Difficulties in the interpretation of coronary angiography early after coronary artery bypass surgery on the beating heart∗

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Abstract

Objective: The major objective of this study was to evaluate the findings in early postoperative coronary angiography in patients who underwent coronary revascularization on the beating heart without cardiopulmonary bypass. Methods: Eighty-four consecutive patients receiving 113 grafts were studied. A coronary angiography was performed 0 to 5 days postoperatively. All the grafts were reviewed and classified in the following way: grade A (unimpaired run-off); grade B1 (<50% stenosis); grade B2 (>50% stenosis); grade O (occlusion). A second coronary angiography was performed in patients with a stenosis grade B2, 4 to 30 months postoperatively. An exercise test was performed by patients with B1 stenosis.

Results: Overall graft patency was 96% in the 113 grafts. None of the 14 patients with B1 stenosis in the early coronary angiography had any clinical signs of ischemia. Eight of the 12 patients who exhibited B2 stenosis either at the anastomotic site, in the graft or in the distal coronary artery at the first coronary angiography had a normal angiogram at the re-angiography.

Conclusion: A majority of stenoses visualized at the early coronary angiography could not be seen at a later coronary angiography, which makes the interpretation of the angiogram unreliable as a tool for the decision as to redo-procedure in the early postoperative period.

Keywords: Coronary bypass graft; Heart surgery; Minimally invasive; Angiography; Graft patency

1. Introduction

New technologies have recently been developed for safe coronary artery bypass surgery on the beating heart [1–6]. This has contributed to the widespread use of the off-pump technique, currently an accepted approach to coronary revascularization. Theoretically, this technique offers some advantages, such as avoiding cardiopulmonary bypass (CPB) and minimizing trauma to the ascending aorta [7–10]. Compared with coronary revascularization on the arrested heart, surgery on the beating heart is technically more challenging, but whether this affects graft patency remains to be elucidated. While graft patency after coronary artery bypass grafting (CABG) on the beating heart has been reported [11,12] there is concern as to the quality of the anastomoses performed on the beating heart. One way to confirm acceptable surgical results is to perform a coronary angiography, although this procedure in the intraoperative or in the first postoperative period reveals a significant frequency of compromised grafts [13–19]. The aim of this study was to evaluate postoperative angiographic findings in patients who underwent coronary revascularization on the beating heart without cardiopulmonary bypass and, specifically, to follow-up patients with postoperative graft stenoses.

2. Material and methods

2.1. Patients

Between April 1996 and October 1997 at our institution, 84 patients underwent CABG on a beating heart and without the use of extracorporeal circulation. An anterior minithoracotomy (n = 23) was chosen for an isolated left anterior descending artery (LAD) stenosis when the necessity for extracorporeal circulation was judged to be minimal and the anatomical circumstances were favorable. A median sternotomy was performed in all other cases. Demographic characteristics are shown in Table 1.
2.2. Surgical procedure

Anesthesia was induced with thiopentone (2–5 mg/kg), fentanyl (3–7 μg/kg) and pancuronium (0.1 mg/kg) and was sustained with other volative agents. Care was taken to keep normothermia during surgery by means of elevated room temperature, warming blankets (Warm-Touch®, Mallincrodt Medical, St. Louis, MO) and a head warmer (IM Medico, Svenska AB, Stockholm, Sweden) in order to facilitate early extubation. An anterior minithoracotomy was performed with a skin incision (approximately 8–12 cm) at the level of the fourth or fifth interspace, and median sternotomy was performed in full length. Equipment for mechanical stabilization of the operating field and rib-lifters were developed by modification of various commercially available retractors, but the Denver-Well’s or Bugge’s retractor was mainly used. Heparin was administered at a dose of 150 units/kg body wt. Pledged 2-0 micron sutures were used as snares proximally and if necessary distally of the intended anastomotic site to achieve occlusion and a bloodless field. Preconditioning (i.e. occlusion before incision in the coronary artery) was performed for 5 min and then interrupted for 3 min before the actual anastomosing. Doppler flow measurements were not performed since no such equipment was available at the time. Transesophageal echocardiography was used to monitor changes in wall motion.

2.3. Postoperative angiography

A selective coronary angiography of the anastomosed vessels was performed during the first postoperative period (0–5 days). The angiography was performed before and after administration of intracoronary nitroglycerin to relieve spasm. All anastomoses were reviewed and classified as described by FitzGibbon and associates [20]. However, grade B2 was divided further into two subgroups as described below:

Grade A, graft with unimpaired run-off;
Grade B1, stenosis reducing the lumen of graft, anastomosis, or grafted vessel to <50%;
Grade B2, stenosis reducing the lumen of graft, anastomosis, or grafted vessel to >50%;
Grade O, occlusion of graft or grafted vessel.

2.4. Postoperative follow-up of patients with stenosis in their early postoperative coronary angiogram

All patients with a grade B1 stenosis underwent an exercise test (12-lead ECG on an exercise bicycle) during which the appearance of chest pain was measured according to the New York Heart Association and any ischemic signs were recorded on ECG. All patients with a grade B2 stenosis were examined in an additional coronary angiography.

3. Results

There was no early (30 days) mortality. The mean number of grafts (n = 113 grafts) was 1.4 ± 0.1. One hundred and two arterial grafts and 11 saphenous vein grafts were used. LAD was anastomosed in 56 cases and LAD plus a diagonal branch in 13 cases. LAD and the right coronary artery (RCA) were anastomosed in 12 cases, RCA only in one case and LAD plus RCA plus a diagonal branch in two cases. All grafts but one were single grafts, the only sequential graft running between LAD and a diagonal branch. Fifty-seven percent of all patients were extubated in the operating room. Ninety-six percent of the patients were extubated within 3 h. The mean intensive care time was 7 h (0–3 days) but it should be noted that 60% of the patients did not require any time in intensive care. The mean hospital time was 7.1 days (2–25 days). Three patients with occluded grafts developed transmural myocardial infarction.

3.1. Early graft patency

According to the first postoperative coronary angiogram, patency was 96% (grade A plus grade B). The postoperative coronary angiogram showed occlusion of ITA in four patients and occlusion of a vein graft to the RCA in one patient (Table 2). Three of these patients were re-grafted using cardiopulmonary bypass, one of whom with a vein graft and the other two with a reimplantation of the ITA. In one patient who had had three previous percutaneous transluminal coronary angioplasty (PTCA) procedures performed in the LAD, the vessel was judged to be too heavily calcified for further grafting. One patient who had an occlusion in the vein graft to RCA was an elderly man who was judged to be beyond further attempts for surgery, although he did have a well functioning left ITA to LAD (Fig. 1).

3.2. Postoperative follow-up of patients with grade B1 stenosis

Fourteen patients had a non-significant grade B1 stenosis (Table 2). None of these had any chest pain at the time of

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Table 1

<table>
<thead>
<tr>
<th>Demographic data on patients operated with CABG on a beating heart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (%)</td>
</tr>
<tr>
<td>Female (%)</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Diabetes (%)</td>
</tr>
<tr>
<td>Hypertension (%)</td>
</tr>
<tr>
<td>Body mass index</td>
</tr>
<tr>
<td>Higgin’s score</td>
</tr>
<tr>
<td>LVEF (%)</td>
</tr>
</tbody>
</table>

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a CABG, coronary artery bypass grafting.
b LVEF, left ventricular ejection fraction.
follow-up. Of these 14 patients, 12 had no signs of ischemia on the exercise test. One patient had signs of ischemia in inferior leads in spite of a lack of chest pain. One other patient did not perform an exercise test. The patients with grade B1 stenosis did not undergo further coronary angiography.

3.3. Postoperative follow-up of patients with stenosis grade B2

Twelve patients had 13 significant stenoses (grade B2). The first patient who exhibited with a stenosis grade B2 was re-grafted with a vein using CPB (Table 3). Another patient with a significant stenosis at the anastomotic site had severe chest pain and was re-grafted with a vein using CPB 11 months after the primary operation. Two patients showed remaining significant stenoses but had no clinical signs of ischemia. One patient who had two stenoses in the first angiogram, one in LAD and another at the anastomotic site, developed chest pain; a re-angiogram revealed a significant stenosis in the LAD but no stenosis at the anastomotic site. This patient was successfully treated with PTCA and a stent implantation in LAD. Eight of the significant stenoses at the first postoperative angiogram (67%) did not appear in a repeat angiography (Table 3).

4. Discussion

The introduction of new surgical techniques requires careful assessment of the surgical result and outcome. Coronary angiography is considered the method of choice for evaluating coronary graft patency and is used at our institution [21–23]. However, our study demonstrates difficulties in interpreting the findings in the early postoperative coronary angiogram. With an increasing number of stenoses observed in the postoperative angiograms and in the absence of clinical symptoms, we became doubtful about the relevance of the radiological findings. It was observed that the contrast had a quick run-off from the graft into the anastomosed vessel despite significant stenosis. A redo procedure based on the radiological findings as the sole indication did not seem prudent, which is why it was decided to repeat the coronary angiography after approximately 5 months of expectance. Much to our surprise, we found that 2/3 of the significant stenoses in both the trunk and LAD were transient, as they were not visualized in the second postoperative coronary angiogram. This is an important observation since too aggressive an attitude could have resulted in unnecessary

<table>
<thead>
<tr>
<th>Grafted vessel</th>
<th>No. of grafts</th>
<th>Grade (no. of grafts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>83</td>
<td>A: 58, B1: 10, B2: 11, O: 4</td>
</tr>
<tr>
<td>Diagonal</td>
<td>15</td>
<td>A: 13, B1: 2, B2: 2, O: 1</td>
</tr>
<tr>
<td>RCA</td>
<td>15</td>
<td>A: 12, B1: 2, B2: 1, O: 1</td>
</tr>
<tr>
<td>Total</td>
<td>113</td>
<td>A: 82, B1: 14, B2: 12, O: 5</td>
</tr>
<tr>
<td>Total (%)</td>
<td>100</td>
<td>A: 73, B1: 12, B2: 11, O: 4</td>
</tr>
</tbody>
</table>

*a* Graft patency = A + B1 + B2 = 108 grafts (96%).

*b* Grade A = excellent run off; grade B1 = non-significant stenosis; grade B2 = significant stenosis; grade O = occlusion.

*c* LAD, left anterior descending artery.

*d* RCA, right coronary artery.

![Fig. 1. Postoperative coronary angiography showing a significant stenosis at the anastomotic site of ITA to LAD (right) and at the re-angiography 5 months later no stenosis was visualized (left).](image-url)
surgery and patient morbidity. Moreover, none of the patients with non-significant stenosis in the early postoperative coronary angiography had clinical signs of coronary ischemia at the time of follow-up. Since the natural course of non-significant stenosis due to surgery is not known, we believe that something can be learned by following these patients closely with yearly exercise tests and repeat angiography. Diegler et al. has also reported that stenoses observed at the first angiogram were not visualized in 25% of the cases which is less than what we have observed [19]. This could be due to differences in technique but it could also be due to the radiologist’s classification of the stenoses. However, the overall success rate appears to be comparable (91 vs. 92%).

Considering the different locations of the stenoses and their transiency, several causal mechanisms may be suspected. It can be hypothesized that the ‘stenosis’ at the suture line of the anastomosis or on the graft itself was caused by edema, in the latter case caused by the vessel occluder. In those cases where a stenosis was observed in the LAD distal to the anastomotic site, hemorrhage caused by the occluding suture may be suspected [15]. As a result, we prefer if possible to avoid the distal occlusion suture and use intracoronary shunts instead. Spasm is another mechanism of action, perhaps more easily provoked in the early postoperative period. Keeping these mechanisms in mind, it seems prudent to consider reoperation in patients only when a technical failure appears to be the probable cause of the stenosis and the patient has ischemic symptoms.

It should be noted that this series of patients reflects the development of a new surgical technique where the lack of properly designed instruments and unaccustomed surgeons probably initially contributed to the learning curve. Of the five graft occlusions, three were among the first ten patients who underwent minimal direct coronary bypass grafting via a mini-thoracotomy, where both equipment and surgical technique were still under development [15,17].

In the classification of graft run-off and stenoses we chose to report and classify even very slight defects that normally would be classified as non-stenotic areas. This of course decreases our number of perfect grafts, even though these slight lumen changes may not have had any influence on run-off and graft function.

In our series there were two patients with significant stenoses but without clinical signs of ischemia. These patients will be followed with repeat coronary angiographies to identify the future course of their stenoses.

Centers with access to intraoperative coronary angiography will most likely benefit from the use of this technique and avoid some of the difficulties in the interpretation of the angiogram as edema, has not yet developed so early after the operation [15–17]. However, it is difficult to prove whether the stenoses observed with intraoperative coronary angiography as reported from other groups, are transitory, as it would be unwise not to revise the compromised anastomoses in the same session.

Intraoperative blood flow measurement with a transit Doppler flow meter in grafts is recommendable when there is a clinical suspicion of impaired run-off [25]. Although this technique and other non-angiographic methods such as thermal imaging and color-Doppler are promising, these have not been compared with the ‘golden standard’ of angiography in large prospective studies [22,24].

On the basis of the experience described above, we have now adopted the following scheme of action: Doppler flow measurements are done on all grafts intraoperatively. If no or low flow is shown, the anastomosis is revised in the same session until acceptable surgical results are achieved. In the case of ischemic symptoms in the early postoperative period, a coronary angiogram is performed.

In conclusion, a majority of stenoses visualized at the early coronary angiography could not be seen at a later coronary angiography, which makes the interpretation of the angiogram unreliable as a sole tool for a decision for redo-procedure in the early postoperative period. Subse-

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Table 3
Development of significant stenoses from the first to the second postoperative coronary angiography

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>First angiogram</th>
<th>Site of stenosis</th>
<th>Second angiogram</th>
<th>Time between angiograms (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>ITA, reoperated</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>B2</td>
<td>ITA</td>
<td>A&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>B2</td>
<td>Ana</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>B2</td>
<td>Ana</td>
<td>B2, no chest pain</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>B2</td>
<td>LAD&lt;sup&gt;v&lt;/sup&gt;</td>
<td>A</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>B2</td>
<td>Ana</td>
<td>A</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>B2 × 2</td>
<td>LAD + ana</td>
<td>A and B2 (PTCA)</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>B2</td>
<td>Ana</td>
<td>A</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>B2</td>
<td>Ana</td>
<td>B2, reoperated</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>B2</td>
<td>Ana</td>
<td>B2, no chest pain</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>B2</td>
<td>Ana</td>
<td>A</td>
<td>21</td>
</tr>
<tr>
<td>12</td>
<td>B2</td>
<td>Ana</td>
<td>A</td>
<td>16</td>
</tr>
</tbody>
</table>

<sup>a</sup> ITA, internal thoracic artery; LAD, left anterior descending artery; ana, anastomosis.<br><sup>b</sup> A = excellent run off; B2 = significant stenosis.
quently, we do not recommend reoperation for an angiographic stenosis seen in the early postoperative period in the absence of ischemic symptoms and with an acceptable intraoperative flow measurement.

References


Appendix A. Conference discussion

Dr J. Pomar (Barcelona, Spain): I am sure this accounts for any single CABG surgery. Probably it is not exclusive of beating heart surgery. Dr Wiklund: No, I don’t think so.

Dr Pomar: Because I think the paper would be even much better if you had also a control group with normal CABG surgery to see that it is not really exclusive of this non-beating or heartbeating surgery. The second is, do you have any explanation? I am sure you have been thinking about why it happens. It is an inflammatory reaction maybe, or what do you think? Dr Wiklund: Yes, I think so, because one drawback in our study is not to have the possibilities of intraoperative coronary angiogram. We performed postoperative coronary angiograms on day 3 and 4, and the stenosis at the anastomosis could be caused by edema or be a result of an inflammatory response. Some of the stenoses were at the place of the occluding snare which we used at that time. Those stenoses could be caused by hemorrhage compressing the target vessel.

Dr D. Hoffman (New York, NY): One question I have is about angiography. Did you have any protocol for administering antispasmodic drugs? Certainly in other arterial graft situations we have seen isolated spasm that has disappeared.

Dr Wiklund: Yes, all patients got nitroglycerin according to the radiologist’s protocol.

Dr V. Subramanian (New York, NY): I would caution that we do early angiography for all of our beating heart surgery patients. We have about a 92% study rate, and we also have a follow-up rate of well over two and a half years in LIMA to LAD MIDCAB. Early on we gave up the qualitative angiographic analysis, because when you do a quantitative coronary angiography looking at the mean luminal diameter of proximal and distal LAD and draw interpolated diameter of the anastomosis, some of these B2 grades will fall into about roughly 28–30% mean stenosis. So I think it won’t fall into a significant category. And I also can tell you that the longer you go, some of these so-called B1 also progress, and so there is no real way of predicting which grade is going to progress either way. The only thing predicted for us was the diameter of the LAD less than 1.5 up to 1.8 mm; it happens. It is an inflammatory reaction maybe, or what do you think?

Dr Wiklund: And I also can tell you that the longer you go, some of these so-called B1 also progress, and so there is no real way of predicting which grade is going to progress either way. The only thing predicted for us was the diameter of the LAD less than 1.5 up to 1.8 mm; it happens. It is an inflammatory reaction maybe, or what do you think?
Dr Wiklund: We will follow all patients with stenoses both grade B1 and B2 closely regarding cardiac events.

Dr H. Shennib (Montreal, Canada): It confirms an observation that we all have seen but we have never actually pursued as a full study. If you were to take this study and project on your next study, let’s say you are planning to do follow-up angiograms, what do you think is the ideal time to do so, where you would be comfortable that you have done a good bypass and you have gone beyond all the postoperative inflammatory processes and so on? Is it 3 months, 6 months, a year? Here we are talking about designing a new study. That is number one. The second question is, what is your institutional protocol when the patient goes back to the cath lab, you had done a follow-up on a patient who has had a LIMA to LAD and you see a stenosis there? I was surprised that although they were asymptomatic, your angioplasty guys did not stent them, or dilate them at least, at least do an angioplasty. So what is your protocol in there? You go in, you have a patient that has got, let’s say, a 60% stenosis 3–6 months after the operation. What do your angiologists do, do they just back off when the patient is asymptomatic? Do you wait for symptoms?

Dr Wiklund: Concerning the timing, well, it is difficult to answer if 3 months would be better than 6 months. In the studies we are performing now we do a coronary angiogram after 6 months just to be sure not to be influenced by findings like in this study. Our cardiologists, they don’t perform PTCA in asymptomatic patients. The two patients who had significant stenosis but no symptoms will be followed with exercise tests, and another coronary angiogram to see what happened with the stenoses. If the stenoses will still be there, I suppose some day they will progress and give symptoms.

Dr D. Javidi (Tehran, Iran): You just mentioned hemorrhage from the snaring point of the LAD as a possible cause for stricture or stenosis. Have you come across cases that you had distal stenosis due to the stricture of the snaring point?

Dr Wiklund: I am not sure. One of the patients who underwent PTCA with a stent implanted, it could have had a stricture.

Dr Svennevig (Oslo, Norway): We very much have the same experience in Oslo as you do have with interpreting the very early angiography, but in addition we measure flow. Did you measure flow in your patients?

Dr Wiklund: We did not measure flow at that time, but we do that today. If we see no flow or low flow, then we revise the anastomosis, and then if the patient turns out to have ischemic signs, then we do a coronary angiogram. However, we have not had to do many coronary angiograms for that reason.