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The Impact of the Preoperative Severity of Target-Vessel Stenosis on the Short-Term Patency of Radial Artery Grafts

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The fate of a grafted radial artery remains unknown. The purpose of this study was to determine whether the preoperative severity of stenosis of the target vessel influence short-term patency of radial artery (RA) grafts used as coronary artery bypass conduits. In 54 patients who had coronary artery bypass grafting (CABG) with RA grafts, RA patency was determined with multi-slice computed tomography (MSCT) 1 year after CABG. These patients were divided into three groups on the basis of the percentage of the target vessel stenosis: mild (< 60%, n=17), moderate (60% to 79%, n=19), and severe (≥ 80%, n=18). MSCT was also performed 1 week later to exclude early occlusion of RA grafts. In 3 patients, the MSCT failed to adequately discriminate the status of the RA graft due to poor image resolution. The overall incidence of RA occlusion was 23.5% (12 of 51) at 1 year in the entire population. The mild stenosis, moderate stenosis and severe stenosis group showed an occlusion rate of 50% (8 of 16), 23.5% (4 of 17) and 0% (0 of 18), respectively. The severe stenosis group had significantly lower rate of RA graft occlusion compared to the mild stenosis group ($p<0.001$) and moderate stenosis group ($p<0.05$). No difference in occlusion between grafts used for the different coronary artery branches could be demonstrated. Preoperative severity of the target coronary artery significantly affected the short-term RA grafts patency. Correct indication is the key factor for short-term RA patency.

Key Words: Bypass, revascularization, radial artery, multi-slice computed tomography

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INTRODUCTION

Since its reintroduction into coronary artery surgery by Acar and collegues,[1] the radial artery (RA) has generated significant interest as an alternative arterial conduit for coronary artery bypass grafting. After publication of the initial favorable results,[2-5] the RA gained wide popularity. The RA is an attractive conduit because it can be harvested simultaneously with the internal mammary artery (IMA) and may be taken bilaterally if additional conduits are required. Its thick vessel wall and large diameter facilitate the performance of anastomoses, and its length is sufficient to accommodate sequential grafting for even distal targets. The mid-term and long-term clinical results after RA grafting are satisfactory and the severity of stenosis of the target vessel are known to influence mid-term and long-term RA patency.[6,7] However, it is not clear how much the severity of target vessel influence RA patency and there is no report to suggest that the severity of target vessel stenosis influence short-term RA patency. Recently, multi-slice computed tomography (MSCT), with improved spatial resolution and premedication with oral β-blockade, permits detection of graft patency with a high degree of accuracy and low rate of unevaluable grafts following CABG.[8-11] The purpose of this study was to determine whether the preoperative severity of stenosis of the target vessel influence short-term RA patency used as coronary artery bypass conduits.

MATERIALS AND METHODS

Patient population and surgical technique

Fifty-four patients (38 men and 16 women) were investigated by MSCT 1 month and 1 year after CABG. The patients' age ranged from 44 to 74 years, with a mean age of 60 years. All operations were performed by the same surgical team. Twenty-eight patients underwent conventional CABG with 78 bypass grafts and 26 underwent off-pump CABG (OPCAB) with 76 bypass grafts. RA grafts were used as a Y or T grafts with left internal mammary artery (LIMA) in 47 patients and right internal mammary artery (RIMA) in one patient. In 6 patients, RA grafts were directly anastomsed to the ascending aorta. The distal anastomosis sites of RA grafts were the obtus marginal branch (n=31), the diagonal branch (n=14) and the posterior descending branch (n=9). In all cases before RA harvesting, adequacy of ulnar compensation was assessed with the Allen test. The RA was always harvested from nondominant arm. Long-term calcium channel blocker therapy was prescribed for all patients for the first postoperative year.

Quantitative angiographic measurement

To measure the target coronary artery stenosis, the multiple angiographic views of pre-CABG coronary aniogram were evaluated by two blinded independent observer. With the use of computerized quantitative angiography (Inturis for cardiology, Philips, The Netherlands), analyses were performed on normal area and diameter, stenotic area and diameter, percent area stenosis and percent diameter stenosis of target vessel.

Multi-slice computed tomography

MSCT was performed in a multi-detector row CT scanner (LightSpeed plus, GE medical systems, Milwaukee, WI) with a collimation of 1.25 mm, a rotation time of 0.5 s, at 120 kV and 300 mA. The circulation time was measured with a 15 ml bolus injection of the non-ionic contrast agent, iopamidol (Iopamiro 370 mg/ml, Bracco s.p.a., Milano, Italy), prior to the main scan. The total contrast dose for the main scan ranged from 120 to 150 ml depending on the total scan time, with an injection rate of 4 ml/s for the first half of the scan, plus a delayed period following the injection, and then 2 ml/s for the second half, through an 18- gauge needle into the antecubital vein. Each scan covered the whole heart from just above main pulmonary artery. The raw data were reconstructed routinely at 40 and 70% of the cardiac phase using retrospectively ECG-gated reconstruction at 25 cm of the displayed field of view. The reconstructed images were transferred to a workstation (Advanced workstation 4.0, GE medical systems, Milwaukee, WI, USA) for post-processing. Axial, 3D volume-rendered, and multi-planar reconstructed images were analyzed for evaluation of the number, location and patency of bypass grafts. An occlusion of a graft was diagnosed if the graft was not visualized, or was shown as a stump-like structure along its course.

For evaluating stenosis of native coronary artery or patency of bypass graft, the protocol of CT angiography using MSCT should be different because of some limitations. Bypass grafts, because of their size and relative immobility, can be reliably imaged with less limitation by heart rate and without the necessity of multiple selection of reconstruction windows or premedication to lower the heart rate like in native coronary artery. MSCT for evaluating native coronary artery requires strict selection of patients to constantly acquire assessable quality of images. The most important thing to consider is to maintain the heart rate at less than 70 bpm. As the heart rate increases, the number of arteries that could be evaluated decreases, and overall sensitivity for stenosis was reported as 62% when heart rate was less than 70 bpm compared with a sensitivity of 33% when heart rate was greater than 70 bpm.[12] We included patients who presented with heart rate greater than 70 bpm and did not use premedication to lower heart rate because the study was aimed to evaluate the patency of bypass graft. Therefore, evaluation of native coronary artery stenosis was not consistently possible with the protocol used in the study.

The patients in this study were randomly

selected from those complying with our study. All patients gave their written informed consent after the methods and extra-cost of the MSCT investigation had been fully explained.

Statistical analysis

Patients were grouped on the basis of the percentage of the stenosis of target vessel at preoperative angiography: mild stenosis (< 60%, n= 17), moderate stenosis (60% to 79%, n=19), and severe stenosis (≥ 80%, n=18). Incidence of graft failure was considered a dichotomic variables, as were demographic and clinical characteristics. Continuous data are expressed as mean ± SD. ANOVA test was used to compare the means among three groups; post hoc comparison was performed with a Newman-Keuls test. Categorical variables were compared with by the Chi-Squared test or Fisher's exact test for observations fewer than 5. The statistical analysis was performed using the Statistical Package for Social Science software (SPSS-10.0 for Windows, SPSS, Chicago, IL, USA). All p-values < 0.05 were considered significant.

RESULTS

The main preoperative and intraoperative characteristics of the three groups are summarized in Table 1 and 2. The majority of patients were men in their late sixth decade who had triple-vessel coronary artery disease and almost normal left ventricular ejection fraction. The incidence of three-vessel disease was significantly higher in the severe stenosis group than other groups [mild stenosis; 70.6% (12 of 17), moderate stenosis; 68.4% (13 of 19), and severe stenosis; 94.4% (17 of 18), $p < 0.05$]. However, the other preoperative and intraopertive characteristics were similar between three groups.

The mean follow-up duration was 12 months (range, 11-14), and MSCT investigation was completed in all patients without complication. The mean scanning times for the MSCT was 24 ± 3.5s. It was possible to evaluate RA graft in 51 patients (94.4%). In 21 patients (38.9%), coronary angiography was perfomed simultaneously and matched the result of MSCT except a male patient (Fig. 1 and 2). An unmatched male patient belonged to three patients whom MSCT failed to evaluate the

Table 1. Preoperative Characteristics of the Three Groups

	Mild stenosis (n=17)	Moderate stenosis (n=19)	Severe stenosis (n=18)	Total (n=54)
Male/female ratio	13/4	14/5	11/9	38/16
Mean ± SD age, y	61.1 ± 6.6	59.1 ± 7.1	60.1 ± 8.6	60.0 ± 7.4
Cardiac risk factors, No. patients with				
Diabetes	7 (41.2)	6 (31.6)	8 (44.4)	21 (38.9)
Smoking	6 (35.3)	9 (47.4)	7 (38.9)	22 (40.7)
Dyslipidemia	5 (29.4)	9 (47.4)	5 (27.8)	19 (35.2)
Hypertension	9 (52.9)	10 (52.6)	11 (61.1)	30 (55.6)
Previous stroke	1 (5.9)	3 (15.8)	1 (5.6)	5 (9.3)
Preoperative clinical diagnosis				
Stable angina	4 (23.5)	10 (52.6)	6 (33.3)	20 (37.0)
Unstable angina	8 (47.1)	8 (42.1)	6 (33.3)	22 (40.7)
No. of patients with previous myocardial infarction	3 (17.7)	3 (15.8)	4 (22.3)	10 (18.5)
Severity of coronary artery disease				
Three-vessel disease*	12 (70.6)	13 (68.4)	17 (94.4)	42 (77.8)
Mean ejection fraction	0.66 ± 0.21	0.64 ± 0.18	0.60 ± 0.2	0.64 ± 0.23

Patients were grouped on the basis of the percentage of the stenosis of target vessel at preoperative angiography: mild stenosis (< 60%), moderate stenosis (60% to 79%) and severe stenosis (≥ 80%).
*$p < 0.05$ between the > 80% group and other groups.

Table 2. Intraoperative Characteristics of the Three Groups

	Mild stenosis (n=17)	Moderate stenosis (n=19)	Severe stenosis (n=18)	Total (n=54)
No. of anastomses per patients	3.1	2.7	3.1	2.9
RA graft anastomosis site				
Proximal				
LIMA	15 (88.2)	17 (89.5)	15 (83.3)	47 (87.0)
RIMA		1 (5.3)		1 (1.9)
Aorta	2 (11.8)	1 (5.3)	3 (16.7)	6 (11.1)
Distal				
Left anterior descending coronary artery	4 (23.5)	7 (36.8)	3 (16.7)	14 (25.9)
Intermedius		1	1	
Diagonal	4	6	2	
Circumflex coronary artery	11 (64.7)	8 (42.1)	12 (66.7)	31 (57.4)
Obtuse marginal	11	7	11	
Left posterolateral		1	1	
Right coronary artery	2 (11.8)	4 (21.1)	3 (16.7)	9 (16.7)
Posterior desceding	1	2	2	
Right posterolateral	1	2	1	
Target-vessel diameter (mm)	1.46 ± 0.17	1.53 ± 0.21	1.47 ± 0.12	1.49 ± 0.17
< 1.5 mm	11	11	11	33
> 1.5 mm	6	8	7	21

LIMA, left internal mammary artery; RIMA, right internal mammary artery.

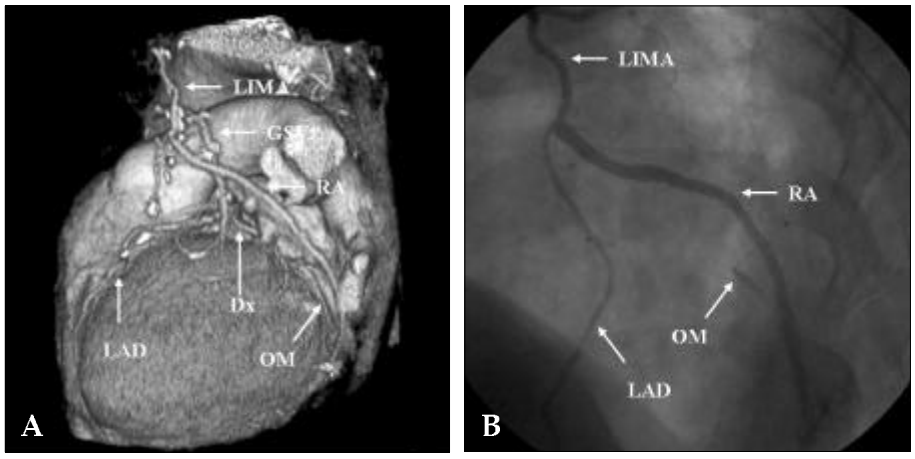

Fig. 1. Sixty-two-year-old man with bypass graft to left anterior descending artery (LAD) with left internal mammary artery (LIMA), first and second diagonal branch (Dx) with sequential great saphenous vein (GSV) graft, and obtuse marginal branch (OM) with radial artery (RA). RA was used as a Y graft with LIMA. A. Multi-slice CT (MSCT) study showed patent LIMA, RA, and sequential SVG. B. Coronary artery angiogram showed patent Y graft of LIMA and RA, and matched images compared with MSCT.

status of the RA graft, and coronary angiography showed string sign of RA graft (Fig. 3).

The short-term results of grafts patency are reported in Table 3. The short-term patency rate were 88.8% (48 of 54) for LIMA; 76.5% (39 of 51) for RA; and 83.4% (35 of 41) for great saphenous

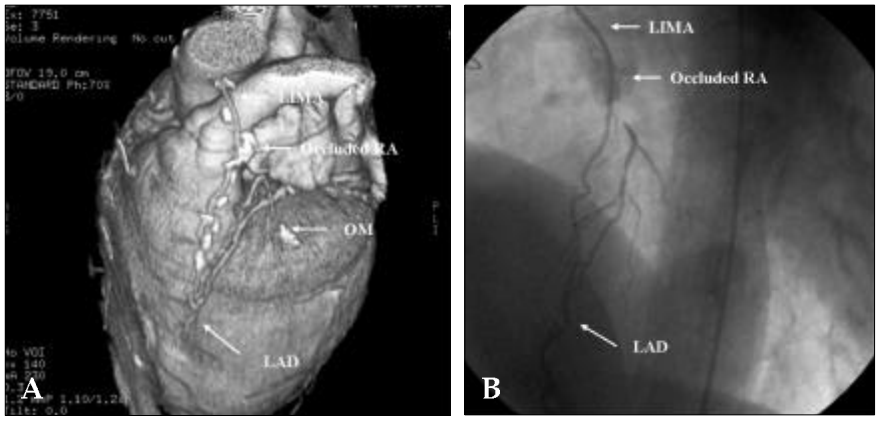

Fig. 2. Fourty-eight-year-old man with bypass graft to left anterior descending artery (LAD) with left internal mammary artery (LIMA), obtuse marginal branch (OM) with radial artery (RA), posterior descending artery with saphenous vein graft. A. Multi-slice CT (MSCT) study showed patent LIMA and occluded RA graft. RA was not opacified and metal clips identified at proximal anastomosis site with LIMA and distal anastomosis site with OM. B. Coronary artery angiogram showed patent LIMA and occluded RA, and matched images compared with MSCT.

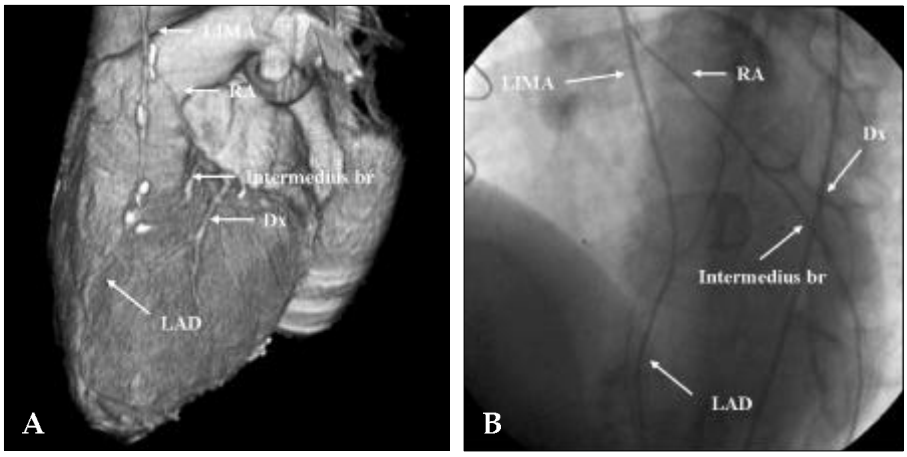

Fig. 3. Fifty-eight-year-old woman with bypass graft to left anterior descending artery (LAD) with left internal mammary artery (LIMA), intermedius branch and diagonal branch (DX) sequentially with radial artery (RA). RA was used as a Y graft with LIMA. A. Multi-slice CT (MSCT) study showed patent LIMA and stenotic RA. B. Coronary artery angiogram (CAG) showed patent LIMA and stenotic RA, and matched images compared with m-CT.

Table 3. Short-term Results of Patency According to the Type of Grafts

	LIMA (n=54)	RA (n=54)	SVG (n=42)	RGEA (n=2)	RIMA (n=2)
Patent	48	39	35	2	2
Fail to evaluate	0	3	1	0	0
Occluded	6	12	6	0	0

LIMA, left internal mammary artery; SVG, saphenous vein graft; RA, radial artery; RGEA, right gastroepiploic artery; RIMA, right internal mammary artery.

vein (GSV) graft. The overall incidence of RA occlusion was 23.5% (12 of 51) at 1 year in the entire population. When RA patency was assessed according to the severity of stenosis of the grafted

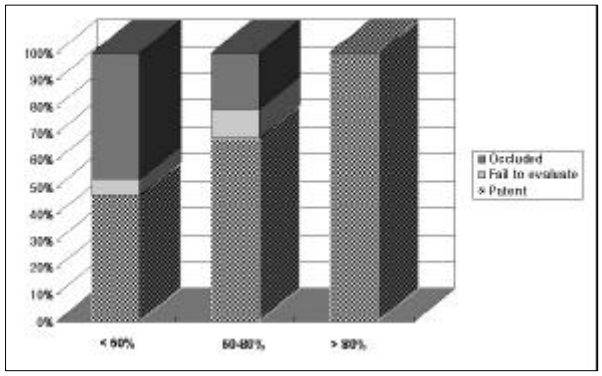

Fig. 4. Mid-term RA graft status evaluated with Multi-slice CT (MSCT) in relation to target vessel stenosis. The >80% stenosis group had lower rates of RA graft occlusion than < 70% group ($p<0.001$) and 60% to 80% group ($p<0.05$).

vessel, the mild stenosis, moderate stenosis and severe stenosis group showed an occlusion rate of 50% (8 of 16), 23.5% (4 of 17) and 0% (0 of 18), respectively (Fig. 4). The results showed that the severe stenosis group had a lower rate of RA graft occlusion than the mild stenosis group ($p<0.001$) and the moderate stenosis group($p<0.05$). RA patency was evaluated in relation to the anastomosis location to the target vessel (Table 2).

DISCUSSION

Currently the RA is a conduit with well-known characteristics and good follow-up data. Several authors reported excellent early, mid and long-term angiographic results,[6,12-14] and serial angiographic and pharmacological studies demonstrated that even the feared hyperspastic tendency of this conduit tended to decrease with time.[6,15] Therefore, several months after CABG, the chronic native competitive flow can be a major determinant of the patency of a RA graft. In the study by Possati et al.,[6] the continued use of calcium-channel antagonists after the first postoperative year did not influence the radial artery graft status, whereas the preoperative severity of the target-vessel stenosis markedly influenced the mid-term RA patency. Recently, the same authors reported that RA grafts had excellent patency and perfect patency rates ten years after surgery. The severity of stenosis of the target vessel clearly influenced long-term RA patency, whereas location of the target vessel and long-term use of calcium channel blockers did not influence angiographic results.[7] However, if the preoperative severity of target-vessel does influence RA patency, the timing of the RA occlusion is not clearly defined. Therefore we evaluated whether the severity of stenosis of the target vessel influence short-term RA patency.

In this study, we used MSCT for evaluating the RA graft status. MSCT has recently been introduced as a method for the noninvasive visualization of coronary artery stenoses and bypass graft patency.[8,9,16,17] With improved spatial and temporal resolution, as well as routine premedication with β-blockers, it is reported to have a sensitivity, specificity and accuracy of 92%, 93% and 93%, respectively in defining luminal obstructive disease compared with traditional coronary arteriography.[9] MSCT showed better results in evaluating bypass graft patency. Ko and colleagues reported sensitivity of 93.3% and specificity of 99.0% for detecting bypass graft occlusion and a sensitivity and specificity was 100% when evaluating the RA graft patency.[10] Yoo and collegues reported that MSCT had a sensitivity of 98% and specificity of 100% in detecting bypass graft occlusion. And the sensitivity and specificity of MSCT for evaluating RA patency was 91%, 100% respectively.[11] In contrast to other non-invasive methods, MSCT has good image quality due to the short scanning time and thin (1.25 mm) slice thickness, even though it covers the entire ascending aorta. It is faster, and has a lesser thickness than any other non-invasive methods. Therefore MSCT could reduce artifacts and improve the image quality. Bypass grafts, because of their size and relative immobility, can be reliably imaged with less limitation of heart rate and without the necessity of multiple selection of reconstruction windows or premedication to lower the heart rate. No drugs or pre-oxygenation were used to control heart rate or increase breath-holding time with all the studies finished during a single breath-hold without any difficulties.

In our study, the severity of target-vessel influenced the RA patency as early as one year. There were no significant differences between grafts used for the different coronary artery

branches. The RA graft anastomsed to target-vessels with severe stenosis ($\geq$ 80% stenosis) showed perfect patency after 1 year. Royse and colleagues reported that the "cut off" for coronary stenosis able to assure a higher patency rates were 80 and 60% for composite and aortocoronary RA grafts, respectively.[14] MSCT was a favorable method to evaluate RA graft status, but the resolution still had a limitation in evaluating small caliber of bypass graft. In three patients whom MSCT failed to adequately evaluate the RA graft status, coronary angiography was perfomed in a patient and showed string sign. After we knew the finding of coronary angiography, it was possible to interpret the undetermined finding of RA graft in MSCT.

This study has several limitations. Firstly, although we used MSCT in evaluating RA graft patency in this study, coronary angiography is still the gold standard for evaluating the status of graft. However, it is invasive, costly, and carries potential procedure-related risk.[18] In this study, we evaluated RA status simultaneously with coronary angiography in 21 patients, and the result perfectly matched with MSCT except in one patient. Secondly, the patency rate of RA graft was poor compared to other previous reports.[6,12-14] The reason for this poor patency rate maybe related to the study population. A half of our patients had less than 70% stenosis of target-vessel. Thirdly, we only evaluated RA graft status only in the aspect of patency or occlusion. Because the definition of stenosis of bypass grafts with MSCT was not established, we only presented data about patency and occlusion of RA graft.

In conclusion, the severity of target vessel influence the short-term RA patency as early as 1 year. Therefore a correct surgical indication (the use of this conduit to revascularization only vessels with severe stenosis) is essential. The proximal anastomosis to the ascending aorta and distal anastomosis site of RA graft do not influence the short-term angiographic status of RA grafts.

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