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Early- and Long-Term Comparison of the On- and Off-Pump Bypass Surgery in Patients with Left Ventricular Dysfunction

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ABSTRACT

Objective: The adverse effects of extracorporeal circulation increase the morbidity and mortality risk of coronary bypass surgery, especially in patients with left ventricular dysfunction. The purpose of this study was to provide a comparison of the early and long-term outcome between patient groups with left ventricular dysfunction (LVEF<40% or LVPS≥15) operated with or without using cardiopulmonary bypass.

Methods: Fifty-one patients with left ventricular dysfunction, who were operated on between October 1992 and March 1994, were investigated retrospectively. They were divided into two groups: BH-group included 26 patients and cardiopulmonary bypass group had 25 patients. Mean age and risk factors were identical. All patients received one vessel bypass left internal mammary artery to left descending artery.

Results: There was no early mortality and perioperative myocardial infarction in either group. In the early postoperative period the need of cardiac support therapy was significantly higher in the cardiopulmonary-bypass group than in the beating heart-group: 32% versus 7.7% ($p<0.05$). The need for blood products (for fresh frozen plasma 3.63 ± 2.15u versus 2.5 ± 1.34u; $p = 0.023$; for packed red blood cells 1.8 ± 0.75u versus 1.25 ± 0.46u; $p = 0.048$), the extubation time (18.2 ± 5.5 hours versus 15.3 ± 3.8 hours; $p = 0.03$) and the hospital stay (10.64 ± 3.2 days versus 7.92 ± 2.25 days; $p = 0.001$) were higher in the cardiopulmonary bypass -group than in the beating heart-group. Actuarial survival for the beating heart-group was 92.3 ± 5.2% at 6 years, and for the cardiopulmonary bypass group was 92 ± 5.4% at 6 years ($p = 0.67$).

Conclusions: In spite of more than four times as many patients in the cardiopulmonary bypass group requiring inotropic support after surgery, survival and cardiac death rates were similar for both groups. Off-pump bypass surgery conserves the blood constituents. The benefits of both techniques to improve the left ventricular performance score and ejection fraction were similar, but postoperative extubation time, length of intensive care unit and hospital stay were reduced significantly in the beating heart group. With these good results of the beating heart coronary bypass surgery and considering its cost effectiveness, we concluded that coronary bypass on a beating heart can be an alternative to cardiopulmonary bypass technique in selective patient groups.

INTRODUCTION

Although current methods of cardiopulmonary bypass (CPB) are remarkably safe, there is incontrovertible evidence that various damaging effects of CPB do occur [Kirklin 1993]. In the majority of patients the adverse effects of CPB are minor and reversible. Patients with significant functional impairment of various organ systems may not tolerate the added deleterious effects of CPB, which may be irreversible and even fatal. Coronary artery bypass grafting (CABG) on the beating heart without using CPB has been offered as an alternative to the standard on-pump technique in selected cases. In the last ten years, several series of CABG operations without CPB were reported [Laborde 1989, Benetti 1991, Pfister 1992, Moshkovitz 1995, Bouchard 1998, Gundry 1998]. The off-pump technique seems more appropriate for patients with left ventricular dysfunction or in some instances in which CPB, hypothermia, or cannulation is not desirable [Akiyama 1999, Ascione 1999].

In patients with left ventricular dysfunction, CABG procedures can have a poor long-term prognosis and increase the risk of hospital mortality. Despite the poor prognosis of advanced left ventricular dysfunction and severe coronary artery disease, there is often reluctance to consider bypass-grafting with/without CPB as a major or early therapeutic option [Luciani 1993, Isik 1997, Moshkovitz 1997, Tasdemir 1998, Trachiotis 1998]. On the other hand, it was reported that patients with severe ventricular dysfunction have better long-term survival expectancies after CABG than with continued medical therapy [Christakis 1992].

In spite of the beneficial advantages of off-pump CABG on the beating heart, there existed no long-term comparison of the follow up of patients with left ventricular dysfunction who have undergone myocardial revascularization concurrently with either CPB-supported CABG or without CBP. This study was designed to compare the results of both techniques. The early and long-term results of isolated CABG performed at our hospital in patients with advanced

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Table-1. Preoperative patients' data.

	BH	CPB
mean age (years)	54 ± 9.5 (39-72)	50.5 ± 8 (35-69)
sex (man/woman)	24/2	23/2
Rhythm	sinusal	sinusal
ECG (preop MI)	24 (92.3%)	22 (88%)
priory PTCA	1 (3.8%)	2 (8%)
preop risk factors		
- smoking	21 (80.8%)	21 (84%)
- familial history	17 (65.4%)	16 (64%)
- hypertension	9 (34.6%)	7 (28%)
- hyperlipidemia	8 (30.6%)	6 (24%)
- obesity	7 (27%)	6 (24%)
- diabetes	6 (23%)	5 (20%)
concomitant diseases		
- chronic obstructive pulmonary disease	17 (65.4%)	15 (60%)
- peripheral arterial disease	4 (15.4%)	1 (4%)
- stenotic carotid occlusion	2 (7.7%)	0
- cerebrovascular accident	3 (11.5%)	3 (12%)
- hepatic insufficiency	2 (7.7%)	2 (8%)
- ascending aorta dilatation	4 (15.4%)	0
- renal insufficiency	2 (7.7%)	0
occluded coronary arteries		
- only LAD	11 (42.3%)	
17 (68%)		
- LMC	2 (7.7%)	0
- two vessels (LAD + RCA or Cx)	7 (27%)	5 (20%)
- three vessels (LAD + Cx + RCA)	6 (23%)	3 (12%)
left ventricular function		
- ejection fraction		
min	29	15
max	40	22
mean	36.1 ± 3.6	17.4 ± 2.1
- performance score		
min	30	15
max	40	21
mean	37 ± 2.8	17.2 ± 1.9

left ventricular dysfunction were reviewed and both survival and post-operative clinical data after bypass grafting were reported.

MATERIAL AND METHODS

The study groups consisted of 51 patients with an ejection fraction (EF) between 30% and 40% or performance score (PS) ≥15. The patients were fully informed about the procedure and gave informed consent. They underwent isolated CABG without CPB on the beating heart or with the conventional technique at Kofluyolu Heart and Research Hospital, between October 1992 and March 1994. Indications for surgery were anginal symptoms (Canada class ≥ III), depressed functional capacity (NYHA class > II), arrhythmia, and viable myocardium at the anterior wall. The preoperative left ventricular EF was determined by two-dimensional echocardiography, while the left ventricular PS (segmental wall motion score) with diseased coronary arteries by angiography. All patients had one or multiple coronary lesions, and confirmation by thallium scintigraphy that there was no viable myocardium at the infarcted areas except anterior and septal segments of the heart. Accordingly, we decided to perform complete or incomplete single CABG only to the left descending artery (LAD) because of the inadequate diameter of the other coronary arteries except LAD or scar tissue on the lateral or inferior segment of the heart. Twenty-six patients were operated on without using extracorporeal circulation on the beating heart (BH-group); 25 patients were operated on with CPB (CPB-group). Preoperative risk factors and patients' characteristics were similar, with the exception of the number of occluded coronary arteries (Table 1,). All of the patients underwent the operation electively. No urgent operation was performed. We used only left internal mammary artery (LIMA) as an arterial graft.

All patients in the BH-group underwent CABG by the same surgical team. After median sternotomy, wet gauze pads were placed under the heart for purposes of exposure. After heparinization, we applied an atraumatic bulldog clamp about 1 cm proximal to the anastomotic area on LAD. We used beta-blocker to slow the heart rate when it was greater than 80 beats per minute. We never clamped the distal segment of the anastomotic area. Mean bulldog-clamp time was 12.7 ± 2.4 minutes (range, 8-19 minutes). After anastomosis, we released the clamps and never gave protamine sulfate.

In the CPB-group, single cannulation of the right atrium and aorta were carried out. The left ventricle was vented to gravity through the aorta. Myocardial preservation was performed by means of systemic hypothermia (28-30°C) and cold blood cardioplegia administered antegrade. Mean aortic cross-clamp time was 22.7 ± 3.8 minutes (range, 18-29 minutes) and extracorporeal perfusion time was 47.7 ± 11 minutes (range, 30-74 minutes).

Follow-up. Follow-up data were obtained from office charts, hospital charts, and interviews with the patients. Complete follow-up data were available in 47 (92%) of 51 patients.

Data analysis. Survival curves were drawn on an actuarial basis using the Kaplan-Meier technique. Survival curves were compared by the Log Rank test. The statistical significance of differences was determined using the unpaired t-test and the paired t test (comparison of pre- and post-operative EF and PS) and chi-square test (comparison of inotropic support therapy).

RESULTS

Survival

No patient died in the hospital. The BH-group was followed for meanly 65.7 ± 5.6 months (range, 44 and 71 months) and the CPB-group for 67.6 ± 7.9 months (range, 42 and 80 months). The follow-up time was not different ($p = 0.057$). There were two late mortalities in each group. The causes were cancer and cardiac-related in the BH-group, whereas the causes were cerebrovascular hemorrhage and cardiac-related in the CPB-group. Cardiac-related cause of

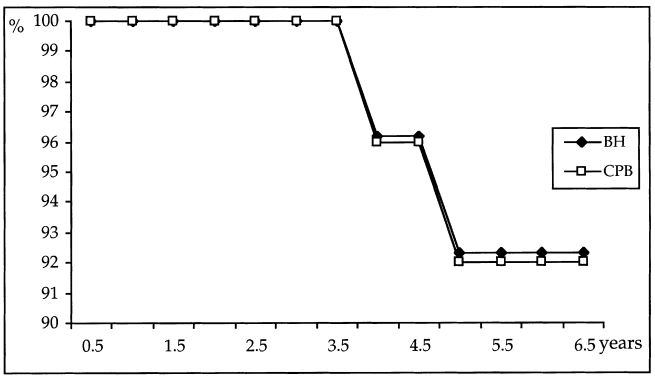

Figure 1. Cumulative survival in the beating heart and cardiopulmonary bypass group.

late mortality was heart failure. Actuarial survival for the BH-group was 96.2±3.8% at 4 years and 92.3±5.2% at 6 years, and for the CPB-group was 96±3.9% at 4 years and 92±5.4% at 6 years (p = 0.67) (Figure 1,).

Required inotropic support

The most common complication in the early postoperative period was low cardiac output syndrome (LCOS). LCOS was observed more frequently in the CPB-group (8 patients; 32%) than in the BH-group (2 patients; 7.7%) (p = 0.038). All of these patients were treated by administering inotropic support therapy; however, four patients in the CPB-group required intraaortic balloon pump at the same time. In all patients, the inotropic support therapy (medical or mechanical) was continued during the first week and then stopped. No patient sustained a new Q-wave myocardial infarction or subendocardial myocardial infarction by criteria used at our hospital (creatine kinase, MB fraction product for the CPB-group >100 IU/liter or for the BH-group >50 IU/liter).

Functional capacity and improvement of the cardiac function

No patient in either group had angina or congestive symptoms in the follow-up period. The majority of patients in both groups had NYHA class II or III functional capacity before operation. After CABG, the improvement of the functional capacity was evident (Table 2,).

This improvement of the functional capacity was correlated with the increase in the EF and PS after coronary revascularization. There was no significant difference between the two groups in the pre- and post-operative periods, but there was a significant increase among the groups (Table 2,).

The need for blood products

Because we did not give protamine sulfate after CABG in the BH-group, we observed conspicuous drainage after operation (811.5 ± 363 cc; range between 450 and 2000 cc), even in the CPB-group (786 ± 400 cc; range between 300 and 2000 cc) (p = 0.813). The CPB-group needed more blood products in the early postoperative period than the BH-group (Table 3,).

Extubation-mobilization-ICU and hospital stay

All patients were extubated the next morning in the absence of complications. The ICU stay was significantly shorter in the BH-group than in the CPB-group (Table 4,).

Hospital cost

The cost of the CABG on the beating heart was 30% cheaper than the conventional technique.

Angiographic results and reintervention

We applied the first control angiography to all patients in the second postoperative month and all anastomoses in both groups were patent. During the follow-up no reoperation or reintervention was necessary, but within this year, we applied the second control angiography to observe whether the anastomoses were patent or not. We observed that there was one occluded anastomosis with prior proximal lesion at LAD in the CPB-group, and one new stenotic lesion at the right coronary artery in each group. PTCA was applied to all of these lesions.

DISCUSSION

To avoid the side effects of extracorporeal circulation and cardioplegia with an aortic cross-clamp, CABG on the beating heart has been popularized in the last decade. Short-term results appear encouraging [Moshkovitz 1995, Sternik 1997, Tasdemir 1998, Omerglu 2000], however only a few long-term studies were available to compare BH bypass to conventional bypass techniques [Moshkovitz 1995, Gundry 1998, Trachiotis 1998]. Moshkovitz and assistants have shown that the established risk factors for CABG with the use of CPB may not necessarily be significant when CPB is avoided [Pfister 1992]. They and others [Pfister 1992, Moshkovitz 1997, Tasdemir 1997] reported that the early mortality of patients with severely impaired ventricles who underwent CABG without CPB was very small (2.5-3%). These results can be explained by the favorable effect of the beating heart on blood supply to the subendocardium and better preservation of interventricular septal contractility reported after CABG without CPB [Laborde 1989]. In this study, there was no mortality and perioperative myocardial

Table 2. The left ventricular function after CABG in beating heart and CPB group.

mean value	BH	CPB	p
Ejection fraction (preop)	36.1±3.6%	37±2.8%	0.35
Ejection fraction (postop)	43.5±5.5%	45.2±5%	0.45
P	0.008	0.012	
Performance score (preop)	17.4±2.1	17.2±1.9	0.91
Performance score (postop)	14.3±2.3	13.3±1.9	0.23
p	0.011	0.01	
NYHA class ≥ III (preop)	50%	52%	0.889
NYHA class ≥ III (postop)	11.5%	12%	0.911
p	0.0027	0.0025	

Table 3. Administration of transfusion products in the intensive coronary unit

	BH	CPB	p
fresh frozen plasma	2.5 ± 1.34 u	3.63 ± 2.15u	0.023
packed red blood cells	1.25 ± 0.46u	1.8 ± 0.75u	0.048

Table 4. Early postoperative follow-up after CABG.

	BH	CPB	p
extubation (hours)	15.3 ± 3.8	18.2 ± 5.5	0.03
mobilization (days)	1.7 ± 0.5	2.3 ± 0.9	0.04
ICU-stay (days)	2.04 ± 0.9	2.8 ± 1.9	0.047
hospital-stay (days)	7.92 ± 2.25	10.64 ± 3.2	0.001

infarction (MI) in either group. It has been reported that perioperative MI was dependent on acute vein graft occlusion [Moshkovitz 1997]. It is well established that the use of LIMA is associated with decreased early mortality and good long-term survival [Moshkovitz 1995, Loop 1998]. The superior results with the use of LIMA may be related to the luminal release of nitric oxide, which induces coronary vasodilatation and inhibits platelet adhesion and aggregation [Pearson 1992]. In our series we used only LIMA as an arterial graft. CABG in patients with advanced left ventricular dysfunction has often been regarded as high risk. Medical therapy for these patients has often been unsatisfactory at controlling angina and has poor long-term survival [Luciani 1993, Trachiotis 1998]. It was reported that a lowered EF was not a predictor of an unfavorable outcome after CABG [Pfister 1992, Moshkovitz 1997]. Poor left ventricular status is far less ominous today compared to the early era of coronary artery surgery [Loop 1998]. Some factors have expanded the indications for surgery in patients with left ventricular dysfunction: (1) documentation of viable/non-viable myocardium; (2) improved myocardial protection and intra-aortic balloon pumping; (3) arterial grafting. The improved results of CABG in patients with left ventricular dysfunction have been attributed to advances in myocardial protection with blood cardioplegia through coronary sinus, surgical techniques and perioperative care [Martin 1994, Elefteriades 1995, Mickleborough 1995, Rashid 1995, Trachiotis 1998].

Incomplete revascularization is an established determinant of the early return of angina. The relatively low number of grafts per patient is primarily related to patient selection. The number of diseased vessels, lower EF, prior MI, and hypertension were strong correlates of incomplete revascularization [Jones 1996]. In this study all patients had a minimum of two risk factors. Inadequate coronary artery bed and prior MI with nonviable myocardium account for the significant decrease in complete revascularization in this series. Despite one graft per patient for multivessel diseased patients in this study, the survival rate was similar for both groups. As this study indicates, impressive results and excellent long-term survival can be achieved in patients with left ventricular dysfunction operated on without CPB, despite incomplete revascularization. The results of our study suggest that CABG, using only a LIMA to LAD, whether on a beating or arrested heart, has the potential to produce actuarial survival comparable to those of a multi-vessel bypass [Bouchard 1998]. This is likely the result of many factors, but may in part be related to the ability to revascularize the LAD [Jones 1996, Loop 1998, Trachiotis 1998]. On the other hand, anginal symptoms do reappear following incomplete revascularization, thus requiring a second intervention. However, Gundry et al reported that subsequent PTCA was usually directed at previously bypassed vessels, rather than non-bypassed vessels [Bouchard 1998]. They found that second intervention had been applied in the BH-group more than in the CPB-group. In our series, the reintervention rate was similar in both groups and we did not observe a renewed anginal symptom in either group. But, when we applied the second control angiography to both groups, we observed one occluded LIMA with precedent proximal lesion on LAD in the CPB-group and a new atherosclerotic lesion on the right coronary artery in one patient in both groups. PTCA was applied successfully to the proximal lesion of LAD in the first patient and to the new lesions in the other two patients.

An important finding in this study is that for properly selected patients with an EF between 0.30 and 0.40, CABG without CPB may be associated with no operative mortality. Furthermore, the incidence of postoperative low cardiac output syndrome and the need for inotropic support was significantly lower in patients operated on with BH. The superiority of the BH-technique can depend on the activation of various mediators of inflammation during CPB [Kirklin 1993], change in left ventricular geometry of the empty heart during CPB which impedes coronary collateral flow supplying potentially ischemic areas of myocardium [Kirklin 1993], paradoxical movement of the interventricular septum after CPB [Akins 1984]. Immediate postoperative myocardial performance depends to a large degree on coronary and graft flow (BH>CPB) [Moshkovitz 1997].

Besides the good results with the BH-technique, economic advantages should also be kept in mind. With this technique it is possible to discharge patients with left ventricular dysfunction in the early postoperative period like patients with normal ventricular function. The significantly lower use of blood products decreases the risk of transmitting diseases or complications related to the use of blood products. We did not observe any significant advantage of CABG on the beating heart during the long-term survival in comparison with the conventional technique, but the beneficial effects of the BH-technique in perioperative and early postoperative periods make it superior to the conventional technique in patients with left ventricular dysfunction.

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