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Off-Pump Coronary Artery Bypass: Analysis of 52 Cases and Review of the Literature

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Abstract **Original Research Article**

This article presents a consecutive monocentric series of 52 patients who underwent off-pump coronary artery bypass (OPCAB), with an average of 3.1 anastomoses per procedure. The results show a 30-day mortality rate of 1.9%, with a conversion to cardiopulmonary bypass (CPB) rate of 1.9%. Postoperative outcomes are straightforward, with low rates of inotropic support (1.9%), postoperative myocardial infarction (1.9%), and transfusions (17.3%). The average duration of postoperative ventilation is 6 hours ± 2, and the average length of hospital stay is 11 days. The off-pump coronary artery bypass technique yields good immediate results, even in multi-vessel disease patients with high surgical risk.

Keywords: Coronary Artery Bypass, Off-Pump, Cardiopulmonary Bypass, Outcomes.

1. INTRODUCTION

Aorto-coronary bypass (CABG) is the most frequently performed cardiac operation in Western countries, although percutaneous coronary interventions (PCI) with stent placement have reduced its scope. Over the past two decades, there has been growing interest in off-pump coronary artery bypass (OPCAB), aiming to reduce the morbidity associated with cardiopulmonary bypass (CPB) and offer a simplified alternative in the face of interventional cardiology. The advantage of OPCAB lies in avoiding cardioplegic arrest, cannulation of the ascending aorta, complete heparinization, and blood contact with foreign surfaces. By reducing costs and shortening hospital stays, off-pump revascularization could provide better long-term outcomes than PCI while being less invasive than conventional CABG. This technique, conceived and practiced as early as 1964 by V. Kolesov, was commonly used for 30 years in countries without easy access to CPB technologies. It has since developed further with the introduction of sophisticated techniques for heart exposure and stabilization. The aim of this study is to evaluate postoperative outcome of OPCAB about 52 consecutive patients.

2. PATIENTS AND METHODS

2.1. Population

Over a one-year period, from March 1, 2023, to February 29, 2024, 52 coronary patients underwent off-pump myocardial revascularization surgery in the cardiac surgery department B at Ibn Sina Hospital, performed by a single surgeon. The mean age of the operated patients was 64.2 ± 6.4 years, with age extremes ranging from 47 to 81 years. The series included 32 men (61.5%) and 20 women (38.5%), with a sex ratio of 1.6. Regarding cardiovascular risk factors (CVRF), hypertension was the most prevalent at 53.8%, followed by diabetes. Active or former smoking concerned 50% of the patients. Additionally, 32.7% of the patients were dyslipidemic, whether treated or not.

Regarding different comorbidities, 7.7% had associated peripheral artery disease, 3.8% had preoperative chronic renal failure, 1.9% had chronic obstructive pulmonary disease, and 1.9% had a history of cerebrovascular accident.

Cardiac-wise, 21.2% of the population had a history of percutaneous angioplasty, and 17.3% of the patients had a history of myocardial infarction (regardless of its age). In three-quarters of the cases (75%), the patients had preserved left ventricular ejection

fraction (LVEF) (greater than 50%). Only 5.8% had an LVEF of less than 35%.

On coronary angiography, 82.7% were triple-vessel disease patients, and 15.4% were double-vessel disease patients. Of all the patients, 32.7% had significant left main coronary artery disease. Only 1.9% of the patients had single-vessel disease, primarily involving the left anterior descending artery (LAD).

Table 1: characteristics of the patients at Baseline

Characteristic		***Nbr (%)***
Average age		*64,7 +/– 6,4*
extreme		*47–81*
Male sex		*32 (61,5 %)*
Smoking		*26 (50 %)*
Diabetes		*27 (51,9 %)*
Hypertension		*28 (53,8 %)*
Dyslipidemia		*18 (32,7 %)*
Chronic obstructive pulmonary disease		*1 (1,9 %)*
Peripheral vascular disease		*4 (7,7 %)*
History of stroke		*1 (1,9 %)*
History of the myocardial infarction		*9 (17,3 %)*
History of coronary angioplasty		*11 (21,2 %)*
Triple vessel disease		*43 (82,7 %)*
Left main disease		*17 (32,7 %)*
LV ejection fraction	*> 50 %*	*39 (75 %)*
	between 35 and 50%	*10 (19,2 %)*
	< 35 %	*(5,8 %)*

2.2 Surgical Technique

The procedure was performed on all our patients via longitudinal median sternotomy. The left internal mammary artery (LIMA), harvested in a skeletonized manner, was primarily anastomosed to the left anterior descending artery (LAD). Similarly, the right internal mammary artery (RIMA), also harvested in a skeletonized manner, was anastomosed to the left coronary system using a Y-graft configuration with the LIMA. After harvesting the grafts, a dose of heparin at 0.5 mg/kg was administered to achieve an activated clotting time (ACT) of 300 seconds. The use of both internal mammary arteries was reserved for patients with a reasonable life expectancy and a low risk of mediastinitis. Depending on the case, saphenous vein grafts were also harvested as needed.

Exposure of the coronary arteries was achieved through pericardial suspensions using the LIMA technique. Stabilization of the anastomotic site required the use of an epicardial stabilizer with suction (Octopus®). The target coronary artery was dissected at the implantation site and occluded with two Bull-Dog microclamps on either side of the anastomosis zone, under intraoperative electrocardiographic monitoring. Proximal anastomoses on the aorta (for vein grafts) were performed first using the standard technique of end-to-side anastomosis with a continuous 6/0 monofilament suture, after lateral clamping of the aorta. Distal anastomoses were performed end-to-side with a continuous 8/0 monofilament suture, or sometimes side-to-side in a diamond shape for sequential grafting.

The LAD was generally revascularized first, although this strategy could be adjusted according to preoperative coronary angiography data. In case of poor hemodynamic tolerance during coronary artery clamping, an emergency conversion to CPB was performed. Once the anastomoses were completed, heparin was neutralized dose-for-dose with protamine.

3. RESULTS

3.1 Intraoperative Results

In this series, the average number of distal anastomoses per patient was 3.1. Among all cases, a single bypass was performed in 7.7% of patients, a double bypass in another 7.7%, a triple bypass in 51.9%, and a quadruple bypass in 32.7%. Overall, 84.6% of patients received three bypasses or more.

Regarding the nature of the grafts, the left internal mammary artery was used in 94.9% of cases to revascularize the LAD territory in the majority of cases. Y-graft mammary arteries were used in 48.1% of cases. Bypass using exclusively arterial conduits (no-aortic touch) was performed in 17.3% of patients, It was necessary to use cardiopulmonary bypass in one patient (1.9%).

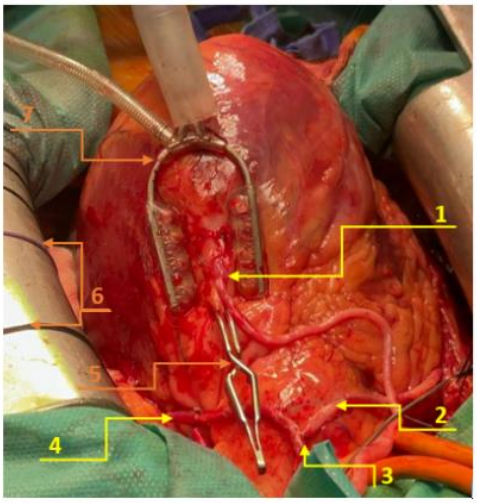

Figure: peroperative image of a triple bypass performed on one of our patients, showing exposure and stabilization. 1) Saphenous vein graft to the diagonal artery. 2) Left internal mammary artery graft (LIMA) to the left anterior descending artery (LAD). 3) Right internal mammary artery graft (RIMA) in a Y configuration with the LIMA. 4) RIMA to the marginal artery. 5) Bull-Dog clamp. 6) Heart suspension point. 7) Octopus-type stabilizer.

Table 2: Revascularization strategy

Number of distal anastomosis per patient		***3,1***
Single bypass		*4 (7,7 %)*
Double bypass		*4 (7,7 %)*
Triple bypass		*27 (51,9 %)*
Quadruple bypass		*17 (32,7 %)*
Bridged territories	*Anterior descending artery bypass*	*52 (100 %)*
	Diagonal bridging	*35 (67,2 %)*
	Circumflex-marginal bypass	*40 (76,9 %)*
	Right coronary bypass	*35 (67,3%)*
Perioperative complications	*Ventricular fibrillation*	*1 (1,9 %)*
	Conversion to cardiopulmonary bypass	*(1,9 %)*

3.2 Postoperative Results

The 30-day hospital mortality rate in this series was 1.9% (1 patient). A postoperative myocardial infarction was also observed in one patient. The majority of patients were extubated within 6 hours postoperatively. Only one patient (1.9%) required inotropic support during the surgery and in the immediate postoperative period.

All patients were in sinus rhythm before surgery, 7.7% documented episode of atrial fibrillation during their hospital stay. The average length of hospital stay was 11.3 ± 4.9 days. Only one patient required reoperation for hemostasis (1.9%).

Table 3: postoperative data and outcome at 30 days

30-day mortality	**1 (1,9 %)**
Postoperative inotropes	1 (1,9 %)
Postoperative intra-aortic balloon pump	0
Postoperative myocardial infarction	1 (1,9 %)
Postoperative hemoglobin	11,9 +/– 4,10
Transfusion	9 (17,3 %)
Reoperation for bleeding	1 (1,9 %)
Atrial fibrillation	4 (7,7 %)
Mediastinitis	(1,9 %)

4. DISCUSSION

This study confirms the feasibility of off-pump coronary artery bypass (OPCAB) in the majority of patients, regardless of the revascularization territory. However, without a control group, it does not allow for a conclusion on its superiority compared to on-pump coronary artery bypass grafting (CABG). With the significant development of percutaneous coronary

intervention (PCI), the patients now referred to surgeons have higher risk profiles and more severe coronary lesions. In this context, the low rate of intraoperative myocardial infarction (1.9%) and 30-day mortality are encouraging.

The early postoperative course was particularly straightforward for almost all patients, with early extubation. However, this series includes a low number of patients with an ejection fraction below 30% (5.8%), and conversely, a high number of left main stenoses (32%). The average number of anastomoses per patient, 3.1, is comparable to the data in the literature.

4.1 Age and Sex

The average age of the patients in our study was 64.7 ± 6.4 years, with ages ranging from 47 to 81 years. Among them, 19.2% were 70 years or older.

Regarding sex, our series shows a predominance of males with a sex ratio of 1.6; 38.5% were women.

Elderly individuals, especially octogenarians, seem to particularly benefit from off-pump revascularization. This technique is associated with a significant reduction in mortality and stroke rates in this population [27-29].

The female gender may benefit from OPCAB, which results in significantly lower morbidity compared to conventional CABG in women (OR 2.07) [30].

4.2 Number and Quality of Anastomoses

The average number of grafts per patient was 3.1. This number is close to the results found in the following three studies: GOPCABE (2.7), ROOBY (2.9), and CORONARY [3].

Given that off-pump anastomoses are technically more challenging, there could be concerns that revascularization results might be inferior and that fewer anastomoses would be performed, leading to incomplete revascularization. However, graft patency at 30 days (94-99%) tends to be similar to that of on-pump CABG once the surgical and anesthetic teams have mastered the technique [20-31].

Numerous controlled and randomized studies comparing medium-term (3 months) and long-term (1, 3, and 5 years) graft patency between the two techniques demonstrate either equality or slight inferiority of OPCAB. In the SMART study (200 randomized patients operated by the same surgeon), graft patency at 30 days (98%) and one year (94%) was identical between the two groups [32].

4.3 Postoperative Outcomes

4.3.1 Hospital Mortality

In our study, the hospital mortality rate was 1.9% (one case), which is consistent with published data indicating low hospital mortality. Most retrospective observational studies comparing the two techniques have shown either identical operative mortality (CORONARY [4], with a rate of 2.5%) or slightly lower in the off-pump group (ROOBY [3] and GOPCABE [5]. In the series by Benedetto *et al*., [6], the opposite was observed.

The comparison of 13,889 OPCAB cases with 35,941 on-pump CABG cases (in New York State Hospitals from 2001 to 2004) shows a reduction in 1-month mortality for OPCAB (OR 0.81) [17].

In an analysis of the National Adult Cardiac Surgery Database (NACSD), risk-adjusted mortality decreased from 2.9% (conventional CABG) to 2.3% (OPCAB) [18].

This discrepancy is probably explained by the fact that OPCAB does not change operative mortality in low-risk patients but significantly reduces it (OR 0.6) in high-risk patients [19, 20].

Table 4: Hospital mortality in various series and its comparison with control groups

Series name or first author	Year of publication	Study Sample Size	Hospital Mortality OPCAB	Hospital Mortality CPB
Matei [1].	2002	746	0,26	
F. Monassier [2].	2005	1080	0,65	
ROOBY [3].	2009	1104/1099	1,6	1,2
CORONARY [4].	2012	2375/2377	2,5	2,5
GOBCABE [5].	2013	1187/1207	2,6	2,8
Benedetto [6].	2019	271/652	1,8	1,1
Our Study	2024	52	1.9	

4.3.2 Myocardial Infarction

In our study population, only one patient (1.9%) presented a postoperative myocardial infarction (MI), which is close to the rates found in the ROOBY, PUSKAS, and BENEDETTO series, with rates of 1.8%, 1.3%, and 1.8%, respectively.

OPCAB shows a tendency to better preserve the myocardium and reduce postoperative cardiac events, with lower troponin and CK-MB levels. However, the incidence of postoperative MI tends to increase and is only reduced in certain series [21-23]. In meta-analyses, this incidence is equivalent [24-26].

Comparing the two bypass techniques in the literature, some authors report a lower rate of postoperative MI after off-pump bypass compared to on-pump bypass [7, 8], possibly due to the specific diffuse inflammatory reaction triggered by the cardiopulmonary bypass (CPB), which in its full form can lead to "post pump syndrome" and multivisceral failure, and due also to the total aortic clamping responsible for myocardial ischemia [9].

4.3.3 Stroke and Neuropsychological Disorders

In our series, only one patient (1.9%) experienced a postoperative ischemic stroke (IS), which is consistent with the results found in the ROOBY, CORONARY, GOBCABE, and BENEDETTO studies, with rates of 1.3%, 1%, 2.2%, and 1.1%, respectively.

Several studies have suggested that CPB causes permanent neurological dysfunction or a decrease in cognitive and motor abilities [10-14].

Off-pump coronary artery bypass (OPCAB) without any manipulation of the aorta (no-touch technique), performed with exclusively arterial grafts, has shown a significant reduction in perioperative strokes and major cardiac and cerebrovascular events in several large non-randomized clinical series [15].

4.3.4 Renal Failure

In our series, only one patient developed acute renal failure postoperatively, which aligns with the results in the literature. According to the literature, the off-pump group would benefit in the short term from fewer detrimental effects of renal dysfunction 16].

Table 5: Post operative renal failure rate across different series

Series name	Acute Renal Failure Rate
ROOBY	0,8 %
CORONARY	1,2 %
GOBKABE	2,4%
BENEDETTO	1,5
Our Study	1,9

4.3.5 Mediastinitis

In our study, only one patient (1.9%) developed mediastinitis. This rate is comparable to that found in the ROOBY series, which was 1%. Most retrospective and comparative studies show that off-pump bypass appears to be associated with a reduced risk of respiratory complications and wound infections.

5. CONCLUSION

Although it remains a subject of debate, off-pump coronary artery bypass (OPCAB) can be considered a safe and reproducible technique in the vast majority of cases. High surgical risk subgroups, with significant comorbidity, seem to particularly benefit from this approach. As shown by the results of our study, the short-term clinical outcomes are satisfactory and should encourage cardiac surgeons to integrate this technique into their therapeutic arsenal.

This series of 52 patients also confirms the feasibility of off-pump coronary artery bypass without the use of CPB in a large majority of patients, regardless of the revascularization territory. However, in the absence of a control group, this series does not allow us to conclude the superiority of this technique over CPB. It is also essential to conduct large randomized controlled trials evaluating not only short-term but also medium- and long-term outcomes to confirm the effectiveness of this technique.

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