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Skeletonized Gastroepiploic Artery for Off-Pump Coronary Artery Bypass Grafting

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ABSTRACT

Background: Skeletonized arterial grafting may reduce the risk of graft spasm and may improve graft patency. Previously we reported a pilot study of skeletonized gastroepiploic artery (GEA) grafting with favorable results. Skeletonized GEA harvesting with an ultrasonic scalpel has now become our routine procedure. In this report, we compare the early clinical outcomes of skeletonized versus pedicled GEA grafting to assess the safety and benefit of use of skeletonized GEA in coronary artery bypass grafting.

Methods: Between July 2002 and October 2003, the GEA was used as a conduit for isolated off-pump coronary artery bypass grafting in 105 patients. Of these, 21 patients (group P) received pedicled GEA and 59 patients (group S) received skeletonized GEA grafts (excluding 25 patients whose results were reported in the pilot study). The perioperative and early follow-up data were prospectively collected and compared.

Results: No graft injury was found in either group. The preoperative characteristics were similar in the two groups except that group S had a smaller body surface area (1.64 ± 0.16 m^2 in group S versus 1.73 ± 0.16 m^2 in group P, $P < .05$) and a significant number of patients with diabetes (36/59, 61.0% versus 7/21, 33.3%, $P < .05$). The number of distal anastomoses was 4.3 ± 1.0 versus 3.9 ± 0.9 (P = not significant [NS]). An in situ GEA composite graft was constructed in 8 (13.6%) of the patients in group S and none of the patients in group P (P = NS). There was one hospital death due to infection in group S. Otherwise, there were no cases of low output syndrome or postoperative myocardial infarction in either group. During early postoperative follow-up, no angina recurrence or myocardial infarction was found.

Conclusion: The GEA can be skeletonized safely with an ultrasonic scalpel. Skeletonization enables a wider variety of choices in the use of GEA grafting.

INTRODUCTION

Complete revascularization using arterial conduits is the main trend in modern coronary artery bypass grafting (CABG) [Royse 1999]. The left internal mammary artery (LIMA) has been unanimously recognized as the best conduit for the left anterior descending artery (LAD). However, the graft of choice for the right coronary artery remains controversial [Dietl 1995, Lev-Ran 2003]. The gastroepiploic artery (GEA) is one of the choices for grafting the right coronary artery [Hirose 2002]. One of the advantages of GEA grafting is that the artery can be used as an in situ graft without an anastomosis to the aorta. However, GEA is known to be more prone to competitive coronary flow and vasospasm than internal mammary artery (IMA) or other arterial grafts [Suma 2000, Uchida 1996]. To optimize graft length and diameter and to prevent vasospasm, skeletonization technique has been more frequently used in arterial graft harvesting [Higami 2000, Amano 2002, Asai 2002]. We have adopted this technique and used it since 2000 to harvest IMA and radial artery using an ultrasonic scalpel [Amano 2002]. Early angiographic study of the radial artery demonstrated that string sign of the radial artery occurred less often after use of the skeletonized technique, and the graft patency rate of the skeletonized radial artery improved from 84.5% to 96.5% [Amano 2002]. Encouraged by the good results achieved with skeletonized radial artery, we began to harvest the GEA in a skeletonized fashion in September 2002. We previously reported the favorable results of our pilot study of skeletonized GEA grafting [Amano 2004]. This study was performed to compare the early results of the new technique of skeletonized GEA grafting with the classic method of pedicled GEA grafting to evaluate the safety and benefits of the skeletonized technique.

METHODS

Patients

Between July 2002 and October 2003, a total of 223 patients underwent isolated off-pump CABG at Juntendo University Hospital. The GEA was used as a conduit in 105

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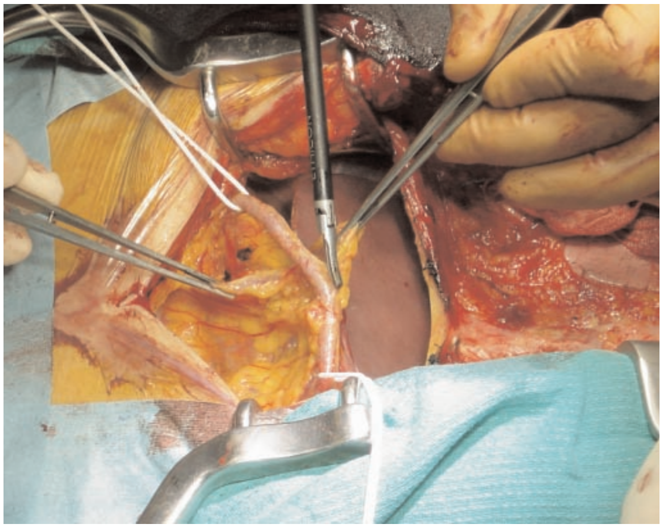

Figure 1. The gastroepiploic artery (GEA) is harvested in a skeletonized manner by use of an ultrasonic scalpel (Harmonic Scalpel, coagulating-scissors; Ethicon Endo-Surgery, Cincinnati, OH, USA). The tip of the scissors was applied between the space of the GEA and the satellite vein.

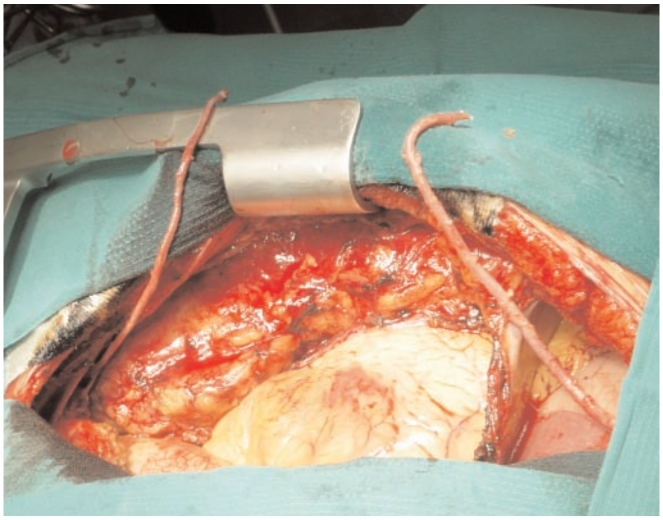

Figure 2. The gastroepiploic artery (GEA) harvested by skeletonized techniques. Satellite veins and surrounding tissue are completely removed. The skeletonized GEA (right) has a larger caliber than the skeletonized left internal mammary artery (left).

(47.1%) of the patients. Of these, 21 patients received pedicled GEA grafts between July 2002 and December 2002 (group P, n = 21). Fifty-nine patients received skeletonized GEA grafts from January 2003 to October 2003 (group S, n = 59). Twenty-five patients receiving skeletonized GEA grafts between September 2002 and December 2002 were excluded from this study to avoid the learning curve and patient selection bias in GEA skeletonization. These initial 25 cases were reported previously [Amano 2004].

Graft Harvesting and Preparations

In all patients throughout the study, skeletonized harvesting of the IMA and the radial artery was performed with an ultrasonic scalpel (Harmonic Scalpel, dissection-hook type; Ethicon Endo-Surgery, Cincinnati, OH, USA).

For harvesting of the GEA, a median sternal incision was extended 5 to 6 cm distally, and the peritoneal cavity was opened. A self-retaining peritoneal retractor was placed to facilitate exposure. The stomach was pulled out of the abdomen, and the GEA was evaluated by finger palpation. The stomach was pulled superiorly, and counter-retraction was applied to the omentum. The anterior layer of the greater omentum was separated by electrocautery until the GEA and its satellite veins were identified. Then the GEA was isolated from the omentum with several vessel loops. Dissection of the GEA was carried out segmentally between the vessel loops by use of an ultrasonic scalpel (Harmonic Scalpel, coagulating-scissors; Ethicon Endo-Surgery).

A major difference between pedicled versus skeletonized harvesting was whether or not the satellite veins and surrounding adipose tissues were preserved. In pedicled GEA harvesting, both satellite vein and adipose tissue were preserved, and the side branches of the GEA were divided 1 cm away from the main trunk.

In skeletonized GEA harvesting, coagulating scissors were inserted into the space between the GEA and the satellite veins, and the arterial branches were divided (Figure 1). Further dissection of the adventitia was performed with microscissor (Figure 2).

After systemic heparinization, the distal end of the GEA was transected, and diluted olprinone or milrinone, phosphodiesterase inhibitor, (0.5 mg/mL) was injected into the lumen of the GEA. The distal end of the GEA was closed and allowed to expand with systemic blood pressure. The conduit was wrapped with warm papaverine-soaked gauze (4 mg/mL) until use.

Coronary Artery Bypass Grafting

After all appropriate grafts were prepared, off-pump coronary bypass was performed. Exposure of the heart and stabilization were facilitated with deep pericardial retraction sutures and an Octopus-3 suction stabilizer (Medtronic, Minneapolis, MN, USA). The target coronary artery was snared proximally with an elastic silicone loop. An intracoronary shunt was used for anastomosis of a high-flow coronary artery or for hemodynamic instability.

Graft Target

The target of the LIMA was primarily the LAD. If the right internal mammary artery (RIMA) was grafted to the LAD, the LIMA was grafted to the diagonal or the circumflex artery. The radial artery was primarily grafted to the circumflex artery. Thus the GEA was mainly used for bypass to the distal right coronary artery. However, bypass of these targets was individually based on the patient's anatomy and the availability of grafts. In patients with calcified aorta, the radial artery was proximally anastomosed to the LIMA or the GEA, making a composite Y graft.

Table 1. Preoperative Characteristics*

Variable	Skeletonized GEA	Pedicled GEA	*P*
Number of patients	59	21	
Age, y	66.7 ± 8.8 (range, 37-82)	65.3 ± 9.02 (range, 46-78)	NS
Female sex, n	13 (22.0%)	2 (9.5%)	NS
Body surface area, m^2	1.64 ± 0.16 (1.27-2.07)	1.73 ± 0.16 (1.49-2.07)	<.05
Cardiac profile, n			
Unstable angina	26 (44.1%)	8 (38.1%)	NS
Acute myocardial infarction	3 (5.1%)	0	NS
Redo operation	4 (6.8%)	1 (4.8%)	NS
Emergency surgery	8 (13.6%)	3 (14.3%)	NS
History of myocardial infarction	24 (40.7%)	11 (52.4%)	NS
History of catheter intervention	7 (11.9%)	5 (23.8%)	NS
Poor ejection fraction (<40%)	5 (8.5%)	1 (4.8%)	NS
Angina class 3 or 4	14 (23.7%)	5 (23.8%)	NS
Triple vessel disease	45 (76.3%)	17 (81.0%)	NS
Left main trunk disease	10 (16.9%)	3 (14.3%)	NS
Associated disease, n			
Renal failure	15 (25.4%)	4 (19.0%)	NS
Cerebral vascular disease	10 (16.9%)	2 (9.5%)	NS
Peripheral vascular disease	1 (1.7%)	4 (19.0%)	NS
Calcified ascending aorta	16 (27.1%)	4 (19.0%)	NS
History of abdominal operation	1 (1.7%)	0	NS
Hypertension	41 (69.5%)	19 (90.4%)	NS
Insulin user	13 (22.0%)	1 (4.8%)	NS
Diabetes	36 (61.0%)	7 (33.3%)	<.05
Hyperlipidemia	35 (59.3%)	15 (71.4%)	NS
Smoking	33 (55.9%)	11 (52.4%)	NS
Obesity	11 (18.6%)	7 (33.3%)	NS
Family history	5 (8.5%)	4 (19.0%)	NS

*GEA indicates gastroepiploic artery; NS, not significant.

Pharmacologic Antispasm Protocol

Systemic nitroglycerin (1 μg/kg per minute) or calcium channel blocker (nicorandil, 0.5 μg/kg per minute) was administered after induction of general anesthesia and continued until the second postoperative day. Oral nicorandil (15 mg/day) was prescribed for at least 1 year. Antiplatelet agents were started on postoperative day 2 along with aspirin 100 mg/day and dipyridamole 75 mg/day.

Clinical Data Collection and Definitions

Perioperative data were prospectively collected and put into a structured database. Postoperative low output syndrome was defined as unstable hemodynamics supported by inotropic agents more than 96 hours or by intraaortic balloon pumping more than 48 hours after surgery. Postoperative myocardial infarction was diagnosed on the basis of the presence of a new Q wave on a postoperative electrocardiogram. Respiratory failure was defined as ventilator support for more than 2 days or reintubation. Mediastinitis was defined as a deep sternal infection requiring debridement.

Follow-up

All patients were followed up in the outpatient clinic after discharge from the hospital. The following cardiac events were recorded: myocardial infarction, recurrence of angina, postoperative intervention, redo CABG, congestive heart failure, arrhythmia requiring hospitalization, and sudden death.

Statistical Analysis

Results were expressed as mean ± SD. Statistical analysis was performed using Student *t* test or Mann-Whitney *U* test for continuous variables or chi-square tests (Fisher exact tests if $n < 5$) for categorical variables, as appropriate. A *P* value less than .05 was considered significant. All statistical analyses were performed with Statview version 5.0 software (SAS institute, Cary, NC, USA).

RESULTS

Preoperative characteristics are shown in Table 1. Group S consisted of 59 patients (46 men and 13 women with a mean age of 66.7 years). Group P consisted of 21 patients (19 men and 2 women with a mean age of 65.3 years). A significant number of patients in group S had a smaller body surface area (1.64 ± 0.16 m^2 in group S versus 1.73 ± 0.16 m^2 in group P, $P < .05$) and diabetes (36/59, 61.0% versus 7/21, 33.3%, $P < .05$). Other preoperative variables did not significantly differ between the 2 groups.

Table 2. Operative Results*

Variable	Skeletonized GEA	Pedicled GEA	*P*
Operative time, min	384.5 ± 97.3 (178-645)	345.5 ± 97.7 (218-671)	NS
Aorta no-touch surgery	22 (37.3%)	8 (38.1%)	NS
Distal anastomosis per patient, n	4.3 ± 1.0 (2-6)	3.9 ± 0.9 (2-5)	NS
Total arterial revascularization, n	48 (81.4%)	19 (90.5%)	NS
Complete revascularization, n	58 (98.3%)	20 (95.2%)	NS
GEA anastomoses per patient, n	1.24 ± 0.47	1.10 ± 0.30	NS
Graft used, n			
LIMA	58 (98.3%)	21 (100.0%)	NS
RIMA	14 (23.7%)	6 (28.6%)	NS
Radial artery	42 (71.2%)	18 (85.7%)	NS
Saphenous vein	11 (18.6%)	2 (9.5%)	NS

*GEA indicates gastroepiploic artery; NS, not significant; LIMA, left internal mammary artery; RIMA, right internal mammary artery.

Operative results are shown in Table 2. There were no intraoperative GEA injuries. Off-pump CABG was successfully performed in all patients. The average time for skeletonized harvesting of the GEA was approximately 25 minutes. The mean number of distal anastomoses (4.3 ± 1.0 in group S versus 3.9 ± 0.9 in group P) and the complete revascularization rate (58/59 [98.3%] in group S versus 20/21 [95.2%] in group P) were not significantly different between the 2 groups.

The LAD was bypassed with one of the IMAs in all patients. The total number of distal anastomoses of the GEA was 73 in group S (1.24 ± 0.47 per patient) and 23 in group P (1.10 ± 0.30 per patient). Distal anastomoses of the GEA were to the distal right coronary artery (61/73 [83.6%] in group S versus 22/23 [95.7%] in group P), the proximal right coronary artery (1/73 [1.4%] versus 1/23 [4.3%]), the circumflex artery (8/73 [11.0%] versus 0/23 [0%]), and the diagonal branch (3/73 [4.1%] versus 0/23 [0%]) (*P* = not significant [NS]). Fourteen (23.7%) of the patients in group S and 2 (9.5%) of the patients in group P had more than 2 distal GEA anastomoses (*P* = NS). Of these, 10 patients in group S and 2 in group P received sequential anastomosis to the posterior descending branch and the atrioventricular branch of the right coronary artery (P = NS). Two patients in group S underwent in situ proximal GEA–posterior descending artery grafting and free distal GEA–diagonal artery bypass with the LIMA for inflow. Total free GEA was used in 2 patients in group S: 1 received a composite graft with the LIMA bypassing to the diagonal and posterolateral branch and distal right coronary artery, and the other received a composite graft with the RIMA making a sequential anastomosis to 2 branches of circumflex artery. The GEA was used for an inflow conduit, making a composite graft with the radial artery in 8 patients in group S but none in group P (*P* = NS). Anastomosis of the ascending aorta was avoided in 22 (37.3%) of the patients in group S and 8 (38.1%) of the patients in group P (*P* = NS).

Postoperative results are shown in Table 3. There was 1 instance of respiratory failure and hospital death in group S. The patient was a 78-year-old man with diabetic nephropa-

Table 3. Postoperative Results*

	Skeletonized GEA (n = 59)	Pedicled GEA (n = 21)	*P*
Intubation time, h	7.7 ± 14.6 (0-87)	9.1 ± 12.0 (0-60)	NS
Intensive care unit stay, d	2.6 ± 2.2 (1-11)	2.4 ± 1.8 (1-9)	NS
Postoperative stay, d	10.8 ± 3.3 (5-22)	12.8 ± 3.8 (8-21)	NS
Rehabilitation days >5 d, n	10 (16.9%)	5 (23.8%)	NS
Major complications, n			
Low output syndrome	0	0	NS
Perioperative myocardial infarction	0	0	NS
Severe arrhythmia	0	0	NS
Cerebral vascular accident	1 (1.7%)	0	NS
Respiratory failure, pneumonia	1 (1.7%)	0	NS
Bleeding requiring exploration	0	0	NS
Mediastinitis	0	0	NS
Sepsis	1 (1.7%)	0	
Postoperative gastric bleeding	0	0	NS
Hospital mortality	1 (1.7%)	0	NS

*GEA indicates gastroepiploic artery; NS, not significant.

thy who was undergoing hemodialysis. He developed cardiogenic shock requiring intubation and insertion of an intraaortic balloon pump preoperatively. Angiographic study demonstrated severe left main disease with acute occlusion of the LAD and severe stenosis of the right coronary artery. The patient underwent emergency off-pump CABG with LIMA, RIMA, and GEA. Although cardiac function was preserved throughout the course, the patient developed pneumonia and died of sepsis on postoperative day 18. Another patient in group S sustained postoperative stroke. The patient was a 59-year-old man who had significant carotid disease (total occlusion on the right and 80% stenosis on the left). He underwent off-pump CABG with in situ LIMA, RIMA, GEA, and RIMA–radial artery composite Y graft without clamping of the aorta; however, the patient developed cerebral infarction on postoperative day 2. There was no low output syndrome, postoperative myocardial infarction, or severe arrhythmia in either group. No abdominal complications such as ileus, delay of feeding, or postoperative gastric bleeding were observed. The intubation time, intensive care unit stay, postoperative stay, and postoperative complications did not significantly differ between the 2 groups.

All surviving patients were followed for a mean of 4.9 ± 2.9 months in group S and 11.0 ± 1.4 months in group P. There was no late mortality or cardiac event during this follow-up period. No delayed abdominal complications such as ileus, bowel obstruction, gastric perforation, or incisional hernia were observed.

COMMENTS

The GEA has been used as a graft for CABG for more than 15 years [Suma 1987]. Long-term angiographic results as well as results of histological and biochemical studies have supported the concept that the GEA is a reliable conduit for CABG [Suma 1987, van Son 1997, Suma 2000]. The major concern of GEA grafting is vasospasm and flow competition. GEA is classified histologically as a muscular artery, which is known to be prone to vasospasm [He 1999]. Anatomically, GEA is the fourth branch of the aorta and has wide variance in size [Mills 1993]. A previous study showed that diastolic pressure is significantly lower in the GEA than in the IMA [Tedoriya 1995]. Therefore the GEA is more prone to insufficient flow if there is competitive coronary flow. The relationship between GEA diameter and graft patency has been well documented: smaller GEA with low GEA flow compared with the native coronary artery has poor angiographic patency [Hashimoto 1996, Suma 2000].

Skeletonization of the GEA has been reported to reduce vasospasm and facilitate sequential anastomosis [Asai 2002]. In our experience skeletonization of the GEA has many advantages. First, it provides more available graft length. As shown in this study, the length of the GEA allowed us to graft not only the distal right coronary artery but also the LAD and/or the circumflex territories. In addition, availability of a longer segment of GEA facilitates use of a more proximal and larger part of the conduit to bypass the high-flow right coronary artery system. The remaining segment can be used as a composite graft with LIMA to graft the diagonal branch. Furthermore, sequential anastomosis to the atrioventricular branch can be constructed easily with the skeletonized GEA. This availability of GEA would be particularly useful for redo operations or procedures on hemodialysis patients who lack other arterial conduits. Second, skeletonization of the GEA ensures larger caliber, because all the perivascular structures are removed and the skeletonized arterial wall is easily dilated with vasodilators. Results of previous studies demonstrated that the size of the GEA was unsatisfactory in as many as 13% of patients [Chavanon 2001]. In our 1 year of experience, despite the relatively smaller body surface area in group S, there was no case in which the GEA was discarded because of its size. The larger conduit size is the most attractive aspect of the skeletonized GEA. Several investigators have recommended that a GEA with a small diameter should not be used as a graft to a noncritically stenosed coronary because of the high possibility of competitive flow with the target coronary artery [Lev-Ran 2003, Suma 2000]. Yasuura and coworkers [2000], using a theoretical model of the bypass system, studied the relationship of GEA flow competition with the recipient coronary artery. The results showed that when the diameter of the GEA was 0.5 mm larger than that of the right coronary artery, the GEA was used to graft the right coronary artery with moderate proximal stenosis without flow competition. Therefore the large caliber of the skeletonized GEA helps to reduce the risk of development of flow competition with the target coronary. Third, skeletonization of the GEA facilitates making a composite graft with other arterial grafts, because the larger size of the skeletonized GEA can provide higher blood flow. In this study, a composite graft using the GEA for inflow was constructed in 8 (13.6%) of the patients. Using the GEA for inflow to the composite graft is an attractive choice that avoids proximal anastomoses to the ascending aorta. This technique would be very useful for patients with a severely atherosclerotic ascending aorta. Fourth, adventitial hematomas are easily avoided in skeletonized GEA because the adventitia is completely removed. Removal of adventitia may prevent graft stenosis caused by hematoma, which occasionally occurs in a pedicled GEA.

One of the main concerns about skeletonization is the risk of graft injury. Unlike an electrocautery, an ultrasonic scalpel produces mechanical vibration and denatures tissue protein [Higami 2000]. The temperature in the tissue is only 80°C with an ultrasonic scalpel, whereas it is approximately 300°C with an electrocautery [Higami 2000]. Results of recent study of the ultrasonic scalpel have indicated that structural damage would not occur in the main trunk of the artery if the ultrasonic scalpel were kept 2 mm away from the GEA [Tanemoto 1998]. Immunohistochemical studies of the patients who received skeletonized IMA showed that skeletonization did not affect arterial wall integrity [Gaudino 1999]. In an animal experiment, the structural and functional integrity of endothelial cells was proved unchanged by skeletonization [Ueda 2003].

Our study showed no low output syndrome or postoperative myocardial infarction in either the skeletonized or the pedicled group. There were no cardiac events during the early follow-up period. Our results may be partially attributed to the use of off-pump CABG and the high complete revascularization rate. Although there were no angiographic data available in this study, all patients who had undergone skeletonized GEA grafting remained symptom free. We did not encounter any graft injury attributed to skeletonization. Thus we considered that skeletonized GEA grafting did not increase the risk of graft injury or the incidence of postoperative angina.

A limitation of this study was its single-hospital, nonrandomized design. The study group (skeletonized group) was compared with a relatively small number of historical cohorts (pedicled group). We were unable to collect old data on pedicled GEA grafts because the staff members involved had moved into Juntendo University Hospital in July 2002. A randomized trial or propensity-matching study to confirm our data may provide interesting results. Angiographic study may be necessary to confirm our clinical results. Another limitation was that our follow-up period was limited. Because the benefits of arterial grafting become more apparent 5 to 7 years after surgery, a longer follow-up study should be done to see the remote clinical and angiographic results.

In conclusion, the GEA can be skeletonized safely with an ultrasonic scalpel, and because of its large caliber size and high graft flow, skeletonization provides a wider variety of choice in the use of GEA grafting, such as sequential anastomosis and/or composite grafting. The combination of off-pump CABG and in situ grafting facilitates complete revascularization without touching the aorta.

REFERENCES

Amano A, Li R, Hirose H. 2004. Off-pump coronary artery bypass using skeletonized gastroepiploic artery. Heart Surg Forum [Epub] January 2004.

Amano A, Takahashi A, Hirose H. 2002. Skeletonized radial artery grafting: improved angiographic results. Ann Thorac Surg 73:1880-7.

Asai T, Tabata S. 2002. Skeletonization of the right gastroepiploic artery using an ultrasonic scalpel. Ann Thorac Surg 74:1715-7.

Chavanon O, Hacini R, Cracowski JL. 2001. Right gastroepiploic artery for coronary artery bypass grafting: a word of caution. Ann Thorac Surg 72:2184-5.

Dietl CA, Benoit CH, Gilbert CL, et al. 1995. Which is the graft of choice for the right coronary and posterior descending arteries? Comparison of the right internal mammary artery and the right gastroepiploic artery. Circulation 92(9 suppl):II92-7.

Gaudino M, Toesca A, Nori SL, et al. 1999. Effect of skeletonization of the internal thoracic artery on vessel wall integrity. Ann Thorac Surg 68:1623-7.

Hashimoto H, Isshiki T, Ikari Y, et al. 1996. Effects of competitive blood flow on arterial graft patency and diameter: medium-term postoperative follow-up. J Thorac Cardiovasc Surg 111:399-407.

He GW. 1999. Arterial grafts for coronary artery bypass grafting: biological characteristics, functional classification, and clinical choice. Ann Thorac Surg 67:277-84.

Higami T, Kozawa S, Asada T, et al. 2000. Skeletonization and harvest of the internal thoracic artery with an ultrasonic scalpel. Ann Thorac Surg 70:307-8.

Hirose H, Amano A, Takanashi S, et al. 2002. Coronary artery bypass grafting using the gastroepiploic artery in 1,000 patients. Ann Thorac Surg 73:1371-9.

Lev-Ran O, Mohr R, Uretzky G, et al. 2003. Graft of choice to right coronary system in left-sided bilateral internal thoracic artery grafting. Ann Thorac Surg 75:88-92.

Mills NL, Hockmuth DR, Everson CT, et al. 1993. Right gastroepiploic artery used for coronary artery bypass grafting: evaluation of flow characteristics and size. J Thorac Cardiovasc Surg 106:579-85.

Royse AG, Royse CF, Tatoulis J. 1999. Total arterial coronary revascularization and factors influencing in-hospital mortality. Eur J Cardiothorac Surg 16:499-505.

Suma H, Fukumoto H, Takeuchi A. 1987. Coronary artery bypass grafting by utilizing in-situ right gastroepiploic artery: basic study and clinical application. Ann Thorac Surg 44:394-7.

Suma H, Isomura T, Horii T, et al. 2000. Late angiographic result of using the right gastroepiploic artery as a graft. J Thorac Cardiovasc Surg 120:496-8.

Tanemoto K, Kanaoka Y, Murakami T, et al. 1998. Harmonic scalpel in coronary artery bypass surgery. J Cardiovasc Surg (Torino) 39:493-5.

Tedoriya T, Kawasuji M, Sakakibara N, et al. 1995. Pressure characteristics in arterial grafts for coronary bypass surgery. Cardiovasc Surg 3:381-5.

Uchida N, Kawaue Y. 1996. Flow competition of the right gastroepiploic artery graft in coronary revascularization. Ann Thorac Surg 62:1342-6.

Ueda T, Taniguchi S, Kawata T, et al. 2003. Does skeletonization compromise the integrity of internal thoracic artery grafts? Ann Thorac Surg 75:1429-33.

van Son JA, Smedts FM, Yang CQ, et al. 1997. Morphometric study of the right gastroepiploic and inferior epigastric arteries. Ann Thorac Surg 63:709-15.

Yasuura K, Takagi Y, Ohara Y, et al. 2000. Theoretical analysis of right gastroepiploic artery grafting to right coronary artery. Ann Thorac Surg 69:728-31.