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Off-Pump Coronary Artery Bypass Grafting in Patients with Left Ventricular Dysfunction: Short-Term Results from a Single Center in Bangladesh

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Abstract

Background: Off-pump coronary artery bypass grafting (OPCAB) is considered a safer alternative to on-pump surgery, especially in patients with left ventricular dysfunction (LVD). **Objectives:** This study assessed short-term outcomes and functional improvements in LVD patients post-OPCAB. **Methods:** The study included 200 coronary artery disease patients who underwent isolated off-pump coronary artery bypass grafting (OPCAB) at the National Heart Foundation Hospital and Research Institute between January 2019 and June 2020. Patients were categorized into Group 1, with a left ventricular ejection fraction (LVEF) of 30% - 39%, and Group 2, with an LVEF of 40% or higher. Echocardiographic assessments of left ventricular dimensions and ejection fraction were performed preoperatively, at discharge, and one month postoperatively. **Results:** In Group 1, preoperative left ventricular internal dimensions during diastole (LVIDd) and systole (LVIDs) were 53.48 ± 4.40 mm and 44.23 ± 3.93 mm, respectively, with a left ventricular ejection fraction (LVEF) of 35.28% ± 2.26%. At discharge, these values improved to 51.58 ± 4.04 mm (LVIDd), 41.23 ± 5.30 mm (LVIDs), and 39.25% ± 3.75% (LVEF). One month postoperatively, further improvements were observed: 46.29 ± 3.76 mm (LVIDd), 37.45 ± 3.68 mm (LVIDs), and 43.22% ± 4.67% (LVEF). Group 2 showed similar positive outcomes, with preoperative values of 47.09

± 5.06 mm (LVIDd), 35.11 ± 5.25 mm (LVIDs), and 50.13% ± 7.25% (LVEF), improving to 42.37 ± 4.18 mm (LVIDd), 31.05 ± 4.19 mm (LVIDs), and 55.33% ± 7.05% (LVEF) at one month postoperatively. Both groups demonstrated significant improvements in left ventricular function and NYHA class, with most patients moving from class III/IV to I/II. Complications were minimal, and no mortality was observed. **Conclusion:** OPCAB is safe and effective for patients with LVEF 30% - 39% and LVEF ≥ 40%, providing significant short-term functional improvements without increased risk.

Keywords

Off-Pump Coronary Artery Bypass Grafting, Left Ventricular Dysfunction (LVD), Short-Term Outcomes

1. Introduction

Coronary artery disease (CAD) is a major medical and public health concern, as it is a prevalent condition and a leading cause of death worldwide. Bangladesh is undergoing an epidemiological shift from communicable diseases to non-communicable diseases (NCDs) [1]. Although the overall mortality rate has significantly decreased over the past few decades, deaths from chronic diseases, especially the "fatal four"—cardiovascular disease (CVD), cancer, chronic respiratory disease, and diabetes—are rising at an alarming rate. CAD is a significant contributor to CVD, one of these four major chronic conditions [1] [2].

Extensive epidemiological studies have established cigarette smoking, diabetes, hyperlipidemia, and hypertension as independent risk factors for coronary artery disease (CAD). These 'conventional' risk factors are pivotal in the development of CAD and have significantly advanced our understanding of this critical condition. Addressing these risk factors has been shown to reduce the likelihood of future cardiac events [3]. Despite significant advancements in medical therapy for CAD, patients with severe disease or persistent angina, even after optimal treatment, often require mechanical revascularization through either coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI). Since the latter half of the 20th century, CABG has been the most commonly utilized method for revascularization [4].

However, in patients with coronary artery disease (CAD), impaired left ventricular function has a significant impact on the clinical outcomes of coronary artery bypass surgery [5]. Topkara *et al.* found that in-hospital mortality and complications were notably higher in patients with depressed left ventricular function compared to those with normal function [6]. For patients with low left ventricular function, studies have shown that CABG offers a long-term survival benefit over medical therapy, even for those with an ejection fraction as low as 30% [7].

Historically, CABG in patients with left ventricular dysfunction (LVD) was associated with high perioperative mortality [8]. However, advances in surgical techniques have improved outcomes, making CABG a relatively safe procedure for selected high-risk patients [9]. Significant inotropic and vasopressor support is often necessary in cardiac surgery for patients with significant LVD, though its use is difficult to quantify. The use of an intra-aortic balloon pump (IABP) often reflects the next step beyond inotropic support. Cross clamp-induced myocardial ischemia and the adverse systemic effects of CPB can cause greater physiological derangement in patients with ventricular dysfunction. However, Off-pump CABG circumvents these issues and may offer benefits [10].

Several meta-analyses have explored the short-term and long-term outcomes of on-pump versus off-pump CABG [11] [12]. A 2011 meta-analysis by Jarrel OA *et al*. found that off-pump CABG might be linked to a lower incidence of early mortality in patients with LVD [13]. The benefits of off-pump CABG compared to conventional on-pump CABG in patients with LVD continue to be debated.

In Bangladesh, most cardiac centers, including the institute where the current study was conducted, routinely perform the majority of CABG procedures using the off-pump technique. However, there are few studies investigating its short-term benefits specifically for patients with LVD.

Given this context, the goal of this study was to investigate the short-term outcomes of off pump CABG for patients with LVD.

2. Materials & Methods

2.1. Study Design and Setting

A comparative cross-sectional study was conducted in the Department of Cardiac Surgery at the National Heart Foundation Hospital and Research Institute (NHFH & RI) in Mirpur, Dhaka, Bangladesh.

2.2. Study Population

The study included patients with coronary artery disease (CAD) who underwent isolated off-pump coronary artery bypass graft (OPCAB) surgery.

2.3. Sample Size Determination

The study evaluated a total of 200 patients, divided into two groups:
- Group 1: 100 patients with an ejection fraction (EF) of 30% - 39%;
- Group 2: 100 patients with an EF of ≥40%.

2.4. Inclusion and Exclusion Criteria

Inclusion Criteria
- Patients with isolated CAD undergo elective OPCAB surgery.

Exclusion Criteria
- Patients undergo combined CABG and valvular or congenital cardiac procedures.
- Patients with systemic diseases such as those requiring dialysis, hepatic impairment, or respiratory failure.

- Patients with a previous history of cardiac surgery.
- Patients undergoing emergency CABG or redo CABG.
- Patients with an LVEF < 30%.

2.5. Pre-Testing and Screening

Detailed histories, clinical examinations, and relevant investigations were recorded preoperatively for all patients. Echocardiography was performed to determine EF in percentage and left ventricular internal diameter in diastole (LVIDd) and systole (LVIDs) using the modified Simpson's method.

2.6. Sampling Technique

Purposive sampling was used to select the patients for the study.

2.7. Data Collection

After obtaining written informed consent, patients were enrolled in the study. Data collection included detailed histories, clinical examinations, and relevant investigations recorded preoperatively. Standard pre-anesthetic and anesthetic protocols were followed. Clinical monitoring included ECG, arterial blood pressure, central venous pressure, SpO_2, urine output, and core temperature.

The surgical procedure involved median sternotomy and harvesting of the great saphenous vein and left internal mammary artery for grafting. Distal anastomosis of the LIMA to LAD and reverse saphenous venous graft to other coronary arteries were performed using stabilizers. Proximal veno-aortic anastomoses were completed using side-biting clamps. The chest was closed after thorough hemostasis, with drains placed in the mediastinum and pleural cavity.

Clinical outcomes were assessed based on various study variables and NYHA class for quality of life. Echocardiographic evaluations of left ventricular performance (LVEF, LVIDd, LVIDs) were conducted preoperatively, at discharge, and one-month post-surgery. Data were collected and recorded in a structured data collection sheet.

2.8. Statistical Analysis

Statistical analysis was performed using SPSS software. Continuous variables were presented as mean ± SD or mean rank, and categorical variables as frequency (percentage). Significance tests included unpaired t-tests between groups, paired t-tests within groups, and Chi-square or Fisher's Exact tests for categorical data. A p-value of <0.05 was considered statistically significant.

2.9. Ethical Considerations

Ethical approval was obtained from the Academic and Institutional Ethics Review Committee (ERC) of NHFH & RI (Reference number: N.HF.H & R.I 4-14/hd./248). Written informed consent was taken from each patient prior to enrollment.

2.10. Study Funding

This study was self-funded.

3. Results

A total of 200 patients undergoing off-pump coronary artery bypass grafting (OP-CABG) were included in this study and categorized into two groups based on pre-operative left ventricular ejection fraction (LVEF). Group 1 consisted of patients with an LVEF < 40%, while Group 2 included those with an LVEF ≥ 40%.

Table 1 demonstrates the distribution of demographic variables between the two groups. It shows that the majority of patients in both groups were aged between 51 and 60 years, with no statistically significant difference in age between the groups ($p > 0.05$). Additionally, the table highlights that male were predominant in both Group 1 and Group 2, with no statistically significant difference in sex distribution between the groups ($p > 0.05$).

Table 1. Demographic characteristics of patients by group.

Demographic Variable	Respondents (N = 200)		
	Group A f (%) (n_1 = 100)	Group B f (%) (n_2 = 100)	p value
	^{A}Age group		
≤40	11 (11.0)	13 (13)	0.623^{ns}
41 - 50	27 (27)	33 (33)	
51 - 60	40 (40)	38 (38)	
>60	22 (22.0)	16 (16)	
	^{B}Mean Age & SD		
	53.49 ± 8.95	52.63 ± 9.14	0.502^{ns}
	^{A}Sex		
Male	92 (92.0)	93 (93.0)	0.788^{ns}
Sex	8 (8.0)	7 (7.0)	
	^{B}BMI		
BMI (kg/m^2)	24.37 ± 3.20	25.16 ± 3.05	0.074^{ns}
	^{B}BSA		
BSA (m^2)	1.67 ± 0.17	1.69 ± 0.12	0.257^{ns}

^{A}Chi-Square test was done to measure the level of significance. ^{B}Unpaired t test was done to measure the level of significance. Figure within parenthesis indicates in percentage. p value > 0.05 was considered not to be significant. N = Total number of respondents, n = Number of subjects in each group, f = Frequency, ns = Not significant, s = significant, BMI = Body mass index, BSA = Body surface area.

Table 2 summarizes the preoperative symptoms and NYHA functional class in both groups, as well as their postoperative outcomes at the 1-month follow-up.

Preoperatively, chest pain was prevalent in both groups (Group 1: 90%, Group 2: 92%). Exertional dyspnea and palpitations were more common in Group 1 (24% and 12%, respectively) compared to Group 2 (8% and 4%, respectively). In terms of NYHA class, most patients in Group 1 were classified as class III (56%) or IV (41%), while in Group 2, 83% were in class III and 13% in class IV. At 1-month follow-up, significant improvements were seen in both groups. In Group 1, 14% of patients moved to class I, 77% to class II, and 9% remained in class III. In Group 2, 4% of patients were in class I, 91% in class II, and 3% in class III. Statistically significant differences were observed in preoperative exertional dyspnea ($p = 0.004$) and NYHA class both preoperatively and postoperatively ($p < 0.05$).

Table 2. Distribution of patients by preoperative symptoms, baseline investigation, types of CAD and pre- and postoperative NYHA functional class.

Symptoms, Baseline investigations, Types of CAD, & NYHA functional Class	Respondents (N = 200)		
	Group 1 f (%) (n = 100)	Group 2 f (%) (n = 100)	p value
[A]Preoperative Symptoms			
Chest Pain	90 (90)	92 (92)	0.805[ns]
Exertional dyspnea	24 (24)	8 (8)	0.004[s]
Palpitation	12 (12)	4(4)	0.068[ns]
[B]Preoperative investigations			
HbA1C	6.80 ± 8.7	6.56 ± 0.98	0.068[ns]
Serum Creatinine	1.15 ± 0.19	1.20 ± 0.71	0.511[ns]
NT pro BNP	445.57 ± 287.73	339.87 ± 235.03	0.005[s]
[A]Types of CAD			
Single vessel disease	1 (1.0)	1 (1.0)	
Double vessel disease	13 (13.0)	14 (14.0)	0.979ns
Triple vessel disease	86 (86.0)	85 (85.0)	
[A]NYHA functional class			
At preoperative			
II	3 (3.0)	4 (4.0)	
III	56 (56.0)	83 (83.0)	<0.001[s]
IV	41 (41.0)	13 (13.0)	
At postoperative			
II	14 (14.0)	6 (6.0)	
III	77 (77.0)	91 (91.0)	0.025[s]
IV	9 (9.0)	3 (3.0)	

[A]Chi-Square test was done to measure the level of significance. Figure within parenthesis indicates in percentage; p value > 0.05 was considered not to be significant. N = Total number of respondents, n = Number of subjects in each group, f = Frequency, ns = Not significant, S = significant, CAD = Coronary Artery Disease, HbA1C = Glycated hemoglobin, NT pro-BNP = N terminal pro brain natriuretic peptide, NYHA = New York Heart Association.

Table 3 summarizes the echocardiographic evaluation of left ventricular (LV) performance in both groups. In Group 1, preoperative measurements showed a mean LVIDd of 53.48 ± 4.40 mm, LVIDs of 44.23 ± 3.93 mm, and LVEF of 35.28% ± 2.26%. In Group 2, the preoperative mean LVIDd was 47.09 ± 5.06 mm, LVIDs 35.11 ± 5.25 mm, and LVEF 50.13% ± 7.25%. The differences between the groups were statistically significant ($p < 0.001$). At discharge, Group 1 showed a mean LVIDd of 51.58 ± 4.04 mm, LVIDs of 41.23 ± 5.30 mm, and LVEF of 39.25 ± 3.75%. Group 2 had a mean LVIDd of 46.35 ± 4.40 mm, LVIDs of 33.93 ± 4.70 mm, and LVEF of 52.31 ± 6.92%, with significant differences between the groups ($p < 0.001$). One month postoperatively, further improvements were noted: Group 1 had a mean LVIDd of 46.29 ± 3.76 mm, LVIDs of 37.45 ± 3.68 mm, and LVEF of 43.22 ± 4.67%, while Group 2 showed a mean LVIDd of 42.37 ± 4.18 mm, LVIDs of 31.05 ± 4.19 mm, and LVEF of 55.33 ± 7.05%. The differences remained statistically significant ($p < 0.001$).

Table 3. Distribution of the patients by Echocardiographic evaluation of LV performances between the groups.

[A]Echocardiography	Respondents (N = 200)		
	Group 1 (n = 100)	Group 2 (n = 100)	p value
LVIDd (mm)			
Preoperative	53.48 ± 4.40	47.09 ± 5.06	<0.001[s]
During Discharge	51.58 ± 4.04	46.35 ± 4.40	<0.001[s]
Postoperative at 1st month	46.29 ± 3.76	42.37 ± 4.18	<0.001[s]
LVIDs (mm)			
Preoperative	44.23 ± 3.93	35.11 ± 5.25	<0.001[s]
During Discharge	41.23 ± 5.30	33.93 ± 4.70	<0.001[s]
Postoperative at 1st month	37.45 ± 3.68	31.05 ± 4.19	<0.001[s]
Ejection Fraction (in Percentage)			
Preoperative	35.28 ± 2.26	50.13 ± 7.25	<0.001[s]
During Discharge	39.25 ± 3.75	52.31 ± 6.92	<0.001[s]
Postoperative at 1st month	43.22 ± 4.67	55.33 ± 7.05	<0.001[s]

[A]Unpaired t test was done to measure the level of significance. Data was expressed as Mean and ± SD. p value ≤ 0.05 was considered to be significant. N = Total number of respondents, n = Number of subjects in each group, s = significant, LVIDd = Left ventricular internal dimensions during diastole, LVIDs = Left ventricular internal dimensions during systole.

Table 4 presents the distribution of patients by intraoperative variables, including the total number of grafts and operation time. In Group 1, 40.0% of patients had 3 grafts, 37.0% had 4 grafts, 14.0% had 5 grafts, 8.0% had 2 grafts, and 1.0% had 1 graft. In Group 2, 42.0% of patients had 3 grafts, 41.0% had 4 grafts, 8.0%

had 5 grafts, 8.0% had 2 grafts, and 1.0% had 1 graft. There was no statistically significant difference in the total number of grafts between the groups ($p > 0.05$). The mean operation time was 5.51 ± 0.58 hours in Group 1 and 5.61 ± 0.56 hours in Group 2, with no statistically significant difference between the groups ($p > 0.05$).

Table 4. Distribution of the patients by intraoperative variables.

Intraoperative Variables	Respondents (N = 200)		
	Group 1 f (%) (n = 100)	Group 2 f (%) (n = 100)	p value
ATotal number of grafts			
1	1 (1.0)	1 (1.0)	0.756ns
2	8 (8.0)	8 (8.0)	
3	40 (40.0)	42 (42.0)	
4	37 (37.0)	41 (41.0)	
5	14 (14.0)	8 (8.0)	
BTotal operation time			
Mean, & ± SD	5.51 ± 0.58	5.61 ± 0.56	0.219ns

AChi-Square test was done to measure the level of significance. BUnpaired t test was done to measure the level of significance. Figure within parenthesis indicates in percentage. p value > 0.05 was considered not to be significant, N = Total number of respondents, n = Number of subjects in each group, f = Frequency, ns = Not significant.

Table 5 presents the distribution of patients by postoperative variables, including ICU stay and the need for inotropic support. In Group 1, 98.0% of patients had a total ICU stay of less than 48 hours, with only 2.0% staying longer. In Group 2, 93.0% of patients stayed less than 48 hours, while 7.0% had a longer stay. The mean ICU stay was 42.99 ± 3.39 hours in Group 1 and 42.17 ± 3.96 hours in Group 2, with no statistically significant difference between the groups ($p > 0.05$). Regarding inotropic support, 52.0% of patients in Group 1 and 62.0% in Group 2 required it, though this difference was also not statistically significant ($p > 0.05$).

Table 5. Distribution of the patients postoperative variable by ICU stay and inotropic support.

APost-operative variable	Respondents (N = 200)		
	Group 1 f (%) (n = 100)	Group 2 f (%) (n = 100)	p value
ICU stays in Hours			
<48 hours	98 (98.0)	93 (93.0)	0.172ns
>48 hours	02 (2.0)	07 (7.0)	

Continued

Inotropic support		
Yes	52 (52.0)	62 (62.0)
No	48 (48.0)	38 (38.0)

[A]Chi-Square test was done to measure the level of significance. Figure within parenthesis indicates in percentage. p value > 0.05 was considered not to be significant, N = Total number of respondents, n = Number of subjects in each group, f = Frequency, ns = Not significant.

4. Discussion

The study included 200 patients undergoing Off-Pump Coronary Artery Bypass (OPCAB) surgery, divided into two groups based on pre-operative echocardiographic evaluation of left ventricular (LV) dysfunction: Group 1 (LVEF 30% - 39%) and Group 2 (LVEF ≥ 40%), each with 100 patients.

In the current study, male predominance was evident in both groups, with 92% in Group 1 and 93% in Group 2, and the majority of patients were within the 51-60 years age range. The mean ages were 53.49 years for Group 1 and 52.63 years for Group 2, closely aligning with the findings of Meharwal *et al*. [14]. The mean BMI was 24.37 ± 3.20 kg/m^2 in Group 1 and 25.16 ± 3.05 kg/m^2 in Group 2, while the mean BSA was 1.67 ± 0.17 m^2 in Group 1 and 1.69 ± 0.12 m^2 in Group 2, with no statistically significant differences observed.

Most patients presented with chest pain preoperatively (90% in Group 1 and 92% in Group 2). Exertional dyspnea was noted in 24% of Group 1 and 8% of Group 2, while palpitations were reported in 12% and 4%, respectively, with statistically significant differences ($p < 0.05$). Preoperatively, most patients were in NYHA class III and IV, with significant postoperative improvement to class I and II at the one-month follow-up. Finding aligning with Salekin *et al*.'s findings [15].

The mean serum creatinine level was 1.15 ± 0.19 mg/dl in Group 1 and 1.20 ± 0.71 mg/dl in Group 2, while the mean HbA1c level was 6.80 ± 0.87% in Group 1 and 6.56% ± 0.98% in Group 2, with no significant differences. However, the mean NT-pro BNP level was significantly higher in Group 1 (445.57 ± 282.73 pg/ml) compared to Group 2 (339.87 ± 235.03 pg/ml, $p < 0.05$).

Preoperatively, Group 1 had a mean LVIDd of 53.48 ± 4.40 mm, LVIDs of 44.23 ± 3.93 mm, and LVEF of 35.28% ± 2.26%. At the one-month follow-up, these values improved to 46.29 ± 3.76 mm, 37.45 ± 3.68 mm, and 43.22% ± 4.67%, respectively. Group 2 showed similar improvements, with preoperative LVIDd, LVIDs, and LVEF of 47.09 ± 5.06 mm, 35.11 ± 5.25 mm, and 50.13% ± 7.25%, respectively, improving to 42.37 ± 4.18 mm, 31.05 ± 4.19 mm, and 55.33% ± 7.05% at follow-up. These improvements were statistically significant ($p < 0.001$) and consistent with findings by Salekin *et al*. [15], and Lslamoglu F *et al*. [16].

The mean total operation time was 5.51 ± 0.58 hours in Group 1 and 5.61 ± 0.56 hours in Group 2. The average number of grafts was 3.55 ± 0.87 in Group 1 and 3.47 ± 0.80 in Group 2, with no significant differences, similar to the study by Y.

Joseph Woo *et al.* [15]. Postoperative ICU stay averaged 42.99 ± 3.39 hours in Group 1 and 42.17 ± 3.96 hours in Group 2, while mechanical ventilation time averaged 13.26 ± 3.61 hours in Group 1 and 13.69 ± 4.34 hours in Group 2, with no significant differences.

There was no mortality in either group. Postoperative complications included two cases of prolonged ventilation in Group 1 and one case in Group 2, with one re-operation for bleeding in each group, consistent with previous studies [15] [17].

Overall, the study demonstrates significant improvements in LV function and symptomatic relief post-OPCAB surgery, highlighting the procedure's efficacy in patients with varying degrees of LV dysfunction.

5. Conclusion

This study demonstrated that patients with preoperative serum albumin levels in the upper normal range experienced better postoperative renal function following OPCAB compared to those with lower, but still normal, albumin levels. Therefore, maintaining serum albumin levels within the upper normal range could be beneficial in routine practice to prevent postoperative acute kidney injury (AKI). This proactive approach could enhance patient outcomes and reduce the risk of complications after surgery.

Limitation of the Study

The study has several limitations. Firstly, the small sample size, partly due to the impact of the COVID-19 pandemic, may introduce biases and variances. Additionally, the single-center design limits the generalizability of the findings to a broader population. The short duration of post-discharge follow-up restricts insights into long-term outcomes. Moreover, other factors that might impact outcomes, such as demographic information (age, sex, BMI etc.) and clinical risk factors aside from left ventricular dysfunction (LVD), were not analyzed in this study. However, the study demonstrates that patients with low ejection fraction can be safely revascularized using the off-pump CABG technique, with satisfactory short-term outcomes comparable to those with an ejection fraction greater than 40%. Despite these limitations, the study provides valuable insights and lays the groundwork for future research aimed at improving surgical outcomes through enhanced preoperative assessment and intervention.

Recommendations

- Preoperative estimation of serum albumin levels should be routinely conducted.
- Correcting serum albumin levels before surgery is crucial to reducing postoperative adverse events. It should be used as a screening tool to identify patients at higher risk for complications following OPCAB.
- Maintaining preoperative serum albumin levels within the upper normal range

is advisable to minimize postoperative AKI and enhance overall postoperative outcomes.

- Larger, multicenter prospective studies are needed to validate and expand upon the findings of this study.

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Authors' Contributions

The first author led the study's design and planning, carefully gathered data from the hospital, analyzed the data, and wrote the initial draft of the manuscript. The second author was key in preparing the manuscript and provided valuable feedback on the study. The last author guided the study process from start to finish. All authors worked together to interpret the findings and have approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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