta[3,4]. Minimizing such manipulation is thus crucial, although intraoperative epiaortic ultrasonography provides valuable information regarding the ascending aorta[5–9]. To reduce the frequency of ascending aortic manipulation, a composite graft constructed from two SVs with a single inflow source, instead of individual inflow sources, was introduced.

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This pilot study evaluated the effectiveness of this composite graft for revascularization in non-LAD territories. Specifically, prevention of embolic events and early graft patency were assessed in patients with an atherosclerotic ascending aorta who underwent CABG.

Materials and Methods

Ethical Approval

Written informed consent for participation and publication was obtained preoperatively from all patients. Ethical approval for this pilot study was obtained from the Nippon Medical School Review Board (approval number: M-2023-154). This pilot study was performed in accordance with the Nippon Medical School's Ethical Review Process[10] and the Declaration of Helsinki and its later amendments.

Enrolled Patients

This pilot study enrolled 17 consecutive patients with an atherosclerotic ascending aorta who had undergone CABG with the LITA plus the composite graft constructed from two SVs with a single inflow source at Nippon Medical School Hospital and its affiliate hospital from September 2014 to April 2023.

Surgical Procedure

The decision on whether to perform on-pump beating CABG or off-pump CABG for isolated CABG was determined by the surgeons based on each patient's condition. The same surgeon was involved in all surgeries, ensuring consistency in surgical procedure and technique.

After median sternotomy, the LITA and two SVs were harvested (all SVs were harvested in conventional fashion). Epiaortic ultrasonography was performed following pericardiotomy to evaluate the manipulation site of the ascending aorta. The first (1st) SV was anastomosed to the ascending aorta using the HEARTSTRING III proximal seal system (GETINGE AB, Gothenburg, Sweden), and the second (2nd) SV was anastomosed to the proximal anastomosis site of the 1st SV. This technique allowed the composite graft constructed from two SVs with a single inflow source instead of individual inflow sources.

In all cases requiring on-pump CABG, cardiopulmonary bypass (CPB) was established via ascending aortic inflow and right atrial appendage drainage after proximal anastomosis of the composite graft with two SVs. Revascularization of right coronary artery (RCA) territories and/or left circumflex artery (LCx) territories was performed with a composite graft constructed from two SVs with a single inflow source. LAD revascularization was always performed using the *in-situ* LITA graft. To evaluate the intraoperative graft patency, a VeriQ transit time flow meter (Medistim ASA, Oslo, Norway) was used to measure graft flow (GF) and pulsatility index (PI) immediately after each anastomosis and before chest closure.

Graft Patency in the Postoperative Early Period

Coronary artery computed tomography (CACT) was used to assess postoperative early patency of the anastomosis (defined <90 days). When CACT was contraindicated, coronary artery magnetic resonance angiography (CAMRA) was used. Occlusion of the anastomosis was defined as absence of graft enhancement on imaging, as assessed by a radiologist.

Data Collection and Statistical Analysis

All data were collected from medical records. Continuous variables are expressed as mean ± SD, while categorical variables are expressed as numbers and percentages of patients. Because of the small sample size for each group, non-parametric tests were used for statistical analysis because the data were not normally distributed. The Mann–Whitney U test was used to compare continuous variables between two groups, and the Kruskal–Wallis test was used to compare continuous variables among the groups (Bonferroni correction was used for multiple comparisons). Fisher's exact test was used for categorical variables. Statistical significance was set at $p<0.05$ in all analyses.

Results

Preoperative Patients' Characteristics

The preoperative patients' cerebrovascular and cardiac conditions are shown in **Table 1**. The proportion of patients with a history of clinical cerebrovascular event was 12%, and carotid artery stenosis (NASCET >75%) was noted in 47%. The proportion of patients with history of myocardial infarction was 82%. All patients had triple vessel disease, and 59% of patients had left main trunk disease. Mean left ventricular ejection fraction was 37.0 ± 19.0%. Emergent surgery was required for 12% of patients.

Surgical Details and Early Outcomes

Surgical details during surgery are presented in **Table 2**. On-pump arrest CABG for concomitant procedure was performed in 3 patients, and on-pump beating CABG for concomitant procedure was performed in 1 patient. On-pump beating CABG and off-pump CABG for isolated CABG were performed in 6 and 7 patients, respectively.

All patients underwent LITA-LAD bypass grafting and revascularization for the RCA and/or LCx with a composite graft constructed from two SVs with a single inflow source. The mean number of distal anastomoses per patient was 3.9 ± 0.8. GF and PI of both LITA and SV were satisfactory, and there were no significant differences in GF and PI among the four subgroups by SV anastomosis (p=0.79 for GF; p=0.76 for PI).

Table 1 Preoperative patients' cerebrovascular and cardiac conditions

	n=17
Age (years old)	75.1 ± 5.8
Gender (male/female)	14/3
History of clinical cerebrovascular event	12% (2/17)
Carotid artery stenosis (NASCET >75%)	47% (8/17)
History of myocardial infarction	82% (14/17)
Previous percutaneous catheter intervention	29% (5/17)
3 vessel disease/2 vessel disease	17/0
Left main trunk disease	59% (10/17)
Left ventricular ejection fraction (%)	37.0 ± 19.0
Emergent Surgery (<24 hours)	12% (2/17)

Variables are expressed as mean ± SD or sum (%).
NASCET: Northen American Symptomatic Carotid Endarterectomy Trials.

One patient died on postoperative 7th day because of a ruptured abdominal aortic aneurysm. However, other patients were discharged from hospital without new major perioperative complications, including new clinical cerebrovascular embolic events.

Early patency of anastomosis was evaluated with CACT in 13 patients and CAMRA in 2 patients. However, CAMRA was inadequate for proper evaluation in 1 patient. Early patency of anastomosis for each graft is presented in **Table 3**. All LITA-LAD bypass were patent. Among the total 40 distal anastomoses by SV, 36 were patent, an overall early patency rate of 90%. Details of the 4 occlusions of the total 40 anastomoses by SV are shown in **Table 4**. Case 1: Occlusion occurred between the posterodescending branch (PD) and the atrioventricular branch (AV) in sequential anastomosis performed by 1st SV. Case 2: Occlusion occurred from the ostium of 2nd SV anastomosis to the diagonal branch (Dx), despite a satisfactory intraoperative GF and PI of 70 mL/min and 2.9. Case 3: Occlusion occurred from the ostium of 2 nd SV in sequential anastomosis to both the Dx and the high lateral branch (HL), despite a satisfactory intraoperative GF and PI of 46 mL/min and 1.6.

Table 2 Surgical details during surgery

	n=17
Concomitant procedure	
On-pump arrest CABG	18% (3/17; AVR in 2, MVP in 1)
On-pump beating CABG	6% (1/17; PVI+LAAC in 1)
Isolated CABG	
On-pump beating CABG	35% (6/17)
Off-pump CABG	41% (7/17)
Use of intra-aortic balloon pumping	59% (10/17)
Number of distal anastomoses	3.9 ± 0.8
GF (mL/min)/PI	
LITA	38.4 ± 18.8/2.0 ± 0.5
SV	
Overall	45.2 ± 32.6/2.8 ± 2.0
RCA	
1st SV	44.7 ± 41.6/3.2 ± 2.3 (n=9)
2nd SV	53.0 ± 47.2/2.2 ± 1.0 (n=7)
LCx	
1st SV	47.3 ± 22.3/2.4 ±1.5 (n=8)
2nd SV	38.6 ± 19.9/3.1 ± 2.5 (n=10)

Variables are expressed as mean ± SD or sum (%).
CABG: coronary artery bypass grafting; AVR: aortic valve replacement; MVP: mitral valve plasty; PVI: pulmonary vein isolation; LAAC: left atrial appendage closure; GF: graft flow; PI: pulsatility index; LITA: left internal thoracic artery; SV: saphenous vein; RCA: right coronary artery; LCx: left circumflex coronary artery.

Table 3 Early patency of anastomosis by each graft

	n=14
LITA	100% (14/14)
SV	
Overall	90% (36/40)
RCA (n=13)	
1st SV	90% (9/10, n=8)
2nd SV	100% (6/6, n=5)
LCx (n=15)	
1st SV	100% (12/12, n=6)
2nd SV	75% (9/12, n=9)
On-pump CABG	91% (21/23, n=8)
Off-pump CABG	88% (15/17, n=6)

Variables are expressed as mean ± SD or sum (%).
LITA: left internal thoracic artery; SV: saphenous vein; RCA: right coronary artery; LCx: left circumflex coronary artery; CABG: coronary artery bypass grafting.

Table 4 Details concerning four occlusions of total 40 anastomoses by SV

Case	Target coronary artery	Graft design of occluded SV	GF (mL/min)/PI during surgery	Occlusion site
1	PD: 99%, AV: 99%	1st SV-PD-AV	146/2.2	Between PD and AV
2	Dx: 90%	2nd SV-Dx	70/2.9	From ostium of 2nd SV
3	Dx: 90%, HL: 99%	2nd SV-Dx-HL	46/1.6	From ostium of 2nd SV

Variables are expressed as mean or sum (%).
SV: saphenous vein; GF: graft flow; PI: pulsatility index; PD: posterodescending branch; AV: atrioventricular branch; Dx: diagonal branch; HL: high lateral branch.

Analysis of the correlation between surgical technique and early graft patency, showed no significant difference in the patency of anastomosis by SV between CABG with and without CPB: the patency rate was 91% (21/23) in CABG with CPB and 88% (15/17) in CABG without CPB (p=0.77; **Table 3**). When focusing on the shape of proximal anastomosis between the 1st and 2nd SVs, the shape of the proximal anastomosis was significantly correlated with the patency of the anastomosis by SV. The patency rate of anastomosis by SV was significantly inferior in the Y-shaped composite graft (77.8%) compared to in the V-shaped composite graft (100%) as presented in **Figure 1** (p=0.03) (The Y-shaped and V-shaped composite grafts are illustrated in **Figure 2**). Moreover, 2 of the 4 remaining patent 2nd SVs in the Y-shaped composite graft were narrowed compared to the corresponding 1st SVs. In contrast, all 1st and 2nd SVs in the V-shaped composite graft maintained adequate caliber and excellent patency, as shown in **Figure 3**.

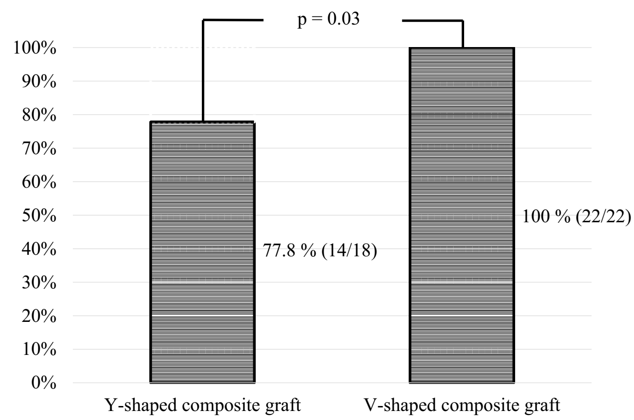

Figure 1 Patency of anastomosis by SV in Y- and V-shaped composite grafts constructed from two SVs with a single inflow source
The patency rate of anastomosis by the SV was 77.8% in Y-shaped composite graft, and 100% in V-shaped composite graft, a significant difference (p=0.03).
Variables are expressed as sum (%). SV: saphenous vein.

Discussion

No new clinical cerebrovascular embolic events occurred in this pilot study, even in patients with an atherosclerotic ascending aorta. Although intraoperative epiaortic ultrasonography yields useful information for avoiding manipulation of atherosclerotic site, the frequency of ascending aortic manipulation should be limited to prevent

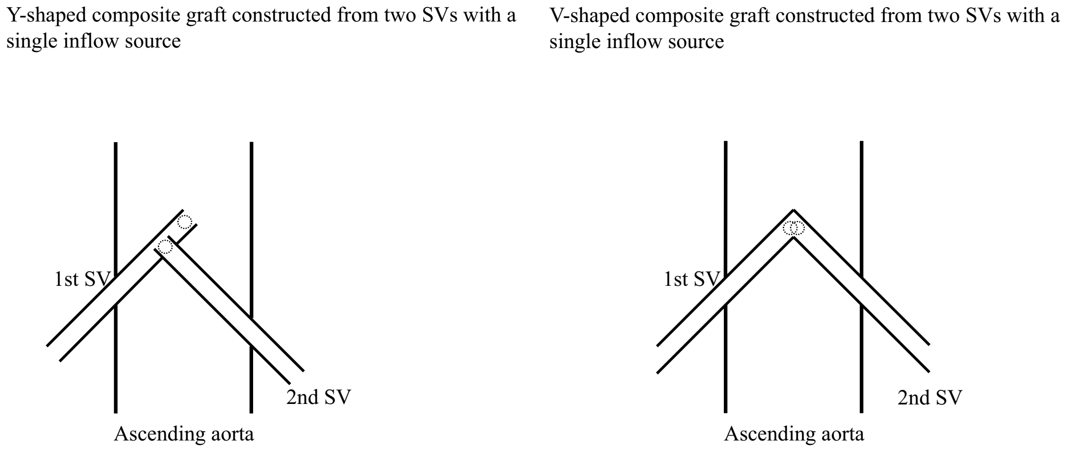

Figure 2 Configurations of Y- and V-shaped composite grafts constructed from two SVs with a single inflow source
Proximal anastomosis sites are shown as the dotted circles. Proximal anastomosis sites of the 1st and 2nd SVs are a short distance apart in the Y-shaped composite graft but overlap in the V-shaped composite graft.
SV: saphenous vein.

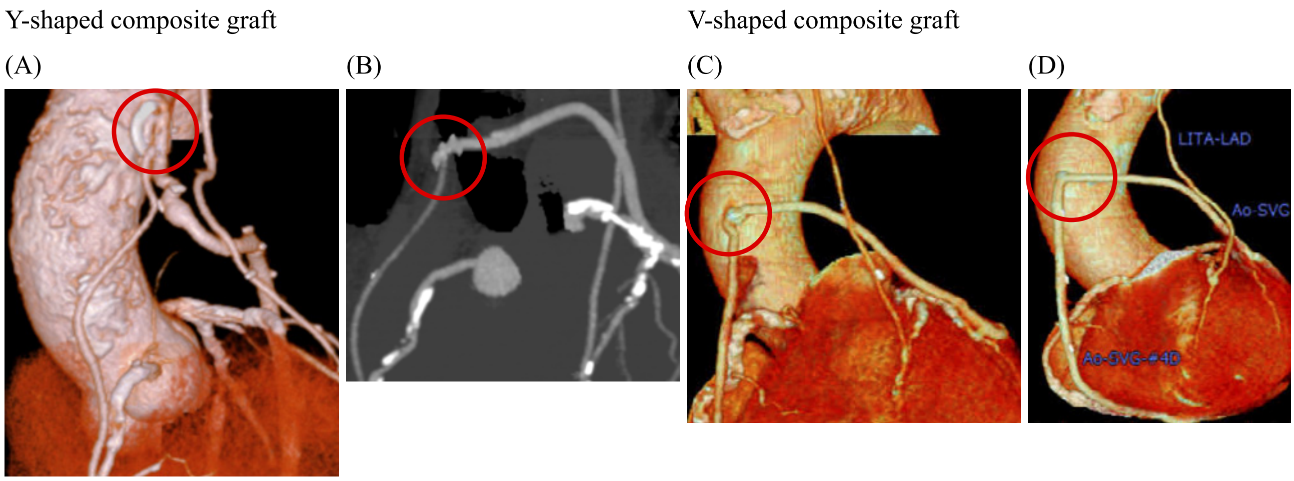

Figure 3 Computed-tomography of patent 2nd SVs in Y- and V-shaped composite grafts constructed from two SVs with a single inflow source
Proximal anastomoses of the 1st and 2nd SVs are shown in the red circles; 2nd SVs are patent but narrower than the 1st SVs in the Y-shaped composite graft shown in A and B. However, the 1st and 2nd SVs both maintain adequate caliber and excellent patency in the V-shaped composite graft shown in C and D.
SV: saphenous vein.

embolic events[3–9]. Moreover, a composite graft constructed from two SVs with a single inflow source minimizes the frequency of ascending aortic manipulation, as it requires only one manipulation. This strategy may have contributed to the absence of new clinical cerebrovascular embolic events in this pilot study.

However, the early patency rate of anastomoses by the composite graft constructed from two SVs with a single inflow source was lower than expected, at 90%. Although a single SV graft can be used for revascularization in non-LAD territories, this pilot study employed individual grafts in each non-LAD territory, to prevent simultaneous revascularization failure in both the LCx and RCA territories due to proximal issues of a single SV graft. Accordingly, Y-shaped and V-shaped composite grafts were designed based on the shape of the proximal anastomosis between the 1st and 2nd SVs. However, revascularization by the Y-shaped composite graft was associated with decreased early patency of anastomosis by SV, and 2nd SVs in the Y-shaped composite graft tended to narrow even though they remained patent, unlike 2nd SVs in the V-shaped composite graft.

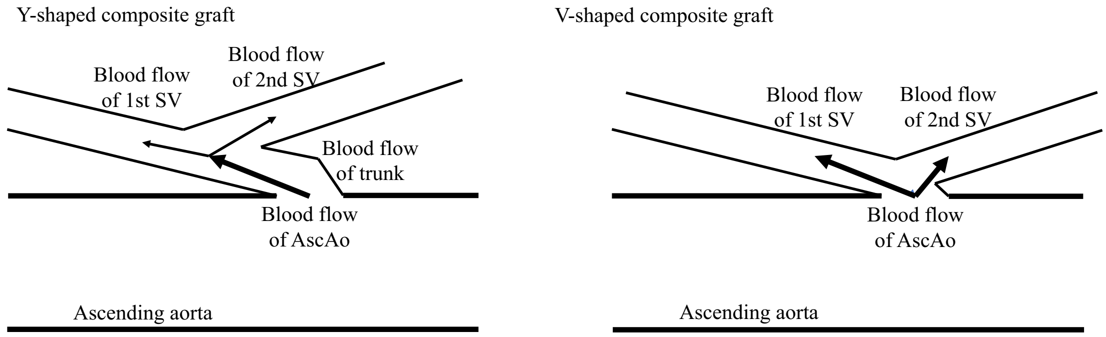

Figure 4 Hypothesis on amount of blood flow in Y- and V-shaped composite grafts constructed from two SVs with a single inflow source
The Y-shaped composite graft has a short trunk from the ascending aorta to the bifurcation of the 1st and 2nd SVs. The amount of blood flow to the 1st and 2nd SVs is thus limited below that of the trunk. Moreover, blood flow to each SV is distributed according to the imbalance of coronary artery resistance in the LCx and RCA territories. In contrast, because the V-shaped composite graft has no trunk, the amount of blood flow to each SV is not determined by the imbalance of coronary artery resistance between the LCx and RCA territories but by the absolute coronary artery resistance in each territory, regardless of inflow factors.
SV: saphenous vein.

It was not possible to identify risk factors for early graft failure in this pilot study. It might be assumed that the patency of anastomosis may be affected by the use of CPB, as previously discussed[11–13]. However, the patency of LITA-LAD graft did not differ between groups, and the patency of anastomosis by SV was not affected by the use of CPB, at least in this pilot study. On the other hand, the shape of the proximal anastomosis between 1st and 2nd SVs was associated with the patency of anastomosis by SV in this pilot study. **Figure 4** illustrates the likely mechanism of SV occlusion. Blood usually flows toward the area of lower resistance rather than higher resistance[14]. The Y-shaped composite graft has a short trunk from the ascending aorta to the bifurcation of the 1st and 2nd SVs, which may limit the amount of blood flow to each SV, as compared to that of the trunk, and the blood flow to each SV is distributed according to the imbalance of coronary artery resistance in the LCx and RCA territories[15–18]. In contrast, because the V-shaped composite graft lacks a trunk, the amount of blood flow to each SV is not determined by the imbalance of coronary artery resistance between the LCx and RCA territories, but rather by the absolute coronary artery resistance in each territory, regardless of any inflow factors[18]. Thus, so-called "steal phenomenon", which eventually leads to graft failure, is more likely in the Y-shaped composite graft than in the V-shaped composite graft[15–18].

The V-shaped composite graft is easily converted to the Y-shaped composite graft by slight shifting the proximal anastomosis site of the 2nd SV. Y-shaped composite graft was reported to have inadequate blood flow[15–18]. Additionally, we previously speculated that V-shaped composite graft may be superior to Y-shaped composite graft in regulating blood flow[19]. Therefore, precise placement of the proximal anastomosis site of the 2nd SV just above the proximal anastomosis site of the 1st SV is crucial for optimizing blood flow.

This pilot study has some limitations. First, the number of enrolled patients in this single-center retrospective observational pilot study was small. Therefore, results of one patient could have significantly influenced the overall results, and it is too difficult to design a case matching study. Therefore, future studies should enroll a larger number of patients. Second, our hypothesis regarding the risk factors leading to early graft failure of SV should be verified in a basic study of fluid mechanics. Despite these limitations, this pilot study is the first to explore early surgical outcomes of a composite graft constructed from two SVs with a single inflow source and provides valuable insights and cautionary considerations regarding this graft design.

In conclusion, a composite graft constructed from two SVs with a single inflow source effectively reduced the need for ascending aortic manipulation during CABG, which may have contributed to the absence of intraoperative cerebrovascular embolic events among patients with an atherosclerotic ascending aorta. Additionally, while the composite graft constructed from two SVs with a single inflow source demonstrated the permissive early patency of anastomosis, V-shaped configuration is preferred for the proximal anastomosis than Y-shaped configuration.

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Conflict of Interest: None declared.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: No generative AI or AI-assisted technologies were used in the writing process.

Data Availability: The data generated and analyzed in this pilot study are not publicly available because of patient privacy concerns.

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