The Heart Surgery Forum #2002-23455
5 (4):2002

Online address: www.hsforum.com/vol5/issue4/2002-23455.html

Midterm Angiographic Results of Off-Pump Coronary Artery Bypass Grafting

(#2002-23455 …. May 7, 2002)

Bora Farsak, MD, Serdar Günaydın, MD, Özer Kandemir, MD, Hilmi Tokmakoglu, MD, Hakan Aydın, MD, Cem Yorgancıoglu, MD, Kaya Süzer, MD, Yaman Zorlutuna, MD

Department of Cardiovascular Surgery, Bayindir Hospital, Ankara, Turkey

ABSTRACT

Background: As off-pump coronary artery bypass grafting (OPCAB) has gained wide attention, the quality of surgical revascularization, which showed favorable initial results, is being frequently questioned. This study was undertaken to assess the midterm outcome of beating-heart coronary anastomosis.

Methods: Seventy-four of 315 patients who underwent beating-heart coronary artery bypass grafting via median sternotomy between March 1994 and December 1995 were randomly selected for angiographic assessment.

Results: The mean period of control angiography was 50.1 ± 22.6 months (range, 22 to 83 months). A total of 109 (1.52 ± 0.55) anastomosis procedures were performed in 74 patients; 38 had single-vessel disease, and 36 had double-vessel disease or disease involving more than 2 vessels. There were no perioperative returns to cardiopulmonary bypass, no major complications, and no hospital deaths. The causes of the need for occlusion included 2 (2.5%) instances of left internal mammary artery–left anterior descending artery anastomosis; 2 (2.5%) of anastomotic site stenosis in left internal mammary artery–left anterior descending artery anastomosis; 7 (19.4%) of saphenous vein graft anastomosis; and 3 (8.3%) of anastomotic site stenosis of saphenous vein graft. Statistical analysis revealed hypercholesterolemia as an independent predictor for graft occlusion (P = .014). The patency rates were not affected by endarterectomy, length of the anastomosed segment, or coronary artery structure. Event-free survival was 73.61% and myocardial infarction–free survival was 91.67%. Reintervention and reoperation rates were 24.3% (18 instances) and 1.4% (1 instance), respectively.

Conclusions: Our results were encouraging for OPCAB, supporting its safety and effectiveness, patency rates and clinical outcome comparable to those of cardiopulmonary bypass, and overall benefits such as reduced hospital costs and postoperative length of stay.

Submitted May 1, 2002; accepted May 7, 2002.

Address correspondence and reprint requests to: Bora Farsak, MD, Department of Thoracic and Cardiovascular Surgery, Atatürk Sitesi Çamık Apt C Blok No 3, OR-AN 06450, Ankara, Turkey; phone: 90-312-4906076; fax: 90-312-4662664 (e-mail: borafarsak@isnet.net.tr).

INTRODUCTION

With the increased interest in off-pump coronary bypass grafting (OPCAB) since the early 1990s, the number of beating-heart procedures has expanded worldwide [Cartier 1999,Tasdemir 1998, Diegeler 1999]. The wider the acceptance of OPCAB, the greater the questioning of the quality of surgical beating-heart revascularization. Arguments promoting OPCAB are based on its suppression of the deleterious effects of cardiopulmonary bypass (CPB) and a significant reduction in the costs and the perioperative morbidity and mortality. Nevertheless, objective analysis leads to scepticism concerning the 2 major limiting factors: incomplete revascularization and early anastomotic dysfunction. Despite reports of many early and short-term results [Hirose 2000, Diegeler 1999,Tezcaner 2000], there are 2 aspects yet to be defined: safety and effectiveness in terms of the long-term benefit. These aspects are the golden issues for the coronary artery patient and cardiovascular surgeon. Until now there were only a few reports concerning the midterm results of the beating heart procedures [Ömeroglu 2000]. The purpose of our study was to present the midterm angiographic results of our beating-heart procedures and to evaluate patient selection criteria as well as the technique.

PATIENTS AND METHODS

Three hundred fifteen patients underwent beating-heart operations performed by 2 surgeons (YZ, KS) during the period from March 1994 through December 1995. In each case, the beating heart was accessed through a median sternotomy. All patients were followed for a mean period of 73 ± 7.8 months. During this period, 21 patients were lost to follow-up and 13 patients died (6 of cardiac events and 7 of noncardiac events). Of the 315, 74 patients (56 male,18 female; mean age, 59.0 ± 9.9) were chosen randomly for the midterm angiographic assessment of the beating-heart procedure.

Patient characteristics and risk factors are presented in Table 1. Three operations were performed on an emergency basis, 2 for coronary artery dissection following percutaneous transluminal coronary angioplasty (PTCA) procedure, and 1 for evolving myocardial infarction.

Patients were selected from those recommended as coronary artery bypass grafting (CABG) candidates because of severe lesions in coronary arteries, established through angiography. Accessibility of coronary arteries, possibility of a

Table 1. Patient Characteristics, Risk Factors, and Associated Disease in 74 Patients*

	No. of patients	%
Smoking	56	75.6
Hyperlipidemia	48	64.8
Familial history	46	62.1
Hypertension	38	51.3
Diabetes mellitus	16	21.6
Alcohol abuse	12	16.2
Obesity	15	20.2
Prior MI	27	36.4
Angina		
Unstable	13	17.5
Stable	56	75.6
Previous intervention		
PTCA	7	9.4
Stent	1	1.3
CABG	0	0
LVEDP (mmHg)	12.2 ± 4.2	
Ejection fraction, %	56.2 ± 10.3	
Preoperative LVPS		
<10 (Normal)	41	55.4
10-14 (mild LVD)	19	25.6
≥15 (severe LVD)	14	18.9
Mean	10.2 ± 3.1	
Peripheral arterial disease	9	12.1
Carotid artery disease	3	4.0
Chronic obstructive pulmonary disease	11	10.8
Gastrointestinal hemorrhage	1	1.3
Chronic renal insufficiency	1	1.3
Malignancy	2	2.6

*MI indicates myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty; LVEDP, left ventricle end diastolic pressure; LVPS, left ventricle performance score; LVD, left ventricle dysfunction.

nonintramuscular route, absence of diffuse coronary disease, and good caliber of the target coronary arteries determined feasibility of the operation. The final decision to perform a beating-heart surgery was left to the operating surgeon in the operating room after evaluation of the coronary arteries. The design of the operating theater allowed switching to an open-heart operation in the event of intolerable hemodynamic deterioration due to cardiac rotation or development of any complication that necessitated CPB. After administration of 1 mg/kg heparin, exposure of the left anterior descending artery (LAD) and diagonal branches was accomplished with sponges placed behind the heart. The right coronary artery was exposed by way of a stay sponge around the inferior vena cava or with stay sutures passed from the acute margin of heart. We did not use an intraluminal shunt to obtain a bloodless, arrested field; snare sutures or bulldog clamps were placed at proximal and distal sites of the planned anastomosis region.

The majority (38) of the 74 patients (51.3%) had single-vessel disease. Sixty-eight patients (91.8%) received complete revascularization and 6 (8.1%) received incomplete revascularization (Table 2). Totally harvested left internal mammary artery (LIMA) was the graft of choice to LAD except in 1 case with low flow. One patient experienced 2 anastomoses for LAD (LIMA + saphenous vein graft [SVG] because of 2 consecutive critical lesions. Angiographic lesions were defined as important when stenosis was >60% and negligible when stenosis was <40%; lesions with stenosis between 40% and 60% were evaluated by a treadmill test and/or thallium myocard perfusion scintigraphy. Ventricular performance score was obtained through evaluation of the wall motion in 7 left ventricular segments [Tasdemir 1998].

Statistical Analysis

Results are expressed as mean value ± standard deviation unless otherwise indicated. Statistical analysis comparing 2 groups was performed with unpaired 2-tailed t test for the means or χ^2 or Fischer exact test for categorical variables. Paired t test was used for comparison of preoperative and

Table 2. Operative Data*

Variable	No. of patients	%
Approach		
Median sternotomy	74	100
Thoracotomy	0	0
Number of bypassed vessels		
1	38	51.3
2	33	44.5
3	3	4.0
Revascularization		
Complete	68	91.8
Incomplete	6	8.1
Coronary artery occlusion time		
LIMA	10.59 ± 4.44 min	
SVG	9.13 ± 2.97 min	
Mean	10.78 ± 4.01 min	
Use of LIMA		
Individual	73	98.6
Free	0	
Sequential	0	
Grafts bypassed		
LIMA	73	98.6
SVG	36	48.6
RIMA	0	
Bypassed coronary arteries		
LAD	75	101.3
Dia	16	21.6
Cx branches	0	0
RCA	15	20.2
RPD	3	4.0
Endarterectomy		
LAD	1	1.3
RCA	3	4.0

*LIMA indicates left internal mammarian artery; RIMA, right internal mammarian artery; SVG, sapheneous vein graft; LAD, left anterior descending coronary artery; Dia, diagonal coronary artery; RCA, right coronary artery; Cx, circumflex coronary artery; RPD, right posterior descending coronary artery.

Table 3. In-Hospital Morbidity*

Morbidity	Number	%
Perioperative MI	4	5.4
ECG changes	9	12.1
Arrythmias		
Atrial	27	36.4
Ventricular	7	9.4
Positive inotropic support	3	4.0
IABP	1	1.3
Ventilatory support†	6.29 ± 2.52	
Length of ICU stay, d†	1.2 ± 0.4	
Length of hospital stay†	5.16 ± 1.97	
Noncardiac complications		
Wound infection	2	2.7
Mediastinitis	0	0
Revision	0	0
Drainage†	567.7 ± 157.4	
Dehisence	0	0
Adult respiratory distress syndrome	0	0
Cerebrovascular accident	1	1.3
CPK-MB†		
4th hour	25.6 ± 12.1	
12th hour	22.2 ± 9.9	
24th hour	14.5 ± 6.7	

*ECG indicates electrocardiographic; IABP, intraaortic balloon counter pulsation; MI, myocardial infarction; CPK-MB, creatinin phosphokinase-myocardial band.

†Mean value.

postoperative numerical values. Freedom-from-death and freedom-from-reintervention plots showed the estimated survival probability by the Kaplan-Meier method, with log-transformed 95% point-wise confidence intervals. Comparison of patency rates according to time intervals were made by log-rank analysis.

RESULTS

The mean interval from operation to angiography was 50.1 ± 22.6 months (range, 22 to 83 months).

Hospital Data

There was no hospital death. The most frequently observed complication during the perioperative and early postoperative period was transient ECG changes, which correlated well with the levels of myocardial band enzymes of creatine phosphokinase (CPK-MB) levels (Table 3). Transient arrhythmias, especially atrial fibrillation, was the most common morbidity during the hospital stay; all morbidities are listed in Table 3.The number of angina-free patients was significantly higher in the postoperative period than in the preoperative period ($P < .05$).

Although it did not reach statistical significance, the improvement of the cardiac function correlated with left ventricular performance scores, ejection fraction, and left ventricular end diastolic pressure (LVEDP) (Table 4).

Angiographical Findings

Data are presented in Table 4. All LIMA-LAD grafts except 2 (2.7%) were patent. The patency rates (including partially occluded grafts) for saphenous vein graft (SVG) were 83.3%, as shown in Table 4. Among cases involving patent LIMAs, no stenosis occurred in 69 (94.5%); important stenosis occurred in 1 (1.4%); and negligible stenosis in 1 (1.4%). Among cases of patent SVG, no stenosis occurred in 25 (69.4%); important stenosis occurred in 2 (5.6%); and negligible stenosis in 1 (2.7%). One stenosis occurred in SVG (2.7%).

A log-rank test revealed that patients with an cholesterol level ≥250 mg/dL had a patency rate of 20% in a mean period of 58.4 ± 5.2 months, whereas patients with a cholesterol level <250 mg/dL had a patency rate of 80% in the same time span (P = .0012) for SVG. Cases with LIMA and LAD as graft type and as native coronary artery type grafted had the best results ($P < .05$). Of different predictors, hypercholesterolemia was found to be an independent risk factor for graft patency (P = .014) (Table 5).

Development of New Lesions

There were 37 new lesions in 21 patients; of the 37, 15 were clinically significant and 25 were not. All of the lesions were highly correlated with independent risk factor ($P < .05$).

Table 4. Angiographic Data*

	Patent	Occluded	Stenotic	Total
Type of graft, no. of patients				
LIMA	69	2	2	73
RIMA	0	0	0	0
SVG	25	7	4†	36
Bypassed coronary artery, no. of patients				
LAD	71	2	2	75
Diagonal	11	3	2	16
Cx branches	0	0	0	0
RCA	9	5	1	15
RPD	1	1	1	3
Ejection Fraction				P = .319
Preoperative	56.2 ± 10.3			
Postoperative	58.0 ± 10.8			
LVEDP				P = .202
Preoperative	12.2 ± 4.2			
Postoperative	11.1 ± 4.0			
Postoperative LVPS, no of patients				P = .108
<10 (normal)	46 (62.1%)			
10-14 (mild LVD)	20 (27.0%)			
≥15 (severe LVD)	8 (10.8%)			
Mean	9.5 ± 2.7			

*LVEDP indicates left ventricle end diastolic pressure; LVPS, left ventricle performance score; LVD, left ventricle dysfunction.

†One stenosis in SVG, 5 anastomotic site stenosis.

Table 5. Analysis of Risk Factors Leading to Graft Occlusion*

Risk Factor	Patent	Occluded	*P*
Age	58.9 ± 9.8	59.4 ± 11.08	.89 (NS)
Sex			.67 (NS)
Female	13	2	
Male	51	8	
Smoking			.635 (NS)
Negative	12	2	
Positive	52	8	
Hyperlipidemia			.014
Negative	42	5	
Positive	22	5	
Familial history			.574 (NS)
Negative	25	3	
Positive	39	7	
Hypertension			.3 (NS)
Negative	31	4	
Positive	33	6	
Diabetes mellitus			.823 (NS)
Negative	52	8	
Positive	12	2	
Obesity			.2 (NS)
Negative	59	8	
Positive	5	2	
Number of risk factors			.373 (NS)
≥2	25	5	
≤2	39	5	

*NS indicates not significant.

Reintervention and Reoperation

The reintervention rate was 24.3%. There were 19 reinterventions in 16 patients. Of the 19, 15 were for newly developed lesions, 1 was for recurrent stenosis in SVG, and 3 were for anastomotic stenosis (1 for LIMA-LAD, 3 for SVG). The reoperation rate was 1.4%. One patient underwent reoperation 57 months after the first operation because of the occlusion of LIMA. Event-free survival was 73.61% in a mean period of 56.3 ± 1.1 months (CI, 54.1-58.5), MI-free survival was 91.67% in a mean period of 60.1 ± 0.7 months (CI, 58.7-61.5) (Figures 1 and 2).

DISCUSSION

Coronary artery bypass grafting is the treatment of choice for ischemic heart disease in patients who do not benefit from medical therapy or other invasive interventions, and the use of CPB is the gold standard for coronary artery bypass surgery [Arom 2000, Cartier 2000]. CPB provides all options for revascularization procedures but has its own deleterious effects and potential complications. In the quest to eliminate such complications, OPCAB, considered a novel technique in the early 1990s, has attracted renewed interest and questions regarding its safety and efficacy. However, only a few midterm follow-up results have been reported [Ömeroglu 2000]. In the patient's perspective, of course, a treatment of coronary artery disease (CAD) is attractive if it results in less pain, early postoperative recovery with a short period of hospitalization, and, most important, safety and effectiveness in terms of the long-term benefit—freedom from symptoms and reintervention.

OPCAB patients have a good record of left internal mammarian artery–LAD patency; Puskas [1999] reported an early overall patency rate of 97.8%, with a LIMA-LAD patency rate of 100%. Hirose [2000] found an overall patency rate of 92.7% at a mean interval of 3.6 months. Kim [2001] reported a LIMA patency rate of 96.4% and SVG patency rate of 85.6% before discharge and patency rates of 97.8% and 67.9% for LIMA and SVG , respectively, at the end of the first year. In the series reported by Ömeroglu [2000], the patency rate for LIMA-LAD was 95.5% and their overall patency rate was 79.6% in a mean period of 36.1 months. Our series' rates are in correlation with those findings. We report 2 occluded LIMA grafts (2.7%), in patients who had very high cholestrol levels and who did not use the prescribed antihyperlipidemic medication when hyperlipidemia appeared to be an individual risk factor for graft occlusion in our study. Our overall patency rate was 87.1% at a mean interval of 50.1 ± 22.6 months; these results were encouraging for the LIMA-LAD anastomosis, which had a patency rate of 94.5%. Vural [2001] reported patency rates for individual and sequential SVG grafts as 68% and 82%, respectively, for 5.8 ± 3 years, and Fitzgibbon [1986] reported 81%, 75%, and 50% patency with CPB for 1179 grafts in 1, 5, and >15 years, respectively. In Ömeroglu's [2000] series the patency rate was 45% in a mean period of 3 years. Our results of 7 (16.6%) occlusions and 3 (8.3%) incidences of anastomotic stenosis were encouraging for SVG. Stanbridge [1999] suggested that, to some degree, the low patency rates in SVG may be due to the lack of the use of stabilizers or to the type of graft or to the target coronary artery or presence of hypercholesterolemia but also to the exposure and quality of stabilization in the

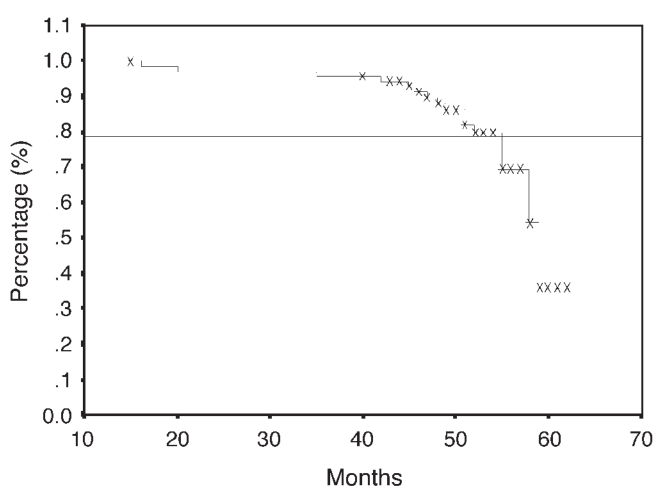

Figure 1. Event-free survival, 73.61% (mean, 56.32 ± 1.13 months; CI, 54.1-58.5).

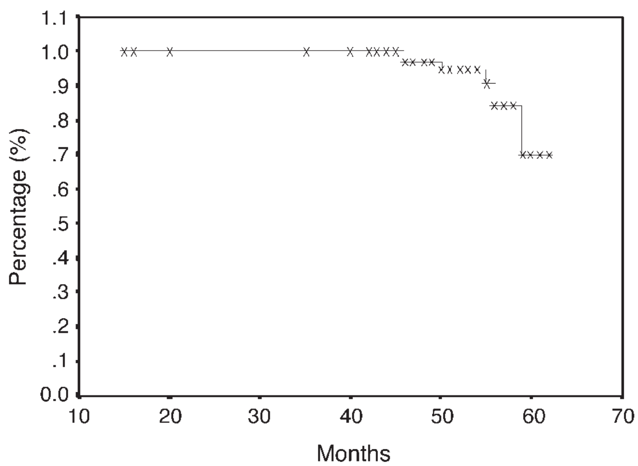

Figure 2. Mycardial infarction–free survival, 91.67% (mean, 60.13 ± 0.7 months; CI, 58.7-61.5).

chest x-ray or branches of RCA. Hypercholesterolemia was an individual risk factor for graft occlusion, but target coronary arteries and graft type did not indicate any significance in graft occlusion. But even in the lack of stabilizers our results both for LIMA-LAD and SVG anastomosis were comparable with those in CPB.

Off-pump CABG is effective to achieve complete revascularization in the majority of selected low-risk patients. Nevertheless, the rate of incomplete revascularization (with a mean number of anastomoses 1 less than that in CPB patients) in these patients undergoing OPCAB is higher [Arom 2000, Gundry 1998]. Cartier [2000] reported a complete revascularization rate greater than 90% in the group without CPB and a conversion rate to CPB of less than 1%. Czerny [2001] reported a rate of 65% for complete revascularization and 22.5% for conversion rate to CPB. Calafiore [1998] reported excellent results with complete revascularization and an overall patency rate of 98.6%, including a patency rate of 96.7% in the posterior wall. Sixty-eight (91.8%) of our patients underwent complete revascularization and our rate for conversion to CPB in those cases was null. These results are comparable to those mentioned above.

Another concern is the safety of operations without CPB. Cardioplegic cardiac arrest is safe and effective for protecting the myocardium during CABG with CPB, and the clinical relevance of myocardial injury related to cardioplegic cardiac arrest is acceptably low [Bonatti 1998]. For patients undergoing CABG without CPB, recent data suggest that temporary occlusion on the beating heart causes less myocardial injury than cardioplegic cardiac arrest in undergoing CABG with CPB [Czerny 2000]. It has also been observed that the left ventricular wall motion was better in beating-heart operations [Pfister 1992, Wos 1998]. Our data also revealed that there was no deleterious effects of off-pump operations on ventricular function, as left ventricle performance scores were increased from 10.2 ± 3.1 to 9.5 ± 2.7 and the left ventricle function (EF) improved postoperatively from 56.2 ± 10.3 to 58.0 ± 10.8; these results were confirmed with the observed left ventricle end diastolic pressures, which were improved from 12.2 ± 4.2 to 11.1 ± 4.0 postoperatively.

Among our group of patients, event-free survival was 73.61% in a mean period of 56.3 ± 1.1 months and MI-free survival was 91.67% in a mean period of 60.1 ± 0.7 months; the rate of recurrent angina was 35.1% (7 unstable angina, 19 stable angina pectoris), and rate of reintervention was 25.6% (18 [24.3%] angioplasty and 1 [1.4%] reperformance of the operation). In Arom's [2000] series, the 1-year recurrent angina and angioplasty rates were 24% and 10%, respectively, after OPCAB versus 9% and 2%, respectively, after CABG with CPB. In a comparative study at 7 years, Gundry [1998] reported a three-fold increase in reinterventions with OPCAB.

Correlating with others [Diegeler 1999, Gill 2000], we also did not experience any de novo stenosis at the site of temporary snaring in our series. But Gundry [1998] found that multivessel CABG without CPB appears capable of producing similar longevity and symptomatic status even years after surgery, as compared with a matched group of patients receiving CABG with CPB. However, twice as many repeat coronary angiography and 3 times as many reinterventions, predominantly at distal snare sites, were required in patients having undergone CABG without CPB [Hammermeister 1980]. Our results also revealed that the patency rates were not affected by endarterectomy, length of the anastomosed segment, or coronary artery structure. These findings are important, as they demonstrate that these kinds of interventions could also be done in off-pump CABG.

Ignoring for the time being the cost-effectiveness, we can answer the the 2 questions posed earlier. Is it safe? Is there an effective long-term benefit? It is safer with the ongoing improvements in the stabilizer technology, and therefore it is more effective, with an improving patency rate that is similar to that of conventional methods and meet expectations [Calafiore 1996].

Overall midterm results of this study were favorable and encouraging. Besides the null early mortality, the low morbidity rates, and early extubation, mobilization, and discharge all improve the surgical outcome and reduce the hospital costs. Additionally, results obtained both for LIMA-LAD and SVG anastomosis were comparable to those obtained with CPB, especially when takes into account the learning curve required and the lack of stabilizers.

Today, OPCAB operations can be performed for lesions in virtually any coronary artery using currently available instrumentation with a high degree of patient safety and surgeon comfort. Whether a surgeon chooses incision or CPB, we need not ignore the gold standard of coronary bypass surgery—complete revascularization.

REFERENCES

Arom KV, Flavin T, Emery RW, Kshettry VR, Janey PA, Petersen PI. 2000. Safety and efficacy of off-pump coronary artery bypass grafting. Ann Thorac Surg 69:704-10.

Bonatti J, Hangler H, Hormann C, Mair J, Falkensammer J, Mair P.

1998. Myocardial damage after minimally invasive coronary artery by-pass grafting on the beating heart. Ann Thorac Surg 66:1093-6.

Calafiore AM, Di Giammarco G, Teodori G, et al. 1996. Left anterior descending Coronary artery grafting via left anterior small thoracotomy without cardiopulmonary bypass. Ann Thorac Surg 61:1658-65.

Calafiore AM, Di Giammarco G, Teodori G, Mazzei V, Vitolla G. 1998. Recent advances in multivessel coronary grafting without cardiopulmonary bypass. Heart Surg Forum #1998-33589 1(1):20-25.

Cartier R, Blain R. 1999. Off-pump revascularization of the circumflex artery: technical aspect and short-term results. Ann Thorac Surg 68: 94-9.

Cartier R, Brann S, Dagenais F, Martineau R, Couturier A. 2000. Systemic off-pump coronary artery revascularization in multivessel disease; experience of three hundred cases. J Thorac Cardiovasc Surg 119:221-9.

Czerny M, Baumer H, Kilo J, et al. 2000. Systemic inflammatory response and myocardial injury in patients undergoing CABG with and without cardiopulmonary bypass. Eur J Cardio Thorac Surg 17: 737-42.

Czerny M, Baumer H, Kilo J, et al. 2001. Complete revascularization in coronary artery bypass grafting with and without cardiopulmonary bypass. Ann Thorac Surg 71:165-9.

Diegeler A, Matin M, Falk V, et al. 1999. Coronary bypass grafting without cardiopulmonary bypass: technical considerations, clinical results and follow-up. J Thorac Cardiovasc Surg 47:14-8.

Fitzgibbon GM, Leach AJ, Keon WJ, Burton JR, Kafka HP. 1986. Coronary bypass fate. J Thorac Cardiovasc Surg 91:773-8.

Gill IS, Higginson LA, Maharajh GS, Keon WJ. 2000. Early and follow up angiography in minimally invasive coronary bypass without mechanical stabilisation. Ann Thorac Surg 69:56-60.

Gundry SR, Romano MA, Shtattuck OH, Razzouk AJ, Bailey LL. 1998. Seven year follow-up of coronary artery by-passes performed with and without cardiopulmonary bypass. J Thorac Cardiovasc Surg 115:1273-7.

Hammermeister KE, Burchfiel C, Johnson R, Grover FL. 1980. Identification of patients at greatest risk for developing major complications at cardiac surgery. Circulation 82:380-9.

Hirose H, Amano A, Yoshida S, Takahashi A, Hagano N. 2000. Off-pump coronary artery bypass: early results. Ann Thorac Cardiovasc Surg 6:110-8.

Kim KB, Lim C, Lee C, Chae IH, Oh BH, Lee MM, Park YB. 2001. Off-pump coronary artery bypass may decrease the patency of saphenous vein grafts. Ann Thorac Surg 72:1033-7.

Ömeroglu SN, Kirali K, Gürler M, et al. 2000. Midterm angiographic assessment of coronary artery bypass grafting without cardiopulmonary bypass. Ann Thorac Surg 70:844-50.

Pfister AJ, Zaki S, Garcia JM, et al. 1992. Coronary artery bypass without cardiopulmonary bypass. Ann Thorac Surg 54:1085-92.

Puskas JD, Wright EC, Ronson RS, Brown WM, Gott JP, Guyton RA. 1999. Clinical outcomes and angiographic patency in125 consecutive off-pump coronary bypass patients. The Heart Surg Forum #1999-95310 2(3):216-21.

Stanbridge R L, Hadjinikolaou LK. 1999. Technical adjuncts in beating heart surgery. Comparison of MIDCAG to off-pump sternotomy: a meta-analysis. Eur J Cardiothorac Surg 16:24-33.

Tasdemir O, Vural KM, Karagöz H, Bayazıt K. 1998. Coronary artery bypass grafting on the beating heart without the use of extracorporeal circulation: review of 2052 cases. J Thorac Cardiovasc Surg 116:68-73.

Tezcaner T, Yorgancıoglu C, Çatav Z, et al. 2000. Coronary artery bypass grafting without cardiopulmonary bypass. Assian Ann 8:97-102.

Vural K, Sener E, Tasdemir O. 2001. Long term patency of sequential and individual saphenous vein coronary bypass grafts. Eur J Cardiothorac Surg 19:140-4.

Wos S, Bachowski R, Ceglarek W, Damaradzki W, Matuszewski M, Kucewicz E. 1998. Coronary artery bypass grafting without cardiopulmonary bypass: initial experience of 50 cases. Eur J Cardiothorac Surg 14:38-42.