

# Occurrence rate and fate of competitive flow of the left internal thoracic artery used in Y-composite grafts



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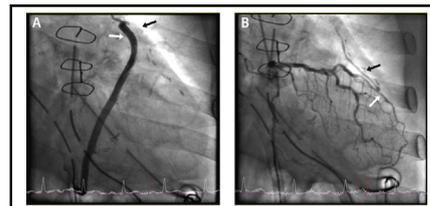
## ABSTRACT

**Objectives:** We evaluated the occurrence rate of competitive flow and the fate of grafts of left internal thoracic artery (LITA)-to-left anterior descending coronary artery (LAD) anastomosis after coronary artery bypass grafting with Y-composite grafts using early and 1-year angiography.

**Methods:** From 2008 to 2017, 923 patients underwent off-pump coronary artery bypass grafting using Y-composite grafting based on the in situ LITA. Early postoperative angiography was performed for all patients. One-year angiography (mean,  $13.2 \pm 3.1$  months) was performed for 86.7% (800 of 923) of patients.

**Results:** The early occlusion rate of LITA with Y-composite graft (CompLITA) to LAD was 0.7%. Among 917 patent CompLITA-LAD grafts, competitive flow was observed in 39 patients (4.3%). Multivariable analysis showed that the degree of LAD stenosis (odds ratio, 0.897; 95% CI, 0.875-0.920;  $P < .001$ ) and 3-vessel disease (odds ratio, 5.632; 95% CI, 1.168-27.155;  $P = .031$ ) were factors associated with the occurrence of competitive flow of CompLITA-LAD grafts. The receiver operating characteristics curve determined that the cutoff degree of LAD stenosis was 82.5% (sensitivity 82.1% and specificity 85.2%). The failure rate of CompLITA-LAD grafts seen on 1-year angiography was 58.3% in patients with competitive flow. Among patients with competitive flow, left main coronary artery disease was a protective factor (odds ratio, 0.055; 95% CI, 0.009-0.337;  $P = .002$ ) against graft failure of the CompLITA-LAD seen on 1-year angiography.

**Conclusions:** In CompLITA-LAD, the degree of LAD stenosis and combined 3-vessel disease were associated with the occurrence of competitive flow. CompLITA-LAD grafts with early competitive flow showed a high 1-year graft failure rate of 58%. (JTCVS Open 2022;11:116-26)



Fifty-eight percent of CompLITA-LAD grafts with early competitive flow had failed at 1-year angiography.

## CENTRAL MESSAGE

In CompLITA-LAD, the degree of LAD stenosis and 3VD were associated with the occurrence of competitive flow. CompLITA-LAD grafts with competitive flow showed a high 1-year graft failure rate of 58%.

## PERSPECTIVE

Despite its safety and efficacy, concerns remain that the use of composite grafts based on the LITA may cause insufficient blood flow from the LITA to the LAD, resulting in competitive flow that affects the patency of grafts. In the present study, we evaluated the occurrence rate and 1 year fate of competitive flow of CompLITA-LAD grafts after OPCAB using Y-composite grafting based on the in situ LITA.

The benefits of constructing composite grafts based on the in situ left internal thoracic artery (LITA) during coronary artery bypass grafting (CABG) include efficient conduit utilization and avoidance of aortic manipulation. Previous

studies have demonstrated the safety and efficacy of CABG using a composite grafting strategy.<sup>1-3</sup> However, concerns remain that the use of composite grafts based on the LITA may cause insufficient blood flow from the LITA with Y-composite graft (CompLITA) to the left anterior descending coronary artery (LAD), resulting in competitive flow that affects the patency of grafts.<sup>4</sup> A previous study showed that when stenosis in the target coronary artery was not severe, the risk of graft occlusion of the LITA increased owing to competitive flow from the native coronary artery, whereas aortocoronary saphenous vein (SV) grafts were not affected by competitive flow.<sup>5</sup> However, few studies have investigated the occurrence of competitive flow and its influence on graft patency after CABG using a composite grafting strategy.<sup>6,7</sup> Therefore, the present study was conducted to evaluate the occurrence rate of

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**Abbreviations and Acronyms**

3VD	= 3 vessel disease
CABG	= coronary artery bypass grafting
CompLITA	= left internal thoracic artery with Y-composite graft
ITA	= internal thoracic artery
LAD	= left anterior descending coronary artery
LITA	= left internal thoracic artery
LMD	= left main coronary artery disease
MDCTA	= multidetector computed tomography angiography
OPCAB	= off-pump coronary artery bypass grafting
SV	= saphenous vein

competitive flow in LITA grafts after CABG using a Y-composite grafting strategy based on the in situ LITA, and to clarify the fate of the LITA grafts with competitive flow 1 year after CABG.

**MATERIALS AND METHODS****Patient Selection**

The study protocol was reviewed and approved by an institutional review board as a minimal risk retrospective study (approval date: March 10, 2021, approval No.: H-2103-045-1203), and the requirement for informed consent was waived owing to the retrospective nature of the study. From January 2008 to December 2017, off-pump CABG (OPCAB) and on-pump CABG were performed in 1593 and 21 patients, respectively, by 2 surgeons. Among these patients, 1183 underwent OPCAB using a Y-composite grafting strategy based on the in situ LITA. After excluding 252 patients who had undergone sequential anastomoses using the LITA and 8 patients who had not undergone early postoperative angiography, data from 923 patients were included in the present study. The mean age at the time of operation was  $66.2 \pm 9.6$  years, and 24.3% of the patients were women (Table 1).

**Operative Techniques and Revascularization Strategy**

Institutional strategies for CABG have been described in previous studies.<sup>8,9</sup> Briefly, aortic OPCAB using a composite grafting strategy based on the in situ LITA was the preferred revascularization strategy for CABG during the study period (Video Abstract). The SV was used as the preferred second conduit for constructing a composite graft, regardless of the degree of target vessel stenosis, in 765 of the patients. The right internal thoracic artery ( $n = 86$ ) or the right gastroepiploic artery ( $n = 72$ ) was used when the SV was not available. The SV was harvested using a no-touch technique, preferably from a lower limb. The SV, right internal thoracic artery, or right gastroepiploic artery was anastomosed to the side of the LITA as a Y-composite graft. CompLITA-to-LAD anastomosis was performed immediately following the completion of the Y-composite graft in all cases. After revascularization of the LAD territory, the left circumflex followed by the right coronary artery territories were grafted. A sequential anastomotic technique was used whenever multiple distal anastomoses were needed.

**TABLE 1. Preoperative characteristics and risk factors of the study patients following the definition of the Society of Thoracic Surgeons (STS) database**

Variable	Total (n = 923)
Age (y)	$66.2 \pm 9.6$
Female	224 (24.3)
STS score	$1.83 \pm 2.83$
<b>Risk factors</b>	
Smoking	340 (36.8)
Hypertension	660 (71.5)
Diabetes mellitus	452 (49.0)
Dyslipidemia	318 (34.5)
Overweight*	360 (39.0)
Chronic renal failure	126 (13.7)
History of stroke	139 (15.1)
Peripheral vascular disease	213 (23.1)
History of percutaneous coronary intervention	148 (16.3)
Acute coronary syndrome	625 (67.7)
Left main coronary artery disease	373 (40.4)
3-vessel disease	721 (78.1)
Left ventricular dysfunction	132 (14.3)
Left ventricle ejection fraction (%)	$53.82 \pm 12.96$

Values are presented as mean  $\pm$  standard deviation or n (%). \*Body mass index  $\geq 25$ .

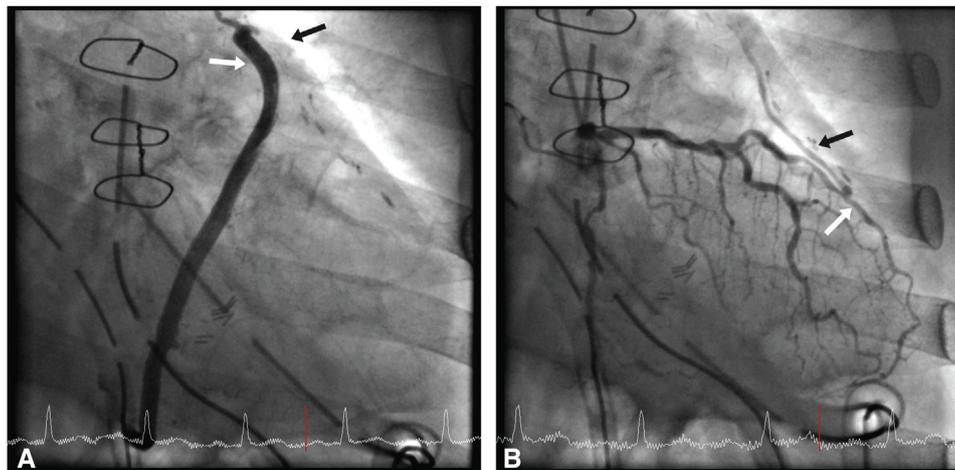
**Evaluation of Graft Patency**

Early postoperative ITA angiography was performed as part of the routine postoperative evaluation protocol in all patients at median 1 day (interquartile range, 1-1 day) after surgery. Bypass graft angiography was performed by manual injection of contrast media at a flow rate of 2.5 mL/sec over 2 seconds. If there were any unclear findings, including competitive flow or suspicious occlusion, graft angiography was performed again at a rate of 3 mL/sec over 2 seconds. Native angiography then followed whenever the findings of ITA angiography were inconclusive. Competitive flow of the CompLITA-LAD was diagnosed when the flow from the LITA to the LAD was not visualized on LITA angiography and the LITA graft was completely filled by retrograde flow from the native LAD on native coronary angiography (Figure 1).<sup>6</sup>

One-year graft angiography using conventional coronary angiography or multidetector computed tomography angiography (MDCTA) was recommended for all patients as a part of the institutional follow-up protocol after CABG. Coronary angiography and MDCTA findings were reviewed by 2 specialists for each examination. Each pair of specialists reached consensus in their interpretations of graft patency. Graft failure was defined when the grafts were either completely occluded or diffusely narrowed (string phenomenon).<sup>10</sup> Occluded grafts that were revised at the discretion of the operating surgeons based on early postoperative angiographic findings were treated as occluded at 1 year.

**Statistical Analysis**

Statistical analysis was performed using IBM SPSS statistics software version 24.0 (IBM-SPSS Inc) and R version 4.0.3 (R Foundation for Statistical Computing). Data are expressed as the mean  $\pm$  SD and median (interquartile range) or proportions. The  $\chi^2$  test or Fisher exact test was used to compare the proportions of categorical variables. For continuous variables, the Shapiro-Wilk test was used to assess the normality of variable distribution and Student *t* test was used for between-group comparisons. Multivariable logistic regression analysis was performed for factors associated with competitive flow of the CompLITA-LAD. For the final multivariable



**FIGURE 1.** Angiography demonstrating competitive flow of the left internal thoracic artery (LITA)-to-left anterior descending coronary artery (LAD) graft after off-pump coronary artery bypass grafting using a Y-composite graft based on the in situ LITA. A, The LITA with Y-composite graft (CompLITA)-LAD graft is not visualized (black arrow) just distal to the Y-composite anastomosis on graft angiography, whereas the saphenous vein graft (white arrow) is well visualized. B, The CompLITA graft is completely filled and visualized (black arrow) by retrograde flow from the native LAD (white arrow) on native coronary angiography.

model, backward selection with a retention criterion of  $P < .1$  was performed for the variables with  $P < .2$  in the univariate analysis. Goodness-of-fit was evaluated using the Hosmer-Lemeshow test. The receiving operator characteristics curves were generated after risk factor analyses. A subgroup analysis was performed to evaluate factors associated with the fate of the competitive CompLITA-LAD grafts, including only patients who had competitive flow of the CompLITA-LAD using another logistic regression model. All tests were 2-tailed.

**RESULTS**

**Operative Data**

The total and average numbers of distal anastomoses using the second conduits were 2358 and  $2.6 \pm 0.8$ , respectively. The mean stenosis degree of the LAD was  $90.1\% \pm 10.5\%$ . The mean maximum stenosis degree of non-LAD vessels, defined as the most severe degree of

stenosis among non-LAD target vessels that had been revascularized with Y-composite grafts, was  $96.3\% \pm 6.2\%$ . Data for the number of distal anastomoses and degrees of stenosis for respective non-LAD target vessels are shown in [Table E1](#).

**Early Angiographic Results**

Early postoperative angiographies demonstrated an overall occlusion rate of 1.6% (52 out of 3281). The occlusion rates of the CompLITA-LAD and distal anastomoses from the second conduits were 0.7% (6 out of 923 anastomoses) and 2.0% (46 out of 2358 anastomoses), respectively ([Table 2](#)). There were 20 cases (2.1%) of graft revision due to early occlusion, graft kinking, torsion, compression, or thrombus formation. Among 917 patent CompLITA-LAD grafts, competitive flow was

**TABLE 2. Early postoperative and 1-year follow-up angiographic results**

Variable	No. of distal anastomoses	No. of occluded anastomoses	Occlusion rates (%)
Early postoperative (n = 923)			
Overall	3281	52	1.6
CompLITA-LAD grafts	923	6	0.7
Y-Composite grafts	2358	46	2.0
Right ITA (n = 86)	172	1	0.6
Right GEA (n = 72)	157	1	0.6
Saphenous vein (n = 765)	2029	44	2.2
1-year follow-up (n = 800)			
Overall	2848	133	4.7
CompLITA-LAD grafts	800	18	2.3
Y-Composite grafts	2048	115	5.6
Right ITA (n = 85)	171	3	1.8
Right GEA (n = 65)	142	13	9.2
Saphenous vein (n = 650)	1735	99	5.7

CompLITA, Left internal thoracic artery with Y-composite graft; LAD, left anterior descending coronary artery; ITA, internal thoracic artery; GEA, gastroepiploic artery.

observed in 39 (4.3%). In these 39 patients, the maximum stenosis degree of the LAD was 72.4% ± 11.3% (range, 50.0% to 99.0%), and it was <70% in 11 out of 39 patients. The maximum stenosis degree of non-LAD target vessels in these patients was 98.2% ± 5.7%.

### Factors Associated with Competitive Flow of the ComplLITA-LAD Anastomosis

Univariate analyses demonstrated that the degree of LAD stenosis, the maximum degree of other target vessel stenosis, ratio of the stenosis degree of the LAD per degree of stenosis in the other target vessels, and underlying 3-vessel disease (3VD) were associated with competitive flow of the ComplLITA-LAD grafts ( $P < .001$ ,  $.040$ ,  $< .001$ , and  $.021$ , respectively). However, the type of the second conduit was not associated with the occurrence of competitive flow ( $P = .252$ ) (Table E2). The multivariable analysis showed that the maximum degree of LAD stenosis (odds ratio [OR], 0.897; 95% CI, 0.875-0.920;  $P < .001$ ) and 3VD (OR, 5.632; 95% CI, 1.168-27.155;  $P = .031$ ) were factors associated with competitive flow of the ComplLITA-LAD grafts (Table 3).

The area under the receiving operator characteristics curve for the maximum degree of LAD stenosis was 0.893 (95% CI, 0.847-0.939;  $P < .001$ ) (Figure 2). The cut-off value of the degree of LAD stenosis for predicting competitive flow of the ComplLITA-LAD grafts was 82.5% (sensitivity 82.1% and specificity 85.2%).

### One-Year Angiographic Results

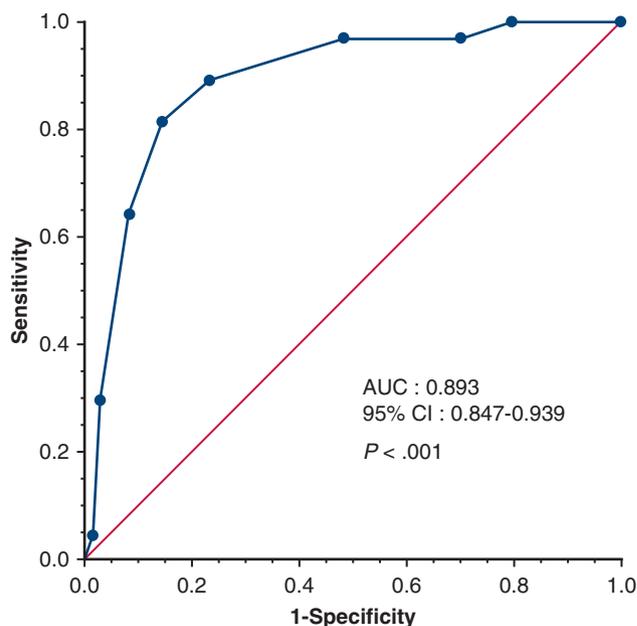
One-year graft angiographies were performed in 86.7% ( $n = 800$ ) of the patients (conventional angiography and

**TABLE 3. Results of multivariable risk factor analysis associated with competitive flow of the left internal thoracic artery with Y-composite graft-to-left anterior descending coronary artery (LAD) grafts\***

Variable†	Odds ratio (95% CI)	P value
Degree of the LAD stenosis (%)	0.897 (0.875-0.920)	<.001
Maximum stenosis degrees of non-LAD target vessels (%)	1.094 (0.993-1.205)	.070
Three-vessel disease	5.632 (1.168-27.155)	.031
Sex	–	.332
Chronic renal failure	–	.146
Acute coronary syndrome	–	.720
Left ventricular ejection fraction (%)	–	.389
Ratio of the stenosis degree of the LAD per other target vessels	–	.531

\*The final model had adequate goodness of fit (Hosmer-Lemeshow test,  $P = .198$ ).

†Only variables entered into multivariable analysis were presented.



**FIGURE 2.** The receiver operating characteristics curve for the degree of left anterior descending coronary artery (LAD) stenosis predicting competitive flow of left internal thoracic artery with Y-composite graft-to-LAD grafts. The area under the curve (AUC) was 0.893 (95% CI, 0.847-0.939;  $P < .001$ ).

MDCTA in 487 and 313 patients, respectively). Thirty-six out of 39 patients (92.3%) who had competitive flow of the ComplLITA-LAD anastomosis underwent angiography (conventional angiography and MDCTA in 26 and 10 patients, respectively). The overall 1-year occlusion rate was 4.7% (133 out of 2848 anastomoses). The 1-year occlusion rates of the ComplLITA-LAD and distal anastomoses from the second conduits were 2.3% (18 out of 800 anastomoses) and 5.6% (115 out of 2048 anastomoses), respectively (Table 2). Among 36 patients with competitive flow of the ComplLITA-LAD, improved ComplLITA-LAD flow was observed in 8 patients via conventional angiography and graft patency was confirmed on MDCTA in another 7 patients. The occlusion rate of ComplLITA-LAD was 36.1% ( $n = 13$ ) and the graft failure rate of ComplLITA was 58.3% when including 8 patients with diffusely narrowed grafts in patients with competitive flow. In contrast, the occlusion rate of ComplLITA-LAD was 0.7% ( $n = 5$ ) and the graft failure rate of ComplLITA-LAD was 2.4% when including 13 patients with diffusely narrowed grafts in patients without competitive flow (Table 4).

### Multivariable Analyses for ComplLITA-LAD Graft Failure at 1 Year

For the 800 patients who underwent 1-year follow-up angiography, multivariable analysis showed that Society of The Thoracic Surgery score (OR, 1.110; 95% CI, 1.008-1.223;  $P = .033$ ), underlying left main coronary artery

**TABLE 4. One-year angiographic results of the left internal thoracic artery with Y-composite graft (COMP-LITA) to left anterior descending coronary artery (LAD) anastomosis in 800 study patients**

Variable	No. of Anastomoses	Occluded Anastomoses	Diffusely narrowed grafts	Graft failure*
Total CompLITA-LAD anastomoses	800	18 (2.3)	21 (2.6)	39 (4.9)
Grafts without competitive flow on early angiography	764	5 (0.7)	13 (3.9)	18 (2.4)
Grafts with competitive flow on early angiography	36	13 (36.1)	8 (22.2)	21 (58.3)

Values are presented as n (%). \*Graft failure refers to occluded or diffusely narrowed grafts.

disease (LMD) (OR, 0.299; 95% CI, 0.129-0.693;  $P = .005$ ), and degree of LAD stenosis (OR, 0.920; 95% CI, 0.899-0.942;  $P < .001$ ) were factors associated with graft failure of CompLITA-LAD grafts at 1 year (Table 5 and Table E3).

In the subgroup analysis for 36 patients with competitive flow, multivariable analysis demonstrated that LMD was the only protective factor (OR, 0.055; 95% CI, 0.009-0.337;  $P = .002$ ) against the occurrence of graft failure of CompLITA-LAD grafts as observed on 1-year follow-up angiography (Table 6 and Table E4); the 1-year CompLITA graft failure rate in 14 patients with LMD was 21.4%, whereas it was 81.8% in 22 patients without LMD.

## DISCUSSION

The present study reports 3 main findings related to patients who underwent CABG using a Y-composite grafting strategy based on the in situ LITA. First, 4.3% of CompLITA-LAD grafts showed competitive flow on early postoperative angiography and a high failure rate of 58% 1 year after surgery. Second, a low degree of LAD stenosis with a cutoff value of 82.5% was associated with competitive flow of the CompLITA-LAD graft. Third, in patients with competitive flow of the CompLITA-LAD graft, the presence of LMD might be helpful for maintaining the patency of CompLITA-LAD grafts 1 year after surgery (Figure 3).

After more than 50 years of surgical experience, various revascularization strategies for CABG have

been developed, including multiple in situ arterial grafts, aortocoronary grafts, and composite grafting based on the in situ LITA. Previous studies have demonstrated the safety and efficacy of CABG using Y-composite grafting strategies.<sup>3</sup> Nonetheless, there remains concern that the use of composite grafts based on the LITA could cause insufficient blood flow of the CompLITA-LAD grafts, resulting in competitive flow that could influence graft patency rates. A previous study<sup>10</sup> demonstrated that the patency of the ITA graft decreased as competitive flow from native coronary artery increased. These findings were consistent with the physiology of arterial grafts; as proximal coronary stenosis decreases, competitive flow increases, and thus demand for ITA graft flow diminishes. This cascade of events results in constriction of the ITA and, over time, increases the risks of atrophy and occlusion of the ITA. Another study evaluated the influence of competitive flow on graft patency in patients who underwent CABG using bilateral ITAs as Y-composite grafts, showing that the outcomes of these strategies were similar to the outcomes of other graft configuration strategies.<sup>4</sup> Although the study also demonstrated that competitive flow was related to native vessel stenosis and predicted graft occlusions, no threshold of target vessel stenosis affecting competitive flow or graft failure was deduced that could change the configuration strategy.<sup>4</sup>

**TABLE 5. Results of multivariable risk factor analysis associated with graft failure of the left internal thoracic artery with Y-composite graft-to-left anterior descending coronary artery (LAD) grafts in 800 study patients who underwent 1-year graft angiography\***

Variable†	Odds ratio (95% CI)	P value
Society of Thoracic Surgeons risk score	1.110 (1.008-1.223)	.033
Left main coronary artery disease	0.299 (0.129-0.693)	.005
Degree of the LAD stenosis (%)	0.920 (0.899-0.942)	<.001
History of percutaneous coronary intervention	2.107 (0.968-4.587)	.060
Acute coronary syndrome	–	.375
Maximum stenosis degrees of non-LAD target vessels	–	.281
Age	–	.404
Left ventricular ejection fraction	–	.296
Ratio of the stenosis degree of LAD non-LAD target vessels	–	.735

\*The final model had adequate goodness of fit (Hosmer-Lemeshow test,  $P = .884$ ). †Only variables entered into the multivariable analysis are presented.

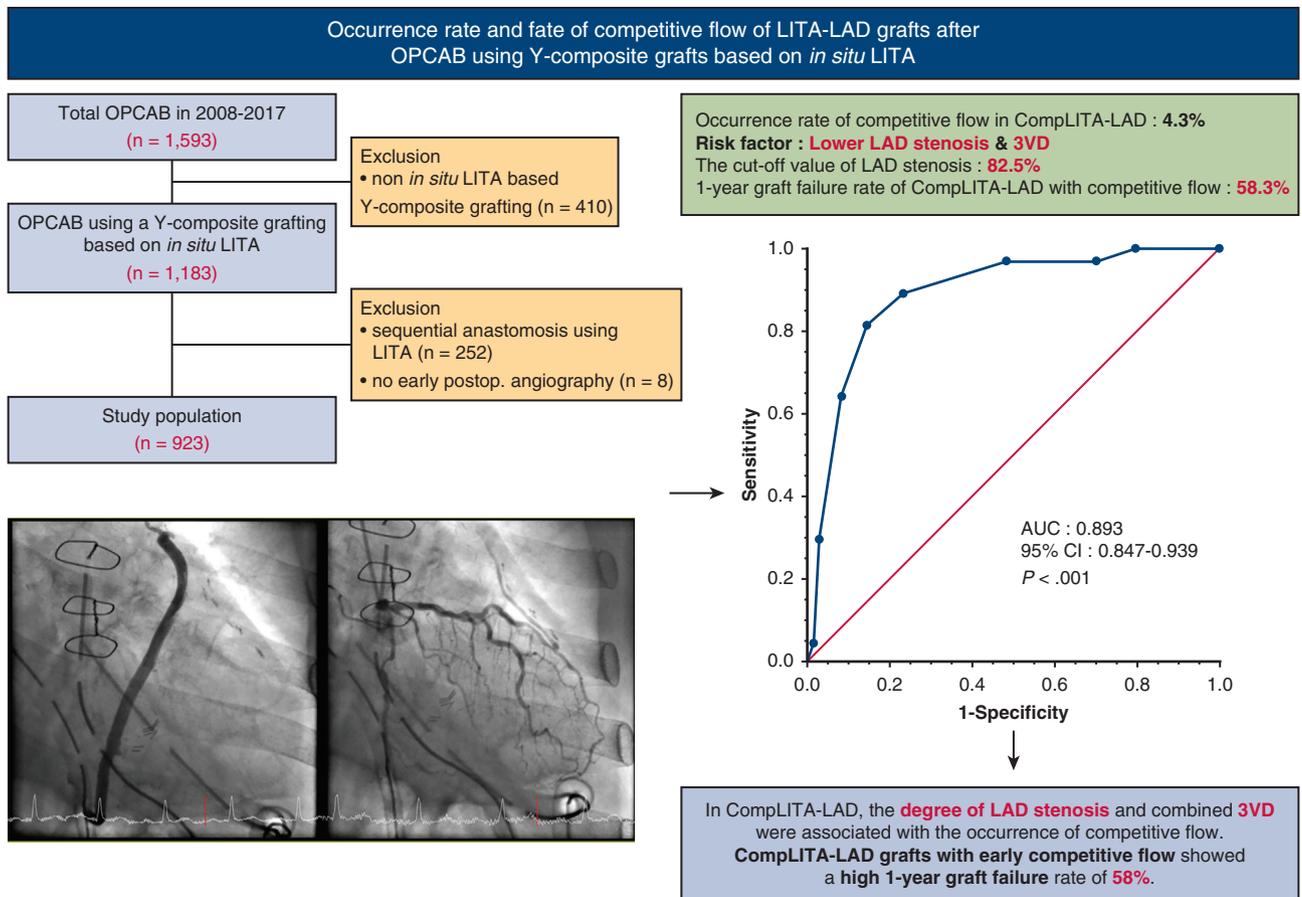
**TABLE 6. Results of subgroup multivariable risk factor analysis associated with graft failure of the left internal thoracic artery with Y-composite graft-to-left anterior descending coronary artery (LAD) grafts in 36 patients with early competitive flow who underwent 1-year graft angiography\***

Variable	Multivariable analysis†	
	Odds ratio (95% CI)	P value
Acute coronary syndrome	0.227 (0.036-1.432)	.115
Left main coronary artery disease	0.055 (0.009-0.337)	.002
Degree of the LAD stenosis (%)	–	.422

\*The final model had adequate goodness of fit (Hosmer-Lemeshow test,  $P = .238$ ).  
 †Only variables entered into the multivariable analysis are presented.

The main limitation of those studies was that they lacked direct evaluation of the competitive flow of grafts and instead used the degree of proximal coronary artery stenosis as a surrogate marker of competitive flow. Conversely, a

strength of the present study was that, excluding 6 patients with early ComplLITA-LAD graft occlusion, 99.3% (917 out of 923) of patients who underwent OPCAB using a Y-composite grafting strategy based on the in situ LITA were directly evaluated for the occurrence of competitive flow of ComplLITA-LAD grafts via ITA and native coronary angiography and found that competitive flow of the ComplLITA-LAD grafts occurred in 4.3% of patients; this was slightly higher than the 3.7% incidence of competitive flow in in situ ITA anastomoses reported by Nakajima and colleagues<sup>6</sup> who performed early postoperative angiography 2 weeks after CABG with sequential and composite arterial grafts. The multivariable analysis demonstrated that low-degree LAD stenosis was associated with early competitive flow of the ComplLITA-LAD. The analysis also showed that the presence of 3VD was associated with competitive flow of the ComplLITA-LAD grafts, and the maximal degree of stenosis in the vessels grafted by side



AUC, Area under curve; CI, Confidence interval; LAD, Left anterior descending coronary artery; ComplLITA, Left internal thoracic artery with Y-composite graft; OPCAB, off-pump coronary artery bypass grafting; 3VD, Three-vessel disease

**FIGURE 3.** Occurrence rate and fate of competitive flow of the left internal thoracic artery (LITA)-to-left anterior descending coronary artery (LAD) graft after off-pump coronary artery bypass grafting (OPCAB) using a Y-composite graft based on the in situ LITA. Competitive flow of LITA with Y-composite graft (ComplLITA)-LAD grafts occurred in 4.3% of patients as shown on early postoperative angiography. The low degree of LAD stenosis and underlying three-vessel disease (3VD) were risk factors for competitive flow of ComplLITA-LAD grafts, and the cut-off value of LAD stenosis for competitive flow was 82.5%. Graft failure occurred in 58.3% of ComplLITA-LAD grafts with early competitive flow. AUC, Area under curve; CI, confidence interval.

branch of the Y-composite graft was marginally significant. This competitive flow in ComplLITA-LAD may occur more frequently when there is imbalance of flow demand between the ITA and the second conduit due to a low degree of stenosis in the LAD, presence of 3VD, or a high degree of stenosis of non-LAD targets. This is in agreement with previous findings showing that the degree of proximal stenosis of target coronary arteries and flow balance between the ITA and second conduit could be related to the occurrence of competitive flow.<sup>4,6,11,12</sup>

In the present study, 1-year graft angiography was performed for more than 85% of patients. The overall graft failure rate of ComplLITA-LAD grafts at 1 year was 4.9%, and it was higher in patients with early competitive flow of the ComplLITA-LAD grafts than in the other patients. These findings were in agreement with previous results showing that the 1-year LITA-LAD graft patency rate ranged from 92% to 98% according to the degree of proximal LAD stenosis.<sup>11</sup> Although LMD was not a risk factor for occurrence of competitive flow in ComplLITA-LAD grafts, the subgroup analysis with 36 patients who had competitive flow and underwent 1-year follow-up angiography revealed that the risk of ComplLITA-LAD graft failure was high in patients without LMD; this was also evident from the multivariable analysis with all 800 patients who underwent 1-year graft angiography. In the presence of LMD, even if competitive flow has already occurred in patients with less severe LAD stenosis, there is increased possibility of decrement in native LAD flow because of progression of LMD or LAD stenosis compared with isolated LAD disease. This could result in a combined protective effect with LMD against graft failure of the ComplLITA-LAD graft showing early competitive flow.

### Limitations

This study has several limitations to be noted. First, it was a retrospective observational study performed at a single institution. Second, 1-year follow-up angiography was not performed for all study patients. Although most patients (36 out of 39) who had competitive ComplLITA-LAD grafts underwent 1-year angiography, unadjusted confounders might have influenced the study results. Third, clinical outcomes were not evaluated because such investigation was beyond the scope of the present study. Fourth, data regarding the functional significance of coronary artery stenosis were not included in the risk-factor analyses because the fractional flow reserve was seldom evaluated during coronary angiography when it was decided that the patients should undergo CABG based on angiographic findings. Fifth, almost all study patients underwent OPCAB because it was the preferred CABG strategy at our institution. There might be some differences in the early postoperative characteristics of coronary vessels and bypass conduits between patients undergoing OPCAB and those undergoing

on-pump CABG owing to the impact of extracorporeal circulation, hypothermia, and cold cardioplegia. However, after recovering from these effects, the vessels and conduits would react similarly as in cases of OPCAB. In addition, there might be possible differences in the 1-year patency rates after OPCAB and on-pump CABG, which was also difficult to analyze in the present study. Finally, the study results were not compared with those after CABG using other grafting strategies because Y-composite grafting based on the LITA was the preferred grafting strategy during the study period regardless of the degree of target vessel stenosis.

### CONCLUSIONS

The ComplLITA-LAD grafts in CABG using a Y-composite grafting strategy showed competitive flow in 4.3% of patients, and 58% of these grafts failed 1 year after surgery. The degree of LAD stenosis and combined 3VD were associated with the occurrence of competitive flow of the ComplLITA-LAD graft, and the absence of LMD was associated with failure of the ComplLITA-LAD grafts with early competitive flow at 1 year. Therefore, alternative revascularization strategies with single LITA-to-LAD anastomosis and additional grafting based on other inflow sources, such as in situ right ITA or aortocoronary grafts, might be considered in these patients to prevent LITA graft failure.

### Conflict of Interest Statement

The authors reported no conflicts of interest.

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

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**Key Words:** coronary artery disease, coronary artery bypass, mammary arteries, coronary angiography

**TABLE E1. The number of distal anastomoses and the degrees of stenosis for respective nonleft anterior descending coronary artery vessels (LAD) in 923 study patients**

	No. of distal anastomoses	Mean degree of stenosis (%)
No. of non-LAD target vessels	2358	
Diagonal	576	90.9 ± 8.7
Ramus intermedius	127	88.8 ± 10.2
Left circumflex branch	922	89.7 ± 10.9
Right coronary branch	733	93.2 ± 10.1

Values are presented as n or mean ± SD.

**TABLE E2. The full univariate and multivariable models of risk factor analysis associated with competitive flow of the left internal thoracic artery with Y-composite graft-to-left anterior descending coronary artery grafts\***

Variable	Univariate analysis		Multivariable analysis	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Age	1.021 (0.985-1.058)	.249		
Sex	1.795 (0.742-4.341)	.194	–	.332
STS score	0.924 (0.765-1.116)	.411		
Smoking	0.847 (0.429-1.671)	.631		
Hypertension	1.174 (0.564-2.444)	.668		
Diabetes mellitus	0.889 (0.467-1.691)	.720		
Dyslipidemia	1.057 (0.542-2.064)	.870		
Overweight†	1.363 (0.716-2.595)	.346		
Chronic renal failure	0.332 (0.079-1.394)	.132	–	.146
History of stroke	0.635 (0.222-1.815)	.396		
Peripheral vascular disease	1.315 (0.643-2.687)	.453		
History of PCI	1.396 (0.628-3.101)	.413		
Acute coronary syndrome	0.606 (0.317-1.159)	.130	–	.720
Left main coronary artery disease	0.916 (0.474-1.771)	.795		
3-vessel disease	5.387 (1.287-22.547)	.021	5.632 (1.168-27.155)	.031
Left ventricular dysfunction	0.497 (0.151-1.639)	.251		
LVEF (%)	1.024 (0.994-1.054)	.116	–	.389
Type of second conduit	1.847 (0.647-5.272)	.252		
Number of sequential anastomoses	0.973 (0.648-1.460)	.893		
Degree of the LAD stenosis	0.904 (0.883-0.925)	<.001	0.897 (0.875-0.920)	<.001
Maximum stenosis degrees of non-LAD target vessels	1.106 (1.005-1.217)	.040	1.094 (0.993-1.205)	.070
Ratio of stenosis degree of LAD per non-LAD target vessels	0.905 (0.885-0.926)	<.001	–	.531

STS, Society of Thoracic Surgeons; PCI, percutaneous coronary intervention; LVEF, left ventricle ejection fraction; LAD, left anterior descending coronary artery. \*The final model had adequate goodness of fit (Hosmer-Lemeshow test,  $P = .198$ ). †Body mass index  $\geq 25$ .

**TABLE E3. The full univariate and multivariable models of risk factor analysis associated with graft failure of the left internal thoracic artery with Y-composite graft-to-left anterior descending coronary artery grafts in 800 study patients who underwent 1-year graft angiography\***

Variable	Univariate analysis		Multivariable analysis	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Age	1.018 (0.982-1.056)	.333		
Sex	1.133 (0.528-2.428)	.749		
STS score	1.066 (0.975-1.166)	.161	1.110 (1.008-1.223)	.033
Smoking	0.738 (0.368-1.480)	.392		
Hypertension	1.002 (0.490-2.049)	.995		
Diabetes mellitus	0.935 (0.490-1.783)	.838		
Dyslipidemia	1.150 (0.593-2.229)	.680		
Overweight†	0.683 (0.341-1.369)	.282		
Chronic renal failure	0.419 (0.099-1.768)	.236		
History of stroke	0.642 (0.224-1.841)	.410		
Peripheral vascular disease	0.932 (0.420-2.067)	.863		
History of PCI	2.422 (1.193-4.915)	.014	2.107 (0.968-4.587)	.060
Acute coronary syndrome	0.575 (0.300-1.102)	.095	–	.375
Left main coronary artery disease	0.341 (0.155-0.751)	.008	0.299 (0.129-0.693)	.005
Three vessels disease	1.115 (0.503-2.470)	.789		
Left ventricular dysfunction	1.515 (0.651-3.529)	.335		
LVEF (%)	0.991 (0.967-1.016)	.481		
Type of second conduit	1.601 (0.615-4.164)	.335		
Number of sequential anastomoses	0.925 (0.617-1.385)	.704		
Degree of the LAD stenosis	0.922 (0.901-0.943)	<.001	0.920 (0.899-0.942)	<.001
Maximum stenosis degrees of non-LAD target vessels	1.045 (0.973-1.122)	.231		
Ratio of stenosis degree of LAD per non-LAD target vessels	0.925 (0.906-0.945)	<.001	–	.281

STS, Society of Thoracic Surgeons; PCI, percutaneous coronary intervention; LVEF, left ventricle ejection fraction; LAD, left anterior descending coronary artery. \*The final model had adequate goodness of fit (Hosmer-Lemeshow test,  $P = .884$ ). †Body mass index  $\geq 25$ .

**TABLE E4.** The full univariate and multivariable models of subgroup risk factor analysis associated with graft failure of the left internal thoracic artery with Y-composite graft-to-left anterior descending coronary artery grafts in 36 patients with early competitive flow who underwent 1-year graft angiography\*

Variable	Univariate analysis		Multivariable analysis	
	Odds ratio (95% CI)	P value	Odds ratio (95% CI)	P value
Age	1.015 (0.933-1.103)	.734		
Sex	0.229 (0.024-2.198)	.201		
STS score	0.973 (0.626-1.513)	.904		
Smoking	0.469 (0.111-1.980)	.303		
Hypertension	0.800 (0.159-4.023)	.787		
Diabetes mellitus	1.125 (0.293-4.326)	.864		
Dyslipidemia	2.062 (0.492-8.654)	.322		
Overweight†	0.656 (0.173-2.488)	.536		
Chronic renal failure	–	1.000		
History of stroke	0.684 (0.085-5.494)	.721		
Peripheral vascular disease	1.600 (0.330-7.769)	.560		
History of PCI	2.031 (0.337-12.236)	.439		
Acute coronary syndrome	0.273 (0.065-1.144)	.076	0.227 (0.036-1.432)	.115
Left main coronary artery disease	0.061 (0.011-0.323)	.001	0.055 (0.009-0.337)	.002
3-vessel disease	–	.999		
Left ventricular dysfunction	–	.999		
LVEF (%)	0.966 (0.901-1.036)	.328		
Type of second conduit	–	.999		
No. of sequential anastomoses	1.096 (0.392-3.068)	.861		
Degree of the LAD stenosis	0.952 (0.887-1.021)	.170		.422
Maximum stenosis degrees of non-LAD target vessels	0.847 (0.594-1.210)	.362		
Ratio of stenosis degree of LAD per non-LAD target vessels	0.981 (0.924-1.041)	.526		

STS, Society of Thoracic Surgeons; PCI, percutaneous coronary intervention; LVEF, left ventricle ejection fraction; LAD, left anterior descending coronary artery. \*The final model had adequate goodness of fit (Hosmer-Lemeshow test,  $P = .238$ ). †Body mass index  $\geq 25$ .