Minimally invasive coronary artery bypass grafting without cardiopulmonary bypass

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Abstract

To determine the feasibility and the effectiveness of minimally invasive direct coronary artery bypass without cardiopulmonary bypass (MICABG) in patients with left anterior descending (LAD) coronary artery disease, we evaluated 90 consecutive patients who underwent MICABG at the University Hospital of Groningen. Patients: Between January 1995 and December 1996, 50 patients (mean age 60 ± 10.3 years) with documented myocardial ischemia and isolated stenosis of the LAD were selected for MICABG. Patients with any associated cardiac disease or with acute or evolving myocardial infarction were excluded. Methods: A small left antero-lateral thoracotomy in the 5th intercostal space was made in all patients, anastomosing the left internal mammary artery (LIMA) to the LAD. A short-term (3 days) postoperative rehabilitation programme was used. Emotional stress (STAY-DY-1 score), wound pain (VAS: visual analogue score) and O₂-saturation after a 6 min walking test were measured during hospitalisation and at the first follow-up examination (2.5 week after discharge). Results: Mean operative time was 92 ± 25 min (range 60–170). We recorded 1 (1.1%) in-hospital death and three cases (3.3%) of perioperative myocardial infarction. In two cases the MICABG was converted to the midline sternotomy. One patient underwent urgent reoperation on postoperative day 1 via midline sternotomy. Mean hospital stay was 4.4 ± 2 days. Emotional stress was significantly reduced during and after hospitalisation, compared with the admission day. Wound pain was mild (3.5/10 VAS) on postoperative day 1 and reduced significantly during hospitalisation and at first follow-up examination. O₂-saturation after a 6 min walking test had significantly improved at the first follow-up examination. Conclusion: These results indicate that MICABG is feasible and effective in patients with LAD stenosis and leads to a fast psycho-physical recovery. © 1997 Elsevier Science B.V.

Keywords: Coronary artery bypass surgery; Cardiopulmonary bypass; Minimally invasive direct coronary artery bypass surgery; Antero-lateral thoracotomy; Internal mammary artery

1. Introduction

Patients with isolated stenosis of the LAD can be treated either with percutaneous transluminal coronary angioplasty (PTCA) or with coronary artery bypass grafting (CABG) [22]. Current research is focused on reducing the rate of morbidity and mortality of CABG and improving psycho-physical recovery of patients [11]. One method is to avoid the use of cardiopulmonary bypass (CPB) [1,4,8,16,19–21,28,29], because this is associated with an intrinsic risk of morbidity and mortality [11,17]. Another method is to minimise the surgical incision [25,27] which may improve recovery. The minimally invasive coronary artery bypass grafting (MICABG) [3,5,24] is a radically new method for myocardial revascularisation that combines the advantages...
of both methods mentioned above. MICABG avoids CPB and is performed through a small antero-lateral thoracotomy. However, potential risks and benefits of this new technique are still unclear.

The aim of this retrospective study was to determine the feasibility and the effectiveness of MICABG in patients with isolated stenosis of the LAD. For this purpose, in-hospital morbidity and mortality were evaluated. In addition, psycho-physical recovery was assessed by measuring emotional stress, pain, and O2-saturation after a 6 min walking test.

2. Patients and methods

2.1. Study design

To determine the feasibility and the effectiveness of MICABG, we evaluated the clinical results 90 consecutive patients with isolated stenosis of the LAD who underwent MICABG at the University Hospital of Groningen from January 1995 until March 1996. We assessed MICABG feasibility by evaluating in-hospital morbidity and mortality, and MICABG effectiveness by evaluating psycho-physical recovery (emotional stress, pain and O2-saturation after a 6 min walking test) during hospital stay and at the first follow-up examination.

2.2. Patient population

Patients, 90 (mean age 60±10.3 years; range 31–84) with isolated stenosis of the LAD were selected for MICABG without CPB. The male/female ratio was 71/19. Among them, 79 were primary MICABG and 11 were redo-MICABG. Mean ejection fraction (EF) was 52±11% (range 20–83%). Eight patients had left ventricular dysfunction (EF < 35%).

Clinical status was assessed by means of the Canadian Cardiovascular Society (CCS): 11 patients were in CCS class II, 65 in CCS class III and 14 in CCS class IV. Standard clinical, electrocardiographical and perfusion study criteria were used to define myocardial ischemia. Exercise tolerance was tested with the Bruce protocol. Coronary risk factors were: diabetes in 12 patients, hypertension in 24, hypercholesterolemia in 40 and smoking in 29.

2.3. Indication for surgery

The decision to perform MICABG was made after evaluation of coronary angiography and clinical history.

2.3.1. Inclusion criteria

Patients with isolated stenosis of the LAD and good run-off, either considered at risk for PTCA or with previous PTCA, were selected for the primary MICABG. Patients with previous CABG procedures were selected for redo-MICABG when the left internal mammary artery (LIMA) had not been used at the first coronary operation.

2.3.2. Exclusion criteria

Were the presence of any associated cardiac disease requiring surgical treatment with the use of CPB (e.g. left ventricular aneurysm or valvular disease), acute (within 48 h) or evolving myocardial infarction.

2.4. Surgical technique

A double-lumen endotracheal tube was used. The patient was positioned supine and a small rubber cushion (10 cm thick) was placed underneath the left scapula. The left arm elevated above the head. A skin incision of approximately 8–10 cm was made at the level of the 5th intercostal space, with the medial edge of the incision being approximately 4 cm lateral to the LIMA. According to the technical protocol initially used [3,5], on the first 14 patients the incision was made slightly more toward the midline and a rigid video-thoracoscope was inserted laterally to the skin incision in order to harvest the LIMA. After the 14th patient the technique was changed and we performed the skin incision as described above. Changing the site of the incision permitted a better exposure of the LIMA, more similar to the view normally obtained via the conventional midline sternotomy, thus avoiding the use of the video-thoracoscope. At the same time we developed a self-constructed asymmetric rib-spreader (Fig. 1), directly derived from the midline sternotomy LIMA spreader, that consistently improved the exposure of Fig. 1. The photograph shows the self-constructed rib spreader, derived from the internal mammary artery spreader used for mammary harvesting via midline sternotomy.
the LIMA. In the last 65 patients specially developed instruments became available: a new wound spreader (IMA Retractor, CardioThoracic Systems, Cupertino, CA) developed for LIMA harvesting, and a coronary stabiliser (Access Platform and Stabilizer, CardioThoracic Systems, Fig. 2) which contributed substantially to the development of the technique.

Once the pleural cavity had been opened, the left lung was deflated and the LIMA was identified by palpation. In order to identify the target coronary artery and to find a proper site for the anastomosis, the pericardium was opened after the overlying pericardial fat was dissected.

The wound spreader was secured in place and opened. The LIMA was harvested as a pedicle from the 1st rib down to the 7th rib, starting at the level of the skin incision. The distal part of the LIMA pedicle was visualised by twisting the spreader.

After the LIMA was harvested, a half-dose of heparin was given (150 IU/kg) and the mammary pedicle was divided. The LAD was surrounded by two looping 5–0 polypropylene sutures, proximal and distal to the chosen site for the anastomosis. In order to test the tolerance to regional ischemia the LAD was briefly occluded by means of the two looping sutures before opening. Then the LAD was opened longitudinally, the two looping sutures were pulled up until an adequate hemostasis was provided, and the mammary-to-coronary anastomosis was performed with a running 7-0 or 8-0 polypropylene suture. After the anastomosis was completed, the two looping sutures were cut. To avoid kinking, the LIMA was secured in place by means of two or three 5-0 polypropylene stitches, and the anastomosis was covered with the flap of pericardial fat. The small thoracotomy wound was closed in layers and one pleural drain was left in place.

2.5. Post operative clinical rehabilitation

A short-term (3 days) postoperative rehabilitation programme was used. This programme entailed:

Day 1:
- a.m.: Pulmonary physiotherapy
- p.m.: Mobilisation out of bed

Day 2:
- a.m.: General exercises
- p.m.: Walking exercises on the ward

Day 3:
- a.m.: Stair climbing up and down (one floor)
- p.m.: Cycling on a bicycle ergometer

Emotional stress was measured using the validated Dutch version of the Spielberger State-Trait Anxiety Inventory DY-1 (STAI-DY-1) [6,26]. The STAI-DY-1 contains 20 statements related to feelings of stress. For each statement the patient can indicate whether he or she agrees with that statement at the moment of the test using a four point Likert scale. The minimal score is 20 and the max score is 80. A high score reflects greater feelings of stress. In a population group of people older than 41 mean STAI-DY-1 score is 36.6 ± 12.3 for men and 39.8 ± 13.7 for women. Emotional stress was assessed on the day of arrival in the hospital before the operation, on the day of discharge, and 2.5 weeks after discharge.

Pain was assessed using a 10 cm Visual Analogue Scale (VAS) ranging from no pain at all to maximal pain [23]. Pain was measured in the hospital the first 3 postoperative days (day 1, day 2, day 3) before starting the rehabilitation programme, and 2.5 weeks after discharge.

O₂-saturation after a 6 min walking test was assessed at discharge and at the first follow-up examination using a pulse-oxymeter. These values were then compared with the baseline values, measured at rest (before the 6 min walking test).

2.6. Statistical analysis

All data were collected and processed using the SPSS 6.0 for Windows statistical package (SPSS).

All data are expressed as mean ± S.D.). The two-tailed Fisher’s test for paired data was used to compare the preoperative and postoperative discrete variables. The two-tailed Mann-Whitney test was used to compare the preoperative and postoperative continuous variables. Differences in STAI-DY-1 score, VAS-pain score and O₂-saturation after a 6 min walking test were analysed using the Wilcoxon matched-pairs signed ranks test. We considered a statistical probability of less than 0.05 as indicating significance.
3. Results

3.1. Surgical data

The LIMA was used in all cases to graft the LAD: in three cases a sequential graft on the first diagonal branch and the LAD was performed. In two cases the MICABG was converted to the midline sternotomy and the anastomosis of the left LIMA was made after cardioplegic arrest was performed (see below). In one case the conversion to midline sternotomy was due to difficulties in finding the LAD.

Mean operative time was 92 ± 25 min (range 60–170). Mean time of coronary occlusion was 10.6 ± 4.1 min (range 5–23).

3.2. Clinical results

We recorded one (1.1%) in-hospital death. In three patients (3.3%) a perioperative myocardial infarction occurred. In one case the ECG changes suddenly appeared 24 h after surgery, shortly after extubation. A postoperative angiography was immediately performed, showing a diffuse narrowing of the left LIMA graft. The patient underwent urgent reoperation via midline sternotomy and received an additional vein graft to the LAD with CPB and cardioplegic arrest. In the other two cases an apical myocardial infarction was detected according to ECG, laboratory, and echocardiographic findings. The postoperative angiograms showed normal patency of the grafts; therefore no further treatment was planned.

One case of reoperation for bleeding and six (6.6%) cases of postoperative transient atrial fibrillation occurred. Mean hospital stay was 4.4 ± 2 days (range 3–11). Clinical results are summarised in Table 1.

* Emotional stress. (Fig. 3) The mean STAI-DY-1 score on the day of admission was 45 ± 11, at discharge 38 ± 9, and 2.5 weeks after discharge 33 ± 7. The differences were statistically significant; admission — discharge: \( P = 0.002 \); discharge — 2.5 weeks after discharge: \( P = 0.036 \).

** Table 1 **

<table>
<thead>
<tr>
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<th>Standard deviation</th>
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<td></td>
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<tr>
<td>Perioperative MI</td>
<td>(3/90) 3.3%</td>
<td></td>
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<tr>
<td>CK-MB (IU/L)</td>
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<td>0–1200</td>
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<td>Hospital stay</td>
<td>4.4</td>
<td>2</td>
<td>3–11</td>
</tr>
</tbody>
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Perioperative MI, perioperative myocardial infarction; CK-MB, creatinin kinase MB-isoenzyme.

* Pain. (Fig. 4) The mean VAS-pain score on the first postoperative day was 3.5 ± 2.8 cm, on day 2, 2.2 ± 2.1 cm and on day 3, 1.2 ± 1.9 cm. Weeks, 2.5, after discharge the mean VAS pain was 0.83 ± 1.6 cm. The \( P \)-values were: day 1–day 2: \( P = 0.03 \); day 1–day 3: \( P = 0.001 \); day 1–2.5 weeks after discharge: \( P < 0.001 \).

* \( O_2 \)-saturation after a 6 min walking test. (Fig. 5) The mean \( O_2 \)-saturation after a 6 min walking test was significantly reduced at discharge (96.9% versus 94.4%; \( P = 0.004 \)). Conversely, the mean \( O_2 \) saturation after a 6 min-walking test did not change at the first follow-up examination (97.5% versus 97.1%). The \( O_2 \)-saturation after a 6 min walking test improved significantly at the first follow-up examination compared with the same value measured at discharge (97.1% versus 94.4%; \( P = 0.002 \)).

3.3. Follow-up

A 100% follow-up was achieved. A complete clinical evaluation and a treadmill stress test according to the
Nevertheless, there is still some concern about this technique, the question in particular being whether the technique can be considered safe in an era where conventional coronary surgery has reached well established results [7,9,18]. As far as the risk of coronary occlusion on a beating heart is concerned, the experience with PTCA has demonstrated that the myocardium can tolerate brief periods of coronary occlusion. Therefore the risk of myocardial damage during surgical coronary occlusion seems negligible.

In this study we recorded procedure-related complications leading either to conversion to standard surgery with CPB via midline sternotomy, or to postoperative cardiac complications (only among the first 14 patients). After changing the technique and improving the instruments, we no longer recorded any procedure-related complications among the next 36 patients. In addition, MICABG patients had a shorter recovery than is generally observed in patients operated on with conventional coronary surgery.

The subjective feeling of emotional stress decreased at discharge and in the period after discharge as compared with the admission day. At discharge the scores were comparable to those of the normal population. The results of the VAS-pain score showed that after a MICABG patients experienced only mild pain in the early days after the operation. The pain diminished further in the period after discharge. In addition, patients undergoing reoperative MICABG reported less feelings of pain after the reoperative MICABG than after their first conventional coronary operation via midline sternotomy. Also O₂-saturation after a 6 min walking test improved significantly at the first follow-up examination, thus demonstrating a satisfactory recovery of cardio-pulmonary efficiency.

Coronary surgery without CPB via midline sternotomy and MICABG have also been suggested for patients having reoperative coronary surgery [12,14,15], but this suggestion is still controversial [10]. In fact, although several independent determinants of operative mortality for reoperative coronary surgery have been identified [13], the danger of reoperative coronary surgery seems mainly hidden in the reopening of the sternum and in the preparation of the heart and the old grafts [12]. Therefore, the MICABG appears an ideal technique for reoperations, in particular when the LAD needs to be revascularised and the left LIMA has not been previously utilised. In our experience of reoperative MICABGs, the identification of the LAD was facilitated by the presence of the old occluded vein graft and the mammary-to-coronary anastomosis was facilitated by the reduced motion of the epicardial surface. In fact, in these cases the epicardium was firmly adherent to the pericardium and this consistently reduced the motion of the epicardium itself.

**4. Discussion**

This study indicates that MICABG, by avoiding the use of CPB and minimising surgical incision, is effective in reducing in-hospital morbidity and mortality and in improving psycho-physical recovery of patients with isolated stenosis of the LAD. In previous studies [1,2,4,8,20,21,28,29] the avoidance of CPB improved recovery from the operation, and reduced non-cardiac complications and medical costs. In particular, the reduction of medical costs was due to the decreased use of disposable materials and to the shorter hospital stay. However, patients with isolated stenosis of the LAD are more frequently treated with percutaneous transluminal coronary angioplasty (PTCA) and not with coronary surgery. Despite this, conventional coronary surgery with CPB has better mid- and long-term results than PTCA in terms of event-free survival when the LIMA is used to graft the LAD [7,9,22]. An observation supporting the use of coronary surgery without CPB instead of PTCA in these patients is the improvement in early patient recovery and the reduction of further clinical care [2]. In general, coronary surgery without CPB has a better cost-benefit ratio than PTCA, due to the high early rate of restenosis at follow-up in PTCA-treated patients [2,22].

Bruce protocol were performed one month after discharge, then after 1 year. Postoperative evaluation after 1 month showed a significant improvement in clinical status, according to CCS. All patients were free of recurrent myocardial ischemia at the first control. All patients have remained free of recurrent myocardial ischemia to date. No patient died at follow-up.
In conclusion, MICABG is a promising new technique. It can be considered an alternative technique to PTCA, and a complementary technique to conventional CABG. The technique is well tolerated by patients and leads to a fast psycho-physical recovery. The expanding use of MICABG, long-term angiographic studies, and prospective randomised trials with PTCA and conventional coronary surgery will further clarify the relationship between these three methods of myocardial revascularisation.

Acknowledgements

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References


Appendix A. Discussion

Dr Pavie (Paris, France): Do you make rib resection or the resection of the costal cartilage when you perform your thoracotomy?

Dr Boonstra: No, we don’t take down the cartilage. We only make an incision in the intercostal space and spread it. We never replaced it, because we have a nice access with this procedure.
Mr Westaby (Oxford, England): There seems to be a completely new industry growing up around less invasive coronary surgery, but I think it is very important to stress that if you try to do these operations with just conventional instruments, they are technically difficult when you start, but some of the new stabilizing devices and retractors are making this an awful lot easier. Together with the pharmacology, the opportunities to use drugs like esmolol and adenosine to slow the heart really does make the anastomosis easier, but I think a lot of us would like to see angiographic follow-up from at least one large series of cases.

Do you think everybody should do less invasive coronary surgery or do you think it should be restricted to a few experienced centers?

Dr Boonstra: No. If we can do it, everybody can do it. But if you start, and that was the main topic to my talk and that was by warning, you need special equipment, you need another view for harvesting the IMA. It is a complete other way than you have always. And the second is, the other difficult point is making the anastomosis on the beating heart. In the beginning we had the same trouble. There are, of course, big dangers that you will make your stitch in the wrong way, but by using a stabilizer, you can see every stitch easily and you can be sure at the end of the operation that your anastomosis was the same as during the procedure in an arrested or cardioplegic heart. So if you start, be careful.

Dr Melo (Carnaxide, Portugal): You have shown that you have used this technique in nine reoperated patients. Can you comment on the difficulties you have met in doing these procedures in the reoperations?

Dr Boonstra: As I said, one of the difficulties is the beating of the heart. But in the reoperative procedure, the heart is almost completely immobilized by all the scar tissue. So in particular in this group of patients it is easier to do the procedure because there is already a heart that is not moving.

Dr Melo: Yes, but what about the location of the vessels?

Dr Boonstra: Oh, that is very easy because you always see the vein graft that leads you to the place where you have to make your anastomosis.