

Off-Pump Redo Coronary Artery Bypass Grafting: Technical Aspects and Early Results

(#2001-6916 ... June 27, 2001)

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Presented at the Fourth Annual Scientific Meeting of the International Society for Minimally Invasive Cardiac Surgery, June 27-30, 2001, Munich, Germany.

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ABSTRACT

Background: redo coronary artery bypass grafting (CABG) represents an high-risk surgical procedure, because of an increased incidence of perioperative death, myocardial infarction and stroke. Theoretically, the avoidance of cardiopulmonary bypass may reduce surgical traumatism and ameliorate early results.

Materials and Methods: From January 1995 to May 2001, we performed 123 redo CABGs, of which 53 (44%) off-pump. Off-pump procedure represented respectively 90% of redo CABG in the period 2000-2001 versus 30% in the 1995-1999 period. The mean age was 66.4 years, males were 39 (73%). The mean 2D-echo ejection fraction was 56% and in 9 cases (17%) was less than 40%. Three operations (5.6%) were performed on an urgent base. The access was median sternotomy in all cases. The mean number of grafts per patient was 1.9 (1.7 in the period 1995-99 vs. 2.3 in the period 2000-01, $p=0.01$). In 20 cases (38%) we grafted the circumflex artery branches (19% in the period 1995-99 vs. 55.5% in the period 2000-01, $p=0.015$). Improvements in surgical techniques were achieved over time. The current operative strategy includes the use of deep traction stitches in the posterior pericardium and wall stabilizers to expose target vessels, coronary intraluminal shunts during construction of the

anastomoses and continuous trans-esophageal echocardiographic monitoring. Urgent conversion to on-pump procedure was not required in any case.

Results: We recorded no in-hospital death, one perioperative myocardial infarction (1.9%), one fifth postoperative day-stroke (1.9%) and 9 atrial fibrillations (17%). Mediastinal re-exploration for bleeding was performed in no one patient; 13 patients (24.5%) required postoperative blood transfusion. The mean length of postoperative stay was 7.5 days, ranging from 6 to 18 days.

Conclusions: In our experience off-pump redo CABG is a safe and effective alternative to on-pump procedure and now off-pump is our first choice-technique in redo CABG. A complete revascularization is technically feasible with a low incidence of perioperative complications.

INTRODUCTION

In the last twenty years the incidence of reoperative coronary artery bypass grafting (CABG) is continuously increased, in spite of widespread use of a graft with high long-term patency rates, as internal mammary artery. The U.S. national database Society of Thoracic Surgeons (STS) reported reoperative CABG represented 1.9% of all CABG procedures in 1980, 7.0% in 1990 and finally 7.7% in 1997 [Edwards 1994]. This trend may be explained by the increasing number of patients who have undergone to primary CABG, the progressive failure of saphenous vein grafts and the progression of coronary atherosclerotic disease.

Redo CABG is associated with significant mortality and morbidity rates, higher than in first procedure. Thus, during years several strategies have evolved to reduce this increased risk. These strategies involved the technique of sternal re-entry, prior grafts and ascending aorta management, use of new grafts, myocardial protection and avoidance of cardiopulmonary bypass (CPB).

In particular, off-pump CABG was recently reported to be beneficial in patients undergoing reoperation in terms of mortality and morbidity [Stamou 2001]. In this paper we review our six-years experience in off-pump reoperative CABG, focusing on modifications in the operative techniques which allowed to perform safe operations while extending patient selection.

MATERIALS AND METHODS

Patients

From January 1995 to May 2001, 123 patients underwent reoperative myocardial revascularization in our Institution. Among these 123 patients, 53 (44%) underwent CABG on a beating heart without CPB. Mean age was 66.4 years, the 56.6% of patients experienced an unstable angina, the 17% had a 2D-echo ejection fraction less than 40%, the 56.6% had a three-vessel coronary disease. The preoperative data of the patients operated off-pump are reported in Table 1. We have subdivided patients of the whole study period in two cohorts: years 1995-1999 and years 2000-2001, according to the changes in surgical techniques. A significantly greater incidence of patients with three vessel disease in the 2000-2001 period is observed, reflecting the improvements in our off-pump surgical techniques.

Surgical Techniques

After exposure of femoral vessels by groin incision, we performed median resternotomy using a oscillating saw. The sternal undersurface was peeled-off by scissor and electrocautery, opening widely the pleural cavities. Then the graft vessels were harvested. As a general rule, we carried out the minimal dissection required to achieve exposure of coronary target vessels. If patent, old grafts was left undisturbed. Diseased grafts, however, was sistematically ligated and divided.

Off-pump operative strategy

During last six years we have continuously improved our off-pump surgical technique in order to achieve optimal exposure and stabilization. In the first phase (years from 1995 to 1999, 26 patients) we monitored continuously cardiac wall motion and ventricular filling by intraoperative transesophageal echocardiography in all patients. Exposure of the cardiac walls was obtained positioning a pair of thick cloth slings passed through the transverse sinus and

around the inferior vena cava. Further exposure was obtained placing laparotomy pads in the pericardial cavity, behind and laterally to the left ventricle. The stabilization was achieved by a pressure-fixation device (Estech, Inc., Danville, CA, USA). Finally, blood flow in the coronary target vessel was temporarily interrupted by snaring two encircling stitches placed above and below the anastomotic point.

In the recent phase (years from 2000 to 2001, 27 patients) intraoperative transesophageal echocardiography was reserved only to very high-risk cases. Exposure of the cardiac walls was obtained tractioning and positioning a pair of thick cloth slings snared by deep pericardial polyester stitches (Lima stitches), placed in proximity of the left inferior pulmonary vein and between the left inferior pulmonary vein and the inferior vena cava. The traction stitches were passed through a rubber tourniquet in order to avoid accidental myocardial injury due a sewing effect produced by the same stitches. The stabilizer was a suction-fixation device, the Medtronic Octopus III (Medtronic, Inc. - Minneapolis, MN, USA). The Octopus was used only to achieve a motionless anastomotic site after optimal exposure of the target vessel by means of the Lima stitches. We did not place anymore encircling suture around coronary vessels. We routinely inserted through the arteriotomy an intraluminal coronary shunt. The anastomotic site was maintained bloodless by a fine-tip aspiration cannula. The anastomoses were performed with 7-0 or 8-0 polypropilene sutures. The shunt was removed before placing last anastomotic stitch.

In regard to our routine anastomotic sequence, no changes were made between the two study periods. We bypassed first the left anterior descending (LAD) artery. The restoration of the coronary blood flow to LAD-dependent myocardium increases hemodynamic tolerance of the heart luxations for the remaining anastomoses. Therefore, we revascularized the marginal branches and finally the right coronary artery system.

Statistical analysis

An univariate analysis was done to analyse the possible relationship between patient groups and the variables collected. Contingency table analysis for categoric data and *t* test or

Mann-Whitney U test for continuous variables were used. A *p* value less than 0.05 was considered significant.

RESULTS

Figure 1 shows the on-pump/off-pump redo CABG ratio in the years 1995-1999 and 2000-2001. In the last period, the 10% of redo CABG only (3/30) was performed on-pump.

The operative data are reported in Table 2, according to periods 1995-1999 and 2000-2001. In the years 2000-2001, mean bypasses per patients and completeness of revascularization significantly increased in comparison with the previous period (2.3 vs.1.7, *p*=0.01 and 72% vs. 47%, *p*=0.02, respectively), and a significantly higher number of patients received a triple graft and a bypass on the circumflex system (37% vs. 7.5%, *p*=0.02 and 55.5% vs. 19%, *p*=0.02, respectively). Urgent conversion to CPB was required in two cases (7.5%) in the period 1995-1999.

The postoperative results are summarized in Table 3. No in-hospital deaths were observed among patients reoperated off-pump. We observed one case (1.9%) of perioperative myocardial infarction and one case (1.9%) of postoperative stroke, occurred six days after surgery. Postoperative atrial fibrillation occurred in 17% of patients. Postoperative in-hospital length of stay was 7.5 ± 2.2 days. No differences in early results were observed between the study periods 1995-1999 and 2000-2001.

DISCUSSION

Patients candidates to redo CABG have quite different demographic features compared to patients who underwent first surgical revascularization. Infact, they are older and sicker, more often affected by cerebrovascular disease, peripheral artery disease, chronic obstructive pulmonary disease, renal failure and aortic calcification. Such patients may have a reduced tolerance to blood exposure to foreign surfaces and to hypotensive perfusion during cardiopulmonary bypass. Moreover, aortic arteriosclerosis and calcification may make dangerous or unfeasible cannulation and cross-clamping. Surgical maneuvers on the heart,

necessary in order to peel off the mediastinal adhesions, carries a definite risk of atherosclerotic embolization from old grafts into coronary vessels. The detrimental interplay between redo patients and cardiopulmonary bypass contribute to explain the higher risk and worse results of reoperative procedures compared with first procedure. He and coworkers demonstrated that long CPB time and postoperative complications like mediastinal reexploration for bleeding, prolonged mechanical ventilation and renal failure were independently associated with higher mortality [He 1995, Weintraub 1995].

On these basis, avoidance of CPB and cardioplegic arrest is anticipated to be beneficial for patients undergoing coronary reoperation in terms of both mortality and morbidity. From the analysis of the literature it is evident that on-pump redo CABG carries a high incidence of both in-hospital death (ranging from 6.6 to 16.7%) and perioperative myocardial infarction (ranging from 3.1 to 25%) and stroke (ranging from 1.4 to 8%) [He 1995, Weintraub 1995]. Avoidance of CPB in reoperative CABG has been reported to reduce both in-hospital mortality and postoperative complications [Allen 1997, Rivetti 1997, Bergsland 1998, Gu 1998, Struber 1999, D'Ancona 2000, Kilger 2000, Stamou 2000, Trehan 2000] (Table 4). Stamou et al. [Stamou 2000] observed a statistically significant higher mortality rate in conventional CABG compared with off-pump CABG. Allen et al. [Allen 1997] reported a significant reduction in postoperative atrial fibrillation, time to extubation, blood transfusions and length of stay in patients reoperated off-pump compared with patients reoperated on CPB. Avoidance of aortic cannulation and cross-clamping reduces the risk of systemic, and particularly cerebral, embolization of atherosclerotic plaques from the ascending aorta and, if a femoral artery cannulation is performed, from the arch and the descending thoracic and abdominal aorta. Gu [Gu 1998] and Struber [Struber 1999] demonstrated avoidance of cardiopulmonary bypass reduces systemic inflammatory activation during CABG and postoperative morbidity and hospital stay compared with on-pump procedures. Off-pump revascularization produces less myocardial injury, as indicated by serum levels of creatine kinase and troponin I, than on-pump procedures and this evidence may be explained by avoidance of interruption of coronary blood flow by aortic cross-clamping and cardioplegia infusion [Kilger 2000].

However, successful off-pump CABG in redo patients first of all requires quality of coronary anastomoses and completeness of revascularization as good as in on-pump procedures. Thus, our effort was to improve off-pump surgical strategy in order to achieve these goals.

In our early experience on beating heart surgery, off-pump reoperative CABG was reserved only to patients at highest risk for CPB-related complications and to patients in which CPB was contraindicated. We used gauze tapes passed through transverse sinus and under inferior vena cava in order to lift and expose cardiac wall. The major drawback of this technique was the acute reduction of caval blood return and consequently possible hemodynamic collapse. The anastomoses was constructed during intentional myocardial ischemia, due to suture snaring of the coronary vessel. Thus, the anastomosis were performed in a uncomfortable setting: the degree of exposure was often imposed by preload requirements and it was imperative to suture as quickly as possible, in order to minimize ischemic damage, arrhythmias and left ventricular dysfunction.

The recent changes in operative strategy and techniques made off-pump redo CABG our first-choice procedure for all coronary reoperations. In the period January2000-May2001, 27 of our 30 patients (90%) undergoing redo CABG were operated off-pump. This recent extension of the indications to off-pump redo CABG is related to a substantial modification of the former surgical technique. We introduced in our routine deep pericardial traction stitches ("Lima stitch") for heart luxation, more sophisticated wall stabilizers based on suction and intracoronary shunt. The pericardial stitches allow excellent exposure of the lateral and posterolateral walls without hemodynamic compromise. With this technique, the circumflex system was grafted in 55.5% of cases vs. 19% of the previous one, and conversion to cardiopulmonary bypass was not required in any case, versus the 7.5% conversion rate of the 1995-1999 period.

Furthermore, the placement of a intracoronary shunt has several advantages [Rivetti 1997]. First, the blood flow is not interrupted during anastomosis and ischemic time is limited to shunt insertion and removal, generally less than two minutes. Therefore the risk of

myocardial ischemia and consequently of ventricular dysfunction and arrhythmias is greatly reduced. Conversion to CPB because of difficult coronary exposure has been not necessary in any case. Moreover the continuous blood flow through the shunt allows unhurried construction of anastomoses. Finally, the placement of a correctly sized shunt maintains bloodless the surgical field. We believe that the simultaneous employment of the aforementioned techniques (deep pericardial traction stitches, last generation stabilizers and intracoronary shunts) allow the construction of the anastomoses as accurate as in conventional CABG with cardioplegic arrest. Although patients of the last study period showed a greater incidence of three vessel coronary disease, unstable angina and a significantly increased mean number of bypass grafts and circumflex system revascularization rate, results remained stable over time.

In conclusion, off-pump revascularization represent a valid and safe option in reoperative CABG, eliminating the detrimental interplay between such high-risk patients and CPB. In our opinion, the improvements in surgical techniques permit today to extend the benefits of CPB avoidance to the majority of redo patients.

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Table 1. Preoperative data of the patients who underwent reoperative off-pump CABG.

Variables	All the patients	Period 95- 99	Period 00- 01
Number of patients operated off-pump	53	26	27
Mean age (range)	66.4 (49-77)	64.4	67.6
Males	39 (73.5%)	20 (77%)	19 (70%)
Unstable angina	30 (56.6%)	13 (50%)	17 (63%)
Mean 2D-echo ejection fraction	0.56	0.53	0.58
2D-echo ejection fraction < 40%	9 (17%)	4 (15%)	5 (18.5%)
One-vessel disease	15 (28%)	11 (42%)	4 (15%)
Two-vessel disease	8 (15%)	5 (19%)	3 (11%)
Three-vessel disease	30 (56.6%)	10 (38%)	20 (74%)*

*p=0.02 vs. Period 1995-1999.

Table 2. Operative data of the patients who underwent reoperative off-pump CABG.

Variables	All the patients (n=53)	Period 95- 99 (n=26)	Period 00- 01 (n=27)
Urgent operation	3 (5.6%)	1 (3.8%)	2 (7.4%)
Emergency operation	0	0	0
Mean bypasses per patient (range)	1.9 (1-3)	1.7 (1-3)	2.3 (1-4)*
Single graft	24 (45%)	16 (61.5%)	8 (30%)
Double graft	16 (30%)	8 (31%)	9 (33%)
Triple graft	13 (25%)	2 (7.5%)	11 (37%)**
Coronary target vessels			
LAD system	52 (98%)	25 (96%)	27 (100%)
CFX system	20 (38%)	5 (19%)	15 (55.5%***
RCA system	18 (34%)	7 (27%)	11 (41%)
Conduits			
Left internal mammary artery	33 (62%)	17 (65%)	16 (59%)
Right internal mammary artery	7 (13%)	2 (7.7%)	5 (18.5%)
Radial artery	15 (28%)	4 (15%)	11 (41%)
Right gastroepiploic artery	1 (1.8%)	1 (4%)	0
Great saphenous vein	37 (70 %)	14 (54%)	23 (85%) _i
Associated coronary endoatherectomy	2 (4%)	0	2 (7.5%)
Completeness of revascularization	62%	47%	72%#
Conversion to CPB	2 (4%)	2 (7.5%)	0

LAD=left anterior descending coronary artery; CFX=circumflex coronary artery; RCA=right coronary artery; CPB=cardiopulmonary bypass.

* $p=0.01$ vs. Period 1995-1999; ** $p=0.01$ vs. Period 1995-1999; *** $p=0.015$ vs. Period 1995-1999;

_i $p=0.03$ vs. Period 1995-1999; # $p=0.02$ vs. Period 1995-1999.

Table 3. In-hospital results

Variable	All the patients (n=53)	Period 95- 99 (n=26)	Period 00- 01 (n=27)
In-hospital death	0	0	0
Myocardial infarction	1 (1.9%)	1 (3.8%)	0
Postoperative stroke	1 (1.9%)	0	1 (3.7%)
Patients requiring blood transfusion	13 (24.5%)	6 (23%)	7 (26%)
Mediastinal re-exploration for bleeding	0	0	0
Atrial fibrillation	9 (17%)	5 (19%)	4 (15%)
Postoperative length of stay (range)	7.5±2.2 days (6-18)	7.8±1.7 days	7.4±2.4 days

Table 4. Literature results of reoperative myocardial revascularization with and without cardiopulmonary bypass.

Author	Year	Cases	In-hospital mortality	Perioperative MI	Perioperative stroke
ON-PUMP REDO					
He ⁴	1995	622	11.4%		1.4%
Weintraub ⁵	1995	2030	7.0%	5.6%	2.8%
Allen ⁷	1997	12	16.7%	25%	8.0%
STS Database ²	1997	13527	7.4%	3.16%	3.0%
Bergsland ¹³	1998	183	6.6%	12%	3.8%
Stamou ⁶	2000	41	10%	17%	
OFF-PUMP REDO					
Allen ⁷	1997	23	4.3%	4.3%	4.3%
Bergsland ¹³	1998	105	3.8%	4.8%	0
Trehan ¹²	2000	50	4%	4%	
Stamou ⁶	2000	49	1%	9%	
D Ancona ¹⁰	2000	274	3.6%	2.9%	0.7%

MI=myocardial infarction

Figure 1. Changes in on-pump/off-pump redo CABG ratio in the study periods 1995-1999 and 2000-2001.

