Off-pump Versus On-pump CABG: Short Term Results of Composite Arterial Grafts

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objective : **Composite arterial grafting is by itself a complex technique as much as the off-pump technique. Combining two complex procedures is a questionable issue. We investigated the safety of the off-pump technique in total arterial coronary artery bypass grafting (CABG) using composite grafts based on our experience with this procedure over the last year.**

Methods : **In the period from October 2003 to October 2004, 50 consecutive patients were submitted to CABG using composite arterial grafts. Patients who had diffuse coronary artery disease and patients who needed emergency operations were excluded from this study. Patients were randomly assigned to one of two groups: Group I (on-pump CABG) and group II was (off-pump CABG).**

Results : **We operated on 29 patients in group I and 21 patients in group II. There were no significant differences between the two groups in terms of preoperative characteristics apart from significantly lower ejection fraction in group II. Operative time was significantly shorter in group II (p=0.005), although the number of distal anastomoses was comparable in the two groups group I (2.7 ± 0.7) and group II (2.86 ± 0.65) There was no mortality in both groups. There was no statistical significance between the two groups regarding the incidence of post-operative complications apart from bleeding which was significantly lesser in group II.(p=0.003)**

Conclusion : **Off-pump CABG, combined with composite arterial grafts is a safe procedure on the short-term and had only minor advantages over the On-pump technique.**

Neither arterial grafts nor off-pump technique were popular with the begging of the 1970s when Favalaro1 popularized coronary artery bypass grafting(CABG) using saphenous vein grafts (SVGs) and cardiopulmonary bypass(CPB). However, performing CABG in a motionless field without the complications of CPB derived the pioneering efforts of Benetti2 and Buffalo3 in the 1980s to adopt and improve the off-pump technique.

However, due to the trust of most surgical teams in conventional CABG using CPB, the natural resistance to change routine procedures and the doubts about the quality of anastomoses performed during off-pump operation kept this technique isolated for many years. By time, with the development of technical variations- such as the interruption of coronary flow with soft silicone snares, use of drugs to reduce heart rate and oxygen demand, and mechanical stabilizers-the off-pump procedure became safe, effective, reproducible and popular as reported by Shennib4, Gründeman5 and Calafiore6 in the 1990s.

The expanded use of arterial grafts was developing parallel to this achievement in the off-pump CABG. The superiority of the internal mammary artery grafts in terms of patency rates and long-term survival was confirmed by the

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work of Loop7 and Fiore8. However,

The increased need for more arterial conduits raised the idea of using the radial artery by Acar9.Moreover, in order to avoid the anatomical limitations of in situ internal mammary arteries, and to reproduce the physiology of the arterial conduits as a third order branch- composite arterial conduits have been proposed and extensively studied by Tector10, Calafiore11and Tatoulis12.

It would seem logical to combine the advantages offered by the off-pump technique with those of total arterial myocardial revascularization; however up to date clinical data are still lacking, mainly owing to the belief that composite arterial grafting may be too technically demanding to be performed using the off-pump technique.

Patients and Methods

Patient's Selection Criteria

From October 2003 to October 2004, 50 consecutive patients underwent coronary surgery by our team using composite arterial grafts in new Kasr El-Aini teaching hospital, Faculty of Medicine, Cairo University. Patients who needed an emergency CABG and patients who had diffusely diseased coronary arteries with poor distal run-off were excluded from this prospective study. Patients were randomly assigned to group I (on-pump CABG) or to group II (off-pump CABG). The type of surgery was discussed with all patients included in this study. However, the surgeons were allowed to change the operative technique at any time after randomization.

Surgical Technique

All patients underwent total arterial CABG with composite grafts. After midline sternotomy the left internal mammary (LIMA) was harvested as pedicled conduits. Skeletonization was applied whenever BIMA were harvested. BIMA harvesting was avoided in patients with insulin dependent diabetes and/or morbid obesity defined as body mass index (BMI)>30.

A preoperative assessment of the radial artery (Allen test) in the non dominant arm was carried out for all patients scheduled for radial artery harvesting. The radial artery was harvested with its satellite veins and surrounded connective tissue to avoid arterial wall damage. In order to avoid spasm, systemic verapamil infusion 5mg/hour and topical application of a warm cocktail composed of: 300ml ringer solution, 5 mg verapamil 2.5 mg nitroglycerine, 1000 unit of heparin and 0.02 mg of 8.4% sodium bicarbonate.

We routinely perform composite arterial grafts in a Y configuration with an 8-0 polypropylene running suture before institution of CPB. For both groups heparinization was employed as 4 mg/kg/weight. It was controlled by the activated coagulation time (ACT) with 400 seconds being accepted as the minimum value. In group I standard CPB was instituted and warm cardioplegia was used for myocardial protection. In group II target vessel stabilization was achieved with the Octopus® IV vacuum stabilizer system (Medtronic, Minneapolis. USA).

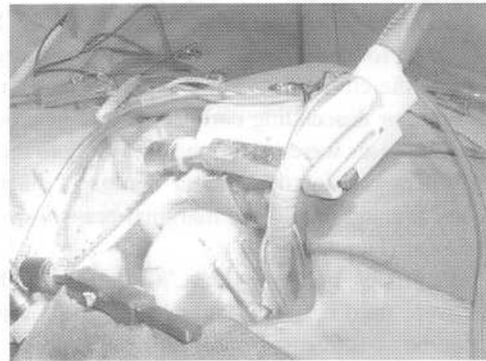

Fig. 1: Octopus stabilizer mounted on a sternal retractor to expose the posterolateral surface of the heart.

Exposure of the lateral and inferior vessels was obtained by means of a pericardial stitch positioned between the inferior pulmonary veins (Fig.2) and by rotation of the operating table. It was kept in the trendelenburg position and rotated to the left or right side according to the different coronary vessels. Target vessels were occluded proximally by a silicone loop (Surg-I loop®, Scanalan international, Saint Paul. USA).

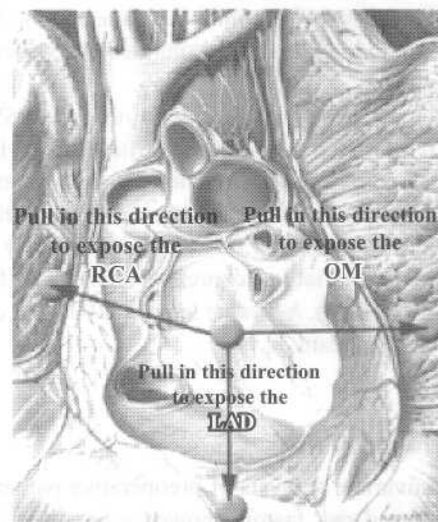

Fig.2: Illustrative diagram showing the relative position of the suture on the posterior pericardium in relation to the heart and the different directions of pulling on it.

We used two different configurations to perform the composite grafts. In the type I configuration the free right internal mammary artery is anastomosed to the LIMA as a Y-graft. In type II configuration the radial artery is anastomosed to the LIMA as a Y-graft. Either RA or right internal mammary artery (RIMA) was used to revascularize the left system as separate or sequential grafts. In both groups RA or SVG are used as free grafts to revascularize the right coronary system.

Distal anastomoses were performed In group I according to the following order: right coronary, marginal branches of the circumflex artery, diagonal, and finally the left anterior descending coronary, while in group II distal anastomoses were performed according to the following order: anterior descending coronary, diagonal, right coronary and finally the marginal branches of the circumflex artery.

In both groups, polypropylene 7/0 sutures with 8mm needles were used for distal anastomoses, while polypropylene 6/0 sutures with 13mm needles were used for proximal anastomoses of SVGs to the aorta while polypropylene 7/0 with 11mm needles were used for the proximal anastomoses of the free RA grafts.

In both groups, all distal anastomoses were performed prior to proximal anastomoses. Heparin was neutralized at the end of the procedure using a 1:1 proportion of protamine sulphate.

Follow-up and Statistical Analysis

Patients were evaluated at a follow-up of 1, 6, and 12 months by a personal interview. We arranged for a stress isotope scintigraphy at 6 months for all patients and angiography at 12 months for patients who had recurrence of angina or those having residual ischemia on scintigraphy.

Statistical analysis was done using SPSS version 7.0 for Windows© and Microsoft® Excel© 2000.Preoperative and postoperative data were analyzed using the □²test or Fisher's exact test for discrete variables and the unpaired *t* test or Mann-Whitney U test for continuous variables (expressed as mean ± standard deviation / median). A *p* value less than 0.05 was considered to be significant.

Results

Preoperative Data

Univariate analysis of preoperative patient characteristics and risk factors showed a homogenous distribution between the two groups apart from ejection fraction which was significantly lower in the off-pump group(p=0.001). Preoperative data are shown in Table 1. Renal impairment was defined as creatinine>1.4 mg/dl and obesity defined as body mass index>30.

Table1: Distribution of preoperative data

	Group I	Group II	p value
Age(years)	53±6*	50.5±6*	NS
Sex(M/F)	27/2	19/2	NS
Hyper-tension	24%(7/29)	24%(5/21)	NS
Diabetes	45%(13/29)	48%(10/21)	NS
COPD	34%(10/29)	38%(8/21)	NS
Renal mpairment	3%(1/29)	9.5%(2/21)	NS
Obesity	14%(4/29)	14%(3/21)	NS
Unstable angina	14%(4/29)	14%(3/21)	NS
EF (%)	58±10*	47±7*	0.001
AMI	24%(7/29)	24%(5/21)	NS
IMI	17%(5/29)	19%(4/21)	NS

*M=male; F=female; COPD=chronic obstructive pulmonary disease; EF=ejection fraction; AMI=anterior myocardial infarction; IMI= inferior myocardial infarction. *= data expressed as mean± standard deviation*

Operative Data

We operated on 29 patients with the on-pump technique(group I) versus 21 patients with the off-pump technique (group II).Type 1 configuration of composite arterial grafts was used in 10.3 %(3/29) of patients in group I while it was used in 9.5% of patients (2/21) in group II. Type II configuration was used in 93.1% of patients in group I and 90.5% of patients in group II with no statistical significance.

In both groups, All RIMAs were anastomosed proximally to the LIMAs. All RIMAs were not used to perform sequential distal anastomoses. RA grafts were used to perform sequential distal anastomoses more frequent in group I than in group II (Table 2).

Table2: Conduits used in the study

	Group I	Group II	p value
BIMA	3/29(10.3%)	2/21(9.5%)	NS
RA	28/29(96.5%)	20/21 (95%)	NS
Seq RA	13/29(44.8%)	8/21(38%)	NS
SVG	9/29(31%)	8/21(38%)	NS

BIMA=bilateral internal mammary artery; RA= radial artery (used either in a separate or sequential manner), Seq=sequential radial artery grafts to obtuse marginal and diagonal, two obtuse marginals, or obtuse marginal and ramus; SVG=saphenous vein graft.

Only one radial artery in each group was used to revascularize the right coronary artery system with the proximal end anastomosed to the aorta. All other radial artery grafts were anastomosed proximally to the LIMA to form the composite grafts.

There was no statistically significant difference between the two groups as regards the number of distal anastomoses. (2.7±0.7 in group I versus 2.86±0.7 in group II, p=0.4). The distribution of grafts was shown in figure 3.

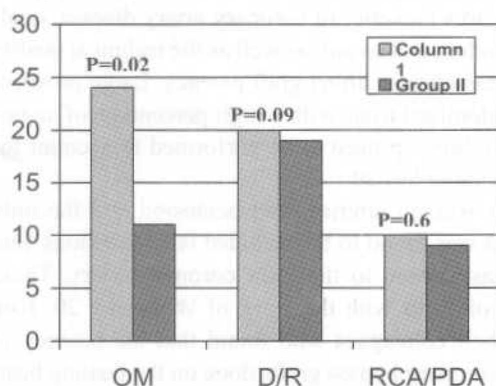

Fig.3: Distribution of grafts: OM=obtuse marginal; D=diagonal; R=ramus; RCA right coronary artery; PDA=posterior descending artery

The goal of performing the off-pump technique was achieved in 42 % of patients. There was no mortality in both groups. Operative time was significantly shorter in group II (3h22 min.±29 min.) than group I (3h42 min.±18 min.) with p=0.005. Conversion to the CPB was required in 2 patients of the off-pump group (9.5%) due to unfavorable anatomy of the native coronary vessels (extensive calcification and thrombosis that necessitated end arterctomy procedure). No conversion to CPB was required due to haemodynamic instability.

ICU and Hospital Data

There was no statistical significance between the two groups regarding the incidence of post-operative complications apart from bleeding which was significantly lesser in group II as shown in table 3. There was no mortality, perioperative infarction, cerebrovascular accidents, or acute renal failure in both groups. The length of postoperative hospital stay was significantly higher in group I (8±1.3 days) than group II (7±1 days); p=0.01.

Table3: Immediate postoperative data

	Group I	Group II	*p* value
Mechanical Ventilation	6.5±5.5 hours* Median=4 hours	4.5±1.8 hours* Median=4 hours	NS
ICU stay	50±16 hours*	43±13 hours*	NS
Atrial fibrillation	2/29(6.7%)	3/21 (14.3%)	NS
Arterial graft spasm	1/29(3.4%)	1/21(4.8%)	NS
Bleeding	423±194 ml*	296±232 ml*	0.003
Blood transfusion	8/29(27.5%)	5/21(23.8%)	NS
Reopening for bleeding	1/29(3.4%)	0/21	NS
Inotropic support	11/29(37.9%)	3/21(14.8%)	NS

***Data expressed as mean± standard deviation**

Follow up Data

Patients of group I were followed for 8.9±2.3 months, while patients of group II were followed for 9.6±2.9 months. There were no late deaths. Recurrence of angina was higher in the off-pump group (4.8%) than the on-pump group (3.4%), although statistically insignificant. Group I patient had a basal anerolateral ischemia as shown by Stress myocardial scintigraphy while angiography revealed a new 50% lesion in the first diagonal. Group II patient had an anerolateral ischemia and mild anastomotic stenoses in the LAD and the OM. 4 month's postoperatively, one patient of group II had an inferior myocardial infarction. Stress myocardial scintigraphy revealed inferior scarring and angiography revealed a SVG occlusion.

Discussion

Although there is enough data supporting the superiority of off-pump technique over the conventional CABG using the cardiopulmonary bypass in some high risk patients13, still there is no enough evidence to support the superiority of this technique in low-risk patients.

The use of arterial grafts gained an incremental popularity over the last decade Because of their long term benefits as regards the patency rates, freedom from angina/myocardial infarction, and patient survival14. This creates the need for more arterial grafts, in order to achieve the goal of total arterial revascularization. The radial artery (being the most popular alternative) arranged as composite grafts proved to overcome the anatomical limitations of in situ grafts10, 12.

In our study, the preoperative characteristics of the patients who belong to both groups were comparable apart from ejection fraction which was significantly

lower in the off-pump group. Despite that, patients in both groups could be classified as low-risk population. The adoption of off-pump technique for patients with poorer left ventricular function matched the findings of Bouchard and Cartier15 that despite cardiac elevation and transient hypotensive episodes, a beating-heart operation can provide adequate myocardial protection compared with cardioplegic arrest.

The off-pump technique was feasible in all patients with no emergency conversion to cardio-pulmonary bypass due to haemodynamic instability or major ventricular arrhythmias.

As regards the major concern of many surgeons about the completeness of myocardial revascularization, there was no statistically significant difference between the two groups as regards the number of distal anastomoses. (2.7±0.7 in group I versus 2.86±0.65 in group II).

Despite the completeness of revascularization in group II, There was a statistically significance difference between the two groups as regards the number of distal anastomoses to obtuse marginal vessels (23 for group I versus 9 for group II, $p=0.02$). In a similar study, Muneretto and associates found that there were no differences in terms of location of target coronary vessels, despite that they adopt the sequential technique. They attributed their success to the use of Guidant axius vacuum stabilizer system and the *Xpose* device for posterolateral vessels (Guidant corporation-cardiac surgery) 16.

Arterial graft spasm was higher in the off-pump group, although statistically insignificant. This was attributed to hypothermia as patients' temperature usually drifts to 34°c by the end of the operation. Adjusting the room temperature and topical rewarming with warm saline solved this issue.

There was a significant reduction in overall blood loss (p=0.003), and operative time (p=0.005), in the off-pump group. Moreover, there was an insignificant reduction in mechanical ventilation, inotropic support, blood transfusion, and reopening for bleeding. Those advantages of the off-pump technique were considered conservative compared to other similar study done by Pandey and associates17 who found that off-pump technique significantly reduces blood loss, inotropic support, and ventilation time (p<0.001).

In the off-pump group, ICU stay was insignificantly shorter while there was a marginal difference in hospital stay. So the reduction in total operative costs was only marginal if ever present. Fouda18 stated in a similar study that his results failed to reach significant statistical difference between the two groups of patients, nevertheless, like others, he have seen over the last few years that off-pump patients do really recover somewhat faster than on pump patients. This will only remain as an observation among surgeons doing off-pump surgery unless it can be supported with strong statistical evidence.

Recurrence of angina was similar in the two groups; however the anastomotic stenoses in the second group patient raised the traditional question about the quality of anastomoses in the off-pump technique. In our work, this observation remains marginal as there is no statistical significance to make it an accountable issue. Moreover, Graft patency is difficult to interpret because many factors (severity of coronary artery disease, quality of conduit, and so on), as well as the technical quality of the anastomosis, affect graft patency. Large prospective, randomized trials with a high percentage of angiographic follow-up need to be performed to account for all these variables. 19

Their was no arterial graft occlusion and the only graft that was found to be occluded is a saphenous vein graft anastomosed to the right coronary artery. These results coincides with the work of Widimsky 20, Kim 21and their colleagues who found that the patency of arterial coronary bypass grafts done on the beating heart is excellent and equal to grafts done on pump while saphenous graft patency per patient was lower in the off-pump group.

Conclusion

Off-pump composite arterial grafting is a safe procedure in the short term as regards mortality and postoperative morbidity. It offers only minor advantages over the on-pump technique as significant reduction in operative time, postoperative bleeding and hospital stay.

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