New Technique

Surgical Revascularization of the Left Anterior Descending Artery with the MIDCAB Technique

Apostolos D. Bisbos, Nikos Skubas, George N. Minadakis, Dimitris Smirlis, George Karkanis, Panagiotis K. Spanos

Interbalkan European Medical Center, Thessaloniki, Greece

Address:
Apostolos D. Bisbos

3 Posidonos St.,
551 32, Thessaloniki,
Greece
Tel.: (+30) 2310-447423

Minimally invasive surgical revascularizations aim to reduce the degree of surgical intervention. The latter is achieved by avoiding usage of the extracorporeal circulation (EC) as well as by using tiny incisions that reduce injuries to the underlying tissue, blood loss etc. At the same time, it is necessary to ensure that these interventions are at least equally successful as the classic revascularization methods and of course to make sure that the patients are not endangered in any way[1,2]. Moreover, these interventions aim at facilitating the quick recovery of the patient and at reducing the overall costs[2,3,4].

Minimally invasive surgical revascularization of the left anterior descending (LAD) artery is possible either through a midline sternotomy (total or partial) or via a limited left anterior thoracotomy (MIDCAB). The latter is clearly a less invasive method[2-4].

In this paper, we present our experience from the use of the MIDCAB technique in patients suffering from LAD disease.

Material-Method

In the last four years (from June 1997 until May 2001) 2483 patients underwent aorto-coronary bypass. Ninety-one patients (3.66%) were operated on with the MIDCAB technique. Seventy-two patients were men and 19 were women. Their age ranged from 41 to 78 years (mean age 62.1± 9.3 years).

Preoperatively 5 patients were class I (patients with silent ischemia) according to the Canadian Cardiovascular Society (C.C.S.), 22 patients were class II, 58 patients were class III and 6 patients were class IV.

Twenty-two patients had an anterior myocardial infarction. Most of the patients suffered from unstable angina (52 patients), 5 patients had silent ischemia and the rest suffered from stable angina (34 patients). Eleven patients had undergone LAD angioplasty with stent placement in the last 6 months. Twelve patients suffered from chronic obstructive lung disease, 3 patients had significant stenosis of the internal carotid artery (>80%), 3 patients had impaired renal function (serum creatinine ≥1.9) and 1 patient had moderate hepatic failure (Table 1).

Cardiac catheterization revealed that 84 patients had a critical stenosis (70-99%) in the initial LAD portion. Another 7 patients, had LAD occlusion immediately after its origin. Among these seven patients, two had previously undergone an aorto-coronary bypass of the LAD using a venous graft, which was shown to be occluded during cardiac catheterization.

Table 1. Medical history - Cardiac catheterization.

Number of Patients	91
Age	41-78 (mean 62.1±9.3 years)
Recent Anterior Infarction	22
Previous PTCA with stent in the LAD	11
Previous CABG surgery	2
LAD Stenosis (70-99%)	84
Occlusion at the origin of LAD	7
Stenosis at the origin of a large 1st diagonal	3
Stenosis of the circumflex artery (60%)	1
Ejection fraction: E.F. ≥55%	48
E.F. 40-54%	34
E.F. 30-39%	7
E.F. 25%	2

PTCA: Percutaneous Transluminal Coronary Angioplasty, CABG: Coronary Artery Bypass Grafting, LAD: Left Anterior Descending Artery, EF: Ejection fraction.

Twelve patients had stenosis at the origin of the 1st diagonal branch: in nine of them the diagonal was a tiny vessel not needing revascularization while in three patients revascularization was required. One patient showed early bifurcation of the LAD immediately after the origin of the 1st diaphragmatic: the two LAD branches were on the interventricular septum, parallel in course and with a small distance between them (~1 cm). Wall lesions in other coronary vessels: A lesion in the left coronary artery stem (≤30%) was observed in 5 patients, while a lesion in the circumflex artery (≤40%) was observed in 15 patients. One patient had a non-critical lesion in the circumflex artery (≤60%). This patient was obese and suffered from chronic lung disease as well as moderate hepatic failure. Left ventricular function was normal (E.F. ≥55%) in 48 patients, impaired (E.F. 55-40%) in 34 patients, decreased (E.F. 30-40%) in 7 patients and significantly decreased (E.F. ~25%) in 2 patients (Table 1).

The indications for MIDCAB surgery were the following: a) high risk patients or patients with contraindications for percutaneous coronary angioplasty, b) patients with stent restenosis, c) patients who need a repeat coronary artery bypass grafting (CABG) with an occluded or stenosed venous graft in the LAD branch[2,3].

Contraindications for MIDCAB surgery: a) a small or calcified LAD, with an endomyocardial course, b) the coexistence of other cardiac diseases which require a concurrent surgical treatment (valve disease or left ventricular aneurysm), c) insufficient flow, diameter or length of the internal mammary artery (IMA) or stenosis of the subclavian artery[2,3].

Monitoring during the operation included continuous assessment of blood pressure, pulmonary artery pressure, heart rate and ECG. The first 6 patients required placement of a double-lumen tracheal tube while in the rest a single-lumen tracheal tube was used.

An 8-10 cm long inframammary incision was made at the 5th intercostal space. In cases where it was particularly difficult to access the LAD branch (8 patients), the existing incision was extended by 1-6 cm. In the last 28 patients the incision did not exceed 11 cm. Extensive adhesions of the left pleural cavity were found in 11 patients. In these patients it was necessary to partially remove these adhesions.

A special retractor was used to prepare the IMA (C.T.S. IMA Retractor). The IMA was fully prepared (at the height of the 1st costa until the 6th intercostal space) in 90 patients while in one patient it was destroyed and we were forced to use a midline sternotomy. Subsequently, heparin was administered (100-150 IU/Kg) and another special retractor was used to carry out the anastomosis (Access Platform; Cardiothoracic Systems Inc.) which was fitted with a special stabilizer (stabilizer, Cardiothoracic Systems Inc.). This special stabilizer exercises localized pressure bilaterally of the anastomotic site, thus immobilizing the heart at this site and facilitating the execution of a proper end-lateral anastomosis. Initially the anastomotic site of the LAD was bilaterally secured with two sutures 4-0 prolene placed distally (2 cm) and proximally (2 cm) of the anastomotic site (first 55 patients). In the last 36 patients, a single intraluminal shunt and blower were used. (A blower is a device for spraying a mixture of vapor and oxygen in order to achieve a bloodless anastomotic field). Anastomosis was performed using a continuous suture 7-0 or 8-0 prolene and after checking for leakages the stabilizer was removed, hemostasis was achieved, a drainage tube was placed, the wound was closed and the intubated patients were transferred to the ICU[5-7].

To control postoperative pain, during the operation the intercostal nerves were infiltrated with a solution of bupivacaine 5%, while morphine was administered intravenously during the first 24 hours postoperatively with concurrent regular administration of oral analgesic tablets. After the 4th postoperative day, the pain had been eliminated in almost all the patients. None of the patients who

were followed up (84/91) reported a chronic costal pain.

During the same period, 16 patients underwent revascularization of the LAD using the classic method (sternotomy and use of EC) for the following reasons: existence of lesion in a large diagonal branch which required revascularization in 9 patients, possible endomyocardial course of the LAD branch in 4 patients, very small LAD (< 1.4 mm) in 2 patients and acute ischemia of the anterior wall in one patient.

Results

The left IMA was fully prepared and used in 90 patients, while in one patient it was destroyed.

Four patients (4.39%) required conversion to midline sternotomy: in the first patient the left IMA was destroyed (the right IMA was used instead without EC), in the second patient the LAD had endomyocardial course (EC was used), the third patient had an anterior infarction during the operation with hemodynamic instability during the transfer phase to ICU (ischemic duration of the LAD branch was 43 min, EC was used and a venous graft was placed in the LAD and the left IMA in a small diagonal branch) and finally the fourth patient showed stenosis of the LAD in coronary angiography at the origin of a diagonal branch. (Preoperatively the length of the diagonal was underestimated. During surgery it was found that the diagonal was a large vessel and the attempt for anastomosis of both vessels with the IMA failed - sequential grafting. The right IMA was prepared via sternotomy and without EC revascularization of the 2 vessels was achieved using the two IMAs (Table 2).

Two patients suffered a perioperative infarction: the first patient died in the ICU after two days (1/91, 1.09%). The occlusion time of the LAD branch in this patient was 43 min. This patient preoperatively had unstable angina of recent onset and the LAD branch had a 70% lesion at the origin. Obviously there was not enough time for the patient to develop collateral circulation and the excessive duration of time during which the LAD branch remained occluded (43 min) led to anterior infarction. The second patient developed an acute anterior septal myocardial infarction in the 1st postoperative day, with an increase in the biochemical markers of ischemia, without hemodynamic instability. This is the same patient who showed an angiographic 90% stenosis in the initial portion of the LAD branch and

Table 2. Postoperative results.

Mortality		1/91 (1.09%)
Myocardial infarction		2/91 (2.18%)
Conversion to Midline Sternotomy		4/91 (4.36%)
IMA Anastomosis in 1st diagonal and LAD (sequential grafting)		2/91 (2.18%)
Supraventricular arrhythmias		12/91 (13.08%)
Pleural effusion		9/91 (9.81%)
Paresis of the Left Hemidiaphragm		2/91 (2.18%)
Wound Infection		2/91 (2.18%)
Angina	Immediately	1/91 (1.09%)
	Mid-term	1/91 (1.09%)
Postoperative coronary angiography	Anastomotic Stenosis	1
	Anastomotic Occlusion	1
	Normal Findings	7

IMA: Internal Mammary Artery,
LAD: Left Anterior Descending Artery.

an early LAD bifurcation immediately after the origin of the 1st diaphragmatic. The two branches (with a diameter of 1.3 and 1.4 mm) were on the interventricular septum, parallel in course and with a small distance between them (<1 cm). Only the larger branch was revascularized (1.4 mm). The IMA flow was good and the ischemia duration of the LAD branch was 15 min. Postoperatively, this patient is asymptomatic and has no clinical symptoms. The repeated maximum stress tests, two years after the operation, were negative (Table 2).

Both patients with above-mentioned aorto-coronary bypass and the occluded venous graft of the LAD were successfully treated with the MIDCAB technique.

Finally, in two patients in whom the proximal LAD lesion included the origin of a large diagonal branch, it was possible to revascularize both coronary vessels with the left IMA-sequential grafting (Table 2).

The duration of the full IMA preparation ranged from 12-76 min (mean 20±3 min), the duration of LAD ischemia, excluding the patient who died, was 14-24 min (mean 17±5 min) and the duration of the operation was 90-180 min (mean 101±18 min). In the last 30 patients, the duration of IMA preparation was less than 20 min, the duration of anastomosis was 14-17 min and the total operation time did not exceed 90 min. During the IMA occlusion period, 7 patients had transient ECG ischemic changes (ST elevation) without hemodynamic instability. These changes were eliminated after the restoration of blood flow in the LAD branch.

Postoperatively the biochemical ischemic control (CPK, CK· MB, T-troponin) was normal in 89 patients. Total postoperative hemorrhage ranged from 390 ml to 600 ml (mean 500±63 ml). It was not necessary to administer homologous blood in any of the patients.

In all the patients, except one, intubation was removed in the ICU within the first 6 hours. One patient, due to operative atelectasis and infection, remained intubated for 2 days.

The duration of stay in the ICU ranged from 24 to 93 hours (mean 29±4 hours) while the postoperative stay in the department was 4-6 days (mean 5.7 days).

One patient with an occluded LAD and a history of unstable angina in the last month before the operation suffered from unstable angina events, starting on the 6th postoperative day accompanied by ECG changes (ST depression in the precordial leads). A new angiography showed a 60% anastomotic stenosis, with adequate diameter of the left IMA graft and sufficient flow of the LAD (proximally and distally of the anastomosis). The angiographic stenosis was attributed to oedema or spasm, thus it was decided to administer calcium channel blockers (nifedipine and diltiazem). Indeed this treatment proved successful and after 18 months the patient is asymptomatic, with a negative stress test and without residual ischemia in the cardiac scintigraphy.

Other minor postoperative complications: supraventricular arrhythmias in 12 patients, pleural effusion in 9, paresis of the left hemidiaphragm in 2, superficial wound infection in 2 and pneumonia in 1 patient. Most of these complications concern the first 60 patients (learning curve of the technique).

Postoperative, long-term follow-up was possible in the majority of patients (84 of 91) for a time period of 3-51 months (mean 25±7 months): one patient developed angina 6 months after the operation, angiography showed an anastomotic occlusion of the IMA which was successfully treated with PTCA and another patient with a previous anterior infarction and a low ejection fraction (E.F. ~30%) was hospitalized a few days after her initial discharge from the department due to heart failure and atrial fibrillation, without ischemia. Since then, this patient is asymptomatic.

Eight patients underwent coronary angiography after hospital discharge. The indication for cardiac catheterization was precordial discomfort with non-specific ECG changes in a period of 6 months - 3 years after the operation. Except for the patient with the anastomotic occlusion of the IMA, in the remaining seven patients, the IMA graft had adequate diameter with patent distal anastomosis and the LAD had sufficient flow (proximally and distally of the anastomosis), (Table 2).

Discussion

Percutaneous transluminal coronary angioplasty (PTCA) with stent implantation is considered the treatment of choice for single proximal stenosis of the left anterior descending (LAD) artery. This method of therapy is widely accepted by patients because of its good results and the fact that it is minimally invasive resulting in a short in-hospital stay and a quick recovery. However, PTCA is accompanied by a relatively high percent of restenosis and consequently a need for new revascularization[8].

The principal causes of postoperative morbidity after a classic aorto-coronary bypass is the use of EC and sternotomy. In a beating heart surgery, all the complications related to use of EC, mediastinitis and unstable sternum can be avoided. The MIDCAB technique was developed with the aim to reduce the surgical wound and at the same time retain the excellent long-term results that derive from use of IMA[10-13].

The most difficult phase of the MIDCAB method is the full preparation of the IMA either thoracoscopically or under direct vision via the limited thoracotomy. The IMA should be fully prepared (from its entry point in the thoracic cavity until its bifurcation) so that it reaches the anastomotic site without tension[5,6,7]. In our patient population, the IMA was fully prepared under direct vision in 90 patients.

A prerequisite to achieve complete anastomosis with beating heart surgery is the local immobilization of the vessel to be anastomozed and the maintenance of a bloodless surgical field. During the early period of aorto-coronary bypass without EC, aside from the local immobilization (1st generation stabilizers) and the presence of a bloodless anastomotic site (two securing sutures), it was also necessary to decrease blood pressure (90-10 mm Hg) and pulses (60-70/min). In the last three years the emergence of a new generation of stabilizers (combination of local pressure and suction), intraluminal shunts (maintenance of the peripheral flow throughout the anastomotic process), devices for spraying a mixture of

vapor-oxygen or even carbon dioxide (blower) as well as the acquisition of adequate surgical experience have greatly contributed to the ability to perform more difficult but also better anastomotic procedures, at the same time avoiding the occurrence of ischemia and maintaining a good hemodynamic status[5-7,14-16].

The myocardial tolerance in ischemia depends on several factors: the location of LAD (proximal or distal) where the blood flow is interrupted, the myocardial mass that is supplied by the vessel (hypertrophy), the duration of ischemia, the degree of proximal stenosis (>75%), the existence of collateral circulation, the decrease of O_2 consumption (administration of clonidine, diltiazem, adenosine and beta-blockers), the use of intraluminal shunts and finally the ischemic preconditioning (increase of myocardial tolerance to infarction)[15-19]. Collateral coronary circulation also plays an important role in ischemic tolerance. The more critical (>80%) and chronic the proximal lesion is, the better the temporary interruption of coronary flow is tolerated[8,9].

The most important phase of the MIDCAB technique is the anastomosis of the IMA to the LAD branch. Extreme caution and a lot of experience is required to perform a complete anastomosis since the target is moving and access is limited.

In the initial period of MIDCAB interventions (1995-1997), the inability to complete revascularization with this technique and the conversion to midline sternotomy were relatively frequent (V. Subramanian: 7%, A. Calafiore: 5,7%). However, with the development of proper tools (stabilizer, shunt, blower) as well as outrunning the learning curve of the technique, the need to convert to midline sternotomy has been limited to 2-3%[2,3]. Out of our first 60 patients, we had to convert to midline sternotomy only in 4 cases.

The results of the IMAGE trial, the largest (645 patients) angiographic examination (within 90 days) of patients who underwent classic CABG surgery (sternotomy, EC usage) and had a IMA anastomosis of the LAD branch, include the following findings: left IMA with good patency (<50% stenosis with normal orthodromic flow) in 584 patients (91%), left IMA stenosis >50% in 50 patients (7.8%), left IMA occlusion in 8 patients (1.2%) and in 3 patients the angiographic findings were inadequate to estimate the patency of the left IMA. In conclusion, the trial reported that the left IMA direct patency was >98% when the anastomosis took place in the LAD branch, while a >50% stenosis was observed in 7.8% of patients[33]. Consequently, even with the classic surgical revascularization method a small percentage of anastomotic complications is inevitable.

Regarding the angiographic patency of the MIDCAB method it is worth mentioning the following: initially this ranged between 85-89% while in the last three years it is ≥95,6%. The anastomotic complications are caused by technical errors, oedema, intramural IMA hematoma, resulting in stenosis or thrombosis of the anastomosis[2,3,20-23,27].

The MIDCAB method clearly reduces operative trauma (avoidance of sternotomy and EC), the need for homologous blood administration, the duration of stay in the ICU, the overall hospitalization period, the surgery cost and it facilitates a faster patient rehabilitation in their social and work environment[22,23,25,26,28-32].

Provided a proper patient screening takes place (anatomy and morphology of the LAD branch), the need for conversion to midline sternotomy is 2-3%, a possibility the patients should of course be informed of, before the operation. The mid-term angiographic patency (6 months) is the same as the angiographic patency of the classic aorto-coronary bypass[20-24].

The first randomized studies of the MIDCAB technique in comparison to PTCA stenting concur that even though there are more minor perioperative complications with MIDCAB, in the mid-term the need for a new revascularization is clearly higher after PTCA[21,24].

In conclusion, it can be said that the MIDCAB technique is a "localized treatment of a localized problem". Although it presents technical difficulties, the frequency and severity of postoperative complications is associated with the learning curve of the technique. It is considered the least invasive surgical technique and in many centers it is the treatment of choice for the surgical revascularization of the LAD branch.

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