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Zakaria Mostafa El Mashtoly
Cardiothoracic Surgery department, Faculty of Medicine, Al-Azhar University, Egypt

Mohamed Hussieny Mahmoud
Cardiothoracic Surgery department, Faculty of Medicine, Al-Azhar University, Egypt

Tarek Zaghlol Mohamed
General Surgery department, Faculty of Medicine, Al-Azhar University, Egypt

Mahmoud Mohamed EL-Damanhory
Cardiothoracic Surgery department, Faculty of Medicine, Al-Azhar University, Egypt,
ctspioneer201749@gmail.com

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ORIGINAL ARTICLE

The Impact of Sequential Coronary Artery Bypass Grafting on the Early Clinical Outcome

Zakaria Mostafa El Mashtoly [a], Mohamed Hussieny Mahmoud [a], Tarek Zaghlol Mohamed [b], Mahmoud Mohamed EL-Damanhory [a,*]

[a] Cardiothoracic Surgery Department, Faculty of Medicine, Al-Azhar University, Egypt
[b] General Surgery Department, Faculty of Medicine, Al-Azhar University, Egypt

Abstract

Background: **Patients with ischemic heart disease undergo coronary artery bypass grafting (CABG) procedures; many modifications, including as the anastomosing technique, have been introduced to improve long-term clinical outcomes.**

Aim of study: **In order to assess the effectiveness and results of sequential grafting for multiple coronary artery bypass.**

Patients and methods: **It is a prospective, randomized study, conducted from April 2021 to June 2022 at Cardiothoracic Surgery Departments, Al-Azhar University Hospitals, Egypt, in Cairo. Forty patients with multivessel coronary artery disease were among the 40 patients who were ready for sequential CABG. Preoperative, intraoperative, postoperative, and 3 months of follow-up examinations were completed.**

Results: **Our research revealed shorter operating times and fewer aortic manipulations, lower incidence of post-operative complication, neither myocardial infarction (MI) nor mortality were noticed with shorter intensive care unit (ICU) and hospital stays as well as improvements of Ejection fraction (EF) %.**

Conclusion: **The sequential strategy to coronary artery bypass grafting appears to be a generally secure and successful CABG therapy.**

Keywords: CABG, Outcome, Sequential anastomosis

1. Introduction

CABG offers a survival benefit when compared to medical treatment in patients with unstable angina and left ventricular (LV) dysfunction, particularly in those with triple vessel disease. Also early CABG for acute myocardial infarction may be appropriate in patients with residual ongoing ischemia despite other types of therapy.[1]

Complete revascularization has been thought to be linked to a lower incidence of adverse cardiac events following coronary artery bypass grafting (CABG).[2]

To attain enduring completion in multivessel disease, several arterial bypass grafts would be appropriate. The use of arterial grafts, however, has typically been thought to increase the risk of peri-operative problems.[3]

Therefore, even in the present day, the majority of patients underwent CABG with one or more venous grafts. The improvement of venous graft patency is still a crucial topic. It has been suggested that monitoring graft flow during surgery can help identify technical issues and foretell graft occlusion. Thrombosis, intimal hyperplasia, and technical failure are the three main causes of early venous graft failure. This is the early stage of atherosclerosis, the key factor contributing to late graft failure.[4]

The technique of sequential coronary artery bypass grafting with the reversed saphenous vein has advocated allowing more complete revascularization, decreasing the bypass time and increasing the blood flow through the graft.[5]

2. Patients and methods

Forty patients with multivessel coronary artery diseases underwent Sequential CABG at Al-Azhar University Hospitals between April 2021 and June

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* Corresponding author at: Cardiothoracic Surgery Department, Faculty of Medicine, Al-Azhar University, Cairo, Egypt.
E-mail address: CTSPioneer201749@gmail.com (M. Mohamed EL-Damanhory).

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2022 were the subject of this prospective, randomized trial.

Ethical consideration: All participants got thorough information on the study's goal and anticipated advantages. The entire project was conducted with the utmost ethical attention. Additionally, permission from the Local Ethical Committee of Faculty of Medicine, Al-Azhar University was acquired. All participants provided written consent after being fully informed, and information confidentiality was guaranteed.

Inclusion criteria: Patients having multivessel diseases, patients having ejection fraction more than 35%, no age or sex limitation and accepted risk factors (hypertension, DM, dyslipidemia and smoking).

Exclusion criteria: Patients having poor left ventricular function (less than 35%), patients having associated valve lesions, high-risk factors (COPD, decompensated liver cell failure, chronic kidney disease and malignancy), patients submitted to CABG previously (Redo CABG), patients who needed emergency CABG at the same day, patients who have mechanical complications of MI and postresuscitation patients.

All patients were managed through three steps:

'*2.1. Preoperative assessment*

History taking: including: **Personal history**: Age, Sex, Special habits, **family history** of ischemic heart diseases and **history of patient's present complaint**, to determine the anginal functioning class according to (CCS & NYHA) classifications.

Physical examination: **General examination**: to detect any associated problems related to other systems; including: vital signs (Blood pressure, pulse criteria, respiratory criteria and temperature), extracardiac systems. **Cardiac examination:** Aiming to detect associated cardiac valve disease and evaluate myocardial function by: Inspection, palpation and auscultation.

Investigations: **ECG**: Rest 12 lead ECG for all cases and stress ECG for symptomatic cases with insignificant ECG changes.

Echocardiography: For all cases to exclude associated valve disease and evaluate global left ventricular function and to detect any resting segmental wall motion abnormality (RsWMA).

Cardiac catheterization: All cases are submitted to coronary angiography to define the affected vessels with the determination of extend and location of each lesion, to evaluate the global left ventricular function and to detect any motion abnormalities.

Radiology: Plain chest X-ray, CT chest and pulmonary function test (if needed in heavy smoking patients), Duplex both carotid arteries, Duplex both lower limbs venous, arterial and pelviabdominal ultra-sound.

Myocardial Viability tests: To evaluate and asses myocardial viability if there is hibernating myocardium tissues with impaired flow and function but viable and will benefit from the surgery: In order to evaluate the integrity of the myocyte membrane, single-photon emission computed tomography (SPECT) monitors thallium or technetium uptake; Fluoro deoxyglucose uptake is measured by positron emission tomography (PET) as a marker of glucose metabolism; Cardiac magnetic resonance (CMR) with late gadolinium enhancement to highlight areas with increased extracellular volume as a sign of infarction and dobutamine stress echocardiography (DSE) measuring contractile reserve.

Laboratory investigations including: Complete blood count (CBC), ESR, C-RP, Electrolyte pannel, blood glucose: Fasting blood sugar, PP blood sugar and HbA1c, liver function & enzymes profile, kidney function profile, ABG, cardiac profile: if there was acute ischemia event and coagulation profile (PT,PC, INR and aPTT).

2.2. Intra-operative assessment

Operative techniques: Internal mammary artery was harvested as the pedicled graft. LIMAs were used as pedicle grafts with harvesting the great saphenous vein. Great saphenous vein distal anastomosis in the form of sequential grafting was done by side-to-side anastomosis to proximal artery, which may be perpendicular sequential side-to-side anastomosis or parallel sequential side-to-side anastomosis depending on the surgeon preference and anatomy of the artery to be grafted, as well as end-to-side anastomosis to distal artery.

The following parameters were recorded: Total operation time, cardiopulmonary bypass time, cross-clamp time, number of grafts, preoperative usage of inotropic support and usage of inta-aortic balloon pump.

2.3. Postoperative assessment

ICU data and medications including: The need for inotropic support, time of ventilation, postoperative ICU stay and total amount of intercostal drainage (ICD). *Postoperative complications* specially: Bleeding and the need for re-exploration, cerebrovascular accident (CVA) as occlusive (ischemic) hemorrhagic in origin, in terms of transient ischemic attack, minor or major stroke, arrhythmias,

wound Infection, myocardial infarction and renal complication including the need of dialysis.

Outcome and follow up: Postoperative hospital stay, postoperative mortality, early postoperative results including echocardiography data before discharge, patients were followed at the outpatient clinic, clinically (for symptoms of angina and NYHA class) and 3 months postoperative follow-up: Clinical and vital data, ECG, Echocardiography, also by Coronary angiography and Multi-slice CT Coronary angiography if indicated (ECG changes with new chest pain, any abnormal wall motion abnormalities or decreased ventricular function).

2.4. Statistical analysis

Version 20 of the Statistical Program for Social Science was used for data analysis (SPSS Inc., Chicago, IL, USA). For quantitative parameters, mean and standard deviation were utilised, whereas for qualitative parameters, number and percentage were employed. The means of one or more variables based on repeated observations of normally distributed variables were compared using the ANOVA test. If the *P* value was less than 0.05, it was deemed significant.

3. Results

As regard age, the mean age of all studied patients was 55.5 ± 6.9 years with minimum age of 35 years and maximum age of 73 years. As regard gender, there were 27 males (67.5%) and 13 females (32.5%) (Table 1).

As regard risk factors, there were 17 hypertensive patients (42.5%), 23 diabetic patients (57.5%), 22 smoking patients (55%), 17 dyslipidemic patients (42.5%) and 13 patients (32.5%) with positive family history in the studied patients. As regard prior medical history, there were 25 coronary artery disease (CAD)patients (62.5%) and 1 cardiovascular accident (CVA) patient (2.5%) in the studied patients (Fig. 1).

As regard LV end-diastolic volume (LVEDV), the mean LVEDV of all studied patients was 108.1 ± 11.7 with minimum LVEDV of 64 and maximum LVEDV of 128. As regard LV end-systolic volume (LVESV), the mean LVESV of all studied patients was 54.4 ± 8.8 with minimum LVESV of 23 and maximum LVESV of 77. As regard EF, the mean EF of all studied patients was 49.8 ± 6.5 with minimum EF of 38.7 and maximum EF of 64. There was RSWMA in 36 patients (90%) of the studied patients (Table 2).

Table 1. Description of age and gender in all studied patients.

	Studied patients ($N = 40$)	
Gender		
Male	27	67.5%
Female	13	32.5%
Age (years)		
Mean ± SD	55.5 ± 6.9	
Min – Max	35–73	

All studied patients (100%) were of 3 VD disease type. LM was affected in 14 patients (35%), LAD was affected in 40 patients (100%), LCX was affected in all studied patients (100%), RCA was affected in all studied patients (100%) and Ramus was affected in 17 patients (42.5%). As regard Syntax score, the mean Syntax score of all studied patients was 24.5 ± 9.1 with minimum Syntax score of 9.7 and maximum Syntax score of 49 (Table 3).

Regarding previous interventions in all studied patients. Previous PCI was done in 10 patients (25%) categorized as the following: 1 patient (10%) had 1 stent, 4 patients (40%) had 2 stents, 4 patients (40%) had 3 stents and 1 patient (10%) had 4 stents. No patients had subjected to previous CABG (Table 4).

As regard total operation time, the mean operative time of all studied patients was 5.3 ± 0.5 h with minimum time of 5 h and maximum time of 6 h. As regard cardio-pulmonary bypass (CPB) time, the mean time of all studied patients was 140 ± 17.6 min with minimum time of 110 min and maximum time of 180 min. As regard cross clamp time, the mean time of all studied patients was 65.1 ± 9.4 min with minimum time of 50 min and maximum time of 80 min. As regard number of grafts, 3 grafts were used in 14 patients (35%), 4 grafts were used in 18 patients (45%) and 5 grafts were used in 8 patients (20%) (Table 5).

As regard post-operative ICU data in all studied patients. There were 35 patients (87.5%) in need for inotropic support and 5 patients (12.5%) in need for intra-aortic ballon pump (IABP). There were 11 patients (27.5%) showed serial ECG changes in the form of premature ventricular complexes and atrial fibrilation (PVCs, AF) and ischemic changes. As regard ventilation time, the mean time of all studied patients was 17.3 ± 21.3hrs with minimum time of 6 h and maximum time of 96 h. As regard the total amount of chest tube drainage, the mean amount in all studied patients was 560 ± 206.1 cc with minimum amount of 300 cc and maximum amount of 1050 cc. As regard post-operative ICU stay, the mean ICU stay of all studied patients was 5.1 ± 1.01 days with minimum stay of 3 days and maximum stay of 7 days (Table 6).

There was need for re-exploration in 4 patients (10%), cerebrovascular event in 1 patient (2.5%),

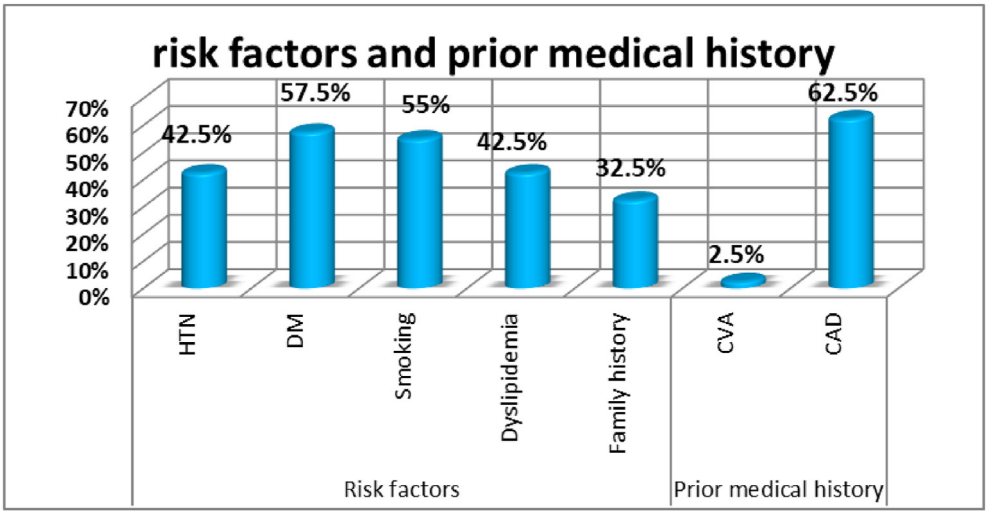

Fig. 1. Description of risk factors and prior medical history in all studied patients.

arrhythmia (PVCs and AF) in 10 patients (25%), wound infection in 8 patients (20%) and renal complications in 6 patients (15%) while there were no postoperative MI or mortality in the studied patients (Fig. 2).

Statistically significant ($P1$ value = 0.003) increased EF % before discharge (52.4 ± 4.5%) when compared with pre-operative EF (49.8 ± 6.5%). No statistical significant difference ($P2$ value = 0.183) between preoperative EF&EF after 90 days after operation. No statistical significant difference ($P2$ value = 0.411) between EF before discharge and EF after 90 days after operation (Fig. 3).

4. Discussion

Flemma et al.,[6] introduced the sequential grafting approach in CABG, and **Bartley** et al.,[7] published it in more detail a year later. Since then, other anastomosis techniques, including single or multiple grafts, have been employed. The effectiveness of these techniques is debatable, though.

Current prospective and randomized trial was done on 40 patients with multivessel coronary artery diseases underwent sequential CABG. Internal mammary artery was harvested as the pedicled graft.

LIMAs were used as pedicle grafts with harvesting the great saphenous vein. Great saphenous vein distal anastomosis in the form of sequential grafting was done by side-to-side anastomosis to proximal artery, which may be perpendicular sequential side-to-side anastomosis or parallel sequential side-to-side anastomosis depending on the surgeon preference and anatomy of the artery to be grafted as well as end-to-side anastomosis to distal artery.

The recruited patients ranged in age from 35 to 73 years, with a mean age of 55.5 ± 6.9 years; the male-to-female ratio was 2:1, with 27 (67.5%) men and 13 (32.5%) women. In accordance with recent discoveries, **Ouzounian** et al.,[8] studied 2354 patients. 1246 (52.9%) of them had CABG using a sequential

Table 2. Description of Echocardiography data in all studied patients.

	Studied patients (N = 40)	
LVEDV		
Mean ± SD	108.1 ± 11.7	
Min - Max	64–128	
LVESV		
Mean ± SD	54.4 ± 8.8	
Min - Max	23–77	
Ejection fraction (EF)		
Mean ± SD	49.8 ± 6.5	
Min - Max	38.7–64	
RSWMA		
No	4	10%
Yes	36	90%

Table 3. Description of angiographic data in all studied patients.

	Studied patients (N = 40)	
Disease type		
SVD	0	0%
2 VD	0	0%
3 VD	40	100%
Vessels		
LM	14	35%
LAD	40	100%
LCX	40	100%
RCA	40	100%
Ramus	17	42.5%
Syntax score		
Mean ± SD	24.5 ± 9.1	
Min – Max	9.7–49	

Table 4. Description of previous interventions in all studied patients.

	Studied patients ($N = 40$)	
Previous Intervention		
PCI	10	25%
CABG	0	0%
Number of stents		
1 stent	1	10%
2 stents	4	40%
3 stents	4	40%
4 stents	1	10%

grafting technique. The patients in this study had an average age of 66.6 ± 9.7 years, and 26.1% of them were female. Joshi et al., 9 investigated 323 patients, 266 of whom were men and 57 of whom were women. The mean age was 62.25 ± 8.62 (42–80).

Recently, 50 patients who underwent pump CABG for multiple vessel coronary artery disease were investigated by **Saleh** et al.,[9] Only two patients (4%) were female, and the age ranged from 45 to 63 years. The mean age was 53.9 ± 8.5 years.

Against the current study, **Jegaden** et al.,[10] Their patients were older (68.3 ± 12.2 years), more often female, had significant heart failure as defined by the NYHA class 2 classification, and more often had left ventricular dysfunction and impaired ejection fraction.

Regards to risk factors among enrolled patients, 17 was hypertensive patients (42.5%), 23 diabetic patients (57.5%), 22 smoking patients (55%), 17 dyslipidemic patients (42.5%) and 13 patients (32.5%) with positive family history in the studied patients. As regard prior medical history, there were 25 CAD patients (62.5%) and 1 CVA patient (2.5%) in the studied patients.

In agreement with the current study, **Saleh** et al.,[9] in their study, 25 patients were smoking (50%). Twenty-four patients were diabetics (48%) with glycosylated hemoglobin 6.09 ± 0.7. 41 patients were Hypertensive (82%), 34 patients were dyslipidemia (68%). The mean body mass index was 28.9 ± 0.8.

Table 5. Description of intra-operative data in all studied patients.

	Studied patients ($N = 40$)	
Total operation time (hours)		
Mean ± SD	5.3 ± 0.5	
Min - Max	5–6	
CPB time (minutes)		
Mean ± SD	140 ± 17.6	
Min - Max	110–180	
cross clamp time (minutes)		
Mean ± SD	65.1 ± 9.4	
Min - Max	50–80	
No. of grafts		
3 grafts	14	35%
4 grafts	18	45%
5 grafts	8	20%

Compared to the current study, **An** et al.,[11] revealed that, 35% of patients were in grade I, 45% in grade II and grade III in 15% of patients, while there was no dyspnea in 5% of studied patients.

Similarly, In **Saleh** et al.,[9] study, 30 patients were suffering from angina class II (60%), while 17 patients in class III (34%) and 3 patients were in class IV (6%).

Ouzounian et al.,[8] Patients receiving consecutive grafts experienced greater rates of systolic dysfunction than those getting nonsequential grafts (14.9% vs. 10.8%, P value = 0.004).

With a minimum LVEDV of 64 ml and a maximum LVEDV of 128 ml, the mean LVEDV of all participants in the study was 108.1 ± 11.7. The mean LVESV of all patients that were evaluated was 54.4 ± 8.8, with a minimum LVESV of 23 ml and a maximum LVESV of 77 ml. The mean EF of all patients that were evaluated was 49.8 ± 6.5, with a minimum EF of 38.7% and a maximum EF of 64%. 36 patients (90%) of the patients under study had RSWMA.

Saleh et al.,[9] found that the mean left ventricular ejection fraction (LVEF) was 59.2%, LVEDD was 5.3 ± 0.6, LVESD was 3.6 ± 0.6, LA was 3.8 ± 0.4, Preoperative segmental wall motion abnormality (SWMA) was found in 11 patient (22%).

Regards to angiographic data, all studied patients (100%) were of 3 VD disease type. LM was affected in 14 patients (35%), LAD was affected in 40 patients (100%), LCX was affected in all studied patients (100%), RCA was affected in all studied patients (100%) and Ramus was affected in 17 patients (42.5%). As regard Syntax score, the mean Syntax score of all studied patients was 24.5 ± 9.1 with minimum Syntax score of 9.7 and maximum Syntax score of 49.

Table 6. Description of post-operative ICU data in all studied patients.

	Studied patients ($N = 40$)	
Need for inotropic support		
No	5	12.5%
Yes	35	87.5%
Need for IABP		
No	35	87.5%
Yes	5	12.5%
Serial ECG changes		
No	29	72.5%
Yes	11	27.5%
Ventilation time (hours)		
Mean ± SD	17.3 ± 21.3	
Min - Max	6–96	
total amount of chest tube drainage (cc)		
Mean ± SD	560 ± 206.1	
Min - Max	300–1050	
post-op. ICU stay (days)		
Mean ± SD	5.1 ± 1.01	
Min - Max	3–7	

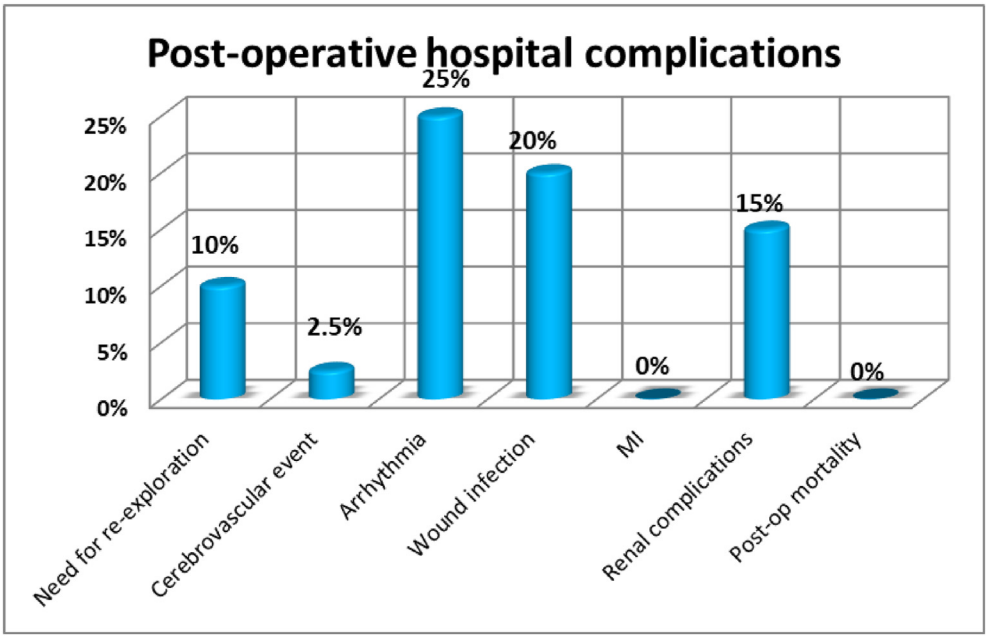

Fig. 2. Description of post-operative hospital complications in all studied patients.

Also **Saleh** et al.,[9] revealed that left main lesions were found in 26 patients (52%), LAD lesion in 50 patients (100%), Diagonal lesion in 38 patients (76%), Ramus in 8 patients (16%), and CX lesion in 45 patients (90%) OM lesion in 25 patients (50%), RCA lesion in 28 patients (56%), PDA in 13 patients (26%) and PL in 3 patients (6%) with total number of lesions 4.6 ± 1.14.

In the current study, the mean operative time of all studied patients was 5.3 ± 0.5 h with minimum time of 5 and maximum time of 6. The mean CPB time was 140 ± 17.6 min with minimum time of 110 and maximum time of 180, while mean cross-clamp time of all studied patients was 65.1 ± 9.4 min with minimum time of 50 and maximum time of 80.

Compared to current study, **Ouzounian** et al.,[8] Sequential grafting patients had more distal anastomoses made (4.0 vs. 3.0, *p* 0.0001), longer cross-clamp and total bypass periods (119.5 vs. 105.3 min, p 0.0001), and more patients receiving inotropic support after surgery (21.8% vs. 15.3%, *p* 0.0001). **Saleh** et al.,[9] found that the operative time was 5.1 ± 0.8 h, bypass time 130.6 ± 21.5 min, cross-clamp time 81.6 ± 16.2.

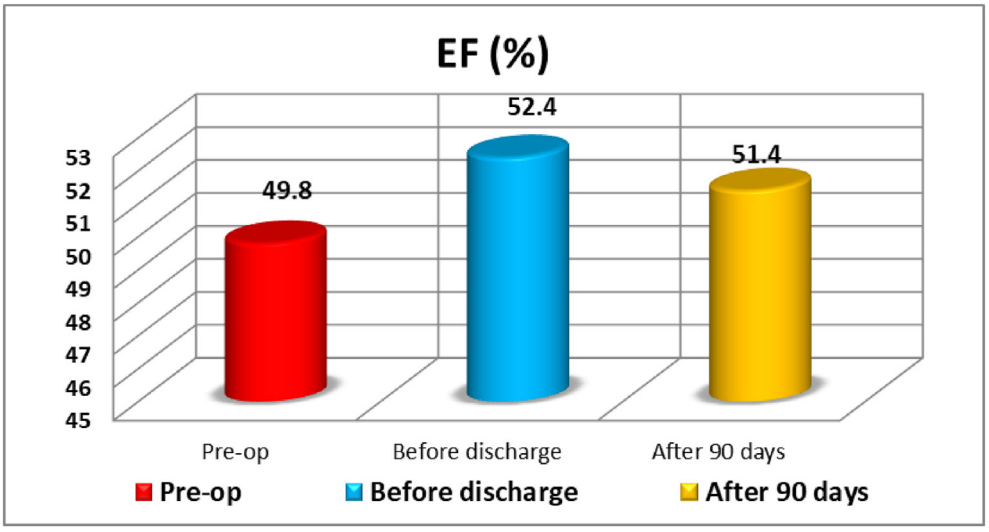

Fig. 3. Comparison of EF throughout the study.

Regards to postoperative ICU, there were 35 patients (87.5%) in need for inotropic support and 5 patients (12.5%) in need for IABP. The mean ventilation time was 17.3 ± 21.3 h with minimum time of 6 and maximum time of 96 and the total amount of chest tube drainage was 560 ± 206.1 cc with minimum amount of 300 cc and maximum amount of 1050 cc. **Al-Ruzzeh** et al.,[12] reported the average duration of mechanical ventilation was 7.46 ± 2.23 h. **Jegaden** et al.,[10] revealed that post-operative LVEDD was 5.3 ± 0.6, LVESD of 3.6 ± 0.5 and LVEF (%) of 59.9 ± 6.8. Also, **Jiao** et al.,[13] found that post-operative LVEF % was 57.6 ± 7.2.

Regards to 90 days outcome, there was vital data odds (hypotension) in 2 patients (5%), typical chest pain in 2 patient (5%), new ECG ischemic changes in 6 patients (15%), cardiac enzymes odds in 6 patients (15%), need for diagnostic coronary angiography in 2 patients (5%), re-infarction in 2 patients (5%), arrhythmia in 6 patients (15%) and cerebrovascular accident in 1 patient (2.5%) while there were no cases with repeat revascularization, MI or death.

As regard 90 days EF, the mean EF was 51.4 ± 5.01%. In agreement with the current study, **Li** et al.,[14] revealed that the mean LVEF was much greater after the operation than it was before (55.23 ± 4.99% vs. 51.00 ± 1.19%, *P* value 0.0001), and the mean LVEDD was significantly lower after the operation than it was (52.30 ± 5.69 mm vs. 54.90 ± 5.99 mm, *P* value 0.05), According to **Gao** et al.,[15] Sequential bypass grafts ($N = 512$) had greater mean flows and better mid- and long-term patency compared to individual grafts ($N = 202$).

In our study, we observed that coronary arteries revascularization by using sequential technique has good results regarding in-hospital and early clinical outcomes. However, some cardiac surgeons did not adopt this technique as a routine use in coronary artery bypass grafting. They have some concerns regarding the relative technical difficulty, prolonged duration of time, which may have worse results regarding outcome.

Sequential grafting was done in our study, but there were no instances of repeat revascularization, perioperative infraction, or hypoperfusion syndrome because the postoperative troponin level was within the normal range (0.95), only 6 patients (15%) experienced arrhythmia, and only one patient (2.5%) experienced CVA, MI or death.

Al-Ruzzeh et al.,[12] retrospectively examined the medical records of 45 patients who underwent isolated coronary bypass surgery using sequential and off-pump grafting methods. No deaths were discovered among the research participants. Atrial fibrillation occurred in 6 individuals (13.3%), leg wound infection in 2 patients (4.4%), and pleural effusion in 1 patient (2.2%) as the main causes of morbidity.

4.1. Conclusion

Our findings suggest that side-to-side anastomosis may be a beneficial technique when it comes to joining the small target arteries at the distal end of the great saphenous vein during sequential CABG. With regard to short-term results and hospital mortality, the sequential method in CABG appears to be clinically regarded as a safe and effective operation that can be done frequently.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article.

Conflicts of Interest

The authors declared that there were no conflicts of interest.

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