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Long Term Changes in Echocardiography Findings After On-Pump and Off-Pump Coronary Artery Bypass Grafting; A Historical Cohort Study

Hamidreza Karimi-Sari [1,2]; Maryam Moshkani Farahani [2,*]; Vahid Talebzadeh [1]; Hamidreza Taghipour [3]

[1]Students' Research Committee, Baqiyatallah University of Medical Sciences, Tehran, IR Iran
[2]Atherosclerosis Research Center, Faculty of Medicine, Baqiyatallah University of Medical Sciences, Tehran, IR Iran
[3]Trauma Research Center, Faculty of Medicine, Baqiyatallah University of Medical Sciences, Tehran, IR Iran

*Corresponding author: Maryam Moshkani Farahani, Atherosclerosis Research Center, Faculty of Medicine, Baqiyatallah University of Medical Sciences, Tehran, IR Iran. Tel/Fax: +98-2181264354, E-mail: moshkani_farahani@yahoo.com

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Background: Coronary artery bypass grafting (CABG) is a revascularization method for coronary artery disease (CAD), which is done with and without cardiopulmonary bypass (CPB). CABG without CPB (off-pump) has been prevalent due to CPB related complications but a number of studies have not demonstrated superiority between these two methods.

Objectives: This study designed to evaluate changes in patients' echocardiography findings during 4 years after CABG with and without CPB.

Patients and Methods: 118 patients who underwent CABG were included in this historical cohort study. Demographic data echocardiographs, serum creatinine and hemoglobin before and after surgery extracted from patients' medical records. In the next visits, history taking, cardiovascular events, physical examination, and echocardiography considered in all patients. Data compared in Off-Pump and On-Pump CABG groups.

Results: One hundred eighteen patients with the mean age of 59.47 ± 9.68 years were included (81 male and 37 female). On-pump CABG was done on 84 patients and off-pump on 34 patients. The mean age was significantly more and numbers of atherosclerotic vessels were less in off-pump patients. Left ventricle ejection fraction (EF) was significantly decreased in on-pump group and increased in off-pump group. Right ventricle EF was significantly decreased in both groups, with significant decrease in on-pump patients. Mitral and tricuspid valves regurgitation were significantly more in on-pump patients ($P < 0.05$).

Conclusions: Our study showed superiority of off-pump CABG regarding LVEF, RVEF and valves regurgitations. Future studies with prospective structure, accurate randomization, longer follow up duration, and larger sample size are needed.

Keywords: Coronary Artery Bypass; Cardiopulmonary Bypass; Echocardiography, Mortality

1. Background

Coronary artery disease (CAD) is one of the prevalent diseases, with high morbidity and mortality rates (1). Coronary artery revascularization plays a major role in case of resistant to medication and clinical risks. One revascularization method is coronary artery bypass grafting (CABG). However, angiography/ angioplasty have been developed recently, CABG is standard treatment of revascularization in complicated patients (2-4). In patients with diabetes and triple- vessel disease (3VD), CABG is more useful than angioplasty (2, 3, 5). CABG is done with and without cardiopulmonary bypass (CPB) (6, 7). By using CPB (on-pump CABG), surgical field is free of blood and anastomosis could be performed accurately but it can cause ischemic adverse events (7-9). CABG without CPB (off-pump) has been prevalent because of CPB related complications such as thrombocytopenia, inflammatory reactions, embolic events and stroke (8-10). Although Society of Thoracic Surgeons showed superiority of off-pump CABG over the on-pump CABG according to mortality and morbidity, (11) a number of studies have not demonstrated superiority between the two methods according to systolic and diastolic ventricular function, ejection fraction, all-cause mortality, and cardiac accidents (12-20). A number of studies showed superiority of on-pump CABG according to survival, re-stenosis, and myocardial relaxation, (7, 21, 22) but Bakaeen study showed superiority of o-pump CABG according to renal injuries, needing dialysis, and operation time (20). Ventricular function is impaired after on-pump CABG because of cardioplegia, ischemia, hypothermia and reperfusion (8). But there were no significant changes in ventricular function after on-pump and off-pump CABG in Sochon et al. study (18). Using off-pump CABG is decreasing during the past 5 years and today only 20 percent of CABGs are done without pump (23).

2. Objectives

This study designed to evaluate long-term changes in patients' echocardiography findings, any- cause of mortality and cardiac events during 4 years after CABG with and without cardiopulmonary bypass (on-pump or off-pump).

3. Patients and Materials

This historical cohort study was approved by Ethics Committee of Baqiyatallah University of Medical Sciences (BMSU). One hundred eighteen patients who underwent coronary artery bypass grafting surgery before March 2011, without any age or gender limitations were included. Demographic data and angiography findings before and after surgery, echocardiographs, serum creatinine and hemoglobin were excluded from patients' medical records. Coronary angiography was done before surgery and echocardiography was performed within 24 hour before surgery and before discharge from hospital for all patients. Angiography and echocardiography results were documented in each patient's record. Coronary artery bypass grafts were done by two cardio-surgeons and echocardiographs were taken by two cardiologists in Baqiyatallah hospital. The both groups were operated by the same surgical team. Inter observers reliability of variables did not show any significant difference. We recalled all patients using their phone numbers. Patients with wrong phone number and not reachable patients excluded from study. Patients referred to other hospitals, patients with a defect in medical records, patients underwent CABG by another surgeon, and echocardiographies were done in another center and other echocardiologists also excluded from study. In secondary visits, history taking, asking about cardiovascular events, physical examination, and echocardiography were done for all patients. All-cause mortality was also checked in patients. Collected data were compared in Off-Pump and On-Pump CABG groups.

3.1. Statistical Analysis

Data were analyzed using statistical package for social sciences (SPSS) version 21 (SPSS Inc. Chicago, IL). Normal distribution variables (approved by one-sample Kolmogorov–Smirnov test) were compared using independent sample t-test between the groups and paired sample t-test within the groups. Nonparametric tests (Mann-Whitney U test between the groups and Wilcoxon test within the groups) were used for variables without normal distribution. Qualitative variables were evaluated by chi square and Fisher's exact tests.

4. Results

One hundred eighteen patients with mean age of 59.47 ± 9.68 years and mean weight of 69.46 ± 12.89 kg were included. Eighty one patients were male and thirty seven patients were female. CABG was done on-pump in 84 patients and off-pump in 34 patients. The mean follow-up duration was 52.47 ± 9.9 months. The mean age was significantly more in patients underwent off-pump CABG ($P < 0.001$). Patients' weight and gender had not significant differences between groups ($P > 0.05$). Sixty one patients (51.7%) had diabetes mellitus, fifty seven patients (48.3%) had dyslipidemia, and sixty seven patients (56.8%) had hypertension. Prevalence of dyslipidemia was significantly more in patients underwent off-pump CABG ($P = 0.023$). Seventeen patients (14.4%) had chronic kidney disease; this prevalence was significantly more in on-pump group ($P = 0.023$). Sixty nine patients had a history of myocardial infarction (MI) and thirty eight patients had a history of angiography/ angioplasty. Prevalence of previous MI was significantly more in on-pump patients ($P = 0.003$). Angiography result were 17.8 percent single vessel disease (SVD), 28 percent two vessel disease, and 54.2 percent three vessel disease. Number of atherosclerotic coronary arteries was significantly more in on-pump patients ($P < 0.001$). The mean intensive care unit (ICU) stay was 2.58 ± 0.99 days; ICU stay was significantly longer in off-pump patients ($P < 0.001$). Angiography/ angioplasty was needed for thirteen patients and 3 patients expired (any cause) during the follow- up period. One off-pump patient expired 2 days after CABG in the hospital due to cardiac arrest and unsuccessful cardiopulmonary resuscitation (CPR) (Table 1). The mean serum creatinine level was 1.54 ± 1.72 mg/dL before operation and 1.43 ± 1.17 mg/dL after operation. The mean baseline serum creatinine was significantly more in on-pump patients ($P = 0.034$), but there was not any significant difference between groups in after operation serum creatinine ($P = 0.119$). Changes in laboratory findings before and after operation are shown in Table 2.

4.1. Echocardiography Findings

The mean percentage of the left ventricular ejection fraction (LVEF) were 49.45 ± 7.42 before surgery, 47.24 ± 7.67 after surgery, and 48.45 ± 7.11 after the follow- up period. LVEF was more in on-pump patients before operation, LVEF was more in off-pump patients after operation and after the follow-up period; but these differences were not statistically significant ($P > 0.05$). In comparison of before-after operation, there was a significant decrease in on-pump patients' LVEF ($P = 0.001$). LVEF changes in other within groups were not statistically significant ($P > 0.05$). The mean percentage of the right ventricular ejection fraction (RVEF) was 50.42 ± 4.65 before surgery, 49.35 ± 5.0 after surgery, and 49.34 ± 5.57 after follow-up period. RVEF was higher in on-pump patients before operation, RVEFs were higher in off-pump patients after the operation and after the follow-up period; but these differences were not statistically significant ($P > 0.05$). Comparison of before-after measurements revealed that RVEF reduced in both groups, but this decrease was more noticeable in on-pump patients ($P = 0.044$).

Table 1. Characteristics of On-Pump and Off-Pump Coronary Artery Bypass Grafting Groups[a,b]

Variable	On-Pump (n = 84)	Off-Pump (n = 34)	Total (n = 118)	P Value
Age, y	56.93 ± 9.1	65.76 ± 8.2	59.47 ± 9.7	< 0.001
Male	61 (72.6)	20 (58.8)	81 (68.6)	0.108
Weight, kg	70.48 ± 13.1	66.94 ± 12.2	69.46 ± 12.9	0.179
Diabetes Mellitus	45 (53.6)	16 (47.1)	61 (51.7)	0.521
Hyperlipidemia	35 (41.7)	22 (64.7)	57 (48.3)	0.023
Hypertension	49 (58.3)	18 (52.9)	67 (56.8)	0.592
Chronic Kidney Disease	16 (19.0)	1 (2.9)	17 (14.4)	0.023
Previous Angiography/ Angioplasty	24 (28.6)	14 (41.2)	38 (32.2)	0.184
Previous MI	63 (75.0)	16 (47.1)	79 (66.9)	0.003
Angiography Result				< 0.001
SVD	5 (6.0)	16 (47.1)	21 (17.8)	
2VD	29 (34.5)	4 (11.8)	33 (28)	
3VD	50 (59.5)	14(41.2)	64 (54.2)	
ICU Stay, days	2.27 ± 0.7	3.35 ± 1.2	2.58 ± 0.99	< 0.001
Follow Up duration, mon	53.09 ± 10.2	50.91 ± 8.9	52.47 ± 9.9	0.277
Needing PCI/ Stenting	7 (8.3)	6 (17.6)	13 (11)	0.143
Any Cause Mortality	2 (2.4)	1 (2.9)	3 (2.5)	0.861

[a] Abbreviations: SVD, single vessel disease; 2VD, two vessel disease ; 3VD, triple-vessel disease; PCI, percutaneous coronary intervention.
[b] Data are presented as No. (%) or Mean ± SD.

Table 2. Comparison of Laboratory Findings among On-Pump and Off-Pump Coronary Artery Bypass Grafting Groups Before and After the Operation [a]

Variable	On Pump (n = 84)	Off Pump (n = 34)	Total (n = 118)	P Value
Creatinine, mg/dL				
Before	1.75 ± 2.0	1.01 ± 0.21	1.54 ± 1.72	0.034
After	1.54 ± 1.4	1.16 ± 0.30	1.43 ± 2.17	0.119
Changes	- 0.21 ± 1.6	0.15 ± 0.16	- 0.11 ± 1.33	0.176
P Value for Trend	0.213	< 0.001	0.378	-
Hemoglobin, mg/dL				
Before	11.44 ± 2.4	11.66 ± 3.2	11.5 ± 2.6	0.684
After	10.39 ± 1.4	11.35 ± 1.9	10.67 ± 1.6	0.010
Changes	- 1.05 ± 2.3	- 0.31 ± 2.6	- 0.83 ± 2.4	0.126
P Value for Trend	< 0.001	0.429	< 0.001	-

[a] Data are presented as Mean ± SD.

Prevalence of mitral valve regurgitation (MR) was 32.2 percent before surgery, 25.4 percent after surgery, and 21.2 percent after follow-up period. There was no significant difference in rate of MR between on/off-pump patients before operation, but after operation and after follow-up, MR rates were significantly more in on-pump patients ($P < 0.05$). Prevalence of tricuspid valve regurgitation (TR) was 40.7 percent before surgery, 44.9 percent after surgery, and 37.2 percent after the follow-up period. There were no significant differences before and after operation rates of TR between on/off-pump patients, but after follow-up period, TR rate was significantly more in on-pump patients ($P = 0.048$). Prevalence of aortic valve regurgitation (AR) was 16.9 percent before surgery, 21.2 percent after surgery, and 18.3 percent after the follow-up period. AR was more prevalent before and after operation in off-pump patients ($P < 0.05$), but there was not significant differences in AR rate between groups after follow-up period ($P = 0.603$). Prevalence of aortic valve stenosis (AS) was 8.5 percent before surgery, 9.3 percent after surgery, and 8.7 percent after the follow-up period. There were no significant differences in AS rates between groups in none of the study stages ($P > 0.05$). Changes in echocardiography findings during the follow-up period are shown in Table 3 Figure 1 and 2.

Table 3. Comparison of Echocardiography Findings among On-Pump and Off-Pump Coronary Artery Bypass Grafting Groups Before and After Operation and After Follow-up Period[a]

Variable	On Pump (n = 84)	Off Pump (n = 34)	Total (n = 118)	P Value
Left Ventricle Ejection Fraction, %				
Before Operation	49.94 ± 7.6	48.24 ± 6.9	49.45 ± 7.4	0.260
After Operation	46.55 ± 7.9	49.06 ± 6.8	47.24 ± 7.6	0.093
Follow Up	47.96 ± 7.6	49.69 ± 5.5	48.45 ± 7.1	0.186
Changes	- 2.35 ± 4.7	1.56 ± 4.3	- 1.24 ± 4.9	< 0.001
P Value for Trend	0.028	0.018	0.037	-
Right Ventricle Ejection Fraction, %				
Before Operation	50.6 ± 5.1	50.0 ± 3.5	50.42 ± 4.6	0.466
After Operation	48.87 ± 5.3	50.63 ± 3.9	49.35 ± 5.0	0.057
Follow Up	49.20 ± 5.9	49.68 ± 5.5	49.34 ± 5.6	0.675
Changes	- 1.79 ± 4.1	- 0.31 ± 3.3	- 1.37 ± 3.9	0.044
P Value for Trend	0.017	0.047	0.001	-
Mitral Valve Regurgitation				
Before Operation	25 (29.8)	13 (38.2)	38 (32.2)	0.248
After Operation	19 (22.6)	11 (32.4)	30 (25.4)	0.192
Follow Up	18 (21.4)	7 (21.2)	25 (21.2)	0.566
Tricuspid Valve Regurgitation, No. (%)				
Before Operation	36 (42.9)	12 (35.3)	48 (40.7)	0.449
After Operation	41 (48.8)	12 (35.3)	53 (44.9)	0.181
Follow Up	35 (42.7)	7 (21.2)	42 (35.6)	0.048
Aortic Valve Regurgitation				
Before Operation	10 (11.9)	10 (29.4)	20 (16.9)	0.022
After Operation	13 (15.5)	12 (35.3)	25 (21.2)	0.018
Follow Up	14 (17.1)	7 (21.2)	21 (17.8)	0.603
Aortic Valve Stenosis				
Before Operation	6 (7.1)	4 (11.8)	10 (8.5)	0.471
After Operation	7 (8.3)	4 (11.8)	11 (9.3)	0.727
Follow Up	5 (6.1)	5 (15.2)	10 (8.5)	0.119

[a] Data are presented as No. (%) or Mean ± SD.

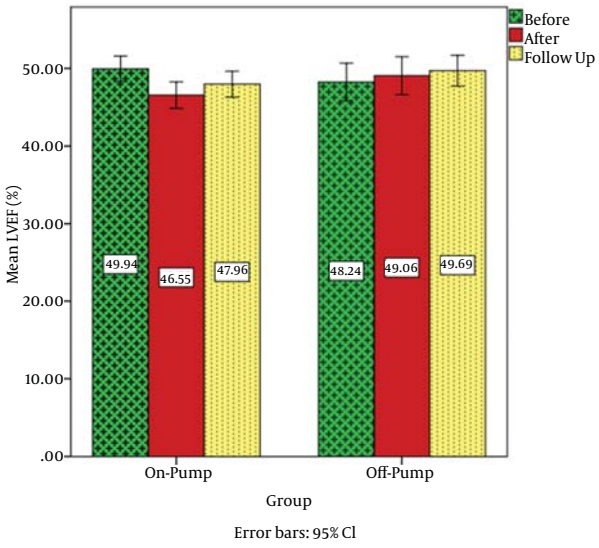

Figure 1. Comparison of Left Ventricle Ejection Fraction (LVEF) Between On-Pump and Off-Pump CABG Groups

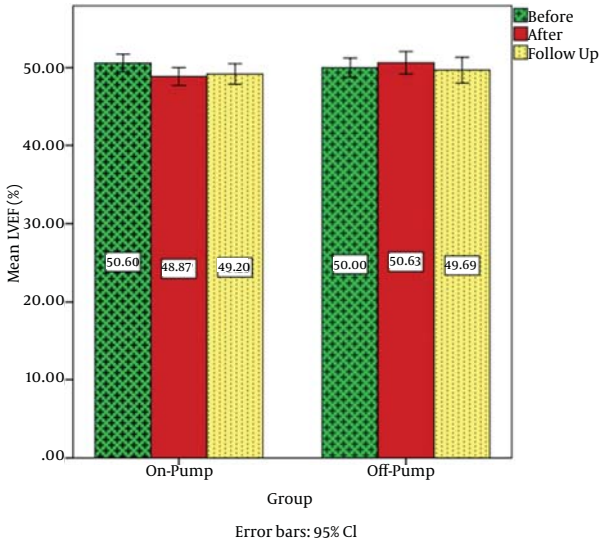

Figure 2. Comparison of Right Ventricle Ejection Fraction (RVEF) between On-Pump and Off-Pump CABG Groups

5. Discussion

Despite the existence of more risk factors such as age, dyslipidemia, previous MI, and number of atherosclerotic vessels in on-pump group in our study, there were no significant differences in needing PCI or stenting and any-cause mortality between groups. Echocardiography study showed superiority of off-pump CABG, but the mean serum creatinine showed a controversy for this superiority. This was because of significantly more serum creatinine in off-pump patients before operation. Using off-pump CABG was decreased during the past 5 years, and today only 20 percent of CABGs are done without pump (23). CABG was done without pump in 29% of patients in our study.

5.1. Preoperative Complications

Our study showed a significant increase in serum creatinine after off-pump CABG. While in Bakaeen et al. study, renal failure and needing dialysis was significantly more in on-pump CABG patients (20). ICU stay was significantly more in off-pump CABG patients in our study, but hospitalization did not significantly differ between groups in Bakaeen et al. study. Surgery duration was significantly longer in on-pump patients in Bakaeen et al. study (20).

5.2. Echocardiography Findings

Our study showed a significant decrease in LVEF in on-pump patients after operation and after the follow-up period. LVEF was slightly increased in off-pump patients after operation and during the follow-up period. In Diller et al. study, left ventricle systolic function did not have significant changes and did not differ between on and off-pump patients during 180 days follow-up. But diastolic function were significantly increased in patients after operation and decreased during 180 days in Diller et al study (16). In de Waal et al. study, improvement of myocardial relaxation, one day after on-pump CABG was significantly more than off-pump patients (21). In Sochon et al. study, there were no significant changes in ejection fraction before and after operation in trans-esophageal echocardiography and there were no significant differences in echocardiography findings between on-pump and off-pump patients (18). RVEF was significantly decreased in both groups in our study during the follow-up period. This decrease was significantly more in on-pump patients. Diller et al. study showed a significant decrease in systolic and diastolic function of right ventricle after operation in all patients and a slight recovery during 180 days without significant difference between groups (16). In contrast, changes in right ventricle function measured by trans-esophageal echocardiography in Michaux et al. study was not significant in before-after evaluation and had not significant difference between on-pump and off-pump groups (17). Valves regurgitations were also evaluated in our study showed superiority of off-pump CABG.

5.3. Interventions and Mortality

There was no significant difference in needing intervention and any-cause mortality between groups during 4 years. Ben-Gal et al. study showed more intervention during 30 days in off-pump patients, but in 1 year evaluation, there were no significant difference in needing intervention and any-cause mortality between groups (7). Also there were no significant differences in cardiac events and mortality between on and off-pump CABG in Moler et al. study (19). One patients in off pump group expired in hospital after CABG, and 2 patients in on-pump group expired during follow-up period. Any-cause mortality during 4 years did not have significant difference between on and off-pump CABG in our study. While ten years survival was significantly more in on-pump CABG patients in Filardo et al. study (22). We suggest more studies about echocardiography findings after on and off-pump CABG with prospective structure, more patients and longer follow-up period. There are fewer primary studies evaluating echocardiography findings after on-pump and off-pump CABG and a secondary study evaluating long-term changes in echocardiography findings is needed for an accurate decision making about superiority between these two methods. Our study showed superiority of off-pump CABG according to LVEF, RVEF and valves regurgitations during 4 years. Future studies with prospective structure, accurate randomization, longer follow-up duration, and larger sample size are needed to evaluate changes in echocardiography findings in on-pump and off-pump CABG.

5.4. Limitations

Non-matched groups, was one limitation of our study that is unavoidable in retrospective studies without randomization. Other limitation was missing data of inaccessible patients that was about 5% of our patients; all of them were alive. The small sample size of off-pump patients and missing data about other echocardiography details (e.g. myocardial relaxation, and lateral wall movement) were other limitations and could be considered in future evaluations.

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Authors' Contributions

Collecting data: Hamidreza Karimi-Sari, Maryam Moshkani Farahani, Vahid Talebzadeh, Hamidreza Taghipour; Statistical Analysis: Hamidreza Karimi-Sari; Drafting manuscript: Hamidreza Karimi-Sari, Maryam Moshkani Farahani, Vahid Talebzadeh; Study supervision: Maryam Moshkani Farahani, Hamidreza Taghipour.

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