Flowmetric Assessment of the Free Right Internal Thoracic Artery Anastomosed Proximally to a Saphenous Vein Graft to Revascularize the Left Coronary Artery System

Mitsuharu Hosono, Hiroshi Yasumoto, Shintaro Kuwauchi, Naoki Taniguchi, Tomohiko Uetsuki, Takayuki Okada, Shinya Kanemoto, Nobuya Zempo, Naoki Minato, and Kohei Kawazoe

Objective: In coronary artery bypass grafting (CABG), we perform proximal anastomosis of the free right internal thoracic artery (RITA) on the hood of the saphenous vein graft (SVG) close to its aortic anastomosis. Our aim was to assess the operative results of CABG using a free RITA and the related flow measurement data. Patients and methods: We retrospectively reviewed 24 patients who underwent solitary CABG using a free RITA proximally anastomosed to a SVG. We measures graft flow after completing all anastomoses, with stable hemodynamics. We recorded the mean flow in the free RITA before and after clamping the SVG, and in the flow of SVG before and after free RITA clamping. Results: The mean (± standard deviation) number of reconstructed coronary arteries using a free RITA was 1.6 ± 0.6. Twenty-one patients underwent angiography, and all RITAs were patent. The average mean free RITA flow was 42.4 ± 18.0 mL/min. In two patients, free RITA flow was < 20 mL/min, and both patients received a free RITA individual graft for a coronary artery with low-grade proximal stenosis. We performed clamping tests in 20 patients and found no significant difference between mean flows in the free RITAs with and without SVG clamping and in the SVGs with and without free RITA clamping. Conclusion: The free RITA and SVG grafts did not affect each other regarding mean flow measurements. The proximal site of SVG is an acceptable proximal anastomotic site for a free RITA. The coronary artery with severe proximal stenosis is recommended as a target of the free RITA. Key words: arterial graft, composite graft, coronary artery bypass grafting, internal thoracic artery, saphenous vein graft

I. Introduction

In coronary artery bypass grafting (CABG), arterial grafts provide superior results compared with saphenous vein grafts (SVGs)^1. Among arterial grafts, using bilateral internal thoracic artery grafts is associated with good survival benefits and graft patency^2–^4. However, in-situ right internal thoracic artery grafting (RITA) is used for limited coronary arteries because of the insufficient length. In contrast, free RITA grafts can be used for sequential multiple grafting and grafting to the distal branches^6. Therefore, in multi-vessel bypass grafting, free RITA grafting can be more feasible than in-situ RITA. In addition, we avoid retrosternal in-situ RITA crossover routing due to concerns about the potential risks of damage to the RITA in re-sternotomy or deep sternal wound infection. For these reasons, the free RITA is used as the second graft alternative in our institute, except in older patients.

When using free RITAs, there are several alternatives as a proximal anastomotic site, such as the aorta, a left internal thoracic artery graft (LITA), a radial artery graft, or a SVG^5–^9. Among these anastomotic sites, SVGs are technically the most simple, and we anastomose a free RITA to the hood of the SVG close to the suture line of its aortic anastomosis. In this technique, there is concern regarding a flow-steal phenomenon between the two grafts as in composite Y-grafting with the LITA^10. However, correlations in the graft flow between a free RITA and an SVG have not been clarified. We report the operative results following CABG using free RITAs in our institute and the results of a flow measurement study of proximally anastomosing a free RITA to the hood of a SVG at its aortic anastomosis.

II. Patients and methods

1. Patients

We retrospectively reviewed 24 patients who underwent solitary CABG using a free RITA proximally anastomosed to an
SVG since June 2016. All clinical data were obtained from patients' medical records. This retrospective study was approved by the Kansai Medical University institutional review board. Combined surgery and redo surgery were not included in this study, and two urgent cases were included. Patients' profiles are summarized in Table 1.

2. Operative data

Mean operation time was 446.8 ± 79.1 minutes. Off pump coronary artery bypass was performed in 13 patients (54.2%).

| Age (years old) | 68.4 ± 6.7 |
|-----------------|------------|
| Male gender     | 19 (79.2)  |
| Hypertension    | 19 (79.2)  |
| Dyslipidemia    | 19 (79.2)  |
| Diabetes mellitus | 16 (66.7)  |
| Smoking history | 18 (75.0)  |
| Hemodialysis    | 6 (25.0)   |
| Peripheral arterial disease | 4 (16.7) |
| Cerebrovascular disease history | 5 (20.8) |
| Carotid artery disease | 3 (12.5) |
| Chronic obstructive pulmonary disease | 1 (4.2) |
| Old myocardial infarction | 4 (16.7) |
| Percutaneous coronary intervention history | 10 (41.7) |
| 3 vessel disease | 22 (81.7) |
| 2 vessel disease | 2 (8.3) |
| Preoperative intra-aortic balloon pumping | 4 (16.7) |
| Canadian Cardiovascular Society functional class III, IV | 8 (33.3) |

Data were expressed as mean ± SD or direct number (%).

The mean bypass number was 4.5 ± 1.0. On-lay patch anastomosis was performed in five patients (using the LITA in three, SVG in one, and RITA in one). Endarterectomy on the left anterior descending artery was performed in one patients.

3. Surgical procedure

The RITA was harvested using an ultrasonic scalpel (Harmonic Scalpel; Ethicon Endo-Surgery, Inc., Blue Ash, Ohio, USA) in a skeletonized fashion, and the RITA was taken down just before use. Distal anastomosis was performed in a parallel end-to-side configuration. In sequential grafting, we used diamond-shaped or parallel side-to-side anastomosis. When we performed the sequential side-to-side anastomosis with distal part of the RITA, we used a parallel configuration. When we performed the sequential side-to-side anastomosis with the proximal part of RITA, we used the diamond-shaped configuration. As an anastomotic site, we selected the proximal region of the target coronary artery as much as possible, since the graft length can be shortened. After all distal anastomoses were completed, we anastomosed the proximal end of the free RITA to the SVG. This proximal side anastomosis was performed at the proximal anastomosis of the SVG to the aorta in a parallel configuration (anastomotic angle 0° or 180°) (Fig. 1). To prevent graft kinking, the graft length was carefully checked to ensure that it was not too long in the proximal anastomosis. The distal end of the SVG was usually anastomosed to the right coronary artery territory or the last branch of the circumflex coronary artery. The proximal anas-

![Fig. 1](image)

**Fig. 1** Multi-detector row computed tomography. The proximal anastomosis the free RITA and SVG were performed in a parallel configuration.

A: The proximal free RITA was anastomosed to the proximal anastomotic site of the SVG, which was distally anastomosed to the right coronary artery territory.

B: The proximal free RITA was anastomosed to the proximal anastomotic site of the SVG, which was distally anastomosed to the circumflex coronary artery territory.
tomosis was performed using Enclose II anastomosis assist device (Novare Surgical Systems, Cupertino, CA) in off-pump operations. In the other cases, the proximal anastomosis was performed without any device before aortic declamping.

4. Flow measurement

We measured the mean graft flow using a transit time flow measurement device (MediStim, Oslo, Norway) after all anastomoses were completed, protamine was injected intravenously, and hemodynamics were stable. After completing the standard measurements, we performed the clamping tests. The flow in the free RITA was recorded before and after clamping the SVG, and the flow in the SVG was recorded before and after free RITA clamping.

5. Statistical analysis

Continuous variables were expressed as means and standard deviations and categorical variables were expressed as frequencies and percentages, where appropriate. Differences between the two groups were assessed using Wilcoxon’s rank sum test for continuous variables or the Chi-square test for categorical variables. We analyzed the results of the clamping test flow measurements using a paired t test. Statistical analyses were performed using the JMP 11 software package (SAS Institute Inc., Cary, NC), and P value <0.05 was considered statistically significant.

III. Results

1. Surgical results

We used a free RITA as an individual graft in 11 patients and as a sequential graft in 13 patients. The mean number of reconstructed coronary arteries using a free RITA was 1.6 ± 0.6. The reconstructed coronary artery details are summarized in Table 2.

There were no hospital deaths. One patient developed mediastinitis, and prolonged mechanical ventilation was required in one patient. There were no re-explorations for bleeding, renal dysfunction, or low out-put syndrome, and no cerebrovascular complications. Twenty-one patients underwent postoperative angiography or multi-slice computed tomography. Overall graft patency was 98.9%, and all free RITAs used in this study were patent.

2. Graft flow measurement

The average mean flow in the free RITA in all patients was 42.4 ± 18.0 mL/min, and the average mean flow in the SVG was 50.4 ± 33.2 mL/min. There were no significant differences between individual and sequential grafting for the mean flow in the free RITA (individual vs sequential: 37.1 ± 19.0 mL/min vs 46.8 ± 16.5 mL/min, respectively). In two patients, free RITA flow was < 20 mL/min, and in both patients, we used a free RITA for a coronary artery with low-grade proximal stenosis (<90%) as an individual grafting. In contrast, in two patients undergoing sequential grafting, mean flows of RITAs anastomosed to two coronary arteries, both with low-grade proximal stenosis, were 45 mL/min and 60 mL/min, respectively.

We performed the clamping tests in 20 patients (Fig. 2). We found no significant difference between flows in the free RITAs with SVG clamping vs without SVG clamping (with SVG clamping: 46.4 ± 18.3 mL/min, without SVG clamping: 46.6 ± 17.8 mL/min; p=0.91). We also found there was no significant difference between flows in the SVG with free RITA clamping vs without free RITA clamping (with free RITA clamping: 42.7 ± 18.0 mL/min, without free RITA clamping: 42.2 ± 17.7 mL/min; p=0.84).

IV. Discussion

Previous studies have reported excellent results using free RITA grafts11-13, although a recent study involving patients who were randomly assigned to undergo bilateral or unilateral ITA grafting in CABG showed no significant difference in 10-year mortality from any cause14. However, in the report, details regarding the free RITA, namely, the target coronary artery, the percentage of patients receiving a Y-composite graft, and the degree of proximal stenosis in the target vessels were unclear. This information is important when using a RITA. Regarding flow competition, composite Y grafts of bilateral ITA grafts should be reserved for patients with severe (70% or more) left anterior descending and circumflex arterial stenosis10,15. Furthermore, Tintin and colleagues reported that a small anastomosis angle for proximal Y and distal anastomoses is associated with higher long-term patency of the free RITA16. In another report, grafting to target coronary arteries with a high-grade stenosis or occlusion and grafting left rather than right coronary arteries were preferable for using a RITA graft17. Therefore, the method of grafting the RITA and the status of the target vessels can affect the results and graft patency. Further studies are needed to determine whether bilateral ITA grafts provide better outcomes than a single ITA graft.

Selecting the target coronary artery and its degree of proximal stenosis are important when using free RITA grafts. In our institute, we used a free RITA for diagonal branches and/or circum-

Table 2 The anastomotic sites of all grafts

| LITA | RITA | SVG |
|------|------|-----|
| Left anterior descending | 23 | 0 | 0 |
| Diagonal | 1 | 17 | 1 |
| Obtuse marginal | 0 | 18 | 0 |
| Posterolateral | 0 | 4 | 13 |
| Right coronary (#3) | 0 | 0 | 3 |
| Posterior descending | 0 | 0 | 19 |
| Atrioventricular node | 0 | 0 | 9 |

LITA: left internal thoracic artery, RITA: right internal thoracic artery, SVG: saphenous vein graft.
flex artery territory. Buxton and colleagues\(^\text{17}^\) reported that the highest RITA failure rates were associated with grafting a native coronary artery with < 60% stenosis compared with 80–100%, and with grafting the right coronary artery. In another study, good mid-term free RITA patency rates were reported using only the left circumflex artery with a high degree of stenosis (mean 87.1 %)\(^\text{12}^\). In our present study, the mean flow in the free RITA used as an individual grafting to the target coronary artery with mild proximal stenosis was low. In contrast, even with mild proximal stenosis, when using sequential grafting, the free RITA flow was good. Fukui and colleagues also recommend sequential grafting with a free RITA\(^\text{9}^\). The flow demand appears to be important for graft flow in the free RITA. Hiraoka et al. reported that intraoperatively measured mean graft flow was associated with the percentages of stenosis in the target vessel and the perfused left ventricular mass volume\(^\text{18}^\). According to these findings, we believe that multiple bypass to branches of the left coronary artery with high-grade proximal stenosis is recommended for using free RITA grafting.

Comparing free- and in-situ RITA grafts, Tatoulis and colleagues reported that free RITA grafts and in-situ RITA grafts have similar patency rates\(^\text{19}^\). Furthermore, in a late angiographic study, a patent free ITA graft showed no evidence of graft atherosclerosis\(^\text{7}^\). These data encourages the use of free RITA grafts. In a recent comparative study between in situ and free RITA grafts, Yoshizumi and colleagues showed that the early and mid-term patency rates of the free RITA grafts were comparable to those when an in-situ RITA or in-situ LITA was anastomosed to the left anterior descending artery\(^\text{25}^\). In the study, the authors used the proximal part of the SVG or a radial artery graft as an interposing cuff between the aortic wall and the free RITA or a foldback technique\(^\text{20}^\) was used in patients in whom the RITA was the sole aorto-coronary free graft. In contrast, Buxton and colleagues\(^\text{17}^\) have reported that patency in the aorto-coronary free RITA was lower than that of an in-situ RITA. In the report, the proximal anastomosis was performed directly to the aorta, and the technical difficulty of direct proximal anastomosis between the free RITA and the thicker aortic wall might affect graft patency data. For these reasons, modifications of the proximal anastomosis of the free RITA have been reported\(^\text{20-23}^\). Among the modifications, the simplest technique is anastomosis to the hood of a SVG or radial artery graft\(^\text{6, 9, 23}^\), which we used in the present study.

In composite Y-grafting with the LITA, there is concern regarding a potential steal phenomenon between the LITA and RITA and potential flow competition with the native coronary artery\(^\text{10}^\). Furthermore, a previous flow measurement study indicated that a free RITA anastomosed to the aorta provides more RITA flow compared with composite Y-grafting\(^\text{24}^\). However, to our knowledge, no study has evaluated the influences on graft flows between saphenous vein graft and RITA graft when proximal anastomosis of the RITA was performed on the SVG. To avoid the influencing patency and flow in both grafts, we performed the proximal anastomotic for both the free RITA

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**Fig. 2** Flow measurement results following the clamping tests. We found no significant differences in the flows in both the free RITA and SVG grafts when comparing with and without clamping of the other grafts.
and the SVG in a parallel configuration. To assess the influence of the grafts with each other in our procedures, we performed a flow measurement study, which revealed that the flow in each graft did not change when comparing before and after the other graft was clamped. This finding indicates that grafts do not affect each other regarding mean graft flow. The possible factors explaining of these flow measurement results are follows. First, as mentioned above, the proximal anastomosis to the SVG was performed as close as possible to the ascending aorta so that the blood flow to each graft was supplied directly from the aorta. Second, in this present study, each graft was mainly used for a separate coronary artery territory; the SVGs were mainly used for the right coronary artery territory, while the RITAs were mainly used for diagonal or circumflex coronary artery territories. Thus, the graft flow might not be affected each other, and this proximal anastomosis seemed to minimize the flow competition or steal phenomenon. A previous report about this type of anastomosis showed that the patency of one graft was not affected by the patency of the other graft\(^2\). Furthermore, the stenosis grade of the target vessel reportedly does not affect the patency rate of the RITA at follow-up angiography\(^6\). Therefore, this type of proximal anastomosis is not likely to be affected by the status of target coronary arteries. Our study has several limitations. First, this study is subject to the limitations inherent in retrospective observational data studies. Second, the target coronary artery was at the discretion of the surgeon and subject to bias. Third, flow demand in the anastomosed coronary artery may affect flow in the grafts, but this was difficult to evaluate. The diameter of the target vessels can also affect graft flow. Because we did not measure the size of all target coronary arteries, we were unable to evaluate this effect. Finally, early patency was good, but late patency is unclear. The flow and patency of each graft might be affected by collateral flow from the other coronary territories and flow demand in the other territories. However, as it was difficult to accurately measure the collateral flow and flow demand, the effect of these factors on the graft flow and patency could not be assessed. Further investigations of the relationship between flow measurements and late patency are necessary.

In conclusion, when proximal anastomosis of the free RITA on the hood of the SVG was performed as close as possible to the ascending aorta and in a parallel configuration, the grafts did not affect each other regarding graft flow. Sequential grafting and grafting to a left coronary artery with severe proximal stenosis is a recommended use for free RITA grafting. 

**Disclosure statement**

None of the authors have a conflicts of interest concerning this study, and none received outside support for this research.

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