Significance and management of early graft failure after coronary artery bypass grafting
Feasibility and results of acute angiography and re-re-vascularization

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Abstract

Perioperative ischaemia and infarction after CABG are associated with increased morbidity and mortality. Objective: To study causes of perioperative ischaemia and infarction by acute re-angiography and to treat incomplete re-vascularization caused by graft failure or any other cause. Methods: Between 1990 and 1995, 2003 patients underwent an isolated CABG operation. Myocardial ischaemia was suspected if one or more of the following criteria were present: New changes in the ST-segment in the ECG; a CKMB value greater than 80 U/L; new Q-waves in the ECG; recurrent episodes of, or sustained ventricular tachyarrhythmia; ventricular fibrillation; haemodynamic deterioration and left ventricular failure. Acute coronary angiography was performed in stable patients, while haemodynamically severely compromised patients were rushed to the operating room. Results: A total of 71 (3.5%) patients of all CABGs with suspected graft failure were identified and included in the study. Patients were grouped according to whether they had an acute re-angiography (n = 59; group 1) or an immediate re-operation (n = 12; group 2) performed. In group 1, the acute re-angiography demonstrated graft failure/incomplete re-vascularization in 43 patients (73%). The angiographic findings were: Occluded vein graft(s) in 19 (32%); poor distal run-off to the grafted coronary artery in ten (17%); internal mammary artery stenosis in four (7%); internal mammary artery occlusion in three (5%); vein graft stenoses in three (5%); left mammary artery subclavian artery steal in two (3%); and the wrong coronary artery grafted in one (2%). Based on the angiography findings, 27 patients were re-operated and re-grafted. At the time of re-operation, 18 patients (67%) had evolving infarction documented by ECG or CKMB. Two patients (3%) experienced stroke in immediate relation to the re-angiography. The 30-day mortality was three (7%). In group 2, graft occlusions were found in 11 patients (92%). The 30-day mortality was six (50%). Conclusion: An acute re-angiography demonstrated graft failure or incomplete re-vascularization in the majority of patients with myocardial ischaemia early after CABG. Re-operation for re-re-vascularization was performed with low risk. Few patients with circulatory collapse could be saved by an immediate re-operation without preceding angiography. © 1997 Elsevier Science B.V.

Keywords: Coronary artery bypass grafting; Graft failure; Perioperative myocardial infarction; Perioperative myocardial ischaemia; Myocardial infarction diagnosis; Myocardial re-vascularization

1. Introduction

Despite technical advances in coronary artery bypass grafting (CABG) during the recent years, the incidence of perioperative myocardial infarction (PMI) has re-
mained constant with a reported incidence of 5–10% [1,2]. PMI is associated with a high morbidity and accounts for up to 68% of the in-hospital mortality [3]. PMI also adversely affects the late survival following CABG [4,5].

The development of infarction is often preceded by a period of myocardial ischaemia [6]. Early detection of perioperative myocardial ischaemia may therefore, prompt institution of therapeutic measures to relieve the ischaemia and decrease the incidence and the size of PMI. Ischaemia appearing shortly after CABG could either be a result of a spasm, incomplete re-vascularization caused by graft failure (a graft related problem able of causing ischaemia), stenosis or occlusion of a native coronary artery.

If incomplete re-vascularization including graft failure is the cause of post-operative ischaemia, a re-operation with new/additional grafting may save myocardium to benefit the patients, in both the short and long term [7].

This paper describes the criteria used as indication for an acute re-angiography in patients having signs of myocardial ischaemia or PMI early after CABG, the angiographic findings and the outcome with and without an acute re-operation.

2. Material and methods

Between November 1990 and November 1995, 2003 consecutive patients underwent isolated CABG at the Department of Cardiothoracic Surgery, Rigshospitalet, Copenhagen, Denmark. Seventy-one (3.5%) patients were identified as having signs of perioperative ischaemia (as defined below) and were included in this study.

2.1. Operative procedures

The CABG was performed using cold crystalloid cardioplegic arrest, moderate systemic hypothermia, topical cooling with ice slush and single aortic cross-clamp for all distal anastomoses. The internal mammary arteries (IMA) and the saphenous veins were the preferred conduits. When harvesting IMA, it was routinely mobilized up close to the take off from the subclavian artery.

2.2. Postoperative management

All patients were monitored with continuous registration of arterial pressure, left atrial pressure, central venous pressure and a 2-lead electrocardiogram (ECG). Standard 12 lead ECGs and CKMB values were obtained at least four times within the first 18–24 h, hereafter daily for the next 3 days and on day 5 post-operatively. Aspirin was re-started within 24 h after surgery.

2.3. Identification and management of suspected perioperative ischaemia

Acute re-angiography was considered if one or more of the following criteria were present:

1. New changes in the ST-segment in the ECG. These were defined as a 2 mm depression or elevation in more than one lead, compared with a pre-operative ECG.
2. A CKMB value greater than 80 U/l at any time post-operatively.
3. Development of new Q-waves in the ECG. Q-waves were defined as significant if they were > 40 ms in two leads.
4. Repeated episodes of ventricular tachyarrhythmia (VT) or ventricular fibrillation (VF).
5. Haemodynamic deterioration with signs of left ventricular failure with decreasing cardiac output and increasing left atrial pressure despite increasing inotropic support.

2.4. Two groups of patient were identified (Fig. 1.)

Group 1: Haemodynamically stable patients had an acute re-angiography including ventriculography using modified Seldinger technique.

Group 2: Patients with either severe sustained VT or VF, rapid haemodynamic deterioration or circulatory collapse were considered too unstable for re-angiography and were taken back to the operating room (OR) for immediate re-operation without an angiography.

2.5. Indications for re-operation after re-angiography (Group 1)

Patients with incomplete re-vascularization corresponding to at least one important coronary artery, judged by the angiography, had re-re-vascularization (re-CABG).

Fig. 1. Flow-chart for patients included in this study.
2.6. Re-CABG procedure (Group 1 and 2)

Re-CABG was performed using the same standard techniques as for the primary operation. Methylene blue was added to the cardioplegic solution (2 ml of 10 mg/ml solution of methylene blue to 1000 ml), to color patent vessels and perfused myocardium blue. This was particularly helpful in patients re-operated early without preceding angiography and facilitated the identification of occluded grafts. All unsatisfactory grafts were substituted, when possible with new graft material and intra-coronary thrombotic material was removed and the vessel rinsed. An internal mammary artery, in which good flow could be re-established, was re-used if possible. If a small caliber internal mammary artery was suspected to be a possible cause of ischaemia, a vein graft was added. The incision in the coronary artery was extended to facilitate and improve the new anastomosis.

Inotropic drugs, intra-aortic balloon pump (IABP) or left ventricular assist device (VAD) were used when required to wean the patient from cardiopulmonary bypass.

3. Data analysis

The design of this study was prospective and longitudinal. Continuous variables are presented as medians (range) and categorical data presented by their actual number and summarized as percentages.

4. Results

Seventy-one patients (3.5% of all CABGs) were identified as suspected of having perioperative ischaemia or infarction and managed as described above. There were 22 females and 49 males with a median age of 59 years (range: 35–80 years). The median number of grafts per patient was three (range 1–4), leading to a median of three (range 1–6) distal anastomoses. The left internal mammary artery was used in 94% of the patients. The median aortic cross-clamp time 58 min (range 17 min to 2 h and 48 min). Eleven (16%) patients were re-do’s. Other baseline clinical characteristics are presented in Table 1.

4.1. Group 1: Stable patients having acute re-angiography

The indications (one or more) for acute re-angiography in the 59 patients were:
1. New changes in the ST-segment, \( n = 50 \) (85%).
2. A CKMB value > 80 U/L \( n = 21 \) (35%).
3. Development of new Q-wave \( n = 21 \) (36%).
enced stroke in immediate relation to the acute re-angiography, one developed a left hemiparesis and the other reduced vision on one eye, both resulting in permanent sequelae.

4.3. Consequences of the re-angiography findings

Of the 43 patients with an abnormal acute re-angiography, 27 (46% of all having a re-angiography) were re-operated. Four of the six patients who were taken directly from the OR to the catheterization laboratory were brought back to the OR for re-operation. Sixteen patients with an abnormal re-angiography were not re-operated upon as it was judged either unnecessary or not feasible because of poor vessel quality or non-availability of graft material.

4.4. Mortality and follow-up

All patients but one could be weaned without problems from cardiopulmonary by-pass (CPB). One patient required IABP and later VAD. There were three (7%) in-hospital deaths (30-days mortality) in group 1, two had an acute re-operation. All three patients who died had verified PMI, either by CKMB values \( > 80 \text{ U/l} \) and/or new Q-waves. At a subsequent follow-up (median observation period of 3 years), another five patients had died, three of which had been re-operated. None of the patients with complete re-vascularization shown by the re-angiography had died.

4.5. Group 2: Unstable patients immediately re-operated without preceding re-angiography

All the patients in group 2 met the criteria of perioperative myocardial ischaemia or PMI, but were too unstable to have an acute re-angiography.

Six (50%) patients had circulatory collapse in the intensive care unit and were rushed to the OR with ongoing resuscitation. Two (17%) patients developed circulatory collapse after sternal closure but before leaving the OR and four (25%) patients had sustained VT or repeated VF. Graft occlusion(s) was/were found in 11 (92%) of these patients at the re-operation. In only one patient, no evident cause of the circulatory collapse was found.

4.6. Mortality and follow-up

Ten (83%) patients were weaned from CPB without major problems, two patients required IABP and later VAD, however there were six (50%) in-hospital deaths (30-days mortality) in group 2. All six patients had verified PMI by CKMB \( > 80 \text{ U/l} \) and/or new Q-waves. At follow-up after a median observation period of 3 years, an additional two patients had died. Six of the eight patients brought to the OR with ongoing resuscitation died.

5. Discussion

Information in the literature on how to detect and manage patients with signs of early myocardial ischaemia or infarction following CABG is surprisingly limited [2,7,8].

Our very first experience addressing the problem was that graft failure was a constant finding in patients with circulatory collapse early after a CABG and that survival after immediate re-operation was possible. This lead to the hypothesis, that if graft failure and/or incomplete re-vascularization are the most common causes of myocardial ischaemia early after CABG, this could/should be diagnosed by angiography and treated by a re-CABG [7,9].

Our intentions with this study were to test criterias to identify post-operative ischaemia, visualize the cause and start treatment before permanent myocardial damage had occurred. Elevated CKMB values and/or new Q-waves were included among the selection criteria in order to detect patients with evolving infarction. It was our hypothesis that the development of PMI is a progressive process over time, where it may be possible to limit size of the infarction by early intervention.

The diagnostic criteria to identify patients suspected of myocardial ischaemia or infarction early after CABG surgery is more difficult to interpret and less

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Table 2

<table>
<thead>
<tr>
<th>Angiography findings in group 1*</th>
<th>n</th>
<th>%</th>
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<td><strong>Vein graft problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occlusion</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>Stenosis</td>
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<td>2</td>
</tr>
<tr>
<td>‘Kink’</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td><strong>IMA graft problems</strong></td>
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</tr>
<tr>
<td>Occlusion</td>
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<td>5</td>
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<tr>
<td>Stenosis</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Subclavian stealb</td>
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<td>3</td>
</tr>
<tr>
<td>Poor run-off</td>
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<td>17</td>
</tr>
<tr>
<td>Displaced graft</td>
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<td>2</td>
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<tr>
<td>No graft failure</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100</td>
</tr>
</tbody>
</table>

* Believed cause of ischaemia or infarction.

b Left mammary artery subclavian artery steal with retrograde flow in the internal mammary artery due to proximal occlusion of the left subclavian artery.
specific than in un-operated patients. ECG changes, especially ST-elevation appearing in many or all leads, have been a recurrent matter of discussion—ischaeemia or post-operative pericarditis? The CPB, manipulation with the heart during surgery and possible suboptimal cardioplegia may also lead to elevated CKMB values immediately after surgery [10–12]. The threshold level of 80 U/l for CKMB was chosen in order to limit the number of false positives. Our choice of selection criteria for acute re-angiography was based on clinical experience with PMI patients having perioperative problems and recommendations in the literature [8,13].

Localized ST-changes were the main criterium on which most of the acute re-angiographies were based. The acute re-angiography identified a possible explanation for myocardial ischaemia in 43 (73%) patients, while in the remaining 16 (27%) patients, no explanation was found. One of these 16 patients was found to be overloaded with a hyperdynamic circulation as a possible explanation. The other 15 patients may wrongly have been identified as having myocardial ischaemia by the reasons mentioned earlier. Twenty-seven (46%) patients, of all patients having an acute re-angiography, were re-operated.

The findings indicate that an acute re-operation without preceding angiography would be less precise, as only occluded and clotted grafts are possible to identify by inspection. This is true also when methylene blue is added to the cardiplegia. Graft stenosis, thrombosis or stenosis of a native coronary artery or subclavian steal are very difficult or impossible to diagnose without an angiography. In this series, the angiographies often demonstrated such findings (Table 2). As a consequence of these findings, a few patients with signs of ischaemia in the OR were taken to the catheterization laboratory for acute angiography if no obvious cause could be identified.

Better clinical examination pre-operatively should minimize the problem of subclavian steal. Both our patients had absent radial pulsations.

Transoesophageal echocardiography is an alternative to angiography and will be able to identify an area with reduced contractility, but will be unable to provide the detailed information about the underlying cause.

Impaired run-off caused by stenoses of the native coronary can often be diagnosed by the pre-operative angiography, but when the main vessels supplying the area are highly stenotic or occluded, distal filling was to poor for this to be possible.

At the re-operation, imperfect anastomoses or technical errors were identified in at least half of the cases. The re-operation was well tolerated and the majority of the Group 1 patients had a normal post-operative course. Myocardial function and haemodynamics were often immediately improved. Although desirable, it has not been possible to performed re-angiography on the re-operated patients.

So far we have considered re-operation more logical when dealing with anastomotic problems, but possibly PTCA is an alternative in some cases, particularly in cases with native coronary artery problems [14,15].

No patients deteriorated haemodynamically and there were no cardiac complications due to the acute angiography. Two (3%) patients suffered stroke in immediate relation to the examination. Although this gives a high incidence of stroke compared to what is to be expected during elective procedures, we consider the observed risk acceptable, compared to the expected morbidity, mortality and adverse effect on the late survival following of PMI [16–18].

6. Conclusion

Localized ST changes indicates a high probability of graft failure, and in combination with CKMB levels above 80 or VF, it is almost indicative.

An acute re-angiography is the most precise investigation to provide diagnosis and to guide the surgeon performing the re-operation. In addition, the outlined acute re-angiography policy gives the best possible feedback to the surgeon and may represent a good minimal level of angiographic quality control after CABGs.

Patients with graft failure can be re-operated with a low risk, if the patient is haemodynamically stable.

Re-operation of the collapsing patient is still worthwhile, although mortality will be high.

Further long-term follow-up will show whether the present aggressive approach to perioperative ischaemia and PMI is superior.

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References


Appendix A. Conference discussion

Dr Walpoth (Bern, Switzerland): I am mainly interested in your group of ten patients who had immediate problems and circulatory collapse and no time to go to angiography. Have you any advice or did you try intraoperative measurements, as for instance, Doppler or transient time flow measurements on those grafts to see whether you could solve the problem directly in the OR before and having a good feel of the correlation to what you had as an amount of ischemia or nonfunction? Could you comment on that?

Dr Thiis (Copenhagen, Denmark): We of course expect most of the grafts and some of them they had thrombosis and were replaced. In the latter part of the series, we monitored the flow in all the grafts, but we actually don’t think that’s a 100% safe procedure because we have had some grafts where we had flow in the graft going in the proximal direction and the graft is occluded from the anastomosis and distally. So there will be a flow but it will be in the wrong direction.

Dr Turina (Zurich, Switzerland): Maybe you could explain the high proportion of female patients in this group. And did you try to correlate the incidence of this complication with the experience of the surgeon performing the operation because there seems to be a substantial number of technical problems involved?

Dr Thiis: There is no doubt that some of those patients are victims of surgeons who are training, that’s for sure, but even the senior surgeons are represented in this material, but they do a lot more operations than the younger ones. The younger ones are overrepresented in this study.

Dr Turina: And the high incidence of females?

Dr Thiis: I don’t think that is really very surprising. Female patients have worse coronaries. In my own experience, I think there is more trouble making good anastomoses on the females than on the males.

Dr Suma (Rome, Italy): I have two questions. Which coronary arteries were commonly responsible for the graft failure in this series, usually LAD or somewhere else? The second question is, how many patients in this group had some abnormal ECG or a low output syndrome at the end of the primary operation?

Dr Thiis: Four patients were taken directly to the cath lab and they got ischemia after the chest was closed. And the first question, could you please repeat it?

Dr Suma: You mentioned some graft failure occurred in the vein graft. Of course the mammary graft may always go to the LAD, but for the vein graft failure, which coronary artery was the most common to be bypassed?

Dr Thiis: The right coronary artery.