Introduction

Complete revascularization is considered as the important determinant of freedom from adverse cardiac events after coronary artery bypass grafting (CABG). For rationale of off-pump coronary revascularization, functional complete revascularization, which was defined as at least one bypass graft to each of the three major vascular regions, may be essential (1,2,3). On the other hand, the efficacy of 4 or more distal anastomoses for 3-vessel disease is still controversial. It may be deleterious in the conventional surgical technique (4), probably because the increase of anastomoses would necessitate longer cardiopulmonary bypass and cardiac arrest time.

Recently, not only the left anterior descending artery (LAD), but also the left circumflex (LCX) and right coronary (RCA) arteries are commonly bypassed with the internal thoracic artery (ITA) or other arterial grafts to achieve long-term patency and improve the clinical outcome (5,6,7).

It has been widely accepted that off-pump CABG reduces the operative morbidity and mortality, and that avoidance of manipulation of the ascending aorta is effective for prevention of perioperative complications, such as stroke. In addition, it was previously reported that the arterial grafts were advantageous for grafting to small coronary vessels, even in off-pump CABG (8). Moreover, we suppose that it is technically demanding in conventional CABG to adjust the graft length and to create sequential grafting to two or more coronary vessels in the LCX and the RCA regions, as compared with off-pump CABG. Accordingly, off-pump sequential and composite grafting may be advantageous, especially for the patients who require 5 or more distal anastomoses.

In the present study, we sought to delineate the safety and efficacy of sequential and composite arterial grafting for five or more coronary branches without cardiopulmonary bypass by examining the clinical results and intraoperative and angiographic bypass flow.

Materials and methods

We reviewed the coronary angiograms of 633 consecutive patients with 2617 bypass grafts, who underwent off-pump CABG for 3-vessel disease using totally arterial grafts

between December 2000 and September 2007. Functional complete revascularization with the in-situ ITA and a free arterial graft, mostly a radial artery, was performed in all cases. The patients who underwent incomplete revascularization, who had an in-situ gastroepiploic artery or saphenous vein graft, or had individual bypass graft only, were excluded. The clinical and angiographic data were based on the cardiovascular surgery database in our institution, which was approved by our institutional review board. All patients provided written informed consent giving them after explanation of the potential risks. There were 501 men and 132 women, and their mean age was 67 ± 9 years.

Group I consisted of 263 (41.5%) patients who had a single in-situ ITA, while group II consisted of 370 (58.5%) patients with the bilateral in-situ ITAs. Each group was divided into two subgroups. Subgroup I-A consisted of 242 patients who had 3 or 4 distal anastomoses, and subgroup I-B consisted of 21 patients who had 5 or more distal anastomoses. As shown in Table 1, there were no significant differences between subgroup I-A and subgroup I-B in the preoperative patients' characteristics. Subgroup II-A consisted of 199 patients who had 3 or 4 distal anastomoses, and subgroup II-B consisted of 171 patients who had 5 or more distal anastomoses. Regarding the preoperative characteristics, there were significant differences in the age at operation, ratio of female gender and distal anastomotic sites (Table 2).

Operative techniques and perioperative management

The details of our surgical technique were described previously (9,10). In the present series, all ITA grafts were harvested with semi-skeletonized or skeletonized technique, and were larger than 1.5 mm in diameter at the distal anastomotic site. The radial artery was harvested from the non-dominant forearm irrespective of the patient's age. It was divided into two pieces when necessary. In the side-to-side anastomosis, we made a longitudinal arteriotomy both on the native coronary artery and the arterial graft long enough for anastomosis without turbulence. The angle of the graft placement was adjusted between 0 to 90 degrees to save the length and avoid kinking. After completion of anastomoses, the

graft flow was measured at the proximal portion of each in-situ ITA using a transit-time flow meter at approximately 90-120 mmHg of arterial pressure.

Total arterial CABG with aorta no-touch technique using one or two in-situ ITAs and radial artery has been our standard technique. The configuration of the bypass conduits were primarily determined by the operative risk and positional relationship of the target sites. The bilateral ITAs were preferably used for patients who were in active life and were less than 75 years of age with neither severe chronic obstructive pulmonary disease nor insulin-dependent diabetes mellitus. As shown in Table 1 and 2, the radial artery was used as a free graft in 607 (95.9%) of these patients.

In the patients with the bilateral in-situ ITAs, one in-situ ITA, usually the left, was anastomosed with LAD and an I-graft of the contralateral ITA, usually the right, and the radial artery was anastomosed with LCX and RCA in a clockwise orientation, which meant a side-to-side anastomosis with LCX and an end-to-side anastomosis with RCA, or in a counterclockwise orientation, which meant a side-to-side anastomosis with RCA and an end-to-side anastomosis with LCX. The orientation was chosen to avoid grafting to the coronary branch with 75% stenosis at the end of the I-graft, because competitive and reversal flow was commonly found at the distal end of the conduit (8,9).

Early postoperative coronary angiography was performed about 2 weeks after surgery. The severity of the native coronary artery stenosis and the graft patency were independently evaluated by cardiologists. The maximal severity of stenosis was recorded for all target branches. The terms in this paper were defined as follows. In brief, a 'patent' graft meant that the graft had a complete continuity of the graft lumen throughout its entire length from the subclavian artery to the target coronary branch, irrespective of the flow direction. Whenever the continuity of the graft lumen from an in-situ ITA graft to the anastomosis with the target coronary branch was interrupted at any level, it was defined as 'occluded' (Grade O). Grade A was defined as a situation in which antegrade graft flow was found in most of the multi-plane ITA angiograms. Grades B and C were competitive and reversal, respectively. Flow grade was recorded for each target coronary branch. In the present

paper, the flow grades were judged as "antegrade flow" (=grade A) and "competitive flow" (=grades B and C).

Statistical analysis

The continuous variables are expressed as the mean values ± standard deviation. These variables were compared by unpaired t-test between the two groups. The data of two independent groups were compared by Fisher's exact probability test. Longitudinal data were estimated by Kaplan-Meier method, and the difference of two groups was compared by the log-rank method. Statistical analyses were performed using SPSS software (SPSS 8.0 Inc., Chicago, IL). The differences in the outcomes were considered statistically significant when the p value was less than 0.05.

Results

Comparisons of group I vs. group II

The early mortality rates in group I and group II were 1.1% (3/263) and 0.5% (2/370), respectively (p=0.40). There were no significant differences in the early complications between the two groups (p=0.93).

Intraoperative graft flow, which was measured at the proximal portion of in-situ ITA, in group II (79±35ml/min) was significantly larger that that in group I (53±31ml/min, p<0.0001). In early postoperative angiography, the graft patency rates in these two groups were similar (98.5% (703/714) vs. 97.7% (1429/1460), p=0.35), while the rate of antegrade flow in group II was significantly higher than that in group I (89.4% (638/714) vs. 92.4% (1349/1460), p=0.02).

Comparisons of subgroup I-A vs. subgroup I-B

Three patients (1.2%, 3/242) in subgroup I-A died, whereas there was no early mortality in subgroup I-B (Table 3). Perioperative myocardial infarction occurred in 6 patients (2.5%) of subgroup I-A.

Intraoperative measurement showed that graft flow in subgroup I-A and I-B were 53±31 ml/min and 55±33 ml/min, respectively (p=0.42) (Figure 1). Early postoperative coronary and graft angiography were performed in 187 patients (77%, 187/242) with 643 distal anastomoses in subgroup I-A and 14 patients (14/21, 67%) with 71 distal anastomoses in subgroup I-B. Angiography revealed that the graft patency rates were 98.3% (632/643) in subgroup I-A and 100% (71/71) in subgroup I-B (p=0.27). The rate of antegrade flow in subgroup I-B was significantly higher than that in subgroup I-A (91.5% vs. 89.1%, p=0.048).

Comparisons of subgroup II-A vs. subgroup II-B

The early mortality rates in subgroup II-A and subgroup II-B were 0.5% (1/199) and 0.6% (1/177), respectively (p=0.91). Perioperative myocardial infarction occurred in 5 patients (2.5%) of subgroup II-A and 3 patients (1.7%) of subgroup II-B. There were no significant differences in the early morbidities between the two subgroups (p=0.89) (Table 4).

Measuring the intraoperative graft flow revealed that the total graft flow in subgroup II-B was relatively larger than that in subgroup II-A (81±35 ml/min vs. 76±35 ml/min, p=0.07) (Figure 2). Early postoperative angiography was performed in 175 (87.9%) patients of subgroup II-A and 148 (86.5%) patients of subgroup II-B. The graft patency rates were 97.3% (648/666) in subgroup II-A and 98.4% (781/794) in subgroup II-B, respectively (p=0.16). There was no significant difference in the rates of antegrade flow between subgroups II-A and II-B (p=0.21) (Table 4).

Discussion

The in-situ ITA graft to LAD is a significant predictor for the survival and freedom from the repeated revascularization, because atherosclerotic changes are rarely found in the ITA graft by histological investigation and its intimal cells have functional superiority to venous grafts regarding nitric oxide or prostacyclin release (11). Especially in the patients who have no considerable operative risks, the use of the bilateral ITAs and more arterial graft is considered as a favorable graft material to LCX and RCA.

Completeness of revascularization to all three major vascular regions is also reported as one of the independent predictors of improved short- and long-term survival after CABG (12,13,14,15,16). Complete revascularization can be more successfully achieved by surgical treatment, as compared with catheter intervention, and this fact supported the clinical benefit of surgical treatment. On the other hand, it was reported that off-pump CABG could be the cause of fewer bypass grafts and incomplete revascularization, which would be explanation of increased recurrence of angina and repeated coronary intervention (17). In the previous reports, the most common reason for incomplete revascularization was too small vessel size (14). The other reasons were severely diseased vessel, non-dominant RCA, presence of prior infarcted tissue (17), and unavailability of proximal anastomosis to ascending aorta (14).

The clinical outcomes and efficacy of bypass grafting to 5 or more coronary branches in excess of functional complete revascularization have not been proved, yet. Vander Salm and colleagues reported that the MI-free survival rate of patients with multiple anastomoses to the non-LAD system was significantly lower than that of patients with no more than one graft insertion to a non-LAD system (4). They reported that there was no independent survival advantage for traditional or functional complete revascularization as compared with incomplete revascularization, and that surgical construction of more than one graft to the LCX and RCA territories could be deleterious (4).

The present study demonstrated that the safety of CABG to 5 or more target branches by sequential and composite grafting, which consisted of an individual in-situ ITA to LAD and sequential anastomoses of the radial artery to the LCX and RCA regions. The

immediate operative results for patients with 5 or more targets were similar to those of patients with 3 or 4 targets, in spite of extensive stenotic lesions and their significantly high age. In addition, the graft patency rate and the incidence of competitive flow were not affected by increasing the target branches, irrespective of the same blood source and graft materials. From the viewpoint of blood supply for the myocardium, the bilateral in-situ ITAs would be feasible in the patients with 3-vessel disease, especially for more than 5 target branches, because the amount of the bypass flow was not increased as compared with that for 3 or 4 target branches.

These results may be explained as follows. First, in contrast to conventional CABG, the increase of distal anastomotic sites in off-pump CABG does not bring about prolongation of cardiopulmonary bypass time or cardiac arrest time. Second, the arterial materials were advantageous for the small coronary vessels. The graft patency rate for the small vessels; i.e., having diameter of less than 1.5 mm, was similar to that for larger branches, 1.5mm or more diameter. This fact could improve the success rate of complete revascularization.

Third, sequential bypass grafting played an important role in current procedure. Previously, Dion and colleagues reported the efficacy of sequential grafting with the ITA graft to LAD and diagonal branch with excellent graft patency concomitant with economizing the length of the graft (18,19). Farsak and colleagues documented the importance of run-off of the most distally located target coronary branch on a sequential venous graft to secure patency of the entire sequential conduit (20), and we reported that the distal end of the sequential radial artery graft should be anastomosed to the near-occluded coronary branch (21). We consider that even if the flow demand of a small coronary vessel is not enough to maintain patency of each arterial graft in an individual fashion, sequential grafting concomitant with the appropriate target vessel for the distal end would avoid physiological narrowing of the entire graft. Moreover, in off-pump CABG, we suppose that adjusting the graft length and angle of anastomosis for prevention of kinking or angulation would be relatively easy, as compared with the arrested heart. Consequently,

no additional graft material was necessary even for several target branches in the LCX and RCA regions in our patients.

This study has some limitations. First, this study is retrospective and not randomized. There were some differences in the preoperative patients' characteristics. Randomization is extremely difficult, because the number of distal anastomotic sites mostly depends on the configuration of coronary artery system and locations of the stenotic lesions. However, the operative procedure and graft materials were comparable between these subgroups, and all patients underwent functional complete revascularization for 3-vessel disease. Second, regarding decision of single or bilateral in-situ ITA, rapid adaptability to blood flow in the lumen and reparability of the stenotic ITA was not taken into account (22, 23). Bilateral in-situ ITA provided greater bypass flow than the single in-situ ITA, but less than twice of the single in-situ ITA. As far as competitive flow is avoided, the single in-situ ITA can be durable as compared with the bilateral in-situ ITA, as the case may be. This may be a paradox on the subject of blood supply and durability of arterial grafts.

In conclusion, total arterial off-pump CABG with sequential and composite grafting is safely applicable and useful for the patients with 5 or more target coronary branches. Since the rate of graft occlusion and competitive flow did not increase, irrespective of the same graft materials, durable completeness of revascularization can be expected. To achieve abundant bypass flow, the bilateral in-situ ITAs would be mandatory in CABG for more than 5 target branches.

Table 1

Baseline characteristics of patients with a single in-situ ITA

	Subgroup I-A	Subgroup I-B	p value
No. of patients	242	21	
Age (yrs)	72 ± 8	71 ± 7	0.37
Male/Female	172 / 70	16 / 5	0.62
Hypertension	139 (58%)	15 (71%)	0.21
Hyperlipidemia	115 (48%)	12 (57%)	0.39
Diabetes	108 (45%)	10 (48%)	0.79
LVEDVI (ml/m2)	82 ± 24	81 ± 30	0.43
Ejection fraction (%)	48 ±11	48 ± 14	0.49
Distal anastomoses			
3	131	0	-
4	111	0	-
5	0	17	-
6~	0	4	-
Graft materials used			
in-situ ITA	242 (100%)	21 (100%)	1.0
free ITA	18 (7%)	0	0.22
RA	224 (93%)	21 (100%)	0.22
Conduit shape			
composite Y-graft	223 (91%)	15 (71%)	0.002
composite K-graft	19 (9%)	6 (29%)	
Total distal anastomoses	837	110	-

ITA; internal thoracic artery LVEDVI; left ventricular end-diastolic volume index
RA; radial artery

Table 2

Baseline characteristics of patients with bilateral in-situ ITA

	Subgroup II-A	Subgroup II-B	p value
No. of patients	199	171	
Age (yrs)	63 ± 9	66 ± 7	0.004
Male/Female	144 / 33	154 / 17	0.03
Hypertension	96 (48%)	79 (46%)	0.69
Hyperlipidemia	102 (51%)	81 (47%)	0.46
Diabetes	91 (46%)	67 (39%)	0.32
LVEDVI (ml/m2)	82 ± 24	81 ± 30	0.39
Ejection fraction (%)	48 ±13	47 ± 11	0.41
Distal anastomoses			
3	44	0	-
4	155	0	-
5	0	116	-
6~	0	55	-
Graft materials used			
in-situ ITA	398	342	1.0
free ITA (distal part of ITA)	1	7	-
free GEA	2	1	-
RA	193	169	0.22
Total distal anastomoses	752	918	-

ITA; internal thoracic artery LVEDVI; left ventricular end-diastolic volume index
RA; radial artery

Table 3

Early results -subgroup I-A vs. subgroup I-B-

	Subgroup I-A	Subgroup I-B	p value
Angiographic Results			
Patients angiography performed	187 (77%)	14 (67%)	-
Distal anastomoses	643	71	
Antegrade flow	573 (89.1%)	65 (91.5%)	0.048
Competitive flow	59 (9.2%)	6 (8.5%)	0.84
Patency rate	632 (98.3%)	71 (100%)	0.27
Diameter of target branch and patency rat	643	71	
1.0 or 1.25 mm	160/166 (96.4%)	30/30 (100%)	0.29
1.5 mm~	420/424 (99.1%)	40/40 (100%)	0.54
not recorded	52/53 (98.1%)	1/1 (100%)	-
Early results			
Mortality	3/242 (1.2%)	0	0.61
Cardiac	0	0	
non-cardiac	3	0	
Morbidity	10/242 (4.1%)	1/21 (4.8%)	0.89
MI (CKMB>100)	6	0	
stroke	1	1	
deep wound infection	2	0	
reoperation for bleeding	1	0	

MI; myocardial infarction, CKMB; Creatinine kinase MB

Table 4

Early results -subgroup II-A vs. subgroup II-B-

	Subgroup II-A	Subgroup II-B	p value
Angiographic Results			
Patients angiography performed	175/199 (88%)	148/171 (85%)	-
Distal anastomoses	666	794	
Antegrade flow	609 (91.4%)	740 (93.2%)	0.21
Competitive flow	39 (5.9%)	41 (5.2%)	0.56
Patency rate	648 (97.3%)	781 (98.4%)	0.16
Diameter of target branch and patency rate			
1.0 mm	14/15 (93.3%)	49/52 (94.2%)	0.90
1.25 mm	151/156 (96.8%)	222/224 (99.1%)	0.10
1.5 mm~	428/436 (98.2%)	498/506 (98.4%)	0.76
not recorded	55/59 (93.2%)	12/12 (100%)	-
Early results			
Mortality	1/199 (0.5%)	1/171(0.6%)	0.91
Cardiac	0	1	
non-cardiac	1	0	
Morbidity	9/199 (4.5%)	7/171 (4.1%)	0.89
MI (CKMB>100)	5	3	
stroke	3	1	
deep wound infection	1	2	
reoperation for bleeding	0	1	

MI; myocardial infarction, CKMB; Creatinine kinase MB

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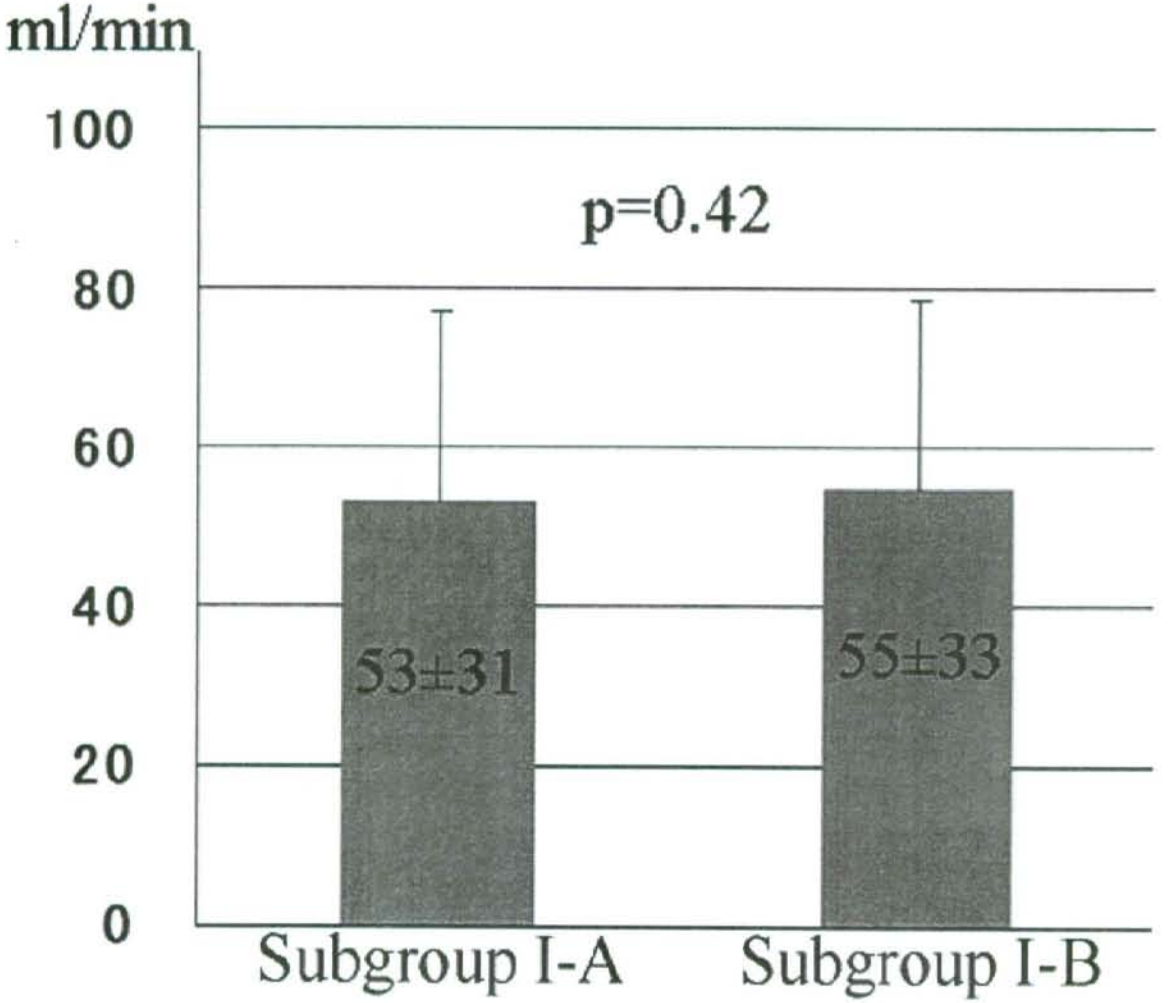
Figure Legends

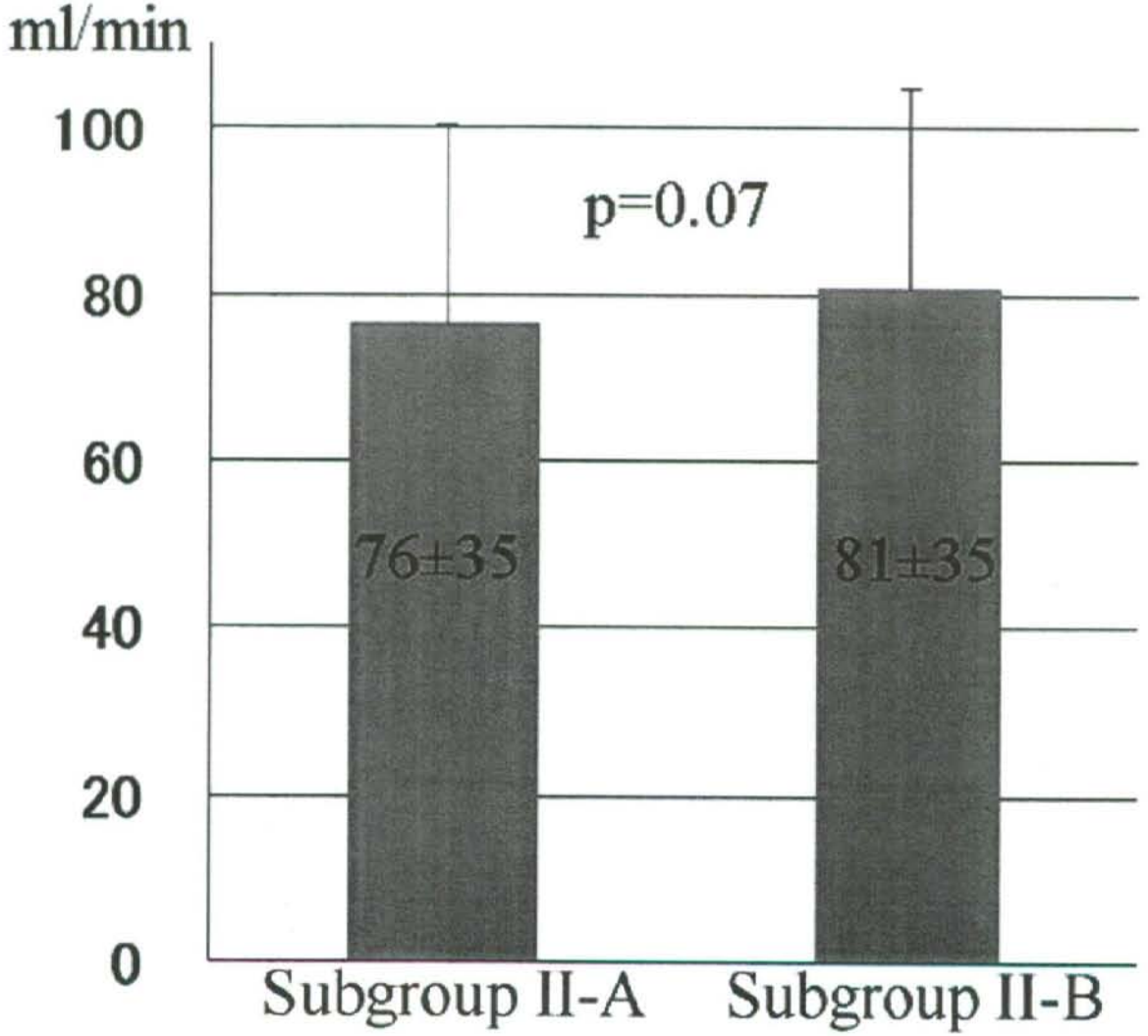
Figure 1,

Comparison of the amount of intraoperative bypass flow: subgroup I-A versus subgroup I-B.

Figure 2,

Comparison of the amount of intraoperative bypass flow: subgroup II-A versus subgroup II-B.


ml/min
100
80
60
40
20
0
p=0.42
53±31
55±33
Subgroup I-A
Subgroup I-B


ml/min
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80
60
40
20
0
p=0.07
76±35
81±35
Subgroup II-A
Subgroup II-B

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Patency rate of the internal thoracic artery to the left anterior descending artery bypass is reduced by competitive flow from the concomitant saphenous vein graft in the left coronary artery

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Abstract

Objective: In coronary artery bypass grafting (CABG), insufficient bypass flow can be a cause of occlusion or string sign of the internal thoracic artery (ITA) graft. A patent saphenous vein (SV) graft from the ascending aorta can reduce the blood flow through the ITA graft, and may affect its long-term patency. In the present study, we examined the impact of the patent SV graft to the left coronary artery on the long-term patency of the ITA to left anterior descending (LAD) artery bypass. **Methods:** We reviewed the coronary angiograms of 313 patients who had two bypasses to the left coronary artery including 1 in situ ITA to LAD graft between March 1986 and December 2006. Patients who had occlusion of either bypass grafts to the left coronary artery in the early angiography, were excluded. In 64 patients (20.4%), bilateral ITAs were individually anastomosed to the LAD and the second target branch in the left coronary artery (BITA group), while 249 patients (79.6%) had the ITA to LAD bypass and the SV graft to the second target branch in the left coronary artery (ITA/SV group). The mean follow-up period was 6.8 ± 4.9 years. **Results:** The cumulative patency rate of ITA-LAD bypasses at 10 years was 100% in the BITA group and 81.4% in the ITA/SV group. The ITA to LAD bypass was occluded in 14 (5.6%) patients of the ITA/SV group. In the ITA/SV group, the cumulative graft patency rate of the ITA to LAD bypass in patients who had severe (≥76%) native coronary stenosis between the two anastomotic sites was 98.6% at 5 years, and was significantly higher than that of 82.3% in patients without severe stenosis ($p < 0.0001$). **Conclusions:** Long-term patency of the ITA-LAD bypass was affected by the presence of the patent SV graft to the left coronary artery, particularly when the native coronary stenosis between the two anastomotic sites was not severe. Competitive flow from SV graft could play an important role in occlusion of the in-situ arterial graft.

Keywords: Coronary artery bypass grafting; Internal thoracic artery; Saphenous vein graft; Competitive flow; Graft arrangement

1. Introduction

The utilization of an internal thoracic artery (ITA) in coronary artery bypass grafting (CABG) has decreased the operative mortality without increasing the operative complications [1,2]. The ITA to the left anterior descending artery (LAD) in coronary revascularization has been proven to have a superior long-term patency rate [3], and it improves the long-term mortality and morbidity in patients with coronary artery disease [4–8] as compared to use of vein grafts to the LAD.

On the other hand, a current issue regarding the ITA graft is that competitive flow in the ITA graft causes graft occlusion or 'string sign', which represents the narrowing of the artery along its whole length [9]. In previous reports, competitive flow usually arose when native coronary stenosis was not severe, and the patency rate of the ITA graft inversely correlated with severity of native stenosis [10–12].

Recently, various grafts such as ITA, radial artery, gastroepiploic artery, and saphenous vein (SV) graft are applied and designed in various configurations. There are several reports investigating the hemodynamic features of bypass grafts. Kawasuji and colleagues compared the flow capacities of arterial grafts and SV graft and demonstrated that the flow capacity of the in situ ITA graft which represented diastolic blood pressure, was less than that of SV graft, whose proximal anastomosis was placed on the ascending aorta [13]. When the in situ ITA and the SV graft were connected to the same coronary artery system, the patent SV graft may affect the in situ ITA graft. Such

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interactions between the SV graft and arterial bypass grafts have not yet been delineated.

The purposes of this study are to examine the effects of the graft material, for the circumflex or diagonal branch on the long-term patency of the ITA to LAD graft, and to delineate the interactive effect between the bypass grafts aiming at establishing appropriate usage of the SV graft and strategy for optimal graft arrangement in CABG.

2. Materials and methods

We reviewed the coronary angiograms of 313 patients who underwent CABG with two bypasses to the left coronary artery including one in situ ITA to LAD graft and early postoperative angiography between March 1986 and December 2006. Of these, 263 were male and 50 female with a mean age of 60.9 ± 8.9 years and a mean follow-up period of 6.8 ± 4.9 years. In our institution, early postoperative coronary and graft angiography was routinely performed about 2 weeks after surgery, except for patients with renal insufficiency, severe atherosclerosis in the aorta or aged more than 80 years. Late coronary angiography was done when patients suffered from chest pain or recurrence of angina pectoris was suspected by electrocardiogram or other clinical symptoms. Late coronary angiograms were carried out on 133 patients in this series (42.5%; 133/313). All coronary angiograms were independently evaluated by cardiologists for coronary artery stenosis and graft patency. Stenoses were grouped as 51–75% and 76–100% by a precise measurement of the minimal luminal diameter and labeled as 'moderate' and 'severe', respectively in the present study.

The in situ ITA graft or the SV graft as an aorto-coronary bypass was exclusively used in an individual fashion for these patients. The patients who did not undergo early postoperative angiography, who had graft occlusion in either of two bypass grafts to the left coronary artery in the early angiography, and who had a gastroepiploic artery, radial artery, sequential or composite graft, were excluded from this study. Patients whose bypass graft to the right coronary artery was occluded, but both bypass grafts to the left coronary artery were patent in early angiography, were included. Ninety-three patients had two bypass grafts in the left coronary artery, and 220 patients had two bypass grafts in the left coronary artery and 1 in the right coronary artery. The second target site in the left coronary artery was the left circumflex artery (LCX) in 270 patients and the diagonal branch (Dx) in 43 patients.

Patients were divided into two groups based on the graft selection for the second target site in the left coronary artery. The BITA group comprised 64 patients in whom the bilateral in situ ITAs were individually anastomosed to the LAD and the second target site (Fig. 1). In the ITA/SV group, 249 patients had a single in situ ITA to LAD and the SV graft to the second target site in the left coronary artery (Fig. 2). Characteristics of both groups are shown in Table 1. In addition, the ITA/SV group was divided into two subgroups based on the severity of native left coronary stenosis between two distal anastomotic sites, which was referred from preoperative coronary angiography (Fig. 3). The subgroup S comprised 189 patients who had

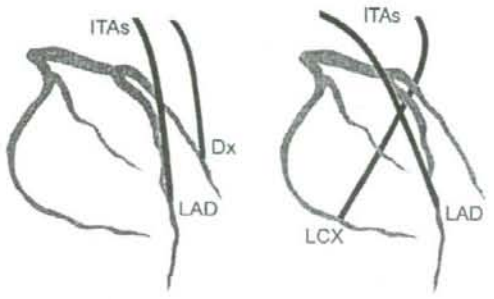

Fig. 1. In the BITA group, bilateral ITAs were individually anastomosed to LAD and the diagonal or circumflex artery. Solid lines indicate the in situ ITA. ITA: internal thoracic artery; LAD: left anterior descending; Dx: diagonal branch; LCX: left circumflex artery.

severe (76–100%) stenosis between two anastomotic sites, while the subgroup M consisted of 60 patients who had moderate (51–75%) or less stenosis between two anastomotic sites. For example, the subgroup S included patients who had severe stenosis at the origin of LAD or circumflex, and the subgroup M included patients with the stenotic lesion localized in the left main trunk.

3. Operative technique

Our current operative technique has been described previously [14]. In brief, our standard technique since 2000 was off-pump CABG without aortic manipulation. Additionally, we preferably use the bilateral in situ ITAs when we place two bypass grafts to relatively large branches in the left coronary artery region in patients without considerable operative risk, such as chronic obstructive pulmonary disease or an advanced age of more than 75 years. A suction-type stabilizer and an apical heart positioner were used for off-pump CABG. The surgical field was maintained by a CO_2 blower and an intracoronary shunt.

Before introduction of an off-pump operation, conventional CABG was performed with ascending aortic and bicaval cannulations. The core temperature was maintained between

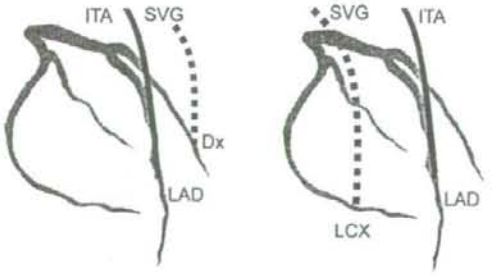

Fig. 2. In the ITA/SV group, an in situ ITA was anastomosed to LAD and the SV graft were anastomosed to Dx or LCX as an aorto-coronary bypass. Solid lines and dash lines indicate ITA and SV graft, respectively. ITA: internal thoracic artery; SV: saphenous vein; LAD: left anterior descending; Dx: diagonal branch; LCX: left circumflex artery.