Original Article

Computed Tomographic Angiography to Evaluate the Right Gastroepiploic Artery for Coronary Artery Bypass Grafting

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Objective: The right gastroepiploic artery (RGEA) is widely used as an in situ arterial graft for coronary artery bypass grafting (CABG); however, it is impossible to measure an RGEA or check for calcification or stenosis and assess its suitability as a graft before angiography or harvest. We evaluated the accuracy of preoperative three-dimensional computed tomographic angiography (3D-CTA) for assessing the suitability of RGEAs for CABG.

Method: We used 4-channel multidetector-row computed tomography with intravenous contrast medium. All the RGEAs had an intraluminar diameter greater than 1.5 mm. RGEAs longer than two-thirds of the greater curvature of stomach, longer than half of the greater curvature, and shorter than half of the greater curvature were defined as large, moderate, and small, respectively.

Result: Of the 36 patients examined, 5 (14%) had a small RGEA, 16 (44%) had a moderate RGEA, and 15 (42%) had a large RGEA. We confirmed intraoperatively that two small RGEAs were unsuitable for grafting because they could not reach the posterior descending artery (PDA). The other three small RGEAs were not used. Two of the large and moderate RGEAs with diffuse narrowing and severe calcification were also unsuitable for grafting. This eliminated the need for a laparotomy to harvest the RGEA in five (14%) patients. Intraoperative findings confirmed that all the moderate RGEAs could be anastomosed to the PDA. All the large RGEAs reached the posterolateral artery (PLA), and more than half reached the PLA branching circumflex artery.

Conclusion: Preoperative noninvasive evaluation by 3D-CT is effective for assessing the suitability of RGEAs for CABG. (Ann Thorac Cardiovasc Surg 2008; 14: 166–171)

Key words: right gastroepiploic artery, coronary artery bypass grafting, three-dimensional computed tomographic angiography, preoperative assessment

Introduction

The right gastroepiploic artery (RGEA) is the second most widely used vessel as an in situ arterial graft for coronary artery bypass grafting (CABG), after the internal thoracic arteries.[1] Excellent late results after CABG with RGEAs have been reported in patients undergoing complete revascularization for multivessel disease, and even in patients undergoing reoperation after the internal thoracic

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arteries or saphenous vein have already been used as grafts.[2] The RGEA graft is commonly used in situ and is mainly anastomosed to the right coronary artery (RCA) or distal sites of the left circumflex artery.[3] Since RGEAs vary in length and are occasionally calcified or narrowed to some extent,[4–6] the anatomical assessment of individual RGEAs before harvesting is recommended. This assessment may prevent unnecessary laparotomy to harvest inappropriate RGEAs for CABG, and it may help the surgeon to plan the best bypass grafting design. Previous investigators have used three-dimensional computed tomographic angiography (3D-CTA) to visualize the RGEA after giving intravenous contrast material to patients undergoing laparoscopic gastrectomy.[7] The main advantage of 3D-CTA is that it can show various vessels concurrently, including the coronary artery, the RGEA, the internal thoracic artery, and the thoracic aorta, with a minimal risk of complications. In fact, 3D-CTA–navigated surgery has become a standard therapeutic strategy, especially in the area of neurosurgery. In this study, we performed 3D-CTA preoperatively to evaluate the suitability of individual RGEAs as a graft for CABG in patients scheduled to undergo revascularization of the inferior or posterolateral surface of the heart, or both.

Patients and Methods

Patient data

We examined a consecutive series of 36 patients scheduled to undergo CABG using the RGEA as a graft to the posterior descending artery (PDA) or the posterolateral artery (PLA). This study was approved by the Medical Ethics Committee of Yamaguchi University School of Medicine, and informed consent was obtained from all the patients enrolled in this study. The 3D-CTA was performed within 1 week before CABG. The indications for using the RGEA as a graft for CABG were as follows: the target ischemic myocardial lesion was more than 90% stenosed in the native RCA; the target ischemic myocardial lesion was more than 75% stenosed in the native coronary artery, but not the RCA; and no gastric mucosal lesion was detected by preoperative gastrointestinal fiberscopy. All of the RGEAs were anastomosed in situ and were pulled up to the pericardial cavity through the diaphragm, passing in front of the stomach and the liver (anterior gastric route).[8]

The patients comprised 29 men and 7 women, with a mean age at the time of surgery of 64.4 ± 10.3 years and a mean body surface area (BSA) at the time of surgery of 1.24 ± 0.18 cm^2. Preoperative coexisting disorders included hypertension in 21 patients, diabetes in 13, hyperlipidemia in 20, renal dysfunction requiring hemodialysis in 1, and chronic obstructive pulmonary disease (COPD) in 3. Twenty-six patients had a history of smoking. Thirty patients underwent isolated CABG: with the off-pump technique in 14 and the on-pump technique in 16. Six patients underwent concomitant procedures, namely, valve operations in two and overlapping left ventriculoplasty under cardiopulmonary bypass in four. The mean number of distal anastomoses was 3.7 ± 1.1.

3D-CTA

We used a four-channel multidetector-row CT scanner (SOMATOM Plus 4; Siemens AG, Forchheim, Germany). After giving the patients a nonionic iodinated contrast agent intravenously via a power injector, we used computer-assisted bolus-tracking technology for arterial phase scanning. Scans were obtained at a voltage of 120 kV, a tube current of 165 mA, rotation of 0.5 s, detector-row beam collimation of 4 mm, a helical pitch of 4.8 mm, and a field of view of 30 cm. The data from the CT scan were reconstructed at 1-mm intervals and transmitted to a workstation (SIEMENS Syngo software). The volume-rendering technique was used for 3-D reconstruction, and the workstation was used to produce 3-D images and to evaluate the anatomical features of each RGEA.

Study groups

We divided the RGEAs, all of which had an intraluminal diameter greater than 1.5 mm, into three groups.[4] Large RGEAs were defined as those longer than two-thirds of the greater curvature of the stomach; moderate RGEAs were defined as those longer than half of the greater curvature; and small RGEAs were defined as those shorter than half the greater curvature. All were measured from the distal end of their inner diameter. Figure 1 shows the 3D-CTA images in each patient in the three groups.

RGEA harvesting

The technique we used to harvest the RGEAs was described previously.[9] Briefly, a median skin incision was extended to 5 cm in the caudal direction from the xiphoid process, the anterior layer of the greater omentum was incised, and all the arterial branches were divided from the RGEA trunk using a Harmonic scalpel™ with coagulating shears (Ethicon Endo-Surgery, Inc., Cincinnati, Ohio). After systemic heparinization, the distal end of the skeletonized RGEA graft was divided and hemoclips were

Table 1. Preoperative three-dimensional computed tomographic angiography findings of the right gastroepiploic arteries

	All RGEAs (n = 36)		
	Large (n = 15)	Moderate (n = 16)	Small (n = 5)
Distal diameter (mm)	1.99 ± 0.51 (range: 1.5-3.4)	1.66 ± 0.24 (range: 1.5–2.0)	1.70 ± 0.27 (range: 1.5–2.0)
Calcification and stenosis (%)	1 (6.7)	1 (6.2)	0 (0)
Candidates for graft (%)	13 (86.7)	15 (93.8)	0 (0)

RGEA, right gastroepiploic artery.

Table 2. Intra- and postoperative findings of the RGEA grafting procedure.

	All RGEAs (n = 29)		
	Large (n = 13)	Moderate (n = 14)	Small (n = 2)
Reachable bypass sites			
RCA posterior descending artery (%)	13 (100)	14 (100)	0
RCA posterolateral artery (%)	13 (100)†	6 (42.9)	0
LCx posterolateral artery (%)	8 (61.5)††	2 (14.3)	0
Actual bypass sites	12*	14	2
RCA posterior descending artery	8	13	2**
RCA posterolateral artery	2	0	0
LCx posterior descending artery	0	1	0
LCx posterolateral artery	2	0	0
RGEA graft patency (%)	100***	100	100

*: One right gastroepiploic artery was not used because the native coronary artery was too small. **: Anastomosis was done as an RGEA-radial artery composite graft. ***: Postoperative coronary angiography was not performed in one patient. RGEA, right gastroepiploic artery; RCA, right coronary artery; LCx, left circumflex artery. †: $p < 0.01$ vs. moderate.††: $p = 0.032$ vs. moderate.

applied. The graft was then wrapped with gauze soaked in a phosphodiesterase-3 inhibitor (olprinone hydrochloride).

Statistical analysis

All values are expressed as means ± standard deviation. Comparisons among the three groups were made with the analysis of variance (ANOVA) test followed by Scheffe's post hoc test, and comparisons between two groups were made with unpaired *t*-tests. Differences between groups were considered significant when the *p*-value was less than 0.05.

Results

The preoperative 3D-CTA findings in all 36 patients are summarized in Table 1. Fifteen (41.7%) patients had a large RGEA, 16 (44.4%) had a moderate RGEA, and 5 (13.9%) had a small RGEA. The inner diameter of each type of distal RGEA was also measured, but there were no significant differences among the three groups. The first two small RGEAs we harvested did not extend up to any part of the surface of the heart; therefore we harvested no more small RGEAs for bypass grafting. We anastomosed the two initially harvested small RGEAs to the PDA as I-shaped composite grafts combined with a radial artery. Sixteen patients had a moderate RGEA, but one (6.2%) had multiple calcified lesions and stenosis, which we judged to be a contraindication to RGEA harvesting, and another was not used at the request of the cardiologist. Fifteen patients had large RGEAs; however, one of these patients had multiple extensively calcified lesions, and another had a gastric mucosal lesion, later confirmed to be a gastric ulcer after surgery. Thus RGEA harvesting was contraindicated in these two patients. Figure 2 shows a 3D-CTA image of an RGEA with calcification and stenosis. Table 2 shows the intra- and postoperative findings of RGEA grafting. The quality of the

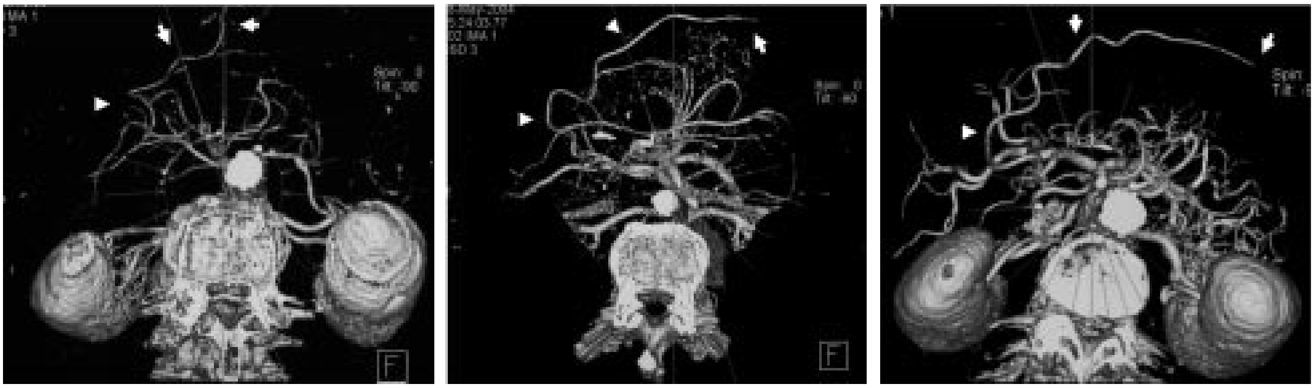

Fig. 1. Three-dimensional computed tomographic image of the right gastroepiploic artery in each patient. **a,** small type; **b,** moderate type; **c,** large type. Arrowheads indicate the right gastroepiploic artery (RGEA).

a | b | c

RGEAs was carefully evaluated by inspection and palpation to ensure that there were no atherosclerotic changes before any of the grafts were used. We confirmed intraoperatively that all of the 14 moderate RGEAs amenable to grafting could reach the RCA-supplied PDA (R-PDA; 100%), six could be extended up to the RCA-supplied PLA (R-PLA; 42.9%), and two up to the left circumflex (LCx)–supplied PLA (L-PLA; 14.3%). Thirteen of the large RGEAs could be extended up to the R-PDA (100%) and R-PLA (100%), and eight of these even reached the L-PLA (61.5%). The large RGEAs were able to be extended up to the posterolateral lesion more easily than the moderate RGEAs, and this observation was significant. A true anastomosis was performed in 12 of the 13 patients with a large RGEA. One was not anastomosed because the native coronary artery was too small, even though this RGEA could reach the L-PLA. Twelve large RGEAs were anastomosed to the R-PDA, R-PLA, and L-PLA. All 14 harvested moderate RGEAs were anastomosed to the R-PDA and L-PDA (Table 2). At the end of the operation, all anastomosed RGEA flows were measured by a 1-channel transit time flowmeter (CardioMed Medical Volume flowmeter CM1000; Medi-Stim AS). Intraoperative mean RGEA flows of large and moderate types and two cases of small type were 32.0 ± 14.6, 39.9 ± 25.9, and 27.6 and 80.9 mL/min, respectively. Those flows of large and moderate types were not significantly different. We performed coronary angiography 1 month after following the operation in the 28 patients who underwent bypass grafting using the RGEA, after the exclusion of one large RGEA from this operation. All RGEA grafts examined postoperatively were patent.

Discussion

The RGEA is the most common artery used for CABG after the internal thoracic artery (ITA), both in situ and as a free graft. Suma et al. reported an excellent long-term outcome for more than 10 years after CABG using RGEA; however, its graft patency is still inferior to that of the ITA.[2] Malhotra et al. found that the morphometric characteristics of the RGEA reflect more defects in the continuity of the internal elastic lamina and richness of smooth muscle cells in the media and an increased propensity for atherosclerosis than the ITA.[5] The length and inner diameter of the RGEA varies in each patient[4]; however, neither the flow nor the size is as consistent as those of ITA grafts. The higher flow rates are related to the inner diameter of the RGEA grafts.[5] The risk factors for RGEA graft occlusion are mainly related to the competition of flow to the native coronary artery, but it is possible to prevent this occlusion by grafting high-quality RGEAs to severely stenosed native coronary arteries.[7] A preoperative assessment of RGEAs that possess the right characteristics is indispensable for CABG. The length of the RGEA must be assessed carefully to determine if it can extend up to the target native coronary artery. The artery must also be checked for atherosclerotic changes with stenosis and calcification, and the diameter of the distal site must be measured to determine if the RGEA possesses the right qualities as a graft for CABG. The 3D-CT provides a minimally invasive method for assessing these characteristics: it can clarify the length of the RGEA, the inner diameter, and the presence of stenosis and calcification. CTA is much less invasive than catheter angiography, requiring only venous access with minimal

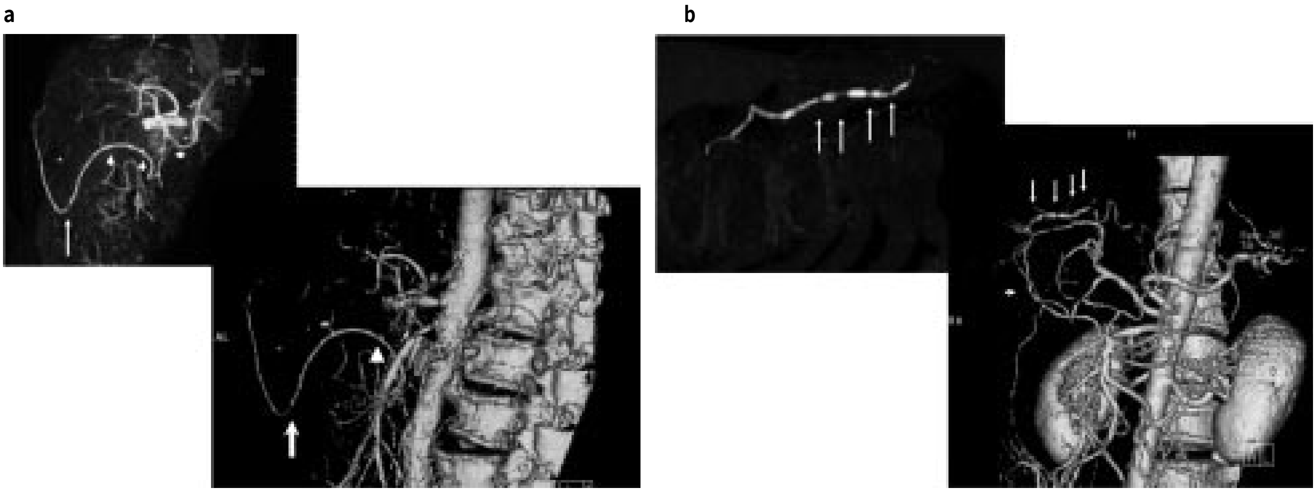

Fig. 2. Three-dimensional computed tomographic image of a right gastroepiploic artery with calcification and stenosis. **a**, a large right gastroepiploic artery with severe calcification and moderate stenosis; **b**, a moderate right gastroepiploic artery with moderate calcification and severe stenosis. Arrows indicate the stenosis. Arrowheads indicate the calcification.

risk and discomfort for the patient and better display of thrombi and arterial wall calcification.[10]

The results of this study can be summarized as follows:

(1) A small RGEA may not reach any part of the surface of the heart and might not be suitable for an arterial graft individually.

(2) Among 36 RGEAs, 2 (5.6%) had severe stenosis and calcification and were not suitable for use as a graft. After the initial two harvested small RGEAs, three other small RGEAs along with these two stenotic and calcified ones, accounting for 5 (13.9%) of the 36 RGEAs, were judged unsuitable for grafting; thus we were able to avoid performing unnecessary laparotomy for graft harvesting in these five patients.

(3) All moderate RGEAs reached the PDA. Moreover, the large RGEAs reached the distal end of the PLA (supplied by the RCA) and the distal branch of the PLA (supplied by the left circumflex artery) more frequently than the moderate ones.

Mills et al.[6] reported that free flow was minor when the inner diameter of a pedicled RGEA at the anastomosis site was only 1.5 mm and that this type of RGEA should be used as a free graft to prevent flow competition. Our data showed that the average inner diameter was 1.8 ± 0.4 cm at the distal end in moderate and large RGEAs, as measured by 3D-CTA. This diameter is comparatively narrow; however, the BSA of our patients was smaller than that of the patients in the study by Mills et al. Moreover, we harvested RGEAs in a skeletonized manner rather than as a pedicle graft to obtain a larger, spasm-free arterial conduit and to improve the flow capacity.[11] Neither flow competition nor graft/anastomosis site stenosis was observed by angiography in the early postoperative period. Thus RGEAs with a distal diameter greater than 1.5 mm as measured by 3D-CTA were acceptable for grafting using the skeletonized technique with Harmonic™ scalpels. A preoperative assessment of RGEAs using 3D-CTA is useful for assisting with the bypass grafting design and selecting the right quality RGEAs, which can result in the exclusion of inappropriate RGEAs, such as those displaying severe stenosis, calcification, and poor development as evidenced by shortness or a narrow inner diameter. This selection procedure can result in excellent bypass patency and prevent unnecessary laparotomy to harvest a poor-quality RGEA.

In conclusion, preoperative evaluation by 3D-CTA is effective for assessing the suitability of RGEAs for CABG. Based on the results of this study, we can obtain the length and distal site of the inner diameter of an RGEA and plan the bypass grafting design, whereby unnecessary laparotomy to harvest an unsuitable RGEA can be avoided. This assessment excluded calcified and stenotic RGEAs that were unsuitable for bypass grafting, which contributed to excellent postoperative bypass patency.

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