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Myocardial Revascularization Using the Arterial T Graft: Which Conduit Should Be Chosen for the Free Graft?

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ABSTRACT

Background: The T graft is achieved by the end-to-side implantation of a free arterial graft into the left internal thoracic artery, which remains in situ. Which conduit is best suited as the free graft is still being discussed.

Methods: Two groups of patients are compared. The right internal thoracic artery (RITA) was used as a free graft in group I (n = 129), and the radial artery was used in group II (n = 84).

Results: The RITA was used more often with male patients ($P < .02$) and with patients presenting a reduced left ventricular ejection fraction ($P < .03$). The average number of coronary anastomoses per patient was higher in group II than in group I ($P < .002$). There were no significant differences between the groups in early mortality (0.8% in group I and 1.2% in group II) and morbidity. Postoperative chest tube output was significantly higher in group I than in group II ($P < .05$). The mean follow-up time was 35.2 ± 28.3 months. There were no significant differences regarding late mortality (6.9% in group I and 5.3% in group II) and the recurrence of angina (group I, 6 cases or 5.5%; group II, 3 cases or 4.2%). Because of the recurrence of angina or questionable chest pain in 22 patients, angiography was performed, and results showed a patency rate of 90.9% in group I and 93.1% in group II.

Conclusions: Based on our experience, we advise using the RITA as a free graft with tall men and also in patients with a reduced left ventricular ejection fraction, diabetes, and obesity. The radial artery should be used with small women if there is a high risk of bleeding and if several coronary anastomoses are necessary.

INTRODUCTION

The clinical results of surgical myocardial revascularization mainly depend on the patency rate of the bypass material used. According to numerous studies, the in situ use of the left internal thoracic artery (LITA) for the revascularization of the left anterior descending artery (LAD) shows excellent results. In comparison, the patient survival rate was lower when venous bypasses were used in this position, and recurrent angina, myocardial infarction, and reoperations occurred earlier and more frequently. Similarly, the use of venous bypasses for the revascularization of the circumflex artery and the right coronary artery did not show any better results. On the basis of these findings, the LITA was established 20 years ago as the conduit of choice for the revascularization of the LAD. At the same time, the question arose about whether the right internal thoracic artery (RITA) would show better results than venous bypasses in ensuring the supply for another stenosed coronary vessel. The bilateral use of the ITA turned out to be the best solution for the problem, as was shown by most of the studies in this field. The clinical trend of replacing venous bypasses with arterial ones was also supported by a number of biochemical studies proving that arterial bypasses show better antithrombotic, antispastic, and antiatherosclerotic qualities. Arterial endothelium produces more prostacyclin than venous endothelium, so there is less risk of a thrombosis with an arterial bypass than with a venous one. In addition, greater levels of vasodilative mediators such as nitrogen monoxide are released from arterial bypasses than from venous ones. Consequently, there is less danger of a spasm when arterial bypasses are used. Antiatherosclerotic qualities such fast lipolysis, slow fat absorption, and well-preserved lymphatic drainage are higher in arterial grafts than in venous ones. On the basis of these results, the demand rose for more arterial bypass material. The radial artery (RA) was used increasingly with good results [Royse 1999] once the original techniques of removal and implantation had been revised. There were also good results with the gastroepiploic artery. However, the excellent results of revascularization of the LAD with the aid of the LITA could not be reached with the RITA, the RA, or the gastroepiploic artery. Therefore, the question arose concerning whether these results were influenced by the quality of the bypass material or by the techniques of implantation. To achieve better hemodynamic conditions for bypass flow, Tector and colleagues used the so-called T graft [Tector 2001]. For this procedure, the LITA was anastomosed in situ with the LAD, and the RITA was used as a free graft for the supply of additional stenosed coronary vessels. The T graft is formed by the implantation of the proximal end of the RITA into the LITA. Myocardial revascularization with the T graft has since been adopted by several research teams and has

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Table 1. Patients' Preoperative Clinical Data*

	LITA + RITA T Graft (n = 129)	LITA + RA T Graft (n = 84)	*P*
Female sex, n	14 (10.8%)	20 (23.8%)	<.02
Mean age, y	59.2 ± 8.9	61.7 ± 9.2	NS
Coronary artery disease, n			
One-vessel	2 (1.5%)	1 (1.2%)	NS
Two-vessel	36 (27.9%)	14 (16.6%)	NS
Three-vessel	91 (70.5%)	69 (82.2%)	NS
Previous myocardial infarction, n	68 (52.7%)	35 (41.6%)	NS
NYHA class, n			
I	2 (1.5%)	2 (2.4%)	NS
II	25 (19.4%)	14 (16.7%)	NS
III	75 (58.1%)	61 (72.6%)	NS
IV	27 (21%)	7 (8.3%)	NS
Diabetes mellitus, n	25 (19.4%)	23 (27.4%)	NS
Hyperlipidemia, n	107 (82.9%)	71 (84.5%)	NS
Obesity, n	66 (51.2%)	51 (60.7%)	NS
Hypertension, n	89 (69%)	65 (77.4%)	NS
Smoking, n	82 (63.6%)	44 (52.4)	NS
Mean LVEF, %	58.1 ± 14.1	62 ± 14.2	<.03
Operative priority, n			
Elective	43 (33.3%)	35 (41.7%)	NS
Urgent	74 (57.4%)	46 (54.7%)	NS
Emergent	12 (9.3%)	3 (3.6%)	NS

*Data are presented as the mean ± SD where appropriate. LITA indicates left internal thoracic artery; RITA, right internal thoracic artery; RA, radial artery; NS, not significant; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction.

been used with very good results [Tatoulis 1999, El Nakadi 2000, Pevni 2001]. A slight variation of this method uses the RA instead of the RITA and has also been used with very good results [Tatoulis 1999, Iaco 2001]. Still being discussed, however, is which of these two conduits provides better results as a free graft. Our study compares the RITA and the RA as parts of a T graft and tries to clarify the advantages and disadvantages of these conduits with respect to short-term and midterm results.

MATERIALS AND METHODS

Patient Population

From June 1997 to June 2001, 213 patients with coronary artery disease underwent total arterial myocardial revascularization with a T graft at our clinic. In 129 cases (group I), the T graft consisted of the LITA in situ and the RITA as a free graft. With 84 patients (group II), the T graft was fashioned from the LITA and the RA as a free graft. The clinical data of these two groups are shown in Table 1. Originally, we saw an indication for revascularization with an arterial T graft for patients younger than 60 years or when the patient's venous bypass material was amiss or insufficient. As our experience grew, we also used this method for patients up to 70 years of age. The necessity for having several coronary anastomoses in patients with a short sternum was found to be a contraindication against using the LITA + RITA T graft. Diabetes, obesity, or a combination of both risk factors was not seen as a contraindication in group I. To establish the blood flow figures within the hand when we planned to remove the RA, we used a preoperative Allen test as described by Royse et al [Royse 1999]. The RA was not used after a positive result was obtained in the Allen test or in patients with renal failure, stenosis of the subclavian artery, or Raynaud or Dupuytren disease. The RA was removed only from the nondominant forearm. With all patients, we aimed for complete myocardial revascularization. All coronary vessels showing a high grade of stenosis (>80%) according to the angiography results were considered for revascularization. In the case of a vessel with a diameter that was too small (<1.5 mm) or of a seriously affected structure of the coronary wall, bypassing was omitted, and the myocardial revascularization was considered incomplete.

Surgical Protocol

With the patients of group I, the first step was to prepare a pedicled LITA with a "no touch" technique. For this procedure, electrical coagulation (Force 2; Valleylab, Boulder, CO, USA) was used at low power (40 W). Large side branches of the LITA were supplied with titanium clips (Ligaclip MCA, Ethicon Endo-Surgery, Cincinnati, OH, USA). The LITA was prepared proximally up to its origin at the subclavian artery and distally down to its fork into the epigastric and musculophrenic arteries. After the distal removal of the LITA, approximately 2 mL of a solution of 50 mg papaverine (Paveron; Linden-Arzneimittel Vertrieb, Heuchelheim, Germany) and 5000 IU heparin (Liquemin N; Hoffmann-La Roche, Grenzach-Wyhlen, Germany) in 100 mL 0.9% sodium chloride was given intravasally, and the distal end of the LITA was occluded. Next, the RITA was freed in an analogous manner from its origin to the bifurcation, removed, and carefully examined for tightness by means of an intravasal application of the heparinized papaverine solution described above. The RITA was then stored in heparinized papaverine solution until implantation. With group II patients, the RA was removed in parallel with the preparation of the LITA. Again, this procedure was carried out with a no-touch technique. The examination of tightness and conduit storage until implantation were conducted with the help of the heparinized papaverine solution. The incision on the forearm was closed after blood stilling and before extracorporeal circulation. All operations were conducted by the same surgeon with extracorporeal circulation at moderately hypothermic conditions (32°C) and a cardioplegic solution (Custodiol; Dr. Franz Köhler Chemie, Alsbach-Hähnlein, Germany) with the patient under cardiac arrest. First, the coronary vessels of the posterior and/or lateral walls were anastomosed to the free graft (RITA for group I and RA for group II), the distal end of the LITA was anastomosed with the LAD, and, finally, the proximal end of the free graft was implanted into the LITA by means of an end-to-side technique. All anastomoses were completed with continuous sewing techniques and an 8-0 polypropylene thread (Prolene; Ethicon, Norderstedt, Germany). The central implantation of

Table 2. Postoperative Complications*

	LITA + RITA T Graft (n = 129), n	LITA + RA T Graft (n = 84), n	*P*
Myocardial infarction	4 (3.1%)	0	NS
Low output syndrome	3 (2.3%)	1 (1.2%)	NS
Reoperation for bleeding	4 (3.1%)	1 (1.2%)	NS
Respiratory failure	12 (9.3%)	12 (14.3%)	NS
Renal failure	2 (1.5%)	0	NS
Sepsis	3 (2.3%)	0	NS
Mediastinitis	1 (0.8%)	1 (1.2%)	NS

*Abbreviations are expanded in the footnote to Table 1.

the free graft took place while the aorta was still cross-clamped to avoid a mismatch at this location.

Spasmolytic Therapy

To reduce the risk of an RA spasm, we gave patients in group II intravenous diltiazem hydrochloride (Dilzem; Gödecke, Berlin, Germany) at a dosage of 0.5 μg/kg per minute immediately after the end of the cross-clamping of the aorta. This spasmolytic therapy was continued for 3 months after the operation via oral administration of diltiazem hydrochloride at a dosage of 180 mg/day.

Statistics

All data were analyzed with the SigmaStat software package (SPSS, Chicago, IL, USA). All continuous values are expressed as the mean ± standard deviation. The data for the two groups were compared by means of the Student *t* test. Categorical data for the two groups were compared with the chi-square test or the Fisher exact test. The data are expressed in absolute and relative terms. A *P* value ≤.05 was considered to indicate a statistically significant difference.

RESULTS

The average number of coronary anastomoses per patient was 3.3 ± 0.8 in group I and 3.7 ± 0.8 in group II, and this difference was significant ($P < .002$). A complete myocardial revascularization was achieved with 72.1% of the group I patients (n = 93) and 86.9% of the group II patients (n = 73), and this difference was not statistically significant. The aorta cross-clamping times averaged 73.2 ± 18.9 minutes in group I and 73.5 ± 17.5 minutes in group II and were not significantly different. Early lethality, defined as death within the first 30 days after the operation, was 0.8% (n = 1) for group I and 1.2% (n = 1) for group II. Postoperative chest tube output averaged 858.4 ± 500.4 mL in group I and 731 ± 380.4 mL in group II and therefore was significantly higher in group I ($P < .05$). Blood substitution volumes, however, showed no statistically significant difference between the two groups, with blood substitution averaging 704.9 ± 436.6 mL in group I and 625 ± 307.6 mL in group II. The analysis of postoperative complications showed no significant differences between the two groups (Table 2). The mean follow-up time was 35.2 ± 28.3 months for 192 of the patients (91%). Nineteen patients (group I, 12 patients; group II, 7 patients) were lost to follow-up. The late mortality rate was 6.9% (n = 8) for group I and 5.3% (n = 4) for group II. This difference did not approach statistical significance, however. One hundred two group I patients (94.4%) and 69 group II patients (95.8%) were asymptomatic. Because of the recurrence of angina or questionable chest pain in 22 patients, coronary angiography was performed. Forty (90.9%) of the 44 examined coronary anastomoses in group I were patent, compared with 27 (93.1%) of the 29 anastomoses examined in group II. The patency rate of the bypass materials used was 96.4% for the LITA, 89.3% for the RITA, and 88.2% for the RA. A reintervention was necessary in 3 patients. One patient in group I initially with a left main coronary artery stenosis had to undergo reoperation because of closure of all peripheral T-graft anastomoses and unstable angina. In 2 other patients with stenosis of the RA free graft, percutaneous transluminal coronary angioplasty of native coronary arteries could be performed to relieve the angina. Angiographic results for 4 patients in group II showed progression of atherosclerosis in coronary arteries other than those operated on. An angioplasty was successfully performed in 3 cases.

DISCUSSION

There still are many open questions concerning the concept of total arterial myocardial revascularization, such as the sequence when choosing the conduit and the technique used for the implantation of the conduit. The supply of the LAD with the aid of the LITA in situ remains the standard procedure. Being debated, however, is which conduit should be chosen in the second instance. Most teams have discussed whether the RITA or the RA offers a better solution. With the use of the bilateral ITA, the disadvantages are longer operation times, complex anastomoses, and reduced conduit length. The use of the RITA in situ drastically limits the possibilities for conducting several coronary anastomoses. The removal of the RA, on the other hand, causes an additional scar and is unpopular with patients for aesthetic reasons. The central implantation of the RITA or the RA as a free graft in the area of the anterior wall of the ascending aorta leads to a mismatch with respect to wall thickness and the diameters of the anastomosed vessels. The transplant is exposed to disadvantageous pressure and flow characteristics in the area of implantation. These conditions lead to a hyperplasia of the intima [Calafiore 1994]. The introduction of the T graft provides an elegant solution for this problem by avoiding the need for an aortic bypass anastomosis.

Our study examines short-term and midterm results after the use of either the RITA or the RA as a free graft within a total arterial myocardial revascularization using a T graft. Among our patients, we have used the RITA as a free graft in a significantly lower percentage of women. Women are mostly smaller than men, and they have a shorter sternum. Therefore, the RITA is expected not to be long enough for the sequential supply of several vessels of the posterior wall. Other teams also tend to use the RA more often with women

than the RITA [Lemma 2001]. Our experience indicates that the implantation of the RITA as a sequential graft is more demanding than implanting the RA, especially in women, because of its morphologic characteristics, such as small diameter, shorter length, and reduced wall thickness.

Some authors consider diabetes and obesity, especially when occurring simultaneously, as risk factors for mediastinitis [Tatoulis 1999, El Nakadi 2000] when both ITA are used. We have distanced ourselves from this hypothesis and have nevertheless been able to keep the rate of mediastinitis in our patients low (0.8%). There was no difference in the rates of mediastinitis for the two groups. From this perspective, the RA does not appear to be more advantageous than the RITA to use with diabetic and obese patients.

With the group I patients, there were significantly fewer coronary anastomoses than with group II patients, whereas the aortic cross-clamping times were the same for both groups. This result, in our opinion, is a hint that the use of the RITA as a free graft is more demanding than the implantation of the RA.

When both ITA are used, the postoperative chest tube output has ranged between 775 ± 580 mL [Uva 1998] and 1042 ± 708 mL [Lemma 2001] per patient. With our patients, chest tube output in group I averaged 858.4 ± 500.4 mL and was significantly higher than in group II. Nevertheless, there was no greater need for blood substitution with the patients of group I. Besides, the rate of reoperations for bleeding was not significantly higher in group I. The use of both ITA causes a larger intrathoracic bleeding area, and, therefore, greater blood loss is to be expected. It is advisable to still bleeding carefully with electric coagulation on the smaller side branches of the ITA and to use titanium clips on the larger ones.

Although the patients of group I showed a comparatively worse status in the beginning (a lower left ventricular ejection fraction and a more frequently incomplete revascularization because of a poor coronary status), rates of early mortality and morbidity showed no statistically significant differences between the two groups. Therefore, such high-risk patients are appropriately treated with myocardial revascularization with a T graft consisting of the LITA and the RITA.

The late mortality rate proved to be higher in group I (6.9%; n = 8) than in group II (5.3%; n = 4). This difference was not statistically significant, however. It can be surmised that certain characteristics of group I patients (eg, poor coronary status and a reduced left ventricular ejection fraction) led to a faster progression of coronary heart disease and cardiac complications and therefore raised the mortality rate. Other teams have reported late mortality rates of 7.5% after 3 years [Pevni 2001] and 13.2% after 4.2 years [Tector 2001] after myocardial revascularization with the help of the LITA + RITA T graft and approximately 1.2% after 9.5 ± 6.1 months [Weinschelbaum 1997] and 12.2% after 35 ± 25 months [Iaco 2001] with the use of the LITA + RA T graft.

The longer-term clinical results for the two groups proved to be equally good; 102 patients (94.4%) of group I and 69 patients (95.8%) of group II showed no angina. With an average follow-up time of 35.2 ± 28.3 months, this result is considered very good. Three reports in the literature indicate that of the patients who underwent operations with a LITA + RITA T graft, 93.4% showed no signs of angina after 35 months [El Nakadi 2000], 94.1% showed no signs after 4.2 years [Tector 2001], and 97.6% showed no signs after 14 to 36 months [Pevni 2001]. The rates for freedom from angina after the use of the LITA + RA T graft is 95.1% after 9.5 ± 6.1 months [Weinschelbaum 1997] and 97.2% after 41 ± 30 months [Iaco 2001].

When carrying out coronary angiographies, we observed 6 cases of occluded anastomoses during the follow-up period: 1 involving the LITA, 3 involving the RITA, and 2 involving the RA. Three of these occlusions (1 LITA and 2 RITA) occurred with the same patient. This patient had undergone revascularization in the left coronary system with the LITA + RITA T graft because of a solitary stenosis of the left main coronary artery. Postoperative coronary angiographic results showed a string phenomenon of the entire T graft. Since this case, there have been no additional arterial T-graft revascularizations in patients experiencing solitary stenoses of the left main coronary artery. The reasons for the 2 closures of the RA anastomoses could not be found. Our rate of open anastomoses for the RA shafts of the T graft, even in symptomatic patients, is higher (88.2% after 35.2 ± 28.3 months) than that reported by Sundt et al [Sundt 1999] of 82% after 9.5 ± 8.3 months. Iaco and colleagues [Iaco 2001] report better results after 48 ± 27 months with a 93.8% patency rate for the RA conduit of the T graft.

On the basis of our study, neither of the two free grafts examined (the RITA or the RA) can generally be recommended as the "conduit of second choice." In our opinion, the choice should be made for each case individually. We prefer using the RITA with tall men when there is no necessity for a large number of anastomoses to obtain a complete revascularization. We also prefer using the RITA also with patients with a reduced left ventricular ejection fraction, with coronary arteries of a small diameter, and in cases where a scar on the forearm is not acceptable. Diabetes and obesity, in our view, are not contraindications to the bilateral use of the ITA. The RA should be chosen for use with small women when there is a high risk of postoperative bleeding and if more than 3 coronary anastomoses are needed for myocardial revascularization.

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