

Ministernotomy in Myocardial Revascularization Without Cardiopulmonary Bypass: Technical Aspects and Early Results

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Giovanni Troise, MD¹, Federico Brunelli, MD¹, Marco Cirillo, MD¹, Zen Mhagna, MD¹, Giordano Tasca, MD¹, Bruno Amari, MD², Gian Battista Danzi, MD³, Eugenio Quaini, MD¹

¹Department of Cardiac Surgery, ²Department of Cardiac Anaesthesia, and ³Catheterization Laboratory, Poliambulanza Hospital, Brescia, Italy

ABSTRACT

Objective: This study attempts to evaluate the feasibility of ministernotomy in beating heart coronary surgery, with special emphasis on technical aspects.

Methods: From September 1997 to September 1999, 137 patients were scheduled for off-pump coronary surgery in our institution. In 61 cases requiring revascularization of the left anterior descending artery (LAD) and right coronary artery (RCA) systems, the approach was either a reversed "L-shaped" ministernotomy (56 patients) or a "T-shaped" ministernotomy (five patients). Mean age of the ministernotomy patients was 64 ± 10 years, and 17 of the patients were female. The mean left ventricular ejection fraction (LVEF) was $60 \pm 11\%$ ($<35\%$ in four patients), and 32 patients (52.5%) had one-vessel disease while 29 (47.5%) had 2-vessel or 3-vessel diseases. There were seven (11.4%) urgent procedures. For these procedures, we used devices that we designed ourselves for sternal retraction and coronary stabilization.

Results: Five patients (8.2%) needed conversion to another method due to hemodynamic instability or ischemia, while 56 of the patients completed the procedure. Fifty-one patients (91.1%) had a single graft on the LAD, four (7.1%) had a double graft on the LAD and the right or diagonal coronary artery, and one (1.8%) had a triple graft on the LAD and two diagonal branches. Mean coronary occlusion times and operative times were 12.1 ± 2.7 and 152 ± 33 minutes, respectively. Mean creatine kinase value was 29.8 ± 24.6 . One patient died of acute myocardial infarction, and one patient had temporary acute renal failure. Mean in-hospital stay was 5.2 ± 1.9 days. Of the 18 patients (32.1%) who had postoperative angiographic control (range of 1 to 13 months), 17 showed patent anastomoses, and one required percutaneous transluminal coronary angioplasty (PTCA) of the anastomosis on the LAD. Mean follow-up time for all patients

was 10.8 ± 6.4 months. Freedom from any kind of repeat procedure was 98.2%.

Conclusion: Ministernotomy is a safe approach for patients not requiring grafts on the circumflex system. The possibility of multiple grafting and the easy conversion to a conventional surgical method make ministernotomy a preferable approach for minimally invasive coronary surgery.

INTRODUCTION

Beating-heart coronary surgery was pioneered many years ago [Kolessov 1967] but was later almost abandoned with the introduction of extracorporeal circulation and myocardial protection techniques. In recent years there has been a renewed interest in off-pump revascularization, especially because of increasing awareness of the advantages of less invasive surgery. A major aim of beating heart surgery is the avoidance of cardiopulmonary bypass (CPB). Avoiding CPB has been shown to reduce hospitalization time and costs [Benetti 1991, Buffolo 1996]. Another goal of less invasive surgery is a smaller surgical incision, which results in more rapid postoperative recovery and improved cosmetic results.

In September 1997, we instituted a minimally invasive cardiac surgery program at our institution that included beating-heart revascularization. For procedures in which a small incision was indicated, we performed a ministernotomy. This report describes the early clinical results of our first 61 patients operated on with this approach and examines some technical considerations.

MATERIALS AND METHODS

Patients Population and Indications

From September 1997 to September 1999, 710 patients underwent isolated coronary artery bypass grafting (CABG) at our institution. Of these patients, 137 (19.2%) were scheduled for coronary surgery without CPB. All patients granted informed consent to the proposed procedure. Indications for off-pump surgery derived from (1) contraindications to CPB (unapproachable arterial cannulation sites, malignancy, severe respiratory failure), (2) increased risk resulting from CPB (age >75 years, renal failure, severe diffuse arteriopathy, organ dysfunction), and (3) our study protocol.

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Address correspondence and reprint requests to: Giovanni Troise, Casa di Cura Poliambulanza, Via Bissolati, 57, 25124 - Brescia, Italy, Phone: +39 030 3515534, Fax: +39 030 3515244, Email: quaini@gynet.it

Table 1. Clinical Characteristics of Patients

Age (yr)	64.6 ± 9.7 (42-79)
Gender (M/F)	44/17
Previous AMI	28 (45.9%)
Previous PTCA	12 (19.6%)
Unstable angina	12 (19.6%)
Parsonnet score	3.8 ± 3.2 (1-12)
Age ≥ 75 yr	11 (18.1%)
Diffuse vasculopathy	8 (13.1%)
Malignancy	5 (8.1%)
Renal failure	3 (4.9%)
Encephalopathy	2 (3.2%)
Tracheostomy	2 (3.2%)
Untouchable aorta	2 (3.2%)
Coagulation disorders	1 (1.6%)
One-vessel disease	32 (52.5%)
Multiple-system disease	29 (47.5%)
EF (%)	60 ± 11 (32-81)
EF <35%	4 (6.5)

EF = ejection fraction; AMI = acute myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty.

In 61 patients (44.5%), off-pump revascularization was performed through a ministernotomy. Angiographic indications for ministernotomy were (1) isolated lesion of the left anterior descending artery (LAD) with or without disease of the diagonal branch (2) multiple-vessel disease with indications to graft the LAD with or without a graft to the diagonal branch (3) coronary anatomy suitable for grafts on the LAD and right coronary artery (RCA) systems. Clinical characteristics of this group are described in Table 1 (●).

Anesthesia Management

The anesthetic protocol is intended to achieve a “fast track” recovery and is composed of the following details:

1. General anaesthesia with orotracheal or nasotracheal intubation;
2. Induction with midazolam 0.2 mg/Kg and pancuronium bromide 0.1 mg/Kg;
3. Remifentanyl 3 mg/Kg bolus in two minutes and continuous infusion 0.05-0.1 µ/Kg/min in combination with propofol;
4. Maintenance of mean arterial pressure ≥ 80 mmHg by volume filling and low dose of vasopressive drugs;
5. No drugs used to reduce heart rate because of the mechanical coronary stabilization; and
6. Early extubation, clinical conditions permitting.

Surgical Instrumentation

A miniaturized Bugge retractor (Romed, Antwerp, Belgium) was used for mammary artery harvesting.

A coronary compression stabilizer, designed by us (Figure 1a, ●), was used to make the anastomotic site as stable as possible. The instrument's feet, about 5 cm long, have a cylindrical section and a slight curvature with a superior concavity, and are

normally covered with rubber. The length of the feet allows a distribution of compressive force on a larger myocardial area. The feet are connected by a small screw to a supporting arm that makes it possible to move to several different positions.

A sternal retractor, also designed by us (Figure 1b, ●), was created exclusively for off-pump surgery through ministernotomy. There is a sliding supporting bar that runs along two cylindrical lines mounted on the superior side of the retractor. The coronary stabilizer is connected to the supporting bar of the retractor by means of an articulated screw.

Surgical Technique

The surgery begins with the identification of two points that are marked on the skin corresponding to the second intercostal space and the xiphoid cartilage. An 8-10 cm. longitudinal median skin incision is made between the two points (Figure 2, ●). A partial left reversed “L” sternotomy from the second intercostal space to the xiphoid cartilage (Figure 3a, ●), or a “T” sternotomy (Figure 3b, ●) to approach the right coronary artery and/or the ascending aorta, is then performed. The left internal mammary artery

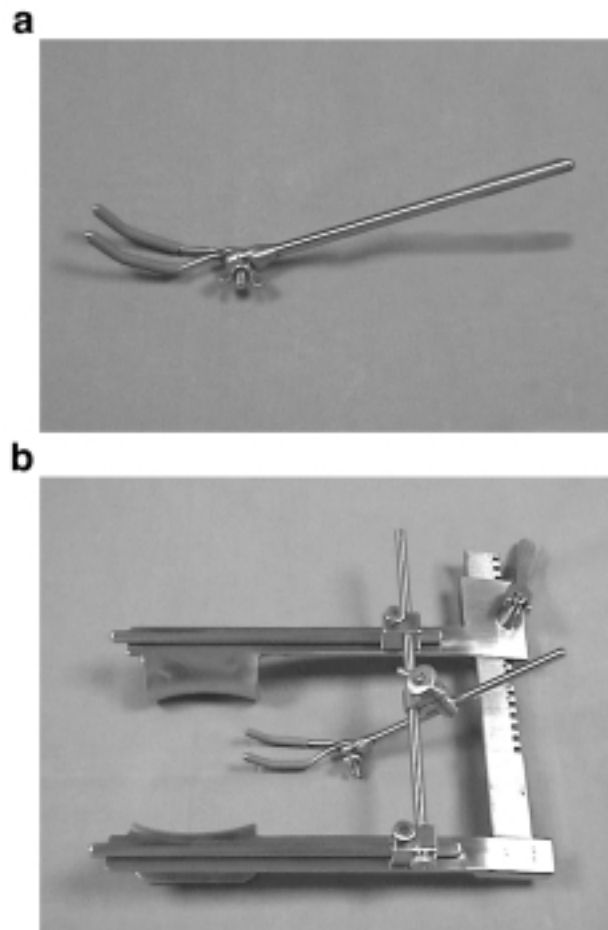


Figure 1. Coronary stabilizer (a); retractor for off-pump surgery via ministernotomy (b).

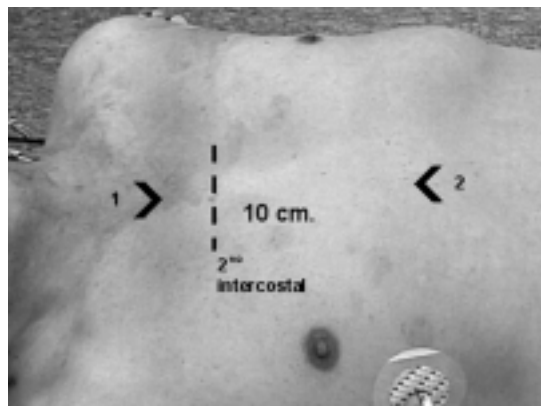


Figure 2. Skin mark points and incision (1 = sternal top; 2 = xiphoid cartilage).

(LIMA) is harvested from its distal bifurcation to the first intercostal space. Heparin is administered (1 mg/Kg), and the distal LIMA is sectioned and clipped. After median longitudinal pericardiotomy, the LAD is exposed by means of one or two pericardial retraction stitches passed 2 cm anteriorly to the phrenic nerve. Pulling these stitches displaces the anterior wall of the left ventricle and consequently the LAD toward the median line. Coronary stabilization is obtained by pushing down the feet of the stabilizer parallel to the coronary artery and connecting it to the support of the retractor.

A bloodless field was obtained at the site of the anastomosis using different methods as follows: (1) for the first 39 patients (from September 1997 to October 1998), coronary proximal occlusion was obtained with a 4-0 polypropylene suture (Prolene, Ethicon, Inc., Somerville, NJ) passed deeply to surround the vessel; (2) for 12 patients (from November 1998 to April 1999) an intracoronary occluder (Flowrester, Bio-Vascular, Inc.) was used; and (3) for the last 10 patients (from May 1999 to September 1999), an intravascular shunt (AnastaFLO, Research Medical, Inc.) was used.

The coronary anastomosis was completed with an 8-0 polypropylene running suture, heparin was reversed with protamine (1/1), and a single subxiphoidal pleuro-mediastinal drain was inserted.

Follow-up

All survivors were interviewed in our outpatient clinic three months after discharge and are periodically followed up by telephone interview. Each patient has undergone at least one postoperative stress test. The 100% complete clinical follow-up ranges from 1 to 23 months (mean of 10.8 ± 6.4 months).

In addition to the interviews and stress tests, we began a program of elective angiographic control one year postoperatively; 18 patients have been controlled so far.

RESULTS

Among the 61 patients scheduled for ministernotomy, 56 had a reversed "L" and five a "T" shaped sternal incision.

For 56 patients the procedure was performed as scheduled, but in five cases (8.2%) the planned surgical procedure was not completed and had to be modified. For one patient who experienced ventricular fibrillation, CPB was established (right atrium and aortic cannulation), and the beating-heart LIMA-LAD anastomosis was completed without converting from ministernotomy. In another case, one patient was converted to total sternotomy and underwent off-pump double grafts because a high diagonal branch could not be exposed. Finally, in three cases the patients were converted to total sternotomy with CPB and cardioplegic arrest. The reason for converting two of these three patients, who had been scheduled for two-vessel revascularization, was ischemia and hemodynamic instability due to exposure of the posterior descending branch. The third instance, involving a patient with three-vessel disease scheduled for LIMA-LAD anastomosis, was a result of ischemia with consequent hemodynamic instability requiring complete revascularization.

Mean coronary occlusion time was 12.1 ± 2.7 minutes (range of 8-18 min), excluding patients treated by using an intra-arterial shunt, for whom the real occlusion time lasted only a few seconds. Mean operation time was 152 ± 33 minutes (range of 105-240 min).

All patients had a LIMA-LAD anastomosis. Four patients had double grafts (two on the LAD and RCA and two on the LAD and diagonal branch), and one patient had a triple graft (LAD and sequential vein on two diagonal branches). All the additional conduits (two radial arteries and three saphenous veins) were anastomosed on the proximal ascending aorta through a "T" shaped ministernotomy.

A 66-year-old man with a history of recent myocardial infarction (MI) consequent to intra-stent occlusion of the LAD and poor left ventricular function (LVEF = 30%) died seven hours after a triple graft (LIMA on the LAD and sequential vein graft on two diagonal branches) because of sudden untreatable arrhythmia, accounting for a mortality rate of 1.6%. One patient had temporary acute renal failure, which was successfully treated with continuous ultrafiltration for 48 hours.

The postoperative level of CK-MB isoenzyme ranged from 11 to 137 U/l, with a mean value of 29.8 ± 24.6 U/l. Mean intubation time was 6.5 ± 3 hours (range of 0-17 hours),

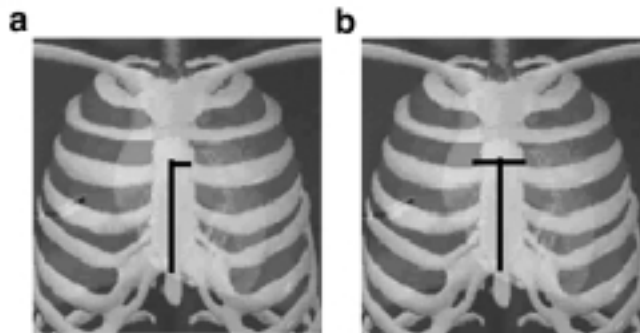


Figure 3. Partial left reversed "L"-shaped sternotomy (a); partial "T"-shaped sternotomy (b).

Table 2. Summary of Immediate Results

	Mean	Range	nr.	%
Coronary occlusion time (min)	12.1 ± 2.7	8-18		
Surgical time (min)	152 ± 33	105-240		
Intubation time (h)	6.5 ± 3	0-17		
CK peak (IU)	663.9 ± 585.9	146-3352		
CK-MB peak (IU)	29.8 ± 24.6	11-137		
Perioperative AMI			1	1.6
Bleeding (ml/24 hr)	362.6 ± 197.6	100-1200		
Blood transfusion			4	6.5
Redo for bleeding			1	1.6
Intensive care LOS (days)	1.5 ± 1.6	1-11		
Total LOS (days)	5.2 ± 1.9	3-18		
Hospital mortality			1	1.6

SD = standard deviation; CK = creatine phosphokinase; CK-MB = MB fraction of creatine phosphokinase; AMI = acute myocardial infarction; LOS = length of stay.

and mean length of ICU stay was 1.5 days. Mean hospital stay was 5.2 ± 1.9 days (range of 3-18 days).

One of the patients who experienced conversion to total sternotomy, CPB, and cardioplegic arrest had a perioperative postero-lateral myocardial infarction. Four patients (6.5%) required blood transfusion.

Eighteen patients (32.1%) underwent postoperative angiographic control 7 days to 13 months after the surgical procedure; one of these was for recurrence of angina and the remaining 17 were for elective control. All but one distal anastomosis was widely patent, and a successful PTCA was performed on a 60% stenotic anastomosis. The remaining patients are currently asymptomatic, with no demonstration of stress-induced myocardial ischemia. No late death has been recorded so far.

A summary of results is shown in Table 2 (●).

DISCUSSION

The conception of “less invasiveness” in coronary surgery is based on avoidance of CPB and, at the same time, reducing surgical trauma by working through a smaller and less painful incision. Increasing worldwide interest in minimally invasive CABG is the result of several potential advantages. First, it offers the possibility of a surgical solution for patients for whom medical treatment would be ineffective, for those who do not have indications for other kinds of revascularization, and for those who have contraindications to CPB. Second, it may reduce surgical risk in patients with severely compromised clinical conditions, as reported by other authors [Moshkovitz 1995]. Third, it offers promise of reducing the inflammatory response caused by CPB and its consequent organic damage to the lungs, kidneys, and nervous system. Although these lesions are generally well tolerated, they can increase morbidity in the elderly and when they occur in conjunction with particular pathological conditions [Gardner 1985, Higgins 1997]. Finally, minimally invasive CABG has become more attractive due to improvements in surgical

techniques resulting primarily from the development of several coronary stabilization devices [Subramanian 1997, Jansen 1998].

The above observations persuaded us to move towards increasing the number of “off-pump” procedures at our institution. In about 20% of patients scheduled for isolated myocardial revascularization, we performed the operation without CPB. The frequency of these procedures rose from 16.7% in the first year of our activity to almost 30% in the last few months. This is partly due to the extension of “beating heart” techniques to candidates for multiple-vessel revascularization through the use of “Lima stitches,” which are four deep, pericardial retraction sutures passed in the mobile posterior pericardium (Ricardo Lima, personal communication).

For patients with an indication for a single graft on the LAD, some different approaches have been proposed to further decrease invasiveness. The most popular is the “LAST operation” (left anterior small thoracotomy) [Calafiore 1998], by which the left internal mammary artery is harvested and anastomosed to the LAD through a small incision in the left fourth or fifth intercostal space. However, at our institution we prefer a low ministernotomy, which has already been proposed by others either for coronary surgery [Arom 1996] or for other cardiac operations [Walterbusch 1998]. As in Moreno-Cabral’s experience [Moreno-Cabral 1997], the first patient for whom we used this approach had a permanent tracheostomy and needed revascularization of the LAD.

Our incision, which was in most cases a reversed “L”-shaped ministernotomy (Figure 3a, ●), has some advantages over a lateral incision. First, it permits expeditious takedown of the LIMA up to the first rib in the usual fashion, either as a pedicled or skeletonized conduit. The miniaturized “Bugge” mammary artery retractor, which we employed for these kinds of operations, is the ideal instrument for pulling up the left side of the sternum, giving a clear exposure of the LIMA. We never had to elongate the LIMA with other conduits, which is sometimes necessary in the LAST operation [Calafiore 1997].

Moreover, by lifting the pericardium, it is possible to expose almost the entire course of the LAD with its diagonal branches. This is noteworthy because a number of our patients had been excluded for PTCA because of previous unsuccessful percutaneous procedures (12 cases) or unsuitable anatomy (small vessel, multiple stenosis, intra-myocardial course of the artery). Although these situations are considered contraindications by some surgeons [Calafiore 1998], we were able to accomplish the “off-pump” anastomosis of LIMA to LAD and, in some cases, of other conduits (radial artery or saphenous vein) to one or two diagonals.

In five cases, by extending the transverse sternal incision at the level of the second intercostal space and transforming the “reversed L” to a “T”-shaped ministernotomy (Figure 3b, ●), we gained a more comfortable access to the RCA, proximal ascending aorta, and right atrium. In this way it was possible to perform bypasses on the principal RCA, anastomose the proximal ascending aorta, and initiate standard cannulation for CPB establishment. In four patients who experienced

hemodynamic instability consequent to ischemia (one case), difficult exposure of the posterior descending branch (two cases), or a high diagonal branch (one case), the ministernotomy was rapidly transformed to conventional total sternotomy. The procedure was completed off-pump for one of these patients, and CPB was established for the other three patients. In our experience, we found it difficult to expose the posterior descending branch through the small incision because of the vessel's deep position, while it was easy to approach the RCA.

Our incidence of perioperative acute MI was very low, considering the high incidence of patients (47.5%) with double-vessel or triple-vessel disease. It consisted of one patient with 3-vessel disease, who was scheduled for a LIMA-LAD graft and was converted to complete revascularization on CPB with cardioplegic arrest.

We wish to emphasize the importance of appropriate instruments in our experience. The peculiar characteristics of our stabilizer (feet with cylindrical section and curvature with superior concavity) (Figure 1a, ) minimize the myocardial trauma due to mechanical compression or suction caused by other devices [Subramanian 1997, Jansen 1998]. Another characteristic of the instrument's feet is that they are covered with rubber for better adherence to the heart. With these features, we were able to obtain excellent heart stabilization.

The sternal retractor (Figure 1b, ) also designed by us, is equipped with a sliding support for the coronary stabilizer. The internal part of the instrument is small enough to adapt itself to the partial sternotomy, but the external overall size is large enough to avoid any interference with the surgeon's movements, and is rather strong to overcome, in the "L" incision, the resistance due to the integrity of the right emisternum.

In accordance with our objective of reducing costs, we decided to avoid as much as possible the use of disposable instrumentation. The stabilizer can be used in all "off-pump" cases performed through a standard sternotomy for which the device is adapted to the Cosgrove's self-retaining mitral surgery retractor (Kapp Surgical, Inc., Cleveland, OH).

CONCLUSION

We believe that ministernotomy results in a less painful incision. Therefore, a partial sternotomy, when possible, can only increase the patient's benefit in terms of either pain reduction or better respiratory function.

Our early results have been good and are comparable to other similar experiences [Subramanian 1995, Subramanian 1997, Calafiore 1998, Possati 1998]. Although our results are only comparable and not clearly superior, the possibility of multiple grafting on the right and diagonal arteries with the support of dedicated surgical instrumentation, and the ease of

conversion to conventional surgery, make ministernotomy preferable to the antero-lateral approach.

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