

## Complete revascularization with or without cardiopulmonary bypass using arterial grafts: The six-month angiographic results

*Arteriyel greft kullanılarak kardiyopulmoner bypassla ya da kardiyopulmoner bypassız gerçekleştirilen tam revaskülarizasyon: Altı aylık anjiyografik sonuçlar*

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**Background:** The aim of this study was to evaluate whether full off-pump arterial revascularization could be performed in patients with three-vessel coronary artery disease without any difficulty.

**Methods:** A total of 40 patients (20 in the off-pump group and 20 in the on-pump group) with three-vessel coronary artery disease were included in this prospective and randomized study, and patients in both groups underwent complete revascularization for the three systems with arterial grafts. Both groups were similar with respect to the preoperative characteristics. In the off-pump group, the left anterior descending artery was revascularized first to provide adequate coronary perfusion during manipulation of the heart for lateral and posterior wall revascularization. Intracoronary shunt was not used in any of these patients.

**Results:** Both groups were similar for pre- and perioperative risk factors. The mean number of distal anastomoses per patient was higher in the on-pump group ( $3.2 \pm 0.4$  versus  $3 \pm 0$ ;  $p=0.042$ ). Postoperative transfusion requirements ( $4.5 \pm 2.1$  units versus  $6.4 \pm 1.8$  units,  $p=0.018$ ), extubation time ( $7.5 \pm 2.5$  hours versus  $10.8 \pm 1.8$  hours,  $p<0.05$ ), intensive care unit stay ( $15.7 \pm 5.6$  hours versus  $54.1 \pm 18.3$  hours,  $p<0.05$ ), and hospital stay ( $5.1 \pm 1.5$  days versus  $6.9 \pm 2.1$  days,  $p=0.004$ ) were found significantly lower in the off-pump group. All left internal thoracic arteries were found patent in the control angiographic studies performed after six months, whereas five right internal thoracic arteries (three in off-pump group and two in on-pump group) and six radial artery grafts (three in off-pump group and three in on-pump group) were occluded.

**Conclusion:** Full arterial revascularization can be achieved by off-pump bypass techniques in three-vessel coronary artery disease as efficiently as in patients operated under cardiopulmonary bypass.

**Key words:** Cardiopulmonary bypass; coronary artery bypass grafting; myocardial infarction; myocardial revascularization; off-pump.

**Amaç:** Bu çalışmada, üç damar koroner arter hastalığı bulunan hastalarda off-pump tam arteriyel revaskülarizasyonun herhangi bir güçlük yaşanmadan gerçekleştirilip gerçekleştirilemeyeceği değerlendirildi.

**Çalışma planı:** Bu ileriye dönük ve randomize çalışmaya üç damar koroner arter hastalığı olan toplam 40 hasta dahil edildi (off-pump grubunda 20, on-pump grubunda 20 hasta) ve her iki gruptaki hastalarda arteriyel greftlerle üç sisteme tam arteriyel revaskülarizasyon uygulandı. İki grup ameliyat öncesi özellikler açısından benzerdi. Off-pump grubunda, kalbin lateral ve posteriyor duvarının revaskülarizasyonu için yürütülen manipülasyon sırasında yeterli koroner perfüzyonun sağlanması için ilk olarak sol ön inen koroner arter revaskülarize edildi. Bu gruptaki hiçbir hastada intrakoroner şant kullanılmadı.

**Bulgular:** İki grup ameliyat öncesindeki ve ameliyat sırasındaki risk faktörleri açısından benzerdi. Hasta başına düşen ortalama distal anastomoz sayısı on-pump grubunda daha yüksekti ( $3.2 \pm 0.4$ 'e karşılık  $3 \pm 0$ ;  $p=0.042$ ). Off-pump grubunda ameliyat sonrası transfüzyon gereksinimi ( $4.5 \pm 2.1$  üniteye karşılık  $6.4 \pm 1.8$  ünite,  $p=0.018$ ), ekstübasyon zamanı ( $7.5 \pm 2.5$  saate karşılık  $10.8 \pm 1.8$  saat,  $p<0.05$ ), yoğun bakım ünitesinde kalış süresi ( $15.7 \pm 5.6$  saate karşılık  $54.1 \pm 18.3$  saat,  $p<0.05$ ) ve hastanede kalış süresi ( $5.1 \pm 1.5$  güne karşılık  $6.9 \pm 2.1$  gün,  $p=0.004$ ) anlamlı şekilde daha düşük bulundu. Altı ay sonraki kontrol anjiyografilerinde tüm sol internal torasik arterler açık bulunurken, sağ internal torasik arterlerden beşi (üçü off-pump, ikisi on-pump grubunda) ve radyal arter greftlerinin altısı (üçü on-pump grubunda, üçü off-pump grubunda) tıkalı bulundu.

**Sonuç:** Tam arteriyel revaskülarizasyon, üç damar koroner arter hastalığında off-pump tekniği ile kardiyopulmoner bypassla ameliyat edilen hastalardaki kadar etkin şekilde gerçekleştirilebilir.

**Anahtar sözcükler:** Kardiyopulmoner bypass; koroner arter bypass greftleme; miyokard infarktüsü; miyokard revaskülarizasyon; off-pump.

Received: January 26, 2010 Accepted: March 26, 2010

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Coronary artery bypass grafting (CABG) plays a central role in the management of patients with multivessel coronary artery disease. Although cardiopulmonary bypass (CPB) has been used to revascularize lateral and posterior walls of the heart for four decades, the side effects of this technique have been well documented. On the other hand, complete revascularization must be the first choice for multivessel coronary artery disease. Technological developments in cardiovascular surgery have given new opportunities to perform CABG procedures without CPB. Exposure of the posterior or lateral wall is more problematic because of a decrease in cardiac output and left ventricular stroke volume during off-pump coronary artery bypass (OPCAB). However, it is possible to revascularize all target vessels with new mechanical stabilizer systems.<sup>[1]</sup>

The long-term patency of grafts is one of the major factors in determining late results of CABG. Midterm angiographic assessment of OPCAB demonstrated a significantly lower patency rate of saphenous vein grafts compared with that of conventional CABG or that of arterial grafts.<sup>[2,3]</sup> Lower vein graft patency rates have encouraged surgeons to perform CABG with arterial grafts to improve the long-term outcome after myocardial revascularization. After advantages with the use of bilateral (versus unilateral) internal thoracic arteries were demonstrated, full arterial revascularization has become more popular.<sup>[4-7]</sup> After our group showed that free arterial grafts with proximal anastomosis on the pedicled arterial graft had worse patency rates than those with proximal anastomosis on the ascending aorta, we prefer using all arterial grafts separately (as in situ or free arterial graft on the aorta).<sup>[8]</sup>

The aims of this study were first to evaluate the feasibility of OPCAB to achieve complete arterial revascularization as compared with the standard CPB, and second to compare angiographic results.

## PATIENTS AND METHODS

A total of 40 consecutive patients without left ventricular dysfunction (ejection fraction  $\geq 40\%$ ) who underwent isolated primary CABG for multivessel coronary artery disease were studied in a prospective randomized manner. Myocardial revascularization was performed off-pump in 20 patients (OPCAB group) and on-pump (CPB group) in 20 patients. Both groups had comparable demographic data (Table 1). Patients undergoing coronary revascularization through a T-sternotomy or under epidural anesthesia were excluded from the study.<sup>[9-11]</sup>

All operations were performed through a full median sternotomy and under general anesthesia. Arterial conduits [the left internal thoracic artery (LITA), the right internal thoracic artery (RITA), the radial artery (RA)] were harvested and wrapped in sponges humidified with a mixture of verapamil and papaverine. Both internal thoracic arteries were used as in-situ grafts for myocardial revascularization on the assumption that bilateral blood sources would be better than a single blood source to improve long-term outcome. A standard skeletonizing technique was used for harvesting bilateral internal thoracic arteries to extend these in-situ grafts to the distal segment of the coronary arteries. When it was necessary we incised the apical part of both pleura to prevent tension on the internal thoracic arteries.<sup>[12]</sup> We assessed the RA in the non-dominant arm.<sup>[13]</sup> Neither T-, nor Y-graft techniques were preferred for the proximal anastomosis of the RA and it was anastomosed directly on the ascending aorta.

**Table 1. Preoperative risk factors**

	OPCAB (n=20)			CPB (n=20)			p
	n	%	Mean±SD	n	%	Mean±SD	
Age (years)			53.95±7.7			49.6±5.7	0.07
Sex (female)	0	0		2	10		0.16
Body mass index (kg/m <sup>2</sup> )			26.6±3.4			28.5±2.3	0.6
Canada class			3.25±1.67			3.1±1.37	0.76
Unstable angina	8	40		6	30		0.48
Diabetes mellitus	1	5		0	0		0.32
Hypertension	8	40		10	50		0.16
Dyslipidemia	12	60		15	75		0.08
Smoking	16	80		14	70		0.16
Chronic obstructive pulmonary disease	4	20		3	15		0.32
Renal insufficiency	1	5		0	0		0.32
Other comorbidities	3	15		0	0		0.08
Previous myocardial infarction	12	60		10	50		0.16
Left main disease	1	5		1	5		–

OPCAB: Off-pump coronary artery bypass; CPB: Cardiopulmonary bypass; SD: Standart deviation.

In CPB group, extracorporeal circulation was instituted, with the arterial cannula placed in the ascending aorta and a single two-stage venous cannula placed in the right atrium. Both antegrade and retrograde cardioplegia cannulas were placed. After the aorta was cross-clamped, the heart was arrested with antegrade isothermic blood cardioplegia and myocardial protection was achieved with continuous retrograde isothermic blood cardioplegia. Systemic hypothermia (mean  $30.5 \pm 1.1$  °C) was used. Distal and proximal anastomoses were performed during a single cross-clamp period. After the patient was weaned from CPB and decannulated, heparin was reversed. The mean perfusion time was  $95 \pm 24.4$  minutes, and mean aortic cross-clamp time was  $77.15 \pm 16.3$  minutes.

In the OPCAB group, commercially available mechanical stabilizers and apical positioners were used to perform distal anastomoses. Beta blockers were used to reduce the heart rate to less than 70 beats per minute. Target vessel hemostasis was obtained with proximal and distal vessel loops, and we did not use any intracoronary shunt. We did not open the right pleural space to minimize right-side compression during cardiac displacement for lateral vessel grafting, and we did not use any deep pericardial traction suture during distal anastomoses to the circumflex (Cx) and the right coronary artery (RCA) branches. To restore blood flow in coronary arteries as early as possible in-situ grafts were anastomosed first. The left anterior descending (LAD) artery was revascularized first to provide adequate coronary perfusion during manipulation of the heart for lateral and posterior wall revascularization. One internal thoracic artery was used to revascularize the LAD. When the RITA was used to revascularize the LAD by crossing the midline, the LITA was used for Cx branches. When the RITA reached the right coronary territory, the LITA was used for the LAD. When the LITA did not reach the Cx branches, it was used for the LAD and the RITA

had to be used for the RCA branches. The RITA was lengthened with a segment (~ 5 cm) of the free RA in three patients. After the LAD was revascularized with one internal thoracic artery, the other internal thoracic artery was anastomosed secondly, and the distal anastomosis of the RA was performed last. The operating table was kept in Trendelenburg position and rotated to the right during Cx or RCA branches anastomoses. The mean distal anastomosis time was  $11.2 \pm 2.4$  minutes. We did not give protamine to reverse heparin at the end of the procedure.

### Statistical analysis

A commercial statistical software package SPSS (Statistical Package for Social Sciences) for Windows, version 13.0 (SPSS Inc, Chicago, Illinois, USA) was used for data analysis. All data are presented as mean  $\pm$  standard deviation. Differences between categorical variables were tested using a Chi-square test; differences between continuous variables were tested using the Student's t-test. A *p* value less than or equal to 0.05 was considered statistically significant.

## RESULTS

Every patient received a minimum three anastomoses and the mean graft number was higher in the CPB group ( $3.2 \pm 0.4$  versus  $3 \pm 0$ ;  $p=0.042$ ). All target coronary arteries could be anastomosed by both techniques (Table 2). Only four patients (20%) in the CPB group received sequential bypass grafting ( $p=0.046$ ). The LITA was used only for the LAD and the RITA only for the RCA in the CPB group. Bilateral internal thoracic arteries were used for left side revascularization only in nine patients (45%) in the OPCAB group (Table 3). Coronary endarterectomy was performed in two patients (10%) in the OPCAB group and in three patients (15%) in the CPB group ( $p=0.317$ ). Hemodynamic instability developed in four patients (20%) in the OPCAB group, but only one of them required inotropic support. This

**Table 2. Revascularized target coronary arteries**

	OPCAB		CPB	
	n	%	n	%
Left anterior descending artery	20	100	20	100
Diagonal branch1	0	0	1	5
Circumflex artery obtus marginal branch1	3	15	2	10
Circumflex artery obtus marginal branch2	8	40	13	65
Circumflex artery obtus marginal branch3	8	40	6	30
Circumflex artery posterolateral branch	1	5	2	10
Right coronary artery	10	50	15	75
Right coronary posterior descending branch	10	50	4	20
Right coronary posterolateral branch	0	0	1	5

OPCAB: Off-pump coronary artery bypass; CPB: Cardiopulmonary bypass.

**Table 3. Arterial grafts and revascularized coronary arteries**

	OPCAB		CPB		<i>p</i>
	n	%	n	%	
Left internal thoracic artery					
Left anterior descending artery	11	55	20	100	<0.001
Circumflex artery branches	9	45	0	0	<0.001
Right coronary artery branches	0	0	0	0	–
Right internal thoracic artery					
Left anterior descending artery	9	45	0	0	<0.001
Circumflex artery branches	0	0	0	0	–
Right coronary artery branches	11	55	20	100	<0.001
Radial artery					
Left anterior descending artery	0	0	0	0	–
Diagonal branch1	0	0	1	5	0.31
Circumflex artery branches	11	55	19	95	0.003
Right coronary artery branches	9	45	0	0	<0.001

OPCAB: Off-pump coronary artery bypass; CPB: Cardiopulmonary bypass.

patient required an intraaortic balloon pump in the intensive care unit. He died on the third postoperative day because of low cardiac output syndrome.

The mean drainage was higher in the CPB group (855±267 mL versus 705±337 mL; *p*=0.11). Patients in the CPB group received more blood products (6.35±1.84 unit versus 4.5±2.06 unit; *p*=0.018). The mean extubation time (10.77±1.84 hours versus 7.52±2.47 hours; *p*<0.05), stay in the intensive care unit (54.1±18.3 hours versus 15.7±5.59 hours; *p*<0.05) and discharge from the hospital (6.9±2.12 days versus 5.05±1.46 days; *p*=0.004) were longer in the CPB group. New atrial fibrillation requiring treatment was observed in eight patients (five in the OPCAB group and three in the CPB group; *p*=0.16). Reversible neurologic deficit was observed in one patient in the CPB group, and he was discharged without any sequel. There was no infection or mediastinitis in both groups. No patient required hemodialysis or hemofiltration, and no patient had gastrointestinal complications.

A control angiography was performed in all patients after six months. The LITA was patent in all patients (100% for LAD and 100% for Cx). The RITA was occluded in three patients (15%) in the OPCAB group

and in two patients (10%) in the CPB group (*p*=0.32). The RA was occluded in three patients (15%) in each group. The occluded arterial grafts were listed in table 4. All occluded RITA grafts in the OPCAB group was lengthened with a part of the RA free graft and an anastomotic failure developed between both arterial grafts.

## DISCUSSION

Most CABG patients require multivessel revascularization and the standard operation is to use a single internal thoracic artery and vein grafts with CPB. Using only arterial grafts and OPCAB are now changing the nature of the standard CABG. The advantages of using bilateral internal thoracic arteries such as enhanced survival and greater freedom from reinterventions with the use of two internal thoracic arteries over one are well known.<sup>[14]</sup> In-situ RITA is considered the second good graft in patients receiving full arterial revascularization, and its best patency rate is achieved when it is grafted to the LAD. Grafting an in-situ RITA to the left coronary system can either be performed through the transverse sinus to revascularize Cx branches or by a route anterior to the aorta to revascularize the LAD.<sup>[15]</sup> It can be also

**Table 4. Occluded grafts at the control angiography**

	LITA		RITA		RA	
	OPCAB	CPB	OPCAB	CPB	OPCAB	CPB
Right coronary artery	0	0	1	1	1	0
Right coronary posterior descending branch	0	0	2	1	0	0
Circumflex artery obtuse marginal branch1	0	0	0	0	0	1
Circumflex artery obtuse marginal branch2	0	0	0	0	0	1
Circumflex artery obtuse marginal branch3	0	0	0	0	2	1

LITA: Left internal thoracic artery; RITA: Right internal thoracic artery; RA: Radial artery; OPCAB: Off-pump coronary artery bypass; CPB: Cardiopulmonary bypass.

used for right side revascularization.<sup>[16]</sup> Skeletonized internal thoracic artery harvesting provides several benefits over pediculate mobilization, especially for revascularization of the distal RCA or Cx branches or for sequential anastomosis.<sup>[17]</sup> Skeletonization of internal thoracic arteries reduces deep sternal infections, especially in diabetic and obese patients.<sup>[18]</sup>

It is well established that off-pump revascularization has better benefits in all groups of patients.<sup>[19]</sup> At the beginning, incomplete revascularization was the first choice for patients with left ventricular dysfunction,<sup>[20]</sup> but nowadays, completeness of revascularization has been found to improve early survival.<sup>[21]</sup> Because the impaired left ventricle has a larger size than the normal heart, using in-situ arterial grafts can be problematic. The main problem is to extend RITA to LAD or LITA to Cx branches. All patients in our study had normal or depressed left ventricular function without significant enlargement of the left ventricle. We had to use RITA-RA composite grafts in three patients with a hypertrophied left ventricle in the OPCAB group, and all three grafts were found occluded at the control angiography. We do not recommend using Y or T arterial grafts, because a second internal thoracic artery or RA is not long enough long to revascularize both lateral and posterior walls. In this situation, venous grafts are preferred.

The contraindications for OPCAB are now limited to intramyocardial or very thin coronary arteries. Anastomosing to an intramyocardial coronary artery under beating heart conditions is unsafe because of the high risk of ventricular perforation. Anastomosing to a calcified coronary artery under beating heart conditions may be technically difficult, but it is not a contraindication for OPCAB. Local endarterectomy or total distal endarterectomy can be performed easily without any perioperative myocardial infarction. The only contraindication is a subtotal occluded coronary artery with antegrade inflow. In this situation CABG should be performed under cardiac arrest with CPB. In this series, we performed coronary endarterectomy in five patients and it was not difficult in both groups. We did not touch the proximal part of the diffusely diseased vessel in the OPCAB group. None of them had any hemodynamic and myocardial complication. Although some surgeons prefer to use intracoronary shunts during distal anastomosis on the beating heart,<sup>[22]</sup> we never use intracoronary shunts because they can damage coronary artery endothelium.<sup>[23]</sup> We showed that shorter (<12 minutes) distal anastomosis time did not need any coronary perfusion system.<sup>[24]</sup>

In this study, we have shown that multivessel arterial revascularization can be performed using off-pump techniques as well as the conventional technique. Early results with graft patency rates and levels of revascular-

ization were similar with both techniques. Early patency rate was 100% for the LITA (to the LAD or Cx) in both groups, and 100% for the RITA to the LAD in OPCAB group, and 72.7% versus 90% (OPCAB vs CPB groups) for the RITA to the RCA. The RA patency rate was 85% in both groups. That means that the internal thoracic artery has best patency rates for all coronary arteries. All three RITAs in OPCAB group were occluded because of RITA-RA-RCA anastomosis. We can conclude that all internal thoracic arteries must be used alone, without an extension using a second graft part. In this situation, saphenous vein grafts must be the first choice to revascularize the RCA branches.

### Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

### Funding

The authors received no financial support for the research and/or authorship of this article.

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