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Computerized Tomography May Underestimate the Patency of Internal Thoracic Artery Composite Grafts

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ABSTRACT

Background: Multidetector-row computerized tomography (MDCT) has been regarded as useful for noninvasive assessment of the bypass grafts after coronary artery bypass grafting (CABG), but there have been few reports validating its accuracy in assessment of composite arterial graft patency.

Methods: In 108 patients who underwent CABG with a Y-composite graft made of bilateral internal thoracic arteries (ITAs), early postoperative (mean interval, 4.9 months) MDCT findings were compared with the findings of subsequent conventional coronary angiography (19 patients, mean 4.7 months after initial MDCT) or later MDCT (89 patients, mean 31.0 months after surgery). A total of 248 grafts with 409 distal anastomoses (mean 3.8/patient) were assessed.

Results: In the early MDCT, the left ITA was patent in 94.4%. The right ITA with multiple sequential anastomoses was completely patent in 73.8% and partially patent in 21.4%. Discrepancy of findings between early computed tomography (CT) and later imaging studies was found in 18 patients (16.7%). Fourteen (42.4%, 4 left and 10 right ITAs) among the 33 initially nonvisualized grafts showed improved patency in later MDCT or conventional angiogram. The positive predictive value of the early MDCT for ITA composite graft occlusion was calculated at 57.6% or lower, whereas the negative predictive value was 97.8% or higher.

Conclusions: For a composite graft made of bilateral ITAs, especially for those with multiple sequential anastomoses, MDCT may reflect only the functional patency and underestimate the actual anatomic patency.

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INTRODUCTION

Computerized tomographic (CT) angiography using multidetector row scanners are now widely used for noninvasive assessment of various vascular diseases including follow-up after coronary artery bypass grafting (CABG) [Marano 2007; Lu 2010]. It provides useful information in the patients who require redo surgery or who present with unusual complications after CABG. In addition, the multidetector row computerized tomography (MDCT) allows for noninvasive investigation of the patency outcome of various grafting strategies in a large cohort of patients [Jung 2009; Nakajima 2011]. However, the clinical impact or benefit of using the MDCT as a follow-up tool after CABG is subject to debate and remains to be defined [Crusco 2007].

It has been reported that the MDCT can diagnose graft occlusion with high accuracy that is better with current scanners than with old generation ones [Houslay 2007; Hamon 2008; Auguadro 2009; Türkvatan 2009]. Most of the previous studies validating the accuracy of MDCT were confined to assessment of the in situ left internal thoracic artery (ITA) and saphenous vein grafts. Though CABG with multiple and composite arterial grafting has been established as a valid option of surgical revascularization [Damgaard 2005], the validity of MDCT in assessment of such grafts in various configurations is not yet fully established. In this study, we compared the early postoperative MDCT findings with later MDCT or conventional angiographic findings in order to provide an indirect insight into the accuracy of the MDCT in assessment of the bilateral ITA composite graft patency.

MATERIALS AND METHODS

Patients

From January 2006 through December 2009, CABG was performed in 526 patients at our institution. Among them, this retrospective review enrolled a total of 108 patients who met the following criteria: (1) left main or multivessel coronary artery disease; (2) use of bilateral ITAs in a Y-shaped composite graft; (3) early (3 to 6 months after surgery) follow-up with

MDCT; and (4) later examination with conventional coronary angiography (CAG) or another MDCT after the early study. The mean age of the patients was 64.3 ± 9.0 years (range, 39-83 years), and there were 28 (25.9%) female patients. For these patients, the report of each follow-up study was reviewed and the first author personally reviewed the images if discrepancies were found between the findings of the different examinations. The Institutional Review Board approved this study and waived the individual patient consent.

Grafting Method

Off-pump technique was used in 71 patients (65.7%). In all patients, the right ITA was harvested as a skeletonized free graft and its proximal end was anastomosed to the side of the in situ left ITA. This Y-shaped composite graft was used to revascularize the branches of the left coronary artery. Sequential anastomoses were made in 85 patients, with the left ITA in 16 patients and the right ITA in 84 patients. For the right coronary artery territory, the distal end of the right ITA arm was used to bypass the branches with ≥ 75% diameter stenosis. In 32 patients (29.6%) who had moderately (<75% diameter) stenotic lesions in the right coronary artery system or whose right ITA was not long enough to reach the most remote target site, aortocoronary bypass graft with the greater saphenous vein was made. A total of 409 distal anastomoses (mean 3.8/patient) were made with 248 grafts.

Coronary CT Angiography

The coronary CT angiography was performed with a 64-slice MDCT scanner (Brilliance 64; Philips Medical Systems, Best, the Netherlands). Scanning was performed with 64 × 0.625 mm section collimation, 420 ms rotation time, 120 kV tube voltage, 800 mA tube current, and electrocardiogram-gated dose modulation. A bolus of 80 mL Iomeprol (Iomeron 400; Bracco Diagnostics, Milan, Italy) was intravenously injected (4 mL/s) followed by a 50 mL saline chaser. With the region of interest placed in the descending thoracic aorta, image acquisition was automatically initiated once a selected threshold (150 Hounsfield units) had been reached with bolus tracking. The patient's electrocardiogram was simultaneously recorded to allow for retrospective segmental data reconstruction. Images were reconstructed at the mid-diastolic phase (75% of the R-R interval) of the cardiac cycle, and additional reconstruction was made if 10 or more motion artifacts were observed. Final CT reports were given after independent analyses of the images with a 3-dimensional workstation (Brilliance, Philips Medical Systems) by 2 experienced radiologists.

Follow-Up Studies

All patients received follow-up from the operating surgeons at least once a year. The mean follow-up period was 34.1 months (range, 10-58 months). In our institution, all patients except for those who rejected further study or had renal dysfunction underwent coronary MDCT between 3 to 6 months after CABG. If the early MDCT showed good patency of all grafts and distal anastomoses, the patients were re-evaluated with another CT at the fourth year of follow-up. For the patients in whom initial postoperative MDCT showed significant problems (eg, nonvisualization of the left ITA to the left anterior descending artery or the entire length of the right ITA), conventional CAG was performed within 1 month after the CT. Even when the early postoperative MDCT showed good patency of all grafts, conventional CAG was performed also in the patients who experienced recurrent angina or major cardiac events during the follow-up. If such patients refused CAG, a follow-up CT was checked after 6 months and yearly thereafter.

CAG was performed in 19 patients. Among them, 13 patients underwent CAG within 1 month after the early CT examination because of significant problems found in the CT. In the remaining patients, the mean interval from the early CT and later CAG was 15 ± 6.4 months (range, 6-32 months). In the 89 patients who were re-evaluated only with MDCT, the mean interval between the surgery and the last CT was 31.0 ± 12.8 months (range, 6-57 months).

RESULTS

Graft Patency in Early CT

In the early MDCT, the left ITA and the saphenous vein graft were widely patent in 94.4% and 75.0% of the cases, respectively. The right ITA was completely patent in 77.8% of patients. In 84 patients in whom the right ITA was sequentially anastomosed to multiple targets, it was patent throughout the entire length in 73.8%, partially patent in 21.4%, and totally nonvisualized in 4.8%. Most (16/18; 88.9%) cases of partial occlusion of sequential right ITA graft occurred in the distal segment anastomosed to the branches of the right coronary artery or distal circumflex artery (Figure 1). In terms of the target anastomosis sites, the patency rates were 94.4% (117/124), 88.0% (221/251), and 73.5% (25/34) for those revascularized with the left ITA, the right ITA, and the vein graft, respectively.

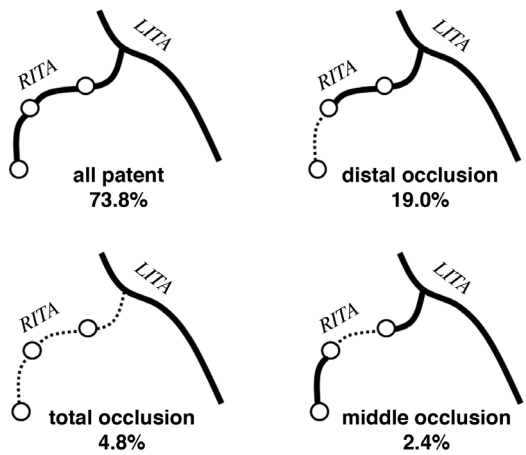


Figure 1. Rate of patency and occlusion of the right internal thoracic artery (ITA) arm of the composite graft. LITA indicates left ITA; RITA, right ITA.

Comparison of Findings between the Early Computerized Tomography (CT) and Conventional Angiography or Later CT

Graft	Early CT	N	Coronary Angiography (CAG)				Late CT (without CAG)				Positive Discrepancy*
			All	Patent	Partial Occlusional	Total Occlusional	All	Patent	Partial Occlusional	Total Occlusional	
Left internal thoracic artery	Patent	102	16	15		1	86	85		1	
	Occlusion	6	3	2*		1	3	2*		1	4/6 (66.7%)
Right internal thoracic artery	Patent	81	8	8			73	71	1	1	
	Partial occlusion	20	6	4*	2		14	2*	11	1	6/20 (30.0%)
	Total occlusion	7	5	3*		2	2	1*		1	4/7 (57.1%)
Saphenous vein graft	Patent	24	2	2			22	20		2	
	Occlusion	8	1			1	7			7	

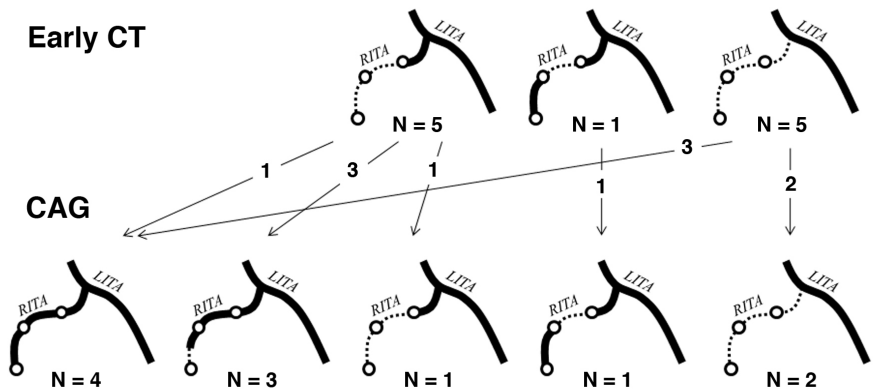
*Positive discrepancy when CAG or CT showed favorable findings (improved patency) compared with the early CT.

Discrepancy between Early CT and CAG

In the early MDCT of the 19 patients who underwent conventional CAG, the left ITA anastomosed to the left anterior descending artery was not visualized in 3 patients. Among them, 2 patients had widely patent left ITA in CAG (Table). Among the 11 patients in whom the right ITA was completely or partially nonvisualized in the early CT, 7 patients showed improved patency in the CAG (Figures 2 and 3).

There was only 1 patient who showed worse finding in CAG than in MDCT. In that patient, the left ITA sequentially grafted to a diagonal and the left anterior descending artery was found occluded after its anastomosis to the diagonal branch whereas the radiologists reported it completely patent in the early CT taken 10 months before the CAG.

Compared with the early CT findings, the subsequent CAG showed better patency findings in 9 grafts (2 left ITAs and 7 right ITAs) of 8 patients. Assuming that CAG findings reflect the actual patency of the grafts, the positive predictive value (number of grafts occluded in CAG ÷ number of grafts occluded in the early MDCT) and the negative predictive value (number of grafts patent in CAG ÷ number of grafts patent in the early MDCT) of MDCT for the diagnosis of ITA composite graft occlusion were calculated at 35.7% and 95.8%, respectively.



F igure 2. Discrepancy between early multidetector row computerized tomography (MDCT) and conventional angiographic findings of right internal thoracic artery (ITA) patency. CT indicates computed tomography; CAG, conventional coronary angiography; LITA, left ITA; RITA, right ITA.

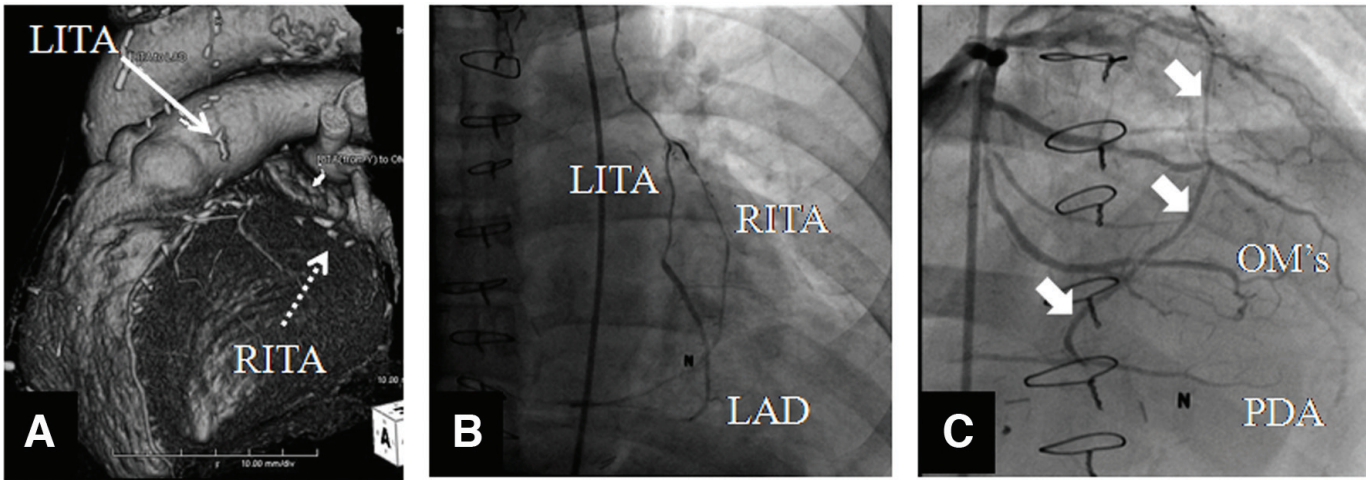


Figure 3. A, Early multidetector row computerized tomography (MDCT) of a 59-year-old male patient showed string-like proximal left internal thoracic artery (LITA) (arrow). The right ITA (RITA) (dotted arrow) and distal LITA were not visualized. B, Both LITA and RITA were patent in the subsequent angiogram taken 1 week later. C, The 4 target vessels of RITA are not opacified by injection into the bypass graft, but all were visible by injection into the left coronary artery. The RITA was widely patent (thick arrows). LAD indicates left anterior descending coronary artery; OMS, obtuse marginal coronary artery; PDA, posterior descending coronary atery.

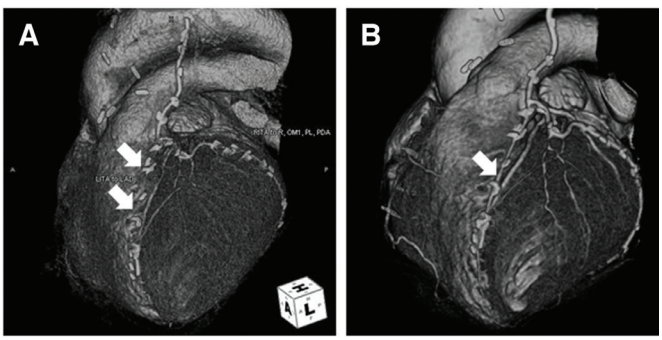


Figure 4. A, The distal segment of the left internal thoracic artery (LITA) (arrows) grafted to the left anterior descending artery was not visualized in the early multidetector row computerized tomography (MDCT). B, In the 15-month follow-up image, it was well visualized (arrow).

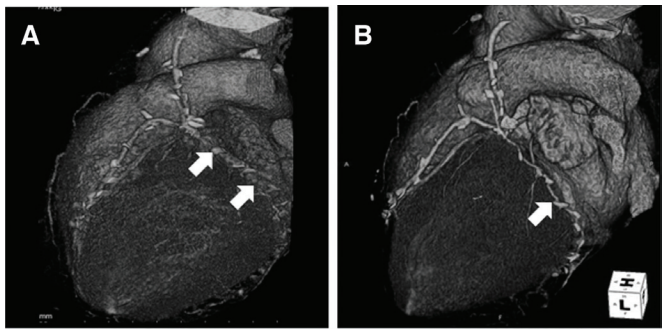


Figure 5. A, The entire length of the right internal thoracic artery (RITA) graft (arrows) with 2 distal anastomoses was thought to be occluded by the early multidetector row computerized tomography (MDCT) finding (A). B, In the 24-month follow-up image, it was widely patent (arrow).

Difference between Early and Later CT Findings

In 6 patients, the later MDCT showed findings worse than the early CT results (Table). Three patent ITAs (1 left and 2 right ITAs) became totally or partially invisible at 45, 7, and 7 months after the early CT, respectively. Partial occlusion progressed to total nonvisualization in 1 right ITA during 46 months. In addition, new occlusion occurred in 2 of 22 saphenous vein grafts during 30 and 33 months.

On the contrary, there were 5 patients who showed improved graft patency in later CT. The left ITA that had been invisible in the early CT became widely patent in 2 patients at 11 and 12 months after the initial CT (Figure 4). Three patients showed widely patent right ITA grafts that had been partially or completely invisible in the early CT taken at 15 to 19 months prior to the last examination (Figure 5).

If both of the CAG and later CT findings are pooled together, the early coronary CT failed to visualize 14 patent grafts (4 left ITAs and 10 right ITAs) in 13 patients. Assuming that the CAG or later CT findings reflect the actual patency of the grafts, the positive predictive value for ITA composite graft occlusion (number of grafts occluded in CAG or later MDCT ÷ number of grafts occluded in the early MDCT) can be calculated at 57.6% or lower, and the negative predictive value (number of grafts patent in CAG or later MDCT ÷ number of grafts patent in the early MDCT) was 97.8% or higher.

DISCUSSION

Even in this small series, a substantial number of segments in the ITA composite grafts nonvisualized in the early MDCT did not actually have anatomic occlusion. Despite the high spatial and temporal resolutions of the current 64-slice CT scanners, the positive predictive value for diagnosis of graft occlusion or significant stenosis is known to be lower (80% to 90%) than the negative predictive value (96% to 100%) [Pache 2006;

Feuchtner 2007]. It was also suggested that the accuracy of the MDCT may be lower for the arterial grafts than for the saphenous vein grafts [Romagnoli 2010]. Our result is concordant with such previous reports and suggests that the MDCT has some limitation in evaluating the composite arterial grafts with multiple sequential anastomoses. When compared with the conventional angiographic findings that were performed in 19 patients, the positive predictive value of MDCT in diagnosis of graft occlusion was only 35.7%, and the negative predictive value was 95.8%. If later CT findings were pooled together and it was assumed that the grafts nonvisualized in the later CT had been actually occluded early after surgery, the positive predictive value of the early CT increased to 57.6%, but it was still lower than the values previously reported for graft occlusion after conventional CABG.

In contrast to conventional angiography, which selectively enhances the bypass graft with pressurized injection of the contrast agent, the nonselective arterial enhancement in MDCT has a limitation in the presence of flow competition that may lead to higher chance of false-positive diagnosis of graft occlusion [Marano 2007]. Such speculation may be supported by our observation that was not described in the results. When we reviewed the preoperative angiographic findings of 13 patients who had positive discrepancy between the early CT and the later examinations, the nonvisualized grafts had at least 1 target vessel that had 80% or lower diameter stenosis in all but 1 case. We also found that the presence of flow competition in a single target site may affect the opacification of the entire sequential graft, as shown in one of the example cases (Figure 3).

It is well known that flow competition between the bypass graft and the target vessel is a risk factor for graft occlusion [Nakajima 2011]. We assume that the graft occlusion caused by flow competition may not be anatomic but functional in some cases. The presence of functionally occluded but anatomically patent grafts can be substantiated by the preceding case reports of spontaneous restoration of angiographic patency in various arterial grafts [Hata 1999; Bonacchi 2001; Fukuda 2003]. In a recent study of a relatively large series of patients undergoing serial MDCT examinations, it was reported that improvement of patency occurred in 60% of initially faint or nonvisualized grafts, especially in the arterial grafts [Kim 2011]. Those observations are in contrast to a long-term follow-up study of sequential and composite arterial grafts with conventional angiography [Nakajima 2011]. In that study, reopening was not observed in the grafts that had been occluded in the early postoperative angiograms. Another study also reported that almost half of the ITA occlusion could be related to competitive flow [Pevni 2007]. However, these 2 studies are different from ours and Kim's in that their patients underwent late angiography only when there were recurrent symptoms, positive thallium scan findings, or other clinical reasons. Considering that the majority of our and Kim's patients were free of symptoms and cardiac events, the negative impact of competitive flow on composite arterial grafts may be less severe than argued by Nakajima's and Pevni's groups. Only a longer follow-up study in a larger scale would resolve the debate.

We observed that the patency was maintained in the vast majority of the ITA composite grafts during the mean follow-up period of 31 months. In serial MDCT examinations of 89 patients, deterioration of ITA patency occurred in 4 patients. Our results can be added to the list of reports that showed the excellent results of using multiple arterial grafts [Bonacchi 2006], even with off-pump techniques [Tagusari 2004], in elderly patients [Muneretto 2003], and for small and diffusely diseased coronary arteries [Nakajima 2010]. However, the actual benefit of our grafting strategy has to be verified by a longer follow-up because some reported that a substantial number of arterial grafts deteriorate even at 1 year after surgery [Manabe 2010].

We conclude that coronary MDCT may reflect only the functional patency and underestimate the actual anatomic patency of the composite arterial grafts. Our early and mid-term MDCT follow-up showed an excellent patency rate of the composite grafts made of bilateral ITAs, and the actual patency rate would be higher.

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