SYSTEMATIC CLINICAL AND ANGIOGRAPHIC FOLLOW-UP OF PATIENTS UNDERGOING MINIMALLY INVASIVE CORONARY ARTERY BYPASS

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Objective: We herein analyze the results of the systematic clinical and angiographic control performed in a series of 77 consecutive patients undergoing minimally invasive coronary artery bypass. **Methods and Results:** From January 1995 to June 1997, 77 patients underwent minimally invasive coronary artery bypass at our institution. There was one inhospital death, one noncardiac late death, and five patients had to be reoperated for graft malfunction. A total of 76 patients underwent postoperative angiographic follow-up. In 66 cases (86.8%) the thoracic artery graft, the target vessel, and the anastomosis were patent and functioning normally. In one case the graft was occluded. In the remaining nine cases the thoracic artery graft was patent but with major anomalies of either the anastomosis, the target vessel, or the course of the thoracic artery. Patients operated using especially designed instruments had angiographic results clearly superior to those of patients operated using conventional instrumentation (perfect patency rate 100% vs 81.8%). At a mean follow-up of 18 months, 98.5% of the surviving patients are asymptomatic with negative myocardial scintigraphy. **Conclusions:** The perfect patency rate of minimally invasive revascularization performed without the use of dedicated instruments is unacceptably low. The use of specific devices is likely to result in a substantial improvement in the angiographic results. (*J Thorac Cardiovasc Surg* 1998; 115:785-90)

Minimally invasive coronary artery bypass (MICABG) is having a rapid worldwide acceptance and probably has the potential to modify the invasive approach to coronary artery disease in the near future.¹

Although only a few years have passed since its introduction, many variants of the MICABG technique have already been proposed,²⁻⁵ and the enormous research effort of many industrial companies has led to a progressive refinement of new specific devices that greatly reduce the technical complexity of MICABG procedures.

We began our experience with MICABG in January 1995⁶ and tried to continuously improve our technique on the basis of the results of the systematic angiographic control.⁷

We herein report the clinical and angiographic results of our first 77 patients and some technical considerations derived from the analysis of what we consider our MICABG learning curve.

Methods

Patient population. From January 1995 to June 1997, 77 patients underwent MICABG at our institution.

There were 54 men with a mean age of 60 years (range 40 to 81 years); the main preoperative clinical and angiographic data of these patients are summarized in Table I.

In 55 cases there was isolated left anterior descending (LAD) coronary artery disease, whereas the remaining 22 patients had multivessel disease. Eighteen of these 22 had reversible ischemia only in the LAD region; the other four patients had end-stage systemic diseases and underwent MICABG as palliative procedure.

Operative technique. All the operations were performed by the same surgeon. The chest was opened at the fourth intercostal space and the ribs retracted; the fourth sternocostal joint was transected only in three initial cases.

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Table I. Main preoperative data

Male	54
Female	23
Mean age (yr)	60 (40-81)
Unstable angina	28 (36.3%)
Previous myocardial infarction	40 (51.9%)
Reoperation	1 (1.2%)
Isolated LAD lesion	55 (71.4%)
Multivessel disease with reversible ischemia only in the LAD region	18 (23.3%)
Palliative LAD revascularization*	4 (5.1%)
Mean ejection fraction	0.62 (0.15-0.88)
Ejection fraction <0.35	9 (11.6%)

LAD, Left anterior descending artery; EF, ejection fraction.

*In patients with end-stage systemic disorders: hepatic cirrhosis in two cases, lung and mediastinal cancer in the others.

After longitudinal incision of the pericardium, the LAD coronary artery was visualized and harvesting of the left internal thoracic artery (LITA) was started.

In five patients (excluded from this report) we had to switch to beating heart bypass through a median sternotomy because of the unusual position, the intramyocardial course, or the poor quality of the LAD.

In the first part of our experience, in the absence of a specific sternal retractor, the LITA was harvested for a short length (4 to 6 cm) under direct vision (52 cases). In four cases the conduit was harvested for its full length using a thoracoscope. In the remaining 21 patients we used specific MICABG instruments, including a chest retractor (which allowed an almost complete harvesting of the LITA) and a mechanical stabilizer for operative field immobilization (CardioThoracic Systems Inc., Cupertino, Calif.).

The LAD was then occluded. The means of LAD occlusion varied considerably during our experience. In the first 15 cases we used 5-0 polypropylene sutures (Ethicon, Somerville, N.J.) passed twice around the vessel and tied using a tourniquet. In the next successive 30 patients we replaced the polypropylene sutures with silicone rubber snares (Intercor, ERCL, Serquigny, France), passed around the vessel and tied in the same way. Finally, in the last 32 cases we decided to use silicone rubber snares passed only once under the vessel and gently pulled upward, without tourniquet occlusion.⁷

Low-dose systemic heparin (1 mg/kg) was used in 51 of our patients; in the remaining 26 we used full-dose heparin (3 mg/kg) combined with preoperative antiplatelet therapy (acetylsalicylate, 300 mg/day, started the day before operation).

After preparation of the distal end of the LITA, intravenous esmolol 100 µg/kg per minute (Brevibloc, Ohmeda PPD Inc., Liberty Corner, N.J.) was started and the anastomosis was completed using continuous 7-0 or 8-0 polypropylene single or double sutures.

Follow-up. All patients were regularly followed up at Catholic University of Rome and underwent stress myocardial scintigraphy 1 and 6 months postoperatively and then every year.

Table II. Operative data

Wound length (cm)	11 ± 1.8
Mean LAD occlusion time (min)	29 ± 6.5 (18-42)
Mean anastomotic time (min)	18 ± 3.7 (14-29)
Mean operative time (hr)	2.1 ± 0.5 (1-4)

LAD, Left anterior descending artery. Results are expressed as mean ± standard deviation.

Transthoracic echo-Doppler follow-up of LITA patency was routinely performed 2 days after operation in the last 42 patients. Moreover, echo-Doppler evaluation was repeated 1 and 6 months after the operation and then every year thereafter.

Angiographic follow-up. With informed consent, all 76 surviving patients underwent postoperative angiography (angiographic follow-up 100% complete).

Postoperative coronary arteriography and selective LITA angiography were usually obtained by use of 6F catheters inserted through the femoral artery; in cases of severe tortuosity of the thoracic aorta and/or left subclavian artery, a left brachial artery approach was used.

In the first 35 consecutive cases postoperative angiography was performed in the catheterization laboratory of the Catholic University of Rome before hospital discharge.

The angiography of the subsequent 41 patients was performed in the Department of Cardiology of the Calai Hospital of Gualdo Tadino, where all patients were transferred for postoperative rehabilitation. Twelve of these 41 patients refused angiography before discharge from the rehabilitation center but were studied in the subsequent months (two of them for angina recurrence).

For this reason, mean interval between operation and postoperative angiography was 1.7 ± 2.8 months (range 0.5 to 13 months). However, 64 of 76 patients (84.2%) were subjected to angiographic follow-up within 15 days after the operation.

Among the 76 patients, 74 (97.3%) were studied for control purposes and 2 for recurrence of symptoms.

Results

Operative data. The main operative results are summarized in Table II. The LAD was kept occluded for a mean of 29 minutes (range 18 to 42 minutes). LAD occlusion was never associated with significant electrocardiographic or hemodynamic changes. The mean time for the anastomosis was 18 minutes (range 14 to 29 minutes) and the mean operative time was 2.1 hours (range 1 to 4 hours).

Early clinical results. One of our first patients died in the hospital: 2 days after surgery he had a large anterior myocardial infarction complicated by cardiogenic shock. In an attempt to improve the hemodynamics, we performed an emergency additional saphenous graft to the LAD, without submitting the patient to reangiography. However, irre-

Table III. *Angiographic results*

Normal functioning grafts	66
Occluded grafts	1
Patent grafts with major anomalies	9
Angled LITA	4
Anastomotic stenosis	2
Stenosis of the anastomosis and the distal LAD	1
Distal LAD stenosis	2

LAD, Left anterior descending artery; LITA, left internal thoracic artery.

versible cardiogenic shock followed the reoperation and the patient died 2 days later from multiorgan failure.

The mean blood loss in the first 12 hours was 173 ml (range 30 to 880 ml). One patient had to be reoperated to control excessive bleeding from an unclipped thoracic collateral vessel. One other patient had to have operative drainage of a loculated thoracic hematoma 4 days after MICABG.

Finally, one patient had a transient cerebral ischemic attack the day after surgery, with complete relief of all the neurologic symptoms in less than 6 hours.

The mean duration of mechanical ventilation was 3 ± 1.5 hours, and the mean stay in the intensive care unit was 6.2 ± 2 hours.

Two asymptomatic patients were reoperated on using cardiopulmonary bypass 2 and 4 days after surgery because of a malfunctioning LITA graft on the predischarge angiogram (LITA occlusion in one case and anastomotic and distal LAD stenosis in the other). A third patient, with predischarge angiographic evidence of anastomotic stenosis while asymptomatic, refused any further invasive procedure.

Late clinical results. One patient died of hepatic failure 14 months postoperatively; this patient had undergone early postoperative angiography, which revealed a normal functioning internal thoracic graft.

Two patients complained of angina recurrence 3 and 6 months after surgery, respectively. Both these patients, who refused early angiography, were rehospitalized, and a new echo-Doppler evaluation, demonstrated a diastolic component of LITA flow clearly reduced compared with the predischarge study. These patients had an angiogram and then underwent reoperation through median sternotomy and cardiopulmonary bypass because of distal LAD stenosis.

A third asymptomatic patient undergoing an angiogram 9 days after surgery was found to have an

Fig. 1. Postoperative angiography: selective thoracic artery injection. The LITA, of excessive length, shows an evident angulation in its distal tract.

anastomotic stenosis and had a successful percutaneous angioplasty in the same session.

All patients reoperated (with either percutaneous or operative techniques) were excluded from the follow-up study.

At a mean interval of 18 months after operation (range 1 to 27 months), 69 of the 70 patients available for midterm follow-up (98.5%) are angina free and have negative stress scintigraphy. Sixty-five of these 69 patients have angiographic demonstration of normal functioning internal thoracic grafts, whereas the remaining four were found to have LITA angulation on postoperative angiography. Finally, one patient (the one who refused reoperation for anastomotic stenosis) has evidence of inducible ischemia in the LAD region.

Angiographic results in the overall population. Detailed angiographic findings of the 76 patients who survived the operation are reported in Table III.

In 66 cases (86.8%) the LITA graft, the LITA-LAD anastomosis, and the LAD adjacent to the anastomotic site were normal.

In one case the LITA was occluded (this patient was reoperated on 5 days after MICABG with conventional technique).

In the remaining nine cases the LITA was patent, but the following anomalies of either the LITA

Fig. 2. Postoperative angiography: selective thoracic artery injection. A sharp angulation, inducing a hemodynamically significant stenosis, is evident in the distal third of the LITA.

course, the anastomosis, or the adjacent LAD were present.

In four patients the LITA showed a marked angulation in the distal tract of its mediastinal course (Fig. 1); the kinking induced an evident stenosis in two cases (Fig. 2). However, because all four patients are actually free from angina and have negative stress scintigraphy, reoperation was not considered necessary.

Three patients had a stenosis of the distal LAD; in one of these three cases a stenosis of the anastomosis was also found (Fig. 3). All three patients were reoperated using the traditional technique.

Finally, in two patients there was an anastomotic stenosis; one of these patients had successful percutaneous angioplasty, whereas the other refused any further invasive procedure.

Angiographic results with reference to the type of instrumentation used at surgery. When analyzing our results with respect to the type of instrumenta-

Fig. 3. Postoperative angiography: selective thoracic artery injection. Stenosis of either the anastomosis and the LAD at the level of application of the occlusive suture.

tion used at surgery (either especially designed for MICABG or not), our patient population has to be divided into two groups: the first 56 patients, operated using the traditional instruments (group A), and the last 21 patients, in whom a dedicated chest retractor and a platform stabilizer were used (group B).

As summarized in Table IV, all grafts were perfectly patent in group B (21 of 21), whereas the patency rate without kinking or stenosis was only 81.8% in group A (45 of 55).

Discussion

In this study we analyze the data derived from the early angiographic study of our first 77 consecutive patients who underwent minimally invasive myocardial revascularization.

Despite the large interest elicited by MICABG and the raised concerns about its possibility to achieve the same optimal results of conventional coronary artery bypass,⁸ no large systematic angiographic study has been reported until now.

In fact, in the major MICABG series postoperative angiography has been performed only sporadically, and indirect techniques (in particular echo-Doppler evaluation of LITA flow pattern) have been widely used. However, angiographic study is

Fig. 4. Postoperative angiography: selective thoracic artery injection. Early angiographic follow-up revealed a thrombuslike image in the LAD immediately proximal to the anastomosis (A). Five months later a second angiogram demonstrated thrombus disappearance (B).

obviously the only means to directly assess the patency and the morphology of the LITA, the anastomosis, and the target vessel and, thus, to evaluate the technical results of a new procedure.

Intraoperative angiography would have probably been ideal in this setting as advocated by some authors⁹; however, structural and organizational problems led us to perform postoperative studies before discharge from either our hospital or the rehabilitation center.

The variable time period in which the patients underwent postoperative angiography (range 0.5 to 13 months) is a major limitation of this study; although almost 82% of the patients underwent angiographic study within 15 days after the operation, the variable time range obviously reduces the homogeneity of our data.

When considering our entire series, only 86.8% of the grafts were found to be perfectly patent at the angiographic follow-up (i.e., the anastomosis was patent and there were no anomalies of the LITA

Table IV. Angiographic results according to the type of surgical instrumentation used

	Group A	Group B
Normal functioning grafts	45	21
Occluded grafts	1	0
Patent grafts with major anomalies	9	0

Group A, Traditional instruments; group B, specific MICABG instruments.

and the distal and proximal LAD), and this percentage is further reduced if the patient who died without having postoperative angiography (and in whom a distally thrombosed LITA graft was found at postmortem examination) is included.

However, when analyzing our data in relation to the instrumentation used at operation (either especially dedicated to MICABG or not), it is evident that the patients operated with specific instruments have a perfect patency rate comparable to that of conventional surgical revascularization and largely superior to that of patients oper-

ated on using traditional instruments (100% vs 81.8%).

It should be also noted that the low perfect patency rate of group A is similar to that reported by Gill and coworkers¹⁰ in a small group of MICABG patients operated on without the use of the dedicated instrumentation.

The patients in whom the specific MICABG tools have been used were subsequent to those operated on using traditional instruments; this temporal succession could obviously have contributed to the different results between the two groups. However, the striking difference in perfect patency rate among group A and B can hardly be justified only on the basis of the improved operative experience. It is our opinion that most of the anomalies found in group A represent the unavoidable consequence of an intrinsically imperfect technique, substantially ameliorated by the introduction of the new instrumentation that allows for complete LITA harvesting and optimal operative field immobilization.

Among the patients in whom the LITA was incompletely harvested through the thoracotomy we found four cases of sharp angulation of the distal tract of the LITA (Figs. 1 and 2). These angulations are likely to have been the consequence of the fact that the limited harvesting of the thoracic artery (where the artery remains fixed to the chest wall for most of its course) prevents a regular adaptation of the conduit to the surrounding mediastinal structures and causes sharp angulations, especially in case of conduits whose length exceeds the exact distance between the chest wall and the anterior surface of the heart (Fig. 1). After these cases we decided to adopt thoracoscopic LITA harvesting (although more invasive and time consuming).

The need for thoracoscopic assistance was obviously eliminated with the use of the new retractors, which allow complete thoracic artery harvesting through the minithoracotomy.

An anastomotic stenosis was found in three of our patients. All cases occurred among the first patients operated using the traditional instrumentation and were obviously related to the difficulty of performing the anastomosis on the beating heart. After the introduction of the mechanical stabilizer, anastomotic imperfections were never observed.

The three cases of LAD stenosis at the level of application of the occlusive sutures (Fig. 3) deserve a special comment.

The need for LAD occlusion obviously has the potential to damage the target vessel, and lesions of

the coronary artery at the level of the application of the occlusive sutures during MICABG have been reported by different authors, including us.^{7, 11}

Damage of the vasa vasorum of the coronary artery and focal endothelial lesions at the level of the occlusive sutures with superimposed thrombosis (facilitated by the low-dose heparin and normal platelet function) can probably play a causative role, and the demonstration of the early formation of an intracoronary thrombus in one of our patients (Fig. 4, A and B) seems to support this hypothesis.

After the described modifications of the LAD occlusion and the use of an anticoagulant and antiplatelet protocol and with the use of the mechanical stabilizer, no further target vessel lesion was observed.

In conclusion, the perfect patency rate of the MICABG grafts performed without specific instrumentation has been unacceptably low in our preliminary experience; our data seem to suggest that the use of dedicated devices can substantially ameliorate these results, allowing the achievement of a patency rate comparable to that of conventional surgical revascularization.

REFERENCES

1. Loop FD. Internal thoracic artery grafts: biologically better coronary arteries. *N Engl J Med* 1996;334:263-5.
2. Calafiore AM, Di Gianmarco G, Teodori G, et al. Left anterior descending coronary artery grafting via a left anterior small thoracotomy without cardiopulmonary bypass. *Ann Thorac Surg* 1996;61:1659-65.
3. Nataf P, Lima L, Regan M, et al. Minimally invasive coronary surgery with thoracoscopic internal mammary artery dissection: surgical technique. *J Card Surg* 1996;11:288-92.
4. Boonstra PW, Grandjean JG, Mariani MA. Improved method for direct coronary grafting without CPB via anterolateral small thoracotomy. *Ann Thorac Surg* 1997;63:567-9.
5. Subramanian VA. Less invasive arterial CABG on a beating heart. *Ann Thorac Surg* 1997;63:S68-71.
6. Alessandrini F, Luciani N, Marchetti C, Gaudino M, Possati G. Early results of the minimally invasive thoracotomy for myocardial revascularization. *Eur J Cardiothorac Surg* 1997;11:1081-5.
7. Alessandrini F, Gaudino M, Glioca F, et al. Lesions of the target vessels during minimally invasive myocardial revascularization. *Ann Thorac Surg* 1997;64:1349-53.
8. Reardon MJ, Espada R, Letsou GV, Safi HJ, McCollum CH, Baldwin JC. Minimally invasive coronary artery surgery: a word of caution. *J Thorac Cardiovasc Surg* 1997;114:419-20.
9. Izzat MB, Yim APC. Trouble shooting in minimally invasive direct coronary artery bypass [letter]. *Lancet* 1997;350:665-6.
10. Gill IS, FitzGibbon GM, Higginson LAJ, Valji A, Keon WJ. Minimally invasive direct coronary artery bypass: a series with early qualitative angiographic follow-up. *Ann Thorac Surg* 1997;64:710-4.
11. Pagni S, Qaqish NK, Senior DG, Spence PA. Anastomotic complications in minimally invasive coronary bypass grafting. *Ann Thorac Surg* 1997;63:S64-7.