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Total Arterial Revascularization for Multiple Vessel Coronary Artery Disease: With or without Cardiopulmonary Bypass

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ABSTRACT

Background: To assess the usefulness of off-pump technique for more technically demanding coronary artery bypass procedures using exclusively arterial conduits.

Methods: Analysis of perioperative data of 324 consecutive patients in whom total arterial revascularization for multiple-vessel coronary artery disease was performed—181 cases on-pump and 143 cases off-pump.

Results: On average in the on-pump group 2.7 ± 0.8 (range, 2-5) grafts per patient were constructed versus 2.4 ± 0.7 (range, 2-4) grafts per patient in the off-pump group (P < .001). Of the total number of 490 anastomoses performed on-pump, 83 (17%) were side-to-side and of 349 anastomoses performed off-pump, 51(15%) were side-to-side, a nonsignificant difference (*P* = .4). The aorta was used as a site for proximal anastomosis of 1 or more arterial conduits in 105 patients (58%) who underwent on-pump surgery and in 57 patients (40%) who underwent off-pump surgery (*P* = .002). In the off-pump group, the right internal thoracic artery (RITA) was rarely (12%) routed through the transverse sinus to circumflex branches compared with the on-pump group (34%) (*P* = .017). RITA in off-pump patients was more often used to revascularize the anterior wall (47% versus 29%; *P* = .08). We observed no difference in mortality (1.7% versus 0%; *P* = .3), incidence of perioperative myocardial infarction (8.8% versus 7.7%; *P* = .8), stroke (1.7% versus 1.4%; *P* = .8), or atrial fibrillation (24% versus 19%; *P* = .3). We observed less inotropic support and less blood-product use in off-pump patients.

Conclusion: Total arterial revascularization for multiple-vessel coronary artery disease may be safely performed off-pump. We observed tendency to somewhat smoother postoperative course in the off-pump group.

INTRODUCTION

The use of left internal thoracic artery (LITA) to left anterior descending (LAD) coronary artery has become a gold standard in coronary artery bypass grafting (CABG). This graft is preferred for both higher patency rates [Barner 1994] and improved survival [Loop 1986]. Reports exist demonstrating that further benefit may be achieved when both ITAs are used [Lytle 1999]. The further development of this reasoning is the strategy of total arterial revascularization aiming at improving long-term results by avoiding the late complication of saphenous vein graft atherosclerosis. This technique, although advocated by some [Munaretto 2003, Tavilla 2004] is avoided by many surgeons because of its "increased complexity" and "safety and efficacy concerns" [Buxton 2003].

The avoidance of cardiopulmonary bypass (CPB) has the potential to obviate the clinical and subclinical manifestations of CPB-related morbidity [Edmunds 2003]. Even though the survival benefit may be difficult to prove, the numerous physiological and clinical advantages of off-pump CABG (OPCAB) over the classical on-pump approach have been demonstrated [Ngage 2003]. Many surgeons, however, remain skeptical about technical limitations of OPCAB and the quality of anastomoses [Kim 2001, Puskas 2001], particularly in cases of total arterial revascularization.

We therefore decided to review our experience in what we consider more technically demanding CABG procedures—those performed using exclusively arterial conduits—and to assess the impact of off-pump strategy on our practice.

MATERIALS AND METHODS

We prospectively gathered and retrospectively analyzed the data on 324 consecutive patients who underwent total arterial revascularization for multiple-vessel coronary artery disease in our institution during a 3-year period (September 2000 through August 2003). Among those patients the operation was performed using CPB in 181 cases and off-pump technique in 143 cases. The groups were comparable from the demographic point of view. Mean age was 55.7 ± 8.9 years (minimum 37 years, maximum 77 years) for the on-pump group and 56.9 ± 8.1 (minimum 39, maximum 73) in the off-pump group (*P* = .254). There were 148 men (82%) who underwent on-pump surgery and 116 men (81%) who underwent off-pump surgery (*P* = .977).

Cardiac status of the patients is described in Table 1.

The comorbidities were comparable between the groups and are shown in Table 2. There were more hypertensive patients and considerably more patients with history of peptic ulceration in the on-pump group.

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Table 1. Preoperative Cardiac Status of the Patients*

	On-Pump (n = 181)	Off-Pump (n = 143)	*P*
LVEF	51.7% ± 12.6% (20%-70%)	53.5% ± 10.5% (30%-73%)	.5
ACS	11 (6.1%)	7 (4.9%)	.8
Acute STEMI	5 (2.8%)	3 (2.1%)	.98
IABP preoperatively	1 (0.6%)	0	.97
CCS class (in stable patients)	2.5 ± 0.7	2.6 ± 0.7	.2
Previous MI	111 (61%)	79 (55%)	.3
Previous PCI	3 (1.7%)	1 (0.7%)	.8
Previous CABG	0	1 (0.7%)	.92

*Parametric data are presented as mean ± SD. LVEF indicates left ventricular ejection fraction; ACS, acute coronary syndrome; STEMI, ST elevation myocardial infarction; IABP, intraaortic balloon pump; CCS, Canadian Cardiovascular Society; PCI, percutaneous intervention; CABG, coronary artery bypass grafting.

STATISTICAL METHODS

The data are presented as mean ± SD for parametric variables and as percentages for qualitative data. To compare the parametric data we used either the *t* test or the Mann-Whitney test where feasible. For qualitative data chi-square contingency table analysis was used applying Yates correction and Fisher-Exact test where required. A *P*-value less than .05 was considered significant in all instances of statistical analysis.

RESULTS

Procedural Details

The on-pump procedures were performed with an average CPB time of 63 ± 22 minutes. The cross-clamp time was 43 ± 17 minutes. We used intermittent cold 4:1 blood cardioplegia in 104 patients (57%) and intermittent warm miniplegia (blood + potassium) in the remaining 77 patients (43%).

The off-pump procedures were performed using either Octopus (Medtronic, Minneapolis, MN, USA) (113 patients, 79%) or Axius Vacuum (Guidant, Santa Clara, CA, USA) (remaining 29 patients) devices for anastomotic site stabilization. To manipulate and expose the heart, we used pericardial stitches and slings in 49 patients (34%), apical suction devices (Axius Xpose, Guidant) in 29 patients, and Starfish (Medtronic) in 65 patients.

On average 2.7 ± 0.8 (range 2-5) grafts per patient were performed in the on-pump group and 2.4 ± 0.7 (range 2-4) in the off-pump group (*P* < .001). Of the total of 490 anastomoses performed on-pump, 83 (17%) were side-to-side, which is not significantly different from 51 (15%) side-to-side anastomoses of 349 performed off-pump (*P* = .4). Y-anastomoses connecting either radial artery to LITA or RITA to LITA were constructed in 67 patients (37%) in the on-pump group and in 60 patients (42%) in the off-pump group (*P* = .4). The aorta was used as a site for proximal anastomosis of 1 or more arterial conduits in 105 patients (58%) in the on-pump group and in 57 patients (40%) in the off-pump group (*P* = .002). The conduit used most often was the LITA in both groups (180 patients [99%] versus 141 patients [99%]; *P* = .9) followed by the radial artery (158 patients [87%] versus 114 patients [80%]; *P* = .1), respectively. RITA was used in 68 patients (38%) in the on-pump group and in 43 patients (30%) (*P* = .2) in the off-pump group. We also used the right gastroepiploic artery in 2 patients in the on-pump group.

The details of the distribution of anastomoses and the grafting strategies are described in Tables 3 and 4.

Early Results

Three patients (1.7%) who underwent surgery with the use of CPB died postoperatively. No deaths occurred in the off-pump group (*P* = .3). Three patients (1.7%) in the on-pump

Table 2. Patient Characteristics*

	On-Pump (n = 181)	Off-Pump (n = 143)	*P*
Diabetes mellitus	26 (14%)	28 (20%)	0.3
Hypertension	114 (63%)	73 (51%)	0.04
Hyperlipidemia	22 (12%)	19 (13%)	0.9
History of peptic ulcers	27 (15%)	4 (2.8%)	<0.001
COPD	3 (1.7%)	3 (2.1%)	0.90
Extracoronary atherosclerosis	6 (3.3%)	4 (2.8%)	0.96
History of CVA	3 (1.7%)	3 (2.1%)	0.90
Varicose veins	6 (3.3%)	1 (0.7%)	0.2
Preoperative creatinine level	0.93 ± 0.20 mg%	0.93 ± 0.19 mg%	0.6
Preoperative bilirubin level	0.98 ± 0.45 mg%	0.88 ± 0.43 mg%	0.5

*Parametric data are presented as mean ± SD. COPD indicates chronic obstructive pulmonary disease; CVA, cerebrovascular accident.

Table 3. Distribution of Anastomoses*

	On-Pump (n = 181) 490 Anastomoses	Off-Pump (n = 143) 349 Anastomoses	P
			.08†
Anterior wall			
LAD area (LAD, D)	198 (40%)	168 (48%)	.03‡
Posterior wall			
Cx area (IM, OM, Cx)	189 (39%)	118 (34%)	.2‡
Inferior wall RCA area			
(RCA, PD, PLB)	103 (21%)	63 (18%)	.3‡

*LAD indicates left anterior descending artery; D, diagonal artery; Cx, circumflex artery; IM, intermediate artery; OM, obtuse marginal artery; RCA, right coronary artery; PD, posterior descending artery; PLB, posterior lateral branch.

†According to the full 2 × 3 contingency table analysis.

‡According to Fisher-Exact test for the proportion in the given row.

group suffered a stroke compared with 2 patients (1.4%) in the off-pump group plus 1 patient who suffered a transient ischemic attack postoperatively. Perioperative myocardial infarction (MI) was found in 16 patients (8.8%) in the on-pump group and 11 patients (7.7%) in the off-pump group (P = .8). In the postoperative period dopamine infusion was used in 176 patients (97%) in the on-pump group and in only 36 patients (25%) in the off-pump group (P < .001). Cardiac status necessitated the use of adrenaline infusion in 23 patients (13%) and intraaortic balloon support in 13 patients (7%) in the on-pump group compared with 3 patients (2%) (P < .001) and 5 patients (3%) (P = .2) in the off-pump group, respectively. The ventilation times were 10.1 ± 5.3 hours and 8.9 ± 3.9 hours (P = .2) in the on-pump and off-pump groups, respectively. The number of patients suffering postoperative atrial fibrillation episodes was similar, 44 (24%) versus 28 (19%) (P = .3) in the on-pump and off-pump groups, respectively.

More patients in the on-pump group (41 [22%]) required red blood cell transfusions postoperatively than in the off-pump group (19 [13%]), P = .04. Nevertheless, postoperative hematocrit levels were significantly, even though not greatly, lower in the on-pump group, 30% ± 3.5% versus 31% ± 3.8%, respectively, (P = .01).

The postoperative creatinine levels were the same in both groups, 1.1 ± 4.4 versus 1.1 ± 0.3 mg% (P = .7). Bilirubin levels were also the same in both groups, 1.2 ± 0.8 versus 1.2 ± 0.9 mg% (P = .06).

Table 4. Grafting Strategies*

	On-Pump (n = 181)	Off-Pump (n = 143)	P
LAD area (LAD, D)	198 Anastomoses	168 Anastomoses	.8†
LITA	169 (85%)	143 (85%)	.9‡
RITA	21 (11%)	20 (12%)	.9‡
RA	8 (4%)	5 (3%)	.8‡
Cx area (IM, OM, Cx)	189 anastomoses	118 anastomoses	.03†
LITA	34 (18%)	26 (22%)	.5‡
RITA	25 (13%)	5 (4%)	.016‡
RA	130 (69%)	87 (74%)	.4‡
RCA area (RCA, PD, PLB)	103 anastomoses	63 anastomoses	.6†
LITA	1 (1%)	0	.8‡
RITA	27 (26%)	18 (29%)	.8‡
RA	73 (71%)	45 (71%)	.9‡
RGEA	2 (2%)	0	.7‡
LITA	204 anastomoses	169 anastomoses	.6†
LAD area (LAD, D)	169 (83%)	143 (85%)	.7‡
Cx area (IM, OM, Cx)	34 (17%)	26 (15%)	.8‡
RCA area (RCA, PD, PLB)	1 (0.5%)	0	.9‡
RITA	73 anastomoses	43 anastomoses	.02†
LAD area (LAD, D)	21 (29%)	20 (47%)	.08‡
Cx area (IM, OM, Cx)	25 (34%)	5 (12%)	.017‡
RCA area (RCA, PD, PLB)	27 (37%)	18 (42%)	.7‡
RA	211 anastomoses	137 anastomoses	.9†
LAD area (LAD, D)	8 (3.8%)	5 (3.6%)	.8‡
Cx area (IM, OM, Cx)	130 (62%)	87 (64%)	.8‡
RCA area (RCA, PD, PLB)	73 (35%)	45 (33%)	.8‡

*LITA indicates left internal thoracic artery; RITA, right internal thoracic artery; RA. radial artery; RGEA, right gastroepiploic artery; other abbreviations are defined in the first footnote of table 3.

†According to the full 2 × 3 contingency table analysis.

‡According to Fisher-Exact test for the proportion in the given row.

DISCUSSION

The application of effective target-vessel visualization and stabilization devices has allowed for more reliable and safe performance of OPCAB procedures [Mueller 2002]. It appears that even more technically demanding total arterial revascularization for multiple-vessel coronary artery disease can be accomplished without CPB [Quigley 2001]. In our department we have gradually shifted toward performing more off-pump procedures. The numbers vary from surgeon to surgeon, but of 324 consecutive total arterial grafting procedures performed within 3 years in our institution, nearly 45% (143) have been performed off-pump.

There are only few centers around the world that would perform nearly 100% of CABG procedures off-pump. Most centers use some selection criteria [Dewey 2003]. We are aware that we are also using some selection criteria, although they were never defined precisely. Some criteria, such as intramyocardial coronary arteries, diffuse atherosclerosis, narrow target vessels, or hemodynamic instability, even though relatively well agreed on [Yokoyama 2001] may not be easily extracted from retrospective analysis. Some of the criteria are less easily recognized but may be sought out in perioperative data and patient characteristics.

We failed to show any difference in cardiac status in the on-pump and off-pump groups of patients. Similarly the other demographic and clinical characteristics did not differ. The difference in incidence of peptic ulcer disease, although highly significant, is unlikely to affect the use of CPB.

One of the obvious factors influencing the choice of the on-pump versus off-pump technique may be the need to revascularize more coronary vessels. The consequences of incomplete revascularization [Jones 1996] must not be forgotten when choosing the operative technique, and we do not believe the avoidance of CPB surpasses the need for complete myocardial revascularization. Complete myocardial revascularization corresponds with a somewhat higher number of anastomoses in cases performed on-pump, suggesting that surgeons were more likely to use CPB when they needed to revascularize more vessels. Our findings, however, suggest that the opposite may be true. We failed to show a significant difference in the number of grafts anastomosed to the posterior or inferior wall of the heart in the on-pump and off-pump groups. Similarly the proportion of side-to-side anastomoses did not differ. As shown in Table 3 the difference was the most apparent when the number of anterior wall grafts was compared. In fact we were able to perform the posterior wall or sequential anastomoses equally well on- and off-pump. Also, when needing to revascularize fewer vessels, particularly in front of the heart, we were very unlikely to use CPB. Therefore the difference in number of grafts per patient might not disappear even when we are able to do almost any case off-pump.

An interesting difference in the grafting strategy is apparent in our data. When using both ITAs for grafting the left side of the heart, the target for RITA differed significantly. In OPCAB procedures RITA was rarely routed through the transverse sinus and anastomosed to the circumflex territory (Table 4). Instead it was anastomosed to LAD, with LITA supplying the lateral and posterior wall. This strategy is particularly useful in off-pump cases. In this situation we anastomose RITA to LAD first. With this graft in place and working, we easily lift and manipulate the heart to achieve all other vessel revascularization. This easy manipulation would not be feasible if LAD was grafted with LITA. At the same time we find anastomosing RITA to circumflex branches off-pump particularly technically demanding (although not impossible). Whether the choice of RITA routing is important from the point of view of graft patency and possible reoperations remains debatable [Ura 1998, Lev-Ran 2001].

Another important technical aspect apparent from our data is the number of proximal anastomoses to the aorta, which is significantly lower in off-pump cases. It has been suggested that side-clamping the aorta during off-pump procedure may be the source of iatrogenic dissection [Chavanon 2001]. Fortunately we did not observe this complication. Another reason not to perform proximal anastomoses to the aorta in off-pump cases is to avoid aortic manipulation altogether and in this way to minimize the risk of stroke [Ngaage 2003]. Unfortunately we found no difference in stroke incidence between the groups, and one of the strokes in an off-pump patient occurred in the patient in whom no anastomosis to the aorta was constructed. Nevertheless both rationales stated above may explain the apparent tendency of surgeons in our department to avoid proximal anastomosis to the aorta in off-pump procedures if possible. Actually when discussing our data during the writing of this manuscript some of the surgeons admitted to choosing the on-pump technique when anastomosis to the aorta was planned.

Not unexpectedly we found no difference in the mortality or incidence of myocardial infarctions between the groups [Van Dijk 2001, Puskas 2003]. However, we observed less need for inotropic support in the OPCAB group. Although the use of "renal" doses of dopamine is considered routine in our institution in on-pump cases and the difference in its use between the groups may be misleading, the need for adrenaline infusion signifies the low cardiac output. In view of the very similar cardiac status of both groups preoperatively and the comparable number of perioperative MIs, we might hypothesize that avoidance of CPB decreased the chances of development of temporary myocardial dysfunction, ie stunning immediately postoperatively, as suggested by other authors [Ngage 2003].

We were disappointed to find no difference in neurological outcomes, more so because one of the strokes that occurred in the off-pump group, as we indicated above, involved a patient in whom no proximal anastomosis and therefore no aortic manipulation was used. Similarly no benefit in ventilation time, renal function, or incidence of atrial fibrillation was observed. The above findings are supported by reports from other groups [Quigley 2001]. Likewise we failed to show any influence of CPB on renal function or on postoperative bilirubin level. One has to remember, however, that our patients had normal preoperative creatinine and bilirubin levels and were therefore low-risk groups from the renal and hepatic function point of view.

The important advantage of the off-pump technique, which has been reported repeatedly by other authors [Ascione 2001, Van Dijk 2001], was less need for blood transfusion. The fact that in spite of the higher transfusion rate in the on-pump group the final hematocrit on discharge was lower in comparison with off-pump patients further stresses the significance of this finding.

We conclude that complete arterial revascularization for multiple vessel coronary artery disease is possible without CPB. With ever better results of coronary surgery it might be very difficult to prove the advantage of this surgical option from the mortality or major morbidity point of view. One should not, however, underestimate the importance of relatively minor benefits of less blood product use or improved early postoperative cardiac function. We propose that off-pump technique could safely be employed in growing numbers of patients without compromising the complexity and quality of revascularization in the struggle for less invasive coronary surgery.

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