When and how to shunt the coronary circulation in off-pump coronary artery bypass grafting

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Abstract

Objective: To assess the sequelae of temporary coronary artery occlusion in off-pump, beating heart CABG, i.e. ischemia, hemodynamic instability and the need for conversion to cardiopulmonary bypass. Methods: In 200 patients (150 male), mean age 60 (range 35–81) years, 365 distal anastomoses were performed, i.e. 1.8 anastomoses per patient through limited and full access. One hundred seventy-six LAD, 61 diagonal, 71 RCA, 7 RPD and 50 circumflex branches were grafted. Patients were pretreated with calcium antagonists, long-acting β-blockade and had thoracic epidural blockade. The anastomosis was constructed using two microvascular clamps, preceded by ischemic preconditioning in non-occlusive disease. Myocardial ischemia was defined as >1 mm S–T segment elevation. A simple aorto-coronary shunt, consisting of two intravenous catheters and a 10 cm connecting tube (flow > 20 ml/min), was used in critical ischemia. Results: Ischemia occurred during 35 (10%) temporary coronary artery occlusions. Fifteen of these (43%) were RCA. In five of these 15 patients, all with non-occlusive disease, critical ischemia occurred with bradycardia, third-degree heart block and subsequently severe hypotension, which normally requires conversion to cardio-pulmonary bypass. Following introduction of the shunt (4 patients) electrocardiographic and hemodynamic parameters normalized within 30 s. The off-pump procedures could be continued uneventfully. There were no peri-operative infarctions. Conclusion: Temporary segmental occlusion is an effective method for anastomosis suturing in off-pump, beating heart CABG. Critical ischemia was observed rarely, only in the RCA and in non-occlusive disease. Temporary aorto-coronary shunting could avoid conversion to cardiopulmonary bypass and myocardial infarction. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Coronary artery bypass grafting; Minimally invasive; Aortocoronary shunts; Off-pump revascularization; Ischemia

1. Introduction

In off-pump beating heart coronary artery bypass grafting (CABG) usually temporary segmental vessel occlusion is employed to construct the distal anastomosis. This technique was introduced in 1964 by Kolessov, who successfully grafted the internal thoracic artery (ITA) to the left anterior descending coronary artery (LAD) through thoracotomy without cardiopulmonary bypass (CPB) [1]. In general, the temporary occlusion of a (sub) totally occluded branch is tolerated well in the presence of sufficient collateral circulation. If not sufficient, myocardial ischemia may reveal in regional hibernation, stunning or even myocardial infarction. Subsequent arrhythmias and hemodynamic instability may occur, necessitating prompt conversion to CPB.

Temporary shunting of a coronary artery may support myocardial perfusion. In 1954, Murray successfully employed an aorto-coronary shunt during off-pump CABG in dogs [2].

In this report we describe the prevalence of severe ischemia following temporary coronary occlusion and its treatment by simple, elective aorto-coronary shunting in patients undergoing complete off-pump myocardial revascularization.

2. Materials and methods

Two-hundred patients underwent off-pump CABG (Table 1) through limited (anterolateral and subxyphoid), or full (sternotomy and left-posterolateral thoracotomy) access. The type of grafting is listed in Table 2. The selection criteria and surgical technique are described elsewhere [3]. Most patients (85%) had a normal left ventricular function. All patients were pre-operatively on β-blocking agents and...
Table 1
Demographic and clinical data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>35–81</td>
</tr>
<tr>
<td>Mean ± standard deviation</td>
<td>60 ± 10</td>
</tr>
<tr>
<td>Female/male ratio</td>
<td>25/75</td>
</tr>
<tr>
<td>Vessel disease (%)</td>
<td>57</td>
</tr>
<tr>
<td>One vessel</td>
<td></td>
</tr>
<tr>
<td>Two vessel</td>
<td>36.5</td>
</tr>
<tr>
<td>Three vessel</td>
<td>6.5</td>
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</tbody>
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Calcium-antagonists. Anesthesia was based on general anesthesia (induction with propofol 1–2 mg/kg and sufentanil 0.3 μg/kg, followed by propofol 2–3 mg/kg/h during the procedure) combined with thoracic epidural anesthesia based on bupivacaine 0.5% (0.05–0.1 ml/kg loading dose, followed by 2–3 ml/h continuous infusion for 36–48 h) [4]. This high thoracic, sympathetic blockade leads to coronary artery and ITA dilatation, recruitment of coronary collaterals, reduction of myocardial oxygen demand and optimization of heart rate. Intraoperative, continuous on-line S–T segments were monitored using leads II, AVR and V5. Myocardial ischemia was defined as more than 1 mm S–T segment elevation in one lead, compared to the baseline. Mean arterial blood pressure, heart rate, mean pulmonary arterial blood pressure, cardiac output, central venous pressure and mixed venous oxygen saturation were observed [3,4].

Local cardiac wall stabilization and displacement for presentation was obtained with the Octopus tissue stabilizer. Myocardial ischemic preconditioning was employed in non-occlusive coronary artery disease using 5 min of local coronary artery occlusion followed by 5 min of reperfusion. Two atraumatic microvascular Acland clamps (S&T Marketing, Neuhausen, Switzerland) were used to obtain a bloodless arteriotomy for accurate anastomosis suturing with a 8–0 or 7–0 polypropylene running suture and to preserve distal myocardial perfusion by collateral circulation. The LAD was usually grafted distally of the first diagonal and the RCA at the level of the bifurcation. In the latter, three Acland clamps were used on the distal RCA, on the right posterior descending (RPD) and right posterolateral branch, respectively.

An aortocoronary shunt was employed in those patients in whom progressive ischemia associated with hemodynamic instability and/or arrhythmias was observed, which did not improve despite ischemic preconditioning. The shunt consisted of two intravenous catheters (Vasculon, Ohmeda, Helsingborg, Sweden), connected to each other with a 15 cm connection tube (Fig. 1). The 16G catheter was introduced into the ascending aorta and fixed with a pursestring/snare. The 20G catheter was introduced in the distal coronary artery through the arteriotomy, using a 6–0 polypropylene vesselloop for gentle occlusion. As all parts were available in every operating room, installation of the shunt and re-establishment of blood flow took 2 min.

Myocardial infarction was defined as the appearance of new Q waves of 0.04 s or more in at least two contiguous leads, or a creatinine kinase-MB fraction > 80 ng/ml in combination with the appearance of new Q waves.

2.1. Statistical analysis

Continuous variables are depicted as means ± standard deviation. Analysis of differences between groups was calculated by applying the χ²-test. A P-value less than 0.05 was considered significant.

3. Results

Threehundredsixtyfive distal coronary anastomoses were constructed on the beating heart in 200 patients, i.e. 1.8 anastomoses per patient (Table 2). The LAD and the distal RCA were the most frequent target sites for off-pump CABG (48 and 19%, respectively). Severe ischemia during myocardial preconditioning was observed in 35 temporary occlusions (10%), in 13 out of 176 (7%) on occlusion of the LAD and in 15 out of 71 cases (21%) on occlusion of the RCA (P < 0.05). Ischemia induced hemodynamic deterioration occurred in five patients, in all five cases after occlusion of the distal RCA. In these patients bradycardia, a third-degree heart block and subsequently severe hypotension occurred (Fig. 2), not improving by blood volume redistribution (Trendelenburg maneuver) and intravenous inotropics. On preoperative coronary angiography of these patients a 50–70% stenosis of the RCA was seen in two and a 70–90% in three cases. Two patients had a concomitant stenosis of the proximal RPD at the level of the bifurcation.

In our early experience one procedure, a patient with chronic atrial fibrillation, was converted to CPB. In the last four patients the shunt was utilized. The free-flow measured 20 ml/min at mean arterial blood pressure of 60...
mmHg in 1 patient. A prompt (within 15 s) improvement occurred in all four patients with a normalization of hemodynamic and electrocardiographic parameters (Fig. 2). The shunt allowed well controlled, accurate anastomosis suturing and thus CPB could be avoided. No infarctions were seen in these four patients.

In this cohort of 200 patients the mean creatinine kinase-MB max was 24 ± 38 ng/ml. Peri-operative infarctions occurred in eight patients (4%). No evidence of ischemia during ischemic pre-conditioning was observed in these 8 patients.
Table 3  
Methods to preserve the distal myocardium in off-pump CABG

| Sympathetic blockade (thoracic epidural anesthesia) | Ischemic preconditioning of the myocardium | Preserving distal stump pressure | Pharmacological vasodilatation (calcium antagonists) | Effective displacement of the heart | Mean arterial blood pressure > 50 mmHg (myocardial perfusion) |

4. Discussion

The temporary segmental coronary occlusion at the middle or distal third for grafting of a (sub) totally occluded vessel on the working heart is generally remarkably well tolerated without signs of major ischemia and without affecting hemodynamics [3,5,6,13]. A 1–2 mm S–T segment elevation in off-pump CABG is reported to occur up to 40% [7,8] and this type of surgery leads to a low myocardial infarction rate of 1–4.8% in large series [5,6,9]. In our experience, ischemia occurred in 10% of cases. This led to hemodynamic deterioration only in 1.4% (five out of 365 anastomoses), all following occlusion of the distal RCA. The simple, temporary aortocoronary shunt was most effective and restored promptly regional and global myocardial function in all four cases allowing well-controlled completion of the anastomosis.

The impact of ischemia on the working heart depends on the duration of ischemia, the mass and status of the myocardium at risk, the myocardial oxygen consumption balance and the presence of collateral circulation. Typically, the anastomosis on a totally occluded vessel in a non-displaced heart is tolerated best.

The tolerance for the regional ischemia depends on several factors (Table 3). The basic conditioning of the patient casu quo the heart is crucial. It requires close cooperation between surgeon and anesthetist. In early experience serious hemodynamic deterioration caused by regional ischemia may have occurred more frequently, reflecting a learning curve. There are no data available about the rate of conversion to CPB in case of ischemia induced hemodynamic instability.

A sympathetic, epidural thoracic blockade is suggested to reduce the myocardial oxygen demand, probably by both α- and β-adrenergic blockade, to dilate the coronary arteries and therefore to improve the ventricular function [10]. Ischemic preconditioning remains to be a controversial topic in off-pump CABG. Murry and colleagues reported about its positive effect on the myocardium in dogs [11] and later Yellon showed that short periods of ischemia paradoxically protected the human myocardium from a subsequent longer ischemic insult [12].

Severe hemodynamic deterioration occurred in five out of 71 (7%) not critically stenosed RCA’s. Bradycardia and a third-degree block occurred and were followed by progressive hypotension. This phenomenon has been reported earlier [13,14]. Restoration of blood flow, particularly to the posterolateral branch of the RCA, was most effective in treating the sequelae of ischemia within 30 s. This may be explained by the fact that the RCA supplies the AV-nodal artery [15]. Temporary atrial and ventricular pacing was not used, as this will not favor the ongoing ischemia.

Trapp described already in 1975 the successful clinical use of a perfusion cannula from the ascending aorta to the distal LAD or RCA in 63 patients, thus avoiding conversion to CPB [16]. Currently there are three types of shunts: (1) an intraluminal shunt in the target vessel at the anastomosis site, whether a tube [17] or seal [18], relying on the residual, native flow, (2) a shunt from the graft to the distal coronary artery (internal shunt) [2], and (3) from the ascending aorta to the coronary artery distally to the anastomosis site (external shunt) [16]. The latter is applicable in bifurcations, easy to install (and extract) with low risk of intimal damage and does not interfere with suturing. It is available in every operating room when it is necessary and ready for use within 2 min. The free-flow of approximately 20 ml/min is apparently sufficient for immediate hemodynamic improvement.

Some surgeons favor routine utilization of an intraluminal shunt for two reasons: hemodynamic stability and control of the anastomosis site [17]. Insertion and extraction require meticulous manipulation to avoid intimal damage. Moreover, the application is limited in more calcified vessels.

Ischemia induced hemodynamic deterioration did not occur in left coronary branches. Even posterior wall revascularization through sternotomy access, necessitating considerable displacement of the heart, was well tolerated.

In this analysis there was no relation between the ischemic signs during myocardial preconditioning and the occurrence of peri-operative myocardial infarctions. All eight infarctions (4%) were related to underrated coronary pathology.

In conclusion, the low prevalence of major ischemic events warrants the current ‘clamp and sew’ policy in off-pump CABG. Critical ischemia is most likely to happen following temporary occlusion of the (non-critically stenosed) RCA. A simple, external aorto-coronary shunt compensated the ischemia within 2 min and allowed precise anastomosis construction, thus avoiding conversion to CPB and/or myocardial infarction. We recommend the preparation of the shunt in advance in high-risk patients i.e. patients in whom ischemic preconditioning shows major S–T segment elevations.

References


