Early angiographic results after revascularization by minimally invasive direct coronary artery bypass (MIDCAB)

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Abstract

Objective: Anastomosing the left anterior descending artery (LAD) by use of the internal mammary artery (IMA) via an anterior minithoracotomy represents the most commonly performed minimally invasive direct coronary artery bypass (MIDCAB). However, little is known about angiographic results beyond patency rates. Methods: Therefore, a retrospective analysis of 205 consecutive control angiographies was performed evaluating anastomotic patency as well as the angiographic morphology of the left IMA and the LAD. Results: The overall anastomotic patency rate was 98.0%. As a result of incomplete IMA preparation (6–15 cm) large side branches (n = 4), or an IMA course under tension (n = 6) were occasionally observed. Despite a tension-free course, the IMA appeared fixed to the chest wall without functional compromise in 21 cases. A restrictive thrombus formation occurred once, IMA dissection was not seen. Two of the grafts developed spasms. A distal IMA stenosis ≥50% was seen in five cases. Stenosis of the anastomosis (≥50%) itself was found once, as well as unexpected malinsertion to diagonal branches (n = 4). Compared with preoperative angiograms, de novo stenoses of the LAD were assessed proximal (≥50%, ≥2 ≥50%) and distal (≥50%, ≥2 ≥50%) to the anastomosis. Elevation of the LAD out of the vascular bed was an additional finding (n = 12) in a few cases. Conclusions: The overall patency of MIDCAB-LAD-grafting appears to be equivalent to conventional IMA grafting to the LAD. Particular angiographic findings, however, may be directly associated to the applied surgical technique. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Minimally invasive coronary surgery; Left internal mammary artery bypass patency; Beating heart surgery

1. Introduction

Over the last few years minimally invasive coronary surgery has left the stage of pioneering procedures and became introduced into many cardiac surgical programs. Between various approaches differing in surgical access or requirement and mode of extracorporeal circulation, beating heart procedures dominate the current discussion [1–4]. Out of these, the minimally invasive direct coronary artery bypass (MIDCAB) grafting the left anterior descending (LAD) artery by use of the left internal mammary artery (LIMA) through a left anterior minithoracotomy, became the most frequently performed minimally invasive cardiosurgical procedure worldwide. Although several groups reported already on procedural results in several hundred patients [5,6] each, controversy still exists about the success rate of beating heart procedures.

In regard to particular technical aspects like application of myocardial surface stabilization and use of perivascular snares or intravascular shunts, angiographic results have been discussed [5,7]. Thereby, the accuracy and quality of the anastomosis has been repeatedly doubted. Moreover, changes of the native LAD and the entire IMA course have also raised concerns about the MIDCAB technique. Induced by these reports and our own experience of additional findings, which so far have not been consistently described, we performed a review of the original control...
angioographies in a group of surgeons and cardiologists, according to a standardized protocol in more than 200 cases.

2. Materials and methods

Since starting our program in June 1996, 306 patients underwent MIDCAB revascularization until August 1998. Early angiographic control of the surgical results was principally intended with the exception of several patients with compensated renal insufficiency or technical problems during the preoperative diagnostic coronary angiography, mainly in cases with severe iliofemoral arterial occlusive disease. Beside this, a few patients refused control angiography.

Respecting reported angiographic findings, an overall patency rate (LIMA, Anastomosis, LAD) of 97.8% (227/232) became evident in 232 patients, but there were four cases with an unexpected attachment of diagonal branches instead of the intended LAD. Along with the description of particular angiographic findings in these reports, a review of the original control angiography material was committed by a group of surgeons and cardiologists. Thus, out of 232 control angiographies, 205 original films could be collected from different heart catheterization laboratories serving for a detailed analysis following a standardized protocol. Beyond only stenoses, particular angiographic findings were checked regarding the course and features of the LIMA like: course under tension, kinking, secondary fixation to the chest wall, dissection, intramural hematoma, intravascular thrombus, dominating side branches, competitive flow and spasm. In addition, all visible stenoses of the LIMA, the Anastomosis and the native LAD (de novo stenoses different from preoperative findings) were separately noted and graded ≤ 50% or > 50%.

2.1. Patients

The preoperative cardiac findings of the 205 patients (162 male, 43 female, 55.7 ± 19 years, median 60 years), whose control angiographies were reviewed are listed in Table 1. Significant comorbidities were present in 119 cases. The reasons for accepting patients with multi vessel disease for only MIDCAB grafting were insignificant lesions or previous myocardial infarctions or non-graftable vessels in non-LAD regions or primarily intended Hybrid procedures.

2.2. Surgical technique

The initial surgical technique has already been previously described in detail [8]. Over a period of time some modifications have been made, which may have direct impact on the angiographic results.

First, the technique of snaring for temporary occlusion of the LAD was changed using 4/0 polypropylene sutures and softer small silicone tubes to encircle the LAD only with one loop. The tension on these loops was very cautiously adjusted accepting some residual bleeding in many cases. Second, to get a better view of the vascular structures we relied on the aid of a blowing device (Medtronic DLP, Grand Rapids, MI). Third, for a better exposure of especially the more proximal segments of the LIMA, the Thoralift® Retractor (Vascular Therapies, Norwalk, USA) was frequently used and allowed for an easier proximal dissection effecting increased IMA pedicle lengths. Otherwise mechanical retractor mounted stabilizers (CTS, Cupertino, CA) served for presentation of a motionless LAD region.

3. Results

Following MIDCAB grafting, the 30-day-mortality of all patients was 1% (3/306) resulting from myocardial infarctions in more complex cases (n = 2; one anterior, one posterolateral) and from pneumonia and consecutive septic multi organ failure. The posterolateral myocardial infarction occurred 12 days after primarily successful MIDCAB grafting of the LAD in a 72-year-old diabetic female patient suffering from unstable angina, presenting a three vessel disease with left main stem stenosis and reduced left ventricular function. Due to further comorbidities this patient was rejected for conventional surgery and also interventional therapy. Beyond that, no further other myocardial infarctions occurred and only two patients were converted to conventional sternotomy procedures. None of the patients received a secondary surgical revascularization of the anterior wall later on.

Reviewing the postoperative control angiographies of 205 patients confirmed a global patency rate of 98.0% (201/205). However, in four cases the LIMA was unintendedly attached to diagonal branches (Fig. 1) resulting in a sufficient retrograde flow to the LAD in three patients, whereas in one patient a subsequent percutaneous transluminal coronary angioplasty (PTCA) of the proximal LAD was required.

<table>
<thead>
<tr>
<th>Cardiac findings (n = 205)</th>
<th>n</th>
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<tbody>
<tr>
<td>One vessel disease</td>
<td>118</td>
</tr>
<tr>
<td>Two vessel disease</td>
<td>55</td>
</tr>
<tr>
<td>Three vessel disease</td>
<td>32</td>
</tr>
<tr>
<td>Proximal LAD occlusion</td>
<td>34</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>35</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>72</td>
</tr>
<tr>
<td>Reduced LV function (EF ≤ 30%)</td>
<td>4</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>5</td>
</tr>
<tr>
<td>Chronic atrial fibrillation</td>
<td>10</td>
</tr>
<tr>
<td>Previous PTCA/stenting</td>
<td>44</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>13</td>
</tr>
</tbody>
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LAD, left anterior descending artery; LV, left ventricular; EF, ejection fraction; PTCA, percutaneous transluminal coronary angioplasty.
Regarding the course, function and quality of the LIMA, a number of findings became evident that are probably directly associated to the surgical technique of IMA harvesting and grafting. Thus, very straight LIMA-courses indicating tension of the pedicle were seen in six cases, whereas in contrast excessive length, resulting in kinking of the LIMA pedicle (Fig. 2), was obvious in 13 angiographies. Although the average prepared length of the LIMA was between 6 and 15 cm, a secondary fixation of the proximal pedicle to the chest wall was noted in 21 occasions, with the effect that only a few distal centimeters of the pedicle were mobile. Dominating side branches (Fig. 3) of nearly the same size as the distal LIMA have rarely been observed \( (n = 4) \), but were not associated with steal phenomena. However, competitive flow to the native LAD circulation as the result of a preoperatively overestimated LAD stenosis was also notable in three cases. Three grafts were completely closed and one LIMA presented a distal intravascular thrombus. An intramural distal hematoma of the LIMA (Fig. 4) was assumed in another case. Localized spasms were noted twice, but dissection of the LIMA wall has not been found. Elevation of the LAD out of the vascular bed occurred in 12 cases as a result of LIMA tension or surgical manipulation of the LAD. Five anastomoses themselves appeared stenosed or narrowed.

Alterations of the native LAD potentially caused by the LAD snare impressed as proximal \( (n = 16, \text{ Fig. 5}) \) or distal \( (n = 17) \) de novo stenoses. The results of graduation of stenoses in \( \leq 50\% \) and \( > 50\% \) are summarized in Table 2. Overall 38 insignificant \( (\leq 50\%) \) stenoses were observed localized at the LIMA \( (n = 5) \), anastomosis \( (n = 4) \) and distal \( (n = 15) \) or proximal \( (n = 14) \) LAD. In contrast stenoses \( > 50\% \) were identified in 10 cases present at the LIMA \( (n = 5) \), the anastomosis \( (n = 1) \) and the distal \( (n = 2) \) and proximal \( (n = 2) \) LAD. Applying criteria as proposed by Fitzgibbons [9] for LIMA evaluation in conventional bypass...
surgery, at least adequate function of widely patent grafts (Fig. 6) without stenoses > 50% (including LIMA, anastomoses and distal LAD) was confirmed in 93.7%.

This calculation included four occluded IMAs, five stenoses of the IMA > 50%, one > 50% stenosis of the anastomosis, two de novo distal LAD stenoses and one malinsertion to a diagonal branch requiring subsequent PTCA (13/205 = 93.7%). In contrast, malinsertions to diagonal branches with unrestricted retrograde flow to the LAD (n = 3) and the two asymptomatic proximal de novo stenoses > 50%, which were close to the significant preoperative LAD lesion, were regarded as adequate functioning grafts.

4. Discussion

Since MIDCAB grafting results have significantly improved with the introduction of mechanical stabilization devices, this procedure became the most popular minimally invasive cardiac procedure. Nevertheless, still major concerns exist about the quality and function of MIDCAB grafting even beyond learning curves. Therefore, intra- or early postoperative control of LIMA patency is recommended by the majority of groups working in this field. Although different means for assessment of graft patency and function appeared primary suitable [10–12], a wide spectrum of particular findings can only be visualized by angiography and would be otherwise be completely missed. This is especially valid for the description and localization of any stenoses and the LIMA course in general. Feedback of this information is absolutely necessary to adapt the surgical technique, regarding for example, the length of the prepared LIMA pedicle and the application and choice of occluding means.

Comparing our results obtained in a relatively large patient population over a 2-year-period with other big volume studies, the functional results appear comparable, but the proportion of control angiographies is evidently higher in our study. For example, Calafiore recently reported on 434 patients with MIDCAB grafting, but the graft patency rate of 93.7% could only be obtained from 271 patients [1]. Similar results were given by Subramanian [6]. A more detailed analysis of angiographic findings, however, is often missing and only patency rates are described. More detailed information is given by a few smaller studies with a high proportion of control angiographies. Thus, Alessandrini et al. [7] reported on de novo LAD stenoses close to the anastomosis, to probably be a result of the particular occluding technique. In the same sense were the results of Possati et al. [13]. Both studies raised major concerns about the quality of MIDCAB-revascularization, but with patient numbers of 35 [7] and 76 [13] the influence of the learning curve appears overrepresented.

The impact of LIMA stenoses and de novo LAD stenoses in early postoperative control angiographies may be less important for the long-term results, as Calafiore [1] reported a frequent resolution of such findings within 3–6 months, documented by serial angiographies. Even though we did not perform regular re-controls, none of our patients with such a stenosis became subsequently symptomatic. Only one patient with a transplant vasculopathy had a scheduled second control with an unchanged finding at 2 months.

Surgical critics of the MIDCAB-concept univocally state that with conventional techniques (sternotomy, heart-lung

Table 2
Graduation of visible stenoses ≤50 and >50% localized at the LIMA, the anastomosis and the LAD distal or proximal to the anastomosis

<table>
<thead>
<tr>
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<th>LIMA (%)</th>
<th>Anastomosis (%)</th>
<th>LAD (%)</th>
</tr>
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<tbody>
<tr>
<td>Stenosis &gt;50%</td>
<td>2.4</td>
<td>0.5</td>
<td>Prox. 1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dist. 1.0</td>
</tr>
<tr>
<td>Stenosis ≤50%</td>
<td>2.4</td>
<td>2.0</td>
<td>Prox. 6.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dist. 7.3</td>
</tr>
</tbody>
</table>

LIMA, left internal mammary artery; LAD, left anterior descending artery; Prox., proximal; Dist., distal.

Fig. 6. Regular angiographic finding of LIMA – LAD MIDCAB-grafting.
machine), regularly IMA patency rates between 97–100% are obtainable as earlier published [14,15]. The angiographic results, however, are usually not further differentiated regarding stenoses of the LIMA or the anastomoses or other irregularities. Referring to more recent results of LIMA-LAD grafting, the IMAGE trial [16] seems appropriate assessing a global LIMA patency of 98.8% but also including 7.8% stenoses (>50%) of the LIMA. Consecutively, widely patent grafts without stenoses ≥ 50% were only seen in 91.0% [16], which is quite similar to our MIDCAB results.

The evaluation of MIDCAB results in contrast to currently representative results of interventional approaches is obviously comparably difficult, as prospective trials investigating both techniques are also still missing. For a general survey, 62 German community hospitals formed the ‘Arbeitsgemeinschaft leitender kardiologischer Krankenhausärzte’ (ALKK) (A. Vogt, personal communication), collected the data of 3816 elective PTCA/Stent procedures and the LAD in 1996 and reported LAD-occlusion rates of at least 15–30% within 6 months. Moreover, these are already selected patients which are assumingly amenable to surgical techniques evenly, irrespective of patients who are only surgical candidates.

We conclude from our findings, that MIDCAB-results can be comparable with conventional LIMA-LAD grafting and superior to current interventional approaches in terms of angiographic results. To get a more precise information prospective, trials comparing MIDCAB with conventional bypass surgery and interventional procedures are absolutely necessary. Finally, to get a substantial feedback of one’s own MIDCAB technique, control angiographies should be mandatory until adequate results are assessed.

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References


Appendix A. Conference discussion

Dr V. Subramanian (New York, NY, USA): As I mentioned in the previous discussion, I want to emphasize the two most important more technical steps in the MIDCAB operation are mechanical stabilization of
the target coronary artery site and stabilization improves the overall anastomotic patency. In fact, occlusion of the graft is extremely rare in our institution in LAD MIDCAB since the stabilization has started.

The second most important step is the LIMA graft harvesting, I think inadequate graft harvesting is one of the important factors which give rise to anastomotic failure and short graft length, the fixation problem you talked about.

Thirdly, clinical follow-up of 205 patients with LIMA LAD have been done since stabilization, and clinical event rate have yielded a low clinical event rate and target vessel revascularization rate. Which is better than the best stent restenosis rate, 15%.

Dr Cremer: So far, we have the same opinion and we changed our technique a little bit and are very cautious with the application of snares. As well, we changed the preparation of the IMA. We go a little bit further up now, and we have the same impression that the distal part especially is very sensitive to vascular wall dissection. Thus, we are very cautious with the preparation here.

Dr A. Wahba (Regensburg, Germany): I think that the finding of distal stenosis of the coronary artery from using snares is quite worrying. In our experience after we started using a blower, very often the distal snare became unnecessary. Now we usually start without applying a distal snare and this should solve the problem of distal stenosis.

Dr Cremer: That is also our impression, and we use now very low tension on the snares and wait when incising the vessel, whether it is bleeding or not. In cases of persisting bleeding, the support of a blowing device allows an adequate visualization of the vascular structures. Since that, we don’t see this problem of snares. So it is an initial experience with the start of the program.

Dr F. Benetti (Santa Fe, Argentina): Only one comment. This is a good operation, it is a difficult operation, you could obtain good results, but for the moment we move to do this operation for what we would call the safer approach, instead of going through the mini thoracotomy, and we think that this approach is easier in terms of harvesting the LIMA and to perform the anastomosis, and it is also less painful initially, and is not also less painful, but you can build the anastomosis more easily and most of the surgeons are used to doing this approach. So we prefer instead, the left anterior thoracotomy at this moment, to go for what we call the safer approach or lower inferior approach.

Dr Cremer: With the problem of pain, there is no absolute solution, so you can’t say patients with a mini-thoracotomy on the left side have less pain than with a sternotomy, but I think over some days the issue of pain can be neglected in the patient’s course.

Dr R. Dion (Brussels, Belgium): You mentioned that 87 patients had a two- or three-vessel disease. Could you explain how you can think to treat two- or three-vessel disease by means of a single mammary artery graft on the LAD?

Dr Cremer: I’ve waited for this question. Part of them received a hybrid procedure and another part of them had a previous infarction with probably no viable tissue or there were also some cases with minor stenosis, less than 50%, and they were referred for an MIDCAB procedure. I think it makes sense.