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Midterm angiographic follow-up after off-pump coronary artery bypass: Serial comparison using early, 1-year, and 5-year postoperative angiograms

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Objective: We analyzed the angiographic changes of the anastomotic sites at three time points for 5 years after off-pump coronary artery bypass surgery.

Methods: Of the 402 patients who underwent off-pump coronary artery bypass surgery between January 1998 and December 2001, 240 patients who received the early, 1-year, and 5-year follow-up coronary angiograms regardless of the patient's anginal symptoms were studied. Morphologic changes of grafts were traced by the FitzGibbon grading system.

Results: Overall graft patency rates (FitzGibbon grade A+B) at early, 1-year, and 5-year angiography were 98.6%, 91.9%, and 88.3%, respectively. Graft patency rates in the left anterior descending artery, left circumflex artery, and right coronary artery territories were similar at early angiograms ($P = .162$). However, graft patency rate in the left anterior descending artery territory was higher than that in the left circumflex artery and right coronary artery territories at both the 1-year ($P < .001$) and 5-year ($P < .001$) angiograms. Of the 31 FitzGibbon grade B arterial grafts (internal thoracic artery and right gastroepiploic artery) at early angiography, 10 became occluded and 19 became grade A at 5-year angiography. In the saphenous vein grafts, grade B lesions gradually increased during the 5 postoperative years (2.6% vs 6.5% vs 13.3%).

Conclusions: Midterm angiographic follow-up demonstrated acceptable patency rates of grafts after off-pump coronary artery bypass surgery. Approximately half of the FitzGibbon grade B arterial grafts in the early angiograms became grade A at 5 years after surgery, but the proportion of grade B saphenous vein grafts gradually increased over the 5 postoperative years.

Several studies have investigated the patency rates of grafts after conventional on-pump coronary artery bypass grafting (CABG) and have shown that arterial grafts have better patency than vein grafts.[1,2] With resurgent interest in off-pump coronary artery bypass grafting (OPCAB) since the mid-1990s, there have been concerns about accuracy and patency of the grafts and the long-term outcome. Some meta-analyses demonstrated that patients undergoing OPCAB demonstrated a lower graft patency than patients undergoing conventional CABG.[3,4] Another meta-analysis[5] demonstrated a statistically insignificant benefit of conventional CABG over OPCAB for arterial graft patency. However, most of these studies were cross-sectional investigations performed at a defined point in time after surgery.

The aims of this study included (1) serial comparison of the graft patency rates in patients who had undergone angiography early postoperatively and 1 and 5 years after OPCAB, (2) evaluation of the graft patency rates based on target territories and revascularization strategies during the 5 postoperative years, and (3) assessment of the serial changes of FitzGibbon B stenotic grafts during the 5 postoperative years.

Patients and Methods

Among the total 522 patients who underwent isolated CABG between January 1998 and December 2001, OPCAB was performed in 402 (77.0%) patients. Operative mortality

Abbreviations and Acronyms
CABG = coronary artery bypass grafting
ITA = internal thoracic artery
LAD = left anterior descending coronary artery
LCX = left circumflex artery
OPCAB = off-pump coronary artery bypass grafting
RCA = right coronary artery
RGEA = right gastroepiploic artery

($\leq$30 days) of the OPCAB patients was 1.24% (5/402). There were 8 late in-hospital deaths (>30 days) and 16 additional deaths during the 5-year follow-up. The early, 1-year, and 5-year follow-up coronary angiograms were performed regardless of the patients' anginal symptoms in 384, 349, and 262 patients, respectively. Of the 402 OPCAB patients, 240 (59.7%) patients who received all the early (postoperative day 1.6 $\pm$ 1.6), 1-year (postoperative month 13.2 $\pm$ 5.2), and 5-year (postoperative month 59.9 $\pm$ 5.7) follow-up angiograms were studied for evaluation of the anastomotic sites and patency of the grafts (Table 1). Patients who died, refused angiographic evaluation, or had renal function impairment were excluded from the angiographic follow-up. However, patients with renal replacement therapy were included in the angiographic follow-up. Follow-up coronary angiography included 4-plane selective coronary and bypass graft angiography. One physician initially reviewed all the coronary angiograms and consensus was reached after review.

Graft patency was graded as described by FitzGibbon, Burton, and Leach[6] (grade A = excellent; grade B = fair; grade A+B = patent). Competitive graft flow was defined as distal graft as well as distal native grafted coronary artery flow not clearly opacified as seen

by graft angiography, but well-visualized graft flow retrogradely as seen by native coronary angiography; it was classified as a grade B anastomosis.

The basic surgical procedures and principles of OPCAB have been previously described.[7] All patients halted aspirin therapy (300 mg/day) the day before the operation and resumed it 1 day postoperatively. The average number of distal anastomoses per patient was 3.1 $\pm$ 1.0. The grafts used for distal anastomoses were left internal thoracic artery (ITA) (n = 234), right ITA (n = 164), right gastroepiploic artery (RGEA) (n = 79), radial artery (n = 6), and saphenous vein (n = 57). Almost all of the left ITA grafts (232/234), half of the right ITA grafts (94/164), and the majority of RGEA grafts (74/79) were used as an in situ graft. The majority of ITA grafts (93.4%, 492/527) were used to revascularize the left coronary artery territory, and the majority of RGEA grafts (92.5%, 74/80) were used to revascularize the right coronary artery (RCA) territory. Saphenous vein grafts were used to revascularize the left anterior descending artery (LAD) territory (24.8%, 30/121), left circumflex artery (LCX) territory (40.5%, 49/121), and RCA territory (34.7%, 42/121) without any preference (Table 2). During the study period, we changed revascularization strategies on the basis of our early patency study after OPCAB.[8] Forty-nine (86.0%) of the 57 patients who received vein grafts underwent OPCAB before 2000, and 77.6% (142/183) of the patients who received total arterial grafts underwent OPCAB after 2000.

The operations were all performed by a single surgeon (K.-B. K.).

The study protocol was reviewed by the institutional review board and approved as a minimal risk retrospective study (Approval No. H-0701-051-196) that did not require individual consent according to the institutional guidelines for waiving consent.

Statistical Analysis

Statistical analysis was performed with the SPSS software package (version 11.0; SPSS, Inc, Chicago, Ill). Comparison of the patency rates between the grafts was performed by the χ^2 test (Pearson χ^2 and Fisher exact tests). In the analysis of the serial changes over the 5 years' duration, nonparametric χ^2 test with McNemar examination was used. All results were expressed as mean $\pm$ standard deviation or as proportions.

TABLE 1. Preoperative characteristics and risk factors of study patients

Patient characteristics	n = 240
Sex (male/female)	158/82
Age (y)	61 $\pm$ 9
Unstable/stable angina	191/49
Risk factors, n (%)	
Hypertension	144 (60.0)
Diabetes mellitus	83 (34.6)
Hyperlipidemia	63 (23.6)
Previous PCI	28 (11.7)
History of stroke	27 (11.3)
LVEF <35%	13 (5.4)
Chronic renal failure	5 (2.1)
Urgent/emergency operation	33 (13.8)
Angiographic diagnosis, n (%)	
Three-vessel disease	148 (61.7)
Two-vessel disease	57 (23.8)
Left main disease with or without peripheral disease	64 (26.7)

PCI, Percutaneous coronary intervention; *LVEF*, left ventricular ejection fraction.

TABLE 2. Grafts and their target coronary arteries

	LAD	D	RI	OM	RCA	PDA	PLB	Total
ITA	222	100	29	141	17	15	3	527
Left ITA	148	74	17	69			1	309
Right ITA	74	26	12	72	17	15	2	218
RGEA				6	13	59	2	80
Radial artery	1	2	1	4			1	9
Saphenous vein	7	23	6	43	20	19	3	121
Total	230	125	36	194	50	93	9	737

LAD, left anterior descending coronary artery; *D*, diagonal branch of the LAD; *RI*, ramus intermedius; *OM*, obtuse marginal branch of circumflex coronary artery; *RCA*, right coronary artery; *PDA*, posterior descending coronary artery; *PLB*, posterolateral branch of right coronary artery; *ITA*, internal thoracic artery; *RGEA*, right gastroepiploic artery.

TABLE 3. Serial angiographic patency rates

	Early (n = 240)	One year (n = 240)	Five years (n = 240)
Total	98.6% (727/737)	91.9% (677/737)*	88.3% (651/737)†
ITA	99.4% (524/527)	95.6% (504/527)*	92.4% (487/527)†
Left ITA	99.4% (307/309)	95.5% (295/309)*	91.9% (284/309)§
Right ITA	99.5% (217/218)	95.9% (209/218)‡	93.1% (203/218)§
RGEA	97.5% (78/80)	91.3% (73/80)	82.5% (66/80)§
Radial artery	100% (9/9)	88.9% (8/9)	88.9% (8/9)
Saphenous vein	95.9% (116/121)	76.0% (92/121)*	74.4% (90/121)

ITA, Internal thoracic artery; *RGEA*, right gastroepiploic artery. *$P < .001$ between early and 1 year postoperatively. †$P < .001$ between 1 year and 5 years postoperatively. ‡$P < .05$ between early and 1 year postoperatively. §$P < .05$ between 1 year and 5 years postoperatively.

Results

Serial Angiographic Patency Rates of the Grafts

Overall postoperative graft patency rates (FitzGibbon grade A+B) at early, 1-year, and 5-year follow-ups decreased significantly (98.6% vs 91.9% vs 88.3%; $P < .001$). Although ITA grafts demonstrated a greater than 90% patency rate at 5 years postoperatively, the patency rate decreased significantly during the follow-up period (99.4% vs 95.6% vs 92.4%; $P < .001$). RGEA grafts showed a significantly decreased patency rate between 1 and 5 years (91.3% vs 82.5%; $P = .016$). Saphenous vein grafts showed a significantly decreased patency rate during the first postoperative year (95.9% vs 76.0%; $P < .001$); however, the patency rate remained stable between 1 and 5 years (76.0% vs 74.4%; $P = .250$) (Table 3).

Graft Patency Rates According to Target Coronary Artery Territories

We defined target territories as the LAD territory, which includes the LAD or diagonal branches; the LCX territory, which includes the ramus intermedius or obtuse marginal branches; and the RCA territory, which includes the RCA, posterior descending artery, or posterolateral branch. Graft patency rates in the LAD, LCX, and RCA territories were similar at early postoperative angiography. However, graft patency rates of the LAD territory became higher than those of the LCX or RCA territories at 1-year and 5-year angiography. There were no significant differences in the graft patencies between the LCX and RCA territories until 5 years after OPCAB (Table 4, A).

In the LAD territory, there were no significant differences in graft patency rates between early and 1 year postoperatively and between 1 year and 5 years postoperatively. Although the number of saphenous vein grafts for the LAD territory was small, they also demonstrated stable patency (100% vs 83.3% vs 83.3%: $P = .052$) (Table 4, B).

In the LCX territory, patency rates of ITA grafts decreased significantly between early and 1 year postoperatively, and

between 1 year and 5 years postoperatively, and they may be affected by the left ITA graft patency rate. The left ITA graft patency rate decreased significantly between early and 1 year postoperatively ($P = .004$), and between 1 year and 5 years postoperatively ($P = .031$). The patency rate of saphenous vein grafts decreased significantly during the first postoperative year (from 91.8% to 71.4%; $P = .002$), whereas it remained stable between 1 and 5 years (Table 4, C).

In the RCA territory, ITA grafts demonstrated stable patency rates during the 5 postoperative years. RGEA graft patency rates decreased significantly between 1 year and 5 years postoperatively (90.5% vs 81.1%; $P = .048$). Saphenous vein

TABLE 4. Serial changes of graft patency rates according to target coronary artery territories

A. Overall graft patency rates			
	LAD territory	LCX territory	RCA territory	P value
Early	99.4% (353/355)	97.8% (225/230)	98.0% (149/152)	.162
One year	96.9% (344/355)	87.8% (202/230)*	86.2% (131/152)*	<.001
Five years	94.9% (337/355)	83.0% (191/230)*	80.9% (123/152)*	<.001

B. LAD territory			
	Early	One year	Five years
ITA	99.4% (320/322)	98.1% (316/322)	96.0% (309/322)
Left ITA	99.5% (221/222)	98.2% (218/222)	95.9% (213/222)
Right ITA	99.0% (99/100)	98.0% (98/100)	96.0% (96/100)
Radial artery	100% (3/3)	100% (3/3)	100% (3/3)
Saphenous vein	100% (30/30)	83.3% (25/30)	83.3% (25/30)

C. LCX territory			
	Early	One year	Five years
ITA	99.4% (169/170)	91.2% (155/170)†	87.1% (148/170)‡
Left ITA	98.8% (85/86)	88.4% (76/86)†	81.4% (70/86)‡
Right ITA	100% (84/84)	94.0% (79/84)	92.9% (78/84)
RGEA	100% (6/6)	100% (6/6)	100% (6/6)
Radial artery	100% (5/5)	80.0% (4/5)	80.0% (4/5)
Saphenous vein	91.8% (45/49)	71.4% (35/49)†	67.3% (33/49)

D. RCA territory			
	Early	One year	Five years
ITA	100% (35/35)	94.3% (33/35)	85.7% (30/35)
Left ITA	100% (1/1)	100% (1/1)	100% (1/1)
Right ITA	100% (34/34)	94.1% (32/34)	85.3% (29/34)‡
RGEA	97.3% (72/74)	90.5% (67/74)	81.1% (60/74)‡
Radial artery	100% (1/1)	100% (1/1)	100% (1/1)
Saphenous vein	97.6% (41/42)	76.2% (32/42)†	76.2% (32/42)

LAD, Left anterior descending coronary artery; *LCX*, left circumflex coronary artery; *ITA*, internal thoracic artery; *RGEA*, right gastroepiploic artery. *$P < .001$ when compared with LAD territory. †$P < .05$ between early and 1 year postoperatively. ‡$P < .05$ between 1 year and 5 years postoperatively.

grafts showed a significantly decreased patency rate during the first postoperative year (from 97.6% to 76.2%; $P = .001$), but remained stable between 1 and 5 years (Table 4, D).

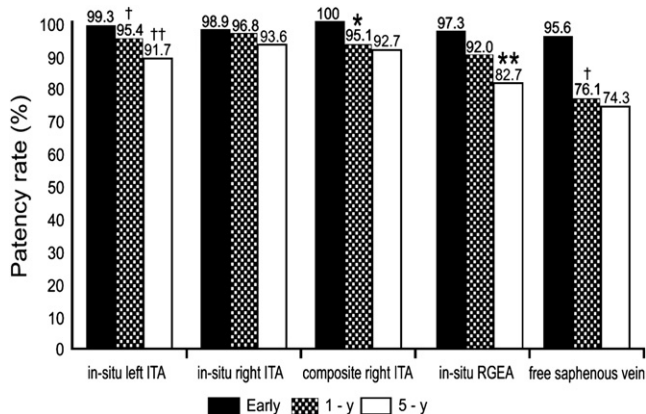## Changes of the Graft Patency Based on Proximal Techniques

Distal anastomoses constructed with in situ left ITA grafts showed progressively decreased patency rates during the 5 postoperative years, whereas distal anastomoses done with in situ right ITA grafts showed no significant differences in patency rates. Distal anastomoses with the composite right ITA connected to the side of the in situ left ITA showed a decreased patency rate during the first postoperative year (100% vs 95.1%; $P = .029$), whereas patency showed no significant difference between 1 and 5 years after OPCAB (95.1% vs 92.7%; $P = .596$). Although distal anastomoses made with in situ RGEA grafts showed no significant differences in patency rates during the first postoperative year, patency decreased significantly between 1 and 5 years after OPCAB. Distal anastomoses with saphenous vein grafts connected to the ascending aorta showed a significantly decreased patency rate during the first year, whereas patency remained stable between 1 and 5 years (Figure 1).

Fates of FitzGibbon Grade B Lesions

The arterial grafts (ITA and RGEA) demonstrated 31, 32, and 33 FitzGibbon grade B grafts in the early, 1-year, and 5-year angiograms, respectively. The proportions of grade B grafts out of patent grafts were as follows: 5.1% (31/602) versus 5.5% (32/577) versus 6.0% (33/553) ($P =$ not significant). The ITA grafts demonstrated 23 FitzGibbon grade B grafts, 26 grade B grafts, and 29 grade B grafts in the early, 1-year, and 5-year angiograms, respectively (4.4% [23/524]

vs 5.2% [26/504] vs 6.0% [29/487]; $P =$ not significant). Thirteen of the 23 grade B ITA grafts showed anastomotic stenosis and the other 10 showed competitive flow patterns in the early angiograms. Of the 13 anastomotic grade B ITA grafts seen in the early angiograms, 9 became grade A and 2 became occluded whereas 2 remained grade B by the 5-year angiograms. Of the 10 competitive grade B ITA grafts seen in the early angiograms, 5 became grade A and 5 became occluded by the 5-year angiograms. Six of the 7 occluded ITA grafts (grade O) by the 5-year angiograms were associated with moderate stenosis (<80%) of the native vessel. There were 20 newly developed FitzGibbon grade B ITA grafts at the 1-year angiograms. Nineteen of the 20 grafts showed competitive flow patterns and the other 1 showed anastomotic stenosis. Of the 19 competitive grade B ITA grafts seen at the 1-year angiograms, 5 became grade A and 3 became occluded whereas 11 remained grade B by the 5-year angiograms. All 3 of the occluded ITA grafts in the 5-year angiograms were associated with moderate stenosis (<80%) of the native vessel (Figure 2).

RGEA grafts demonstrated 8 FitzGibbon grade B grafts, 6 grade B grafts, and 4 grade B grafts in the early, 1-year, and 5-year angiograms, respectively (10.3% [8/78] vs 8.2% [6/73] vs 6.1% [4/66]; $P =$ not significant). Of the 8 grade B RGEA grafts in the early angiograms, 5 became grade A and 3 became occluded at 5 years after surgery. Two of the 3 occluded RGEA grafts were associated with moderate stenosis (<80%) of the native vessel. Seven of the 8 grade B

Figure 1. Changes of graft patency based on proximal techniques. *ITA*, Internal thoracic artery; *RGEA*, right gastroepiploic artery. *$P < .05$ between early and 1 year postoperatively; **$P < .05$ between 1 year and 5 years postoperatively; †$P < .001$ between early and 1 year postoperatively; ††$P < .001$ between 1 year and 5 years postoperatively.
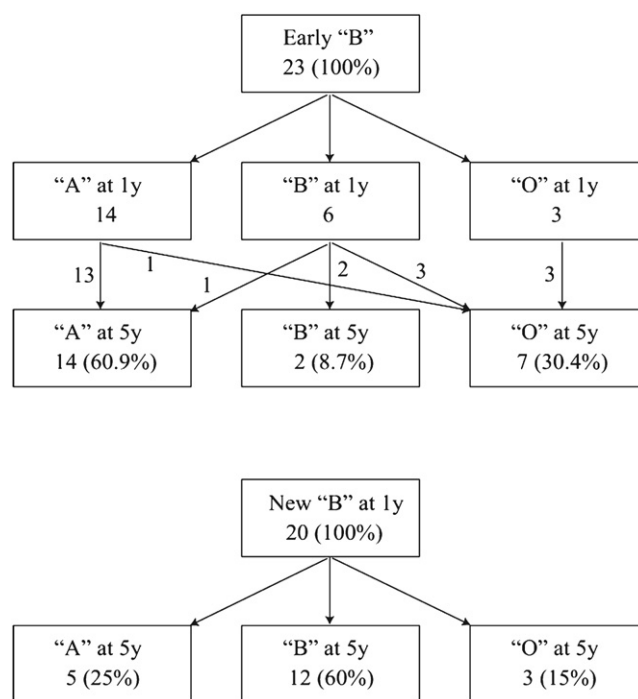
Figure 2. Fate of FitzGibbon grade B internal thoracic artery grafts.

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RGEA grafts showed competitive flow patterns and the other 1 showed anastomotic stenosis. Of the 7 competitive grade B RGEA grafts seen at early angiography, 4 became grade A and 3 became occluded by 5-year angiography. Three newly developed FitzGibbon grade B RGEA grafts at 1 year remained grade B by the 5-year angiograms.

In the saphenous vein grafts, the proportion of grade B lesions out of patent grafts gradually increased during the 5 postoperative years (2.6% [3/116] vs 6.5% [6/92] vs 13.3% [12/90]; P (early vs 5-year) = .006). All 3 of the grade B saphenous vein grafts in the early angiograms demonstrated a stenosis of greater than 50% at the distal anastomosis site and they became grade A at 1 year after surgery. All 6 of the newly developed grade B saphenous vein grafts seen in 1-year angiograms demonstrated segmental narrowings in the graft trunk. Of the 6 grade B vein grafts in 1-year angiograms, 5 remained grade B and 1 became occluded by 5 years after surgery.

Recurrence of Angina

During the first postoperative year, 10 (4.2%) patients experienced the recurrence of angina. Stenosis or occlusion of a graft was associated with the recurrence of angina in 6 patients, and progression of the native coronary artery disease was the cause of angina in 4 patients whose grafts were all widely patent. During the study period between postoperative years 1 and 5, 31 (12.9%) additional patients experienced the recurrence of angina. Stenosis or occlusion of a graft was associated with the recurrence of angina in 18 patients, and progression of the native coronary artery disease was the cause of angina in 13 patients.

Discussion

This study produced four main findings. First, the overall patency rates during the 5 postoperative years after OPCAB showed different patterns of decrease based on the grafts used. Second, the LAD territory showed significantly higher overall patency rates than the LCX and RCA territories in both 1-year and 5-year angiograms, although the patency rates were not different in early angiograms. Third, the graft patency rates during the 5 postoperative years showed different patterns of decrease when analyzed by three coronary territories. Fourth, the proportion of grade B lesions from the patent saphenous vein grafts gradually increased, whereas the proportion of grade B lesions from arterial grafts remained stable during the 5 postoperative years.

With resurgent interest in OPCAB since the mid-1990s, there have been concerns about accuracy and patency of the grafts and the long-term outcome. Two meta-analyses using randomized studies demonstrated that patients undergoing OPCAB demonstrated a lower graft patency than patients undergoing conventional CABG.[3,4] Those differences were mainly attributable to the lower saphenous vein or radial artery graft patency rates. A significantly lowered

patency for saphenous vein grafts than for ITA grafts was suggested to result from the type of graft, presence of hyperlipidemia, the exposure and quality of stabilization, and increased procoagulant activity in OPCAB patients.[7,9,10] Another meta-analysis[5] that included two more randomized trials[11,12] found a statistically insignificant benefit of conventional CABG over OPCAB for arterial graft patency and a statistically significant 28% increase in venous graft occlusion with OPCAB relative to conventional CABG. One study,[13] which reviewed the articles published from 1972 through 1998, examined outcomes of left ITA grafting to the LAD. The early (≤1 month postoperatively) and 1-year patency rates of left ITA grafts in conventional CABG have been reported to be between 94% and 99% and 88% and 93%, respectively. The present study showed that the early and 1-year patency rates of left ITA grafting to the LAD in OPCAB were 99.5% and 98.2%, respectively, both of which were not apparently inferior to those of conventional CABG.

In contrast to most of the previous studies investigating the patency of grafts by cross-sectional study at a specific time point, we performed coronary angiography in all of the 240 patients early postoperatively and 1 and 5 years after OPCAB to trace the changes of the anastomoses and grafts in the same patient population. In the present serial study, overall (grade A+B) graft patency rates early and 1 and 5 years postoperatively decreased significantly when analyzed by comparison between early and 1-year rates, and between 1-year and 5-year rates. We used the χ^2 test with McNemar examination, instead of the simple χ^2 test, because the present study analyzed the morphologic change of anastomotic sites in the same patient group. Although ITA grafts demonstrated a greater than 90% patency rate at 5 years postoperatively, the patency rate of ITA grafts also decreased significantly during the follow-up period. RGEA grafts showed a significantly decreased patency rate between 1 year and 5 years. Saphenous vein grafts showed a significantly decreased patency rate during the first postoperative year; however, their patency rate remained stable between 1 year and 5 years. The occlusion rate of saphenous vein grafts has been reported to be 2% to 2.5% per year between the first and fifth postoperative years.[14] The present study demonstrated that the patency of vein grafts remained stable during the period (76.0%– 74.4%; P = not significant), which was similar to another serial study for conventional CABG.[15] This study supports the idea that very little change occurs between 1 and 5 years in the overall patency rate of saphenous vein grafts.[16]

Like others,[17] we demonstrated that graft patency rates of the LAD territory were higher than those of the LCX or RCA territories at both 1-year and 5-year angiograms, even though graft patency rates in the three territories were similar at early postoperative angiography. In the LAD territory, there were no significant differences in graft patency rates between early and 1 year, or between 1 year and 5 years postoperatively. Although the number of saphenous veins grafted for the LAD

territory was small, saphenous vein grafts also demonstrated stable patency during the 5 postoperative years. The RCA territory, where grafts other than the ITA graft were commonly used, showed a lower patency rate than other territories in some studies.[18,19] Other studies[20,21] demonstrated lower patency rates of right ITA grafts in the RCA territory; however, we did not observe that finding in the RCA territory. Right ITA grafts demonstrated stable patency rates during the 5 postoperative years. RGEA grafts that were preferentially used as in situ grafts for revascularization of the RCA territory showed significantly decreased patency rates between 1 year and 5 years postoperatively despite excellent early and 1-year patency rates. Saphenous vein grafts showed significantly decreased patency rates during the first postoperative year, in contrast to a previous study demonstrating a comparable patency of saphenous vein grafts to ITA grafts in the RCA territory.[17]

When the patency rates were analyzed on the basis of the proximal technique, in situ left ITA grafts showed significantly decreased patency rates during the 5 postoperative years. Because two thirds (71.9%, 218/303) of in situ left ITA grafts were used to revascularize the LAD territory and the remainder for the LCX territory, decreased patency rates of in situ left ITA grafts in the LCX territory might have affected the overall patency rate of in situ left ITA grafts. In the LCX territory, the majority of the left ITA grafts (98.8%, 85/86) were used as in situ grafts whereas the majority of the right ITA grafts (96.4%, 81/84) were used as composite grafts. In situ left ITA grafts may have to bend posteriorly and sometimes be pushed by the pericardial margin when grafting the posterior coronary artery, which may decrease the patency rate in the LCX territory. On the basis of our experience, we have changed our revascularization strategy in OPCAB by avoiding the use of vein grafts if possible and performing total arterial revascularization using composite graft rather than bilateral in situ ITA grafts.

The present study demonstrated that the proportion of grade B arterial grafts (ITA and RGEA) remained stable (5.1% vs 5.5% vs 6.0%) whereas the proportion of FitzGibbon grade B grafts increased in vein grafts (2.6% vs 6.5% vs 13.3%) during the 5 postoperative years. The decreased patency of arterial grafts in the present study seemed to be partly associated with the status of the native coronary artery, because most late occlusions (9/10) of grade B arterial grafts at early angiography were associated with moderate stenosis (<80%) of the native vessel; in contrast, 12 of the 13 newly developed grade B saphenous vein grafts after 1 year demonstrated segmental narrowings in the graft trunks, and 1 graft demonstrated stenosis at the distal anastomosis site. The decrease in vein graft patency was suggested to be associated with disease in the graft itself, demonstrated by segmental narrowing in the vein graft trunks. All 3 grade B saphenous vein grafts in the early angiograms demonstrated a stenosis of more than 50% at the distal anastomosis site. Some of the anastomotic site stenoses seen in the early angiograms might result from local tissue edema, because 9 of the 13 anastomotic grade B ITA grafts and all 3 grade B saphenous vein grafts became grade A at 1 year after surgery.

There are limitations to the present study that must be recognized. First, the present study was a retrospective observational study of a single surgeon in a single institution and was not performed in a randomized manner with regard to the type of conduits and the target vessels; the majority of ITA grafts were used to revascularize the left coronary territory and the majority of RGEA grafts were used to revascularize the RCA territory. These might serve as confounding variables. Second, we changed the revascularization strategies during the study period. A majority of patients who received vein grafts underwent OPCAB in the early study period and most patients who received total arterial grafts underwent OPCAB in the latter part of the study period, which would affect the results. Third, we might have overestimated the patency rates by selecting the patients who survived and had angiograms performed 1 and 5 years after surgery. Fourth, inasmuch as we performed OPCAB in most patients (77.0%) during the study period, it was difficult to obtain an on-pump control group to determine the difference between OPCAB and on-pump CABG. However, when we compared the present data with our previous serial study for conventional CABG (n = 109),[15] there were no differences in 1-year and 5-year graft patency rates between the OPCAB and conventional CABG groups (ITA, 95.6% vs 97.9% at 1 year, 92.4% vs 90.3% at 5 years; saphenous vein, 76.0% vs 82.4% at 1 year, 74.4% vs 80.2% at 5 years) (*P* = not significant).

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Discussion

Dr Brian F. Buxton *(Melbourne, Australia)*. This paper has some fascinating aspects to it. One is the sequential rate of angiography and the second is the excellent results obtained by off-pump surgery. Let me just run through some of the aspects of this study. This is a single-center, in fact almost a single-surgeon, retrospective observational study of 240 out of 402 patients who had off-pump surgery, 60% of whom had repeat angiography unrelated to symptoms. The sequential angiograms were obtained the day after surgery and at 1 year and 5 years. I will confine most of my comments to the main groups rather than the subset analyses presented toward the end.

First, the 5-year angiographic patency studies of the ITA grafts were absolutely excellent, with 92% and 93% 5-year patency for the OPCAB series. In particular, I noted that most or many of the right ITA grafts were in situ. In contrast, the RGEA had 83% and saphenous vein 74% 5-year patency results. There were insufficient

radial arteries in this small series to comment on the patency rates. However, these results overall do confirm the excellent results in the hands of the Korean surgeons in terms of their OPCAB series.

The second point is that the overall patency in relation to target arteries provides no real new information. We know that the right ITA patency is superior to the LCX and RCA, and that was confirmed by these studies.

I think of special interest in this paper are the data provided by the progression of disease in the FitzGibbon 50% stenosis or FitzGibbon B group. This showed several interesting facts. In some of the patients the lesions recovered and in other patients new type B lesions appeared.

Let me run through the progression of disease. The ITA grafts showed very little progression of disease. There were two time frames, zero time to 1 year and 1 year through 5 years, and these failure rates were 4% and 6%, respectively. If we then look at the RGEA grafts, similar figures were 10% for the first 1-year increment and then 6% for the 4 years after that. In contrast, the saphenous vein grafts had double the failure rate of the arterial grafts, even in that relatively short follow-up period of 5 years.

We noted the same observations in our own series published by Shah and associates, that is, that there is very little progression of disease in arterial grafts but quite significant progress in arterial grafts in a slightly longer follow-up period.

It does appear that saphenous vein graft patency may have improved more recently with careful preparation, use of vasodilators, adequate storage techniques, and secondary prevention of the patients after surgery. It may be that this improvement in graft patency, if it is real, will require longer follow-up of these studies to obtain sufficient late data.

Let me just run over some of the deficiencies of this excellent paper. First, it is a single-surgeon, single-institution study, and one raises the question about generalizability of these results. Are we always as good as the Koreans?

Second, it is a retrospective study and therefore data quality comes into question.

I think the most disappointing thing from my perspective is that there was no comparison between off-pump and on-pump surgery. There were no control data, which would be absolutely fascinating. I suspect this could be done in the future prospectively in a way that would give us some really meaningful answers to the question, is off-pump surgery patency as good as on-pump? I think that is the real question that most of us have in mind.

Fourth, there is not really good documentation of the native vessel disease. In other words, how many vessels had serious competitive flow at low-grade stenoses?

I have four questions: What technique did you use to implant the right ITA? Did you go across the anterior midline or through the transverse sinus as a Y graft from the left?

Dr Kim. In this series, the right ITA was used to revascularize the LAD territory by crossing the midline, the ramus, or high obtuse marginal branch through the transverse sinus, and sometimes the RCA or posterior descending artery as an in situ graft. If the right ITA was too short to reach the left coronary territory or if the left coronary territory could not be completely revascularized with bilateral in situ ITA grafts, a Y graft was constructed.

Dr Buxton. Second question: Most surgeons prefer or perhaps are more familiar with the Kaplan–Meier estimation of graft

patency, and this can be done at zero time, 1, and 5 years. Why did you choose to use elective time estimates of 1 and 5 years?

Dr Kim. We studied 240 patients who received all the early, 1-year, and 5-year follow-up angiograms. For the analysis of the serial changes over the 5-year period, we used nonparametric χ^2 test with McNemar examination. We did not use the Kaplan–Meier estimation because we could not recognize the exact time of graft occlusions.

Dr Buxton. Perhaps there are not so many assumptions made in your results as ours that might derive from a Kaplan–Meier analysis.

One of the difficult things about looking at graft angiograms, and particularly anastomotic lesions and stenoses, is the validity and reproducibility of the observations. Can you tell us how many people looked and how independent the observers were in assessing the level of graft stenoses?

Dr Kim. Our cardiologists performed the angiograms and put their initial interpretations. For this study, one physician initially reviewed all the angiograms and consensus was reached after review.

Dr Buxton. One last question: Forty percent of the patients had missing data. Is there any reason for that? Did their grafts all fail? What happened? Why were they missing?

Dr Kim. As I mentioned before, patients who missed any of the three postoperative serial angiograms were excluded from this study. In this study, 240 patients who received all three follow-up angiograms—early, 1 year, and 5 years—evaluation of the anastomotic sites and patency of the grafts, were studied.

Dr Volkmar Falk *(Leipzig, Germany).* I enjoyed your paper, and I have one question. Would it be of value to go back and assess the extent of coronary artery disease by applying the SYNTAX score, which was designed to measure the extent of coronary artery disease? You are in a unique position in that you have angiograms at the time of surgery and 5 years after. You could finally tell us whether the extent of coronary artery disease at the time of surgery is really a predictor of late graft failure. That is one question that is still kind of open and no one is really addressing this. Would you consider doing that? I think this would be a great adjunct to your current study.

Dr Damiano. Can you clarify what you mean by SYNTAX score?

Dr Falk. I'm sorry; I thought that was common knowledge already. The SYNTAX trial was designed to compare treatment of triple vessel disease either by stenting or CABG. It was just finished, so the enrollment is just finished. Specifically for this trial, a new scoring system was developed to determine the extent of coronary artery disease, because most of the trials do not really look at this. Let's say they enroll patients with triple vessel disease, but we all know that there are various types of triple vessel disease that may alter the outcome more so than any of the other risk factors that are commonly applied, such as diabetes or hypertension. The extent of coronary artery disease can be graded. There is a good score for this that was actually designed for the SYNTAX trial but is available. It should be great to look at your angiograms again, apply the score, and then after a period of time assess whether the extent of coronary artery disease plays a role for late graft occlusion.

Dr Damiano. It is a good idea, but I think he will probably have to go back and get the score and then report the data at a later meeting.

Dr Kim. I would like to make some comments. As Dr Buxton indicated, there are limitations to the present study. It was a retrospective study of a single surgeon in a single institution. It was not performed in a randomized manner with regard to the type of conduit and the target vessels. The majority of ITA grafts were used to revascularize the left coronary territory and the majority of RGEA grafts were used to revascularize the RCA territory. This might serve as confounding variables. We have two staff surgeons in the adult cardiac division of our institution. I do most of the isolated CABGs with off-pump technique and the other surgeon does most of the valvular and aortic operations. That is why this study was a single-surgeon experience from a single institution. As we performed OPCAB in most of patients during the study period, it was difficult to obtain an on-pump control group to see the difference between off-pump and on-pump CABG.

ACD