The Heart Surgery Forum 2022-5043
25 (6), 2022 [Epub December 2022]
doi: 10.1532/hsf.5043 Online address: http://journal.hsforum.com

The Impact of Surgical Revascularization on Cardiac Function and Mitral Regurgitation in Patients with Coronary Artery Disease: An Intermediate-Term Single-Center Experience

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ABSTRACT

Introduction: Ischemic heart disease is the most common cause of death worldwide. Coronary artery bypass grafting (CABG) is the most performed cardiac surgical procedure. Studies have shown that CABG can have a beneficial effect on left ventricular ejection fraction (LVEF) and ischemic mitral regurgitation (IMR) without intervention on the mitral valve. This study aims to assess changes in LVEF and IMR after CABG in our population.

Methods: We retrospectively reviewed charts of patients who underwent only CABG at King Faisal Cardiac Center in Jeddah between January 2016 and December 2019 (N = 298). Pre- and postoperative echocardiography data were evaluated. Changes in cardiac function and mitral regurgitation were analyzed.

Results: CABG was performed on 298 patients. The median age was 61 years (interquartile range (IQR)= 54–68), and 78.5% of the patients were male. The median body mass index was slightly higher in females (32.9 vs. 28.6 kg/m2, P = 0.089). Approximately 81% of patients had diabetes and hypertension, but only 24% were active smokers. The median time between pre- and postoperative echocardiography was 8 months (IQR= 3–17). The median preoperative LVEF was 51% (IQR= 44.1–57.9), and 75% of patients had normal-to-mild MR. The median postoperative EF was not different among patients who underwent echocardiography within or after 6 months (53.1% and 50.3%, respectively, P = 0.454). None of the patients progressed to severe MR after surgery, and only 2.7% had moderate-to-severe MR at follow up. Postoperative in-hospital mortality was 0.7%.

Conclusion: Based on international guidelines and the best evidence, surgical revascularization is sufficient for patients with coronary artery disease (CAD) with moderate IMR and is not associated with LVEF worsening or MR progression. Complete revascularization might have an influence on ventricular recovery that might improve or stabilize IMR. Our results are consistent with larger studies reporting very low postoperative mortality of this high-risk patient group.

Received July 29, 2022; received in revised form August 29, 2022; accepted September 20, 2022.

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INTRODUCTION

Heart failure is the leading cause of death for both men and women in the United States and is one of the major causes of mortality and morbidity worldwide [Kochanek 2019; Savarese 2017]. The global prevalence of heart failure dramatically has increased over the last few years [Savarese 2017]. Moreover, the prevalence of heart failure is projected to continue to rise as the global population ages further [Savarese 2017]. The major cause of heart failure in most areas of the world, including the Middle East, is coronary artery disease (CAD) [Savarese 2017]. According to the Centers for Disease Control (CDC), the prevalence of at least one of three key risk factors for the development of CAD (smoking, high low-density lipoprotein (LDL) levels and hypertension) among Americans is 47% [Fryar 2012]. Given the high prevalence and the high associated mortality and morbidity rates, it is important to know the approaches used for treating patients with ischemic heart failure.

According to a study that was published in the Journal of the American College of Cardiology, ischemic cardiomyopathy should be defined as a left ventricular ejection fraction (LVEF) of <40% in the context of left main disease, proximal left anterior descending artery (LAD) disease, a history of revascularization or a history of myocardial infarction (MI) [Felker 2002]. The two established methods for treating ischemic cardiomyopathy are coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI). CABG is associated with lower rates of both all-cause mortality and major adverse cardiovascular and cerebrovascular events (MACCEs) after one year in patients with high-risk multivessel disease [Fanari 2013]. Additionally, compared to patients who underwent PCI using new-generation drug-eluting stents, patients who underwent CABG had a reduced need for reintervention and an improved quality of life, especially those with left main or three-vessel disease with ischemic cardiomyopathy.

Another manifestation of ischemic cardiomyopathy is ischemic mitral regurgitation (IMR). IMR occurs in up to 50% of patients after MI [Cui 2018; Virk 2017]. Although IMR can be caused by rupture of the papillary muscles, most cases occur secondary to left ventricular heart remodeling and dilation [Zhang 2015]. IMR is associated with an increased risk of mortality, and this risk is directly related to the severity of the regurgitation [Virk 2017; Zhang 2015]. While CABG has been associated with a decrease in residual MR, a combination CABG and mitral valve repair surgery has been associated with an even greater reduction in MR [Salmasi 2018]. However, the improvement in MR caused by the combined approach did not translate to a decrease in early or late mortality [Salmasi 2018].

Although heart failure traditionally has been considered a progressive disease, recent studies have shown an improvement in the ejection fraction (EF) of some patients previously diagnosed with heart failure with a reduced ejection fraction (HFrEF) after undergoing revascularization, which has prompted the addition of a new phenotype of heart failure, heart failure with a recovered ejection fraction (HFrecEF) [Ngu 2018]. While the potential benefits of increasing the EF are significant, the risks of undergoing CABG in these patients are also increased [Haxhibeqiri-Karabdic 2014]. Additionally, the post-CABG response in EF has been suggested to differ among patients based on the recruitable contractile reserve [Ngu 2018; Haxhibeqiri-Karabdic 2014]. Despite these significant clinical implications, the post-CABG recovery of EF in HFrEF patients has been severely understudied both in Saudi Arabia and throughout the world. Therefore, we find it of the utmost importance to assess the post-CABG changes in EF and MR in our population by comparing the EF and degree of MR measured before the surgery to those measured during and 6 months after surgery.

METHODS

This study was a retrospective cohort, quantitative chart review that focused on adults who underwent surgical revascularization for CAD at the King Faisal Cardiac Center (KFCC), Jeddah, from January 2016 to December 2019 (N = 298).

Our inclusion criteria were patients with CAD who underwent only surgical revascularization without any other surgical intervention, patients who underwent surgery at KFCC, and patients older than 14 years old.

All patients who underwent surgical revascularization that matched our inclusion criteria and did not meet our exclusion criteria were included.

The data collection was self-administered. Consent to access patient data was obtained from the Institutional Review Board at National Guard Health Affairs, Jeddah. Preoperative data included patient demographics (age, sex, weight, height, BMI, and body surface area (BSA), comorbidities such as ischemic heart disease (IHD), diabetes mellitus (DM), DM medications, hypertension (HTN), dyslipidemia (DLP), chronic kidney disease (CKD), preoperative dialysis, smoking, chronic obstructive pulmonary disease (COPD), stroke, and hospital stay.

CABG related data included preoperative diagnostic coronary catheterization coronary vessels amount of stenosis in percent in each vessel as per the report (left main (LM), left anterior descending (LAD), ramus intermedius (RAMUS), diagonal artery (DIAG), obtuse marginal (OM), right coronary artery (RCA), posterior descending artery (PDA), conduits used on each target (left internal mammary artery (LIMA), right internal mammary artery (RIMA), saphenous vein (Vein), radial artery). Based on Ong and Serruys et al. [Gössl 2012] unconditional definition of incomplete revascularization was defined as significant stenosis in any angiographically identified vessel by the interventional cardiologist who did not receive a bypass graft. Significant stenosis was defined as a LM lesions that ≥50% stenosis or a ≥70% stenosis in a coronary major vessel [Bianco 2021]. In this study, we decided to use the unconditional definition of incomplete revascularization by Ong an Serruys et al. [Gössl 2012], due to its simplicity, yet it is easily reproducible. Preoperative and postoperative echocardiography data included, when available, the date of study, EF, left ventricular end systolic dimension (LVESD), left ventricular end diastolic dimension (LVEDD), left ventricular end diastolic volume indexed to BSA (LVEDVi), mitral valve (MV) inflow e/a ratio, MV E/e ratio, left atrium size, left ventricle size, left atrial volume indexed to BSA, mitral regurgitation (MR) direction, MR severity, MR vena contracta, MR effective regurgitant orifice area, and MR regurgitant volume. Postoperative echocardiography data were categorized based on the timing of the study in relation to surgery (within 6 months from surgery or more than 6 months from surgery). Postoperative data included infections (which is defined as any infection within 90 days from the index procedure), stroke (defined as any confirmed neurological deficit of abrupt onset caused by a disturbance in cerebral blood supply that did not resolve within 24 hours), renal failure (defined whether the patient had acute or worsening renal failure resulting in one or more of the following: 1- Increase of serum creatinine to > 2.0, and 2x most recent preoperative creatinine level, 2- A new requirement for dialysis postoperatively), need for dialysis, and mortality.

Data analysis was conducted using R statistical Package software Version 4.0.2 (R foundation for statistical computing, Vienna, Austria). The mean and standard deviation were used for continuous variables that had a normal distribution and were compared using a 2-sided t-test. Continuous variables that were not normally distributed are reported using the median and interquartile range and were compared using the Wilcoxon rank sum test. Categorical variables are reported as frequencies and percentages and were analyzed by the Chi square test or Fisher's exact test. The Kruskal-Wallis test was used for ordinal attributes. Univariate and bivariate analyses were applied to isolate key factors with a significant influence on myocardial recovery (improvement in ejection fraction and/or decrease in the amount of mitral regurgitation by transthoracic echocardiography (TTE) 6 months after surgery). Statistical significance was determined using the 95% confidence interval and a P-value less than 0.05. All statistical tests were two sided.

RESULTS

Study population: Between 2016 and 2019, a total of 298 patients underwent isolated CABG at King Faisal Cardiac Center, King Abdulaziz Medical City, Jeddah, Saudi Arabia. The general characteristics of patients undergoing isolated CABG are presented in Table 1. (Table 1) The sample population consisted of 234 (78.5%) males and 64 (21.5%) females and had a mean age of 60.6±10.3 years. The mean BMI was 30.4±14.5. Of the whole study population, 81.2% had diabetes, 80.9% had HTN, and 59.1% were dyslipidemic. Sixty-seven percent of the patients were active smokers, and 42% had CKD, of whom only 8% were on renal dialysis prior to surgery. Additionally, 2.7% of patients were found to have COPD, and 6.4% had a past medical history of stroke prior to the surgery. Finally, TTE was performed on 287 (96.3%) patients preoperatively and 206 (70.1%) patients postoperatively (Table 1). All patients who were included in this study had Carpentier type IIIb MR. Preoperative viability testing was performed in only 24 patients (~8% of the study population), out of which 23 underwent cardiac Magnetic Resonance Imaging (cMRI), and only one patient underwent dobutamine stress echocardiography. All these patients who underwent viability testing had an EF of less than 30%. In addition, all patients who underwent myocardial viability testing underwent only CABG.

CABG related data: Most cases were done on-pump (98%). The median aortic cardiopulmonary bypass time was 121 minutes (IQR= 85-146) and the median cross-clamp time was 72 minutes (IQR= 47-122). In addition, most patients had a pedicled LIMA (99%). For patients with LM disease or significant LAD lesions (N = 254), the most common graft to the LAD was the LIMA (95.3%), followed by vein graft (3.5%) but 1.2% of those patients did not receive any grafts. Left main coronary artery disease was present in 82 patients (27.4%). The most common graft for the LAD in LM patients was the LIMA (95.1%) followed by the saphenous vein (4.9%). The most common graft for the OM in LM patients was saphenous vein (69%), however around 31% of patients did not receive any graft. For patients who did not have LM disease and had significant LAD disease (N = 173), the most common graft was the LIMA (95.4%), followed by a vein graft (2.9%), however 1.7% of patients did not receive a graft on the LAD. Figure 1 depicts the revascularization conduits used on each significantly stenosed target. (Figure 1)

Complete revascularization was achieved in 89.4% of patients with LM disease and 72.2% in patients who did not have LM disease but had significant stenotic lesions as per our definition. The main reason for incomplete revascularization was due to small target vessels that were not amenable for grafting by the surgeon performing the procedure.

Change in echocardiographic features based on time of TTE: All measurements were indexed to BSA, if possible. (Table 2) For the LVESD indexed in cm/m^2, the median (interquartile range= IQR) was found to be 1.87 (1.56–2.24) preoperatively, 1.98 (1.59–2.41) at less than 6 months after the surgery, and 1.8 (1.6–2.1) at more than 6 months after the surgery, with P = 0.023. The median (IQR) indexed LVEDD in cm/m2 was 2.26 (1.83–2.49) within 6 months of surgery and 2.4 (2.13–2.66) after 6 months of surgery, and the P-value was <0.001. For the LVEDV indexed in ml/m2, the median (IQR) was 48.3 (41.6–59.1) preoperatively, 49.8 (43.1–68.7) within the first 6 months after surgery and 47.3 (43.1–57.6) after 6 months from surgery, with a P-value= 0.024. The LVEF median (IQR) was calculated as 51 (44.1–57.9) preoperatively, 53.1 (41–58.6) within the first 6 months after

Table 1. General characteristics

Variable	All (*N* = 298)
Age in years, median (IQR)	61 (54-68)
BMI (kg/m^2), median (IQR)	29.2 (26.3-32.9)
HTN = Yes, n (%)	242 (81.2)
DM = Yes, n (%)	241 (81.1)
DLP = Yes, n (%)	176 (59.1)
CKD = Yes, n (%)	42 (14.1)
COPD = Yes, n (%)	8 (2.7)
Active smoking = Yes, n (%)	67 (24)

BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; DLP, dyslipidemia; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; UTI, urinary tract infection; IQR, interquartile range; n, number of patients

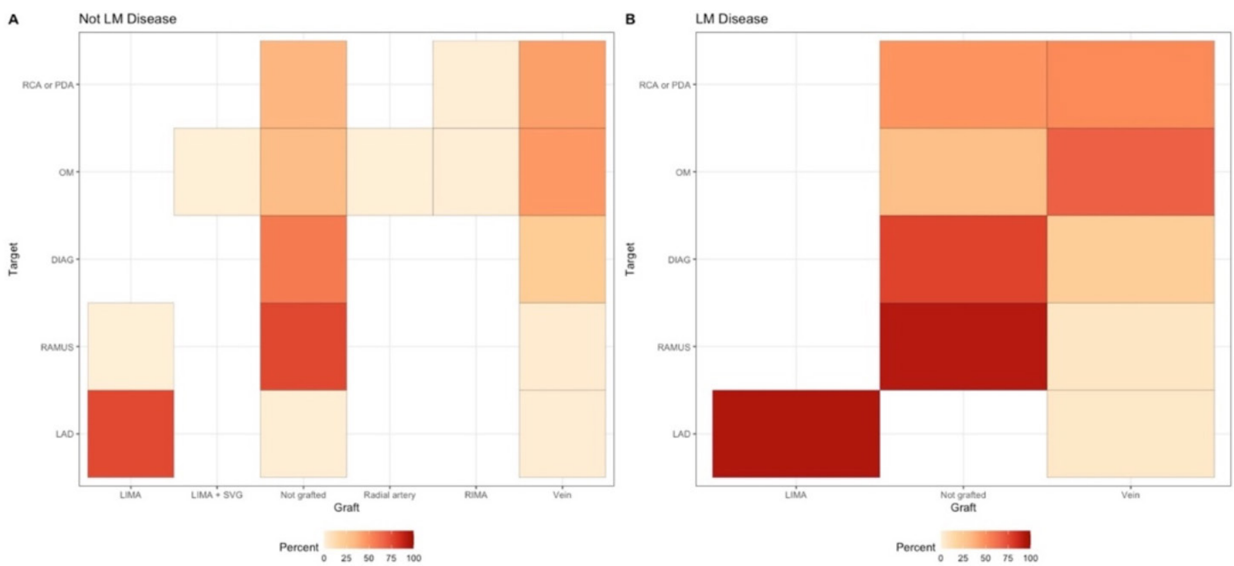

Figure 1. Grafted targets by LM disease. A = Not LM disease, B = LM disease
Targets: LAD, left anterior descending; RCA, right coronary artery; RAMUS, ramus intermedius artery; DIAG, diagonal artery; OM, obtuse marginal artery; PDA, posterior descending artery. Grafts: LIMA, left internal mammary artery; RIMA, right internal mammary artery; SVG, saphenous vein graft; NA, not applicable

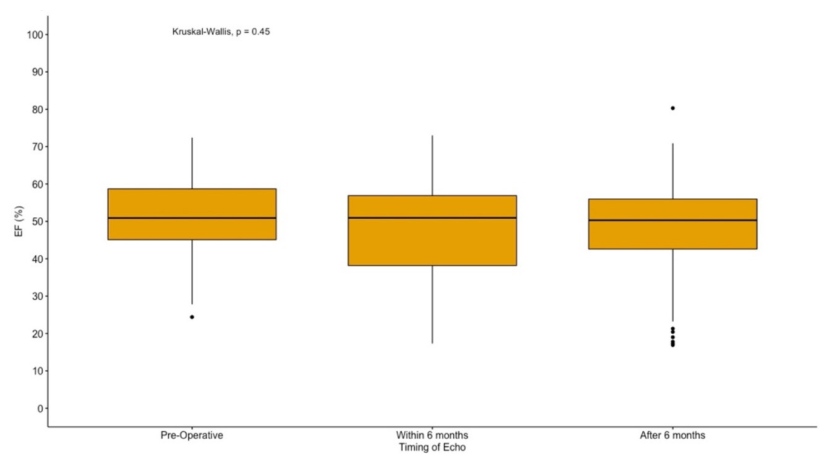

Figure 2. Ejection fraction progression from the preoperative to postoperative period

surgery and 50.3 (43.5–57.3) at 6 months after surgery, with a P-value= 0.454. (Figure 2)

For the LA volume indexed in ml/m^2, the median (IQR) was 31 (23.4–36.6) preoperatively, 32.7 (25.2–39.7) in the first 6 months after surgery and 34.2 (26.3–39.1) 6 months after surgery, with a P-value= 0.011. There were significant differences in volumes and dimensions. (Figure 3)

For the MR vena contracta, the median (IQR) was 0.44 (0.37–0.54) before surgery, 0.47 (0.38–0.52) within the first 6 months after surgery and 0.45 (0.39–0.52) 6 months after surgery, with a P-value= 0.53. The median (IQR) MR effective regurgitant orifice (ERO) area in cm^2 was 0.22 (0.16–0.25) before surgery, 0.2 (0.17–0.29) within the first 6 months after surgery and 0.18 (0.14–0.2) 6 months after surgery, with a P-value= 0.061. All other MV- and MR-related measures did not change and were not statistically significant (Table 2).

Postoperative outcomes in relation to preoperative MR: The postoperative outcomes in relation to preoperative MR are presented in Table 3. (Table 3) In this study, 214 (91.5%) patients had mild MR, while 20 (8.5%) had moderate to severe MR. Postoperative wound infection (which is defined as any wound infection within 90 days from the index procedure) was the most prevalent outcome and was observed in 40 patients (17.1%), 37 of whom had mild MR, while three had moderate to severe MR. Urinary tract infection (UTI) was found in 14 (6%) patients, of whom 12 had mild MR and two had moderate-to-severe MR. Nine (3.8%) patients had postoperative stroke of these, eight had mild MR, and one had moderate-to-severe MR. Postoperative pneumonia was observed in seven (3%) patients, six of whom had mild MR, while one had moderate to severe MR. Postoperative dialysis was required in six (2.6%), which was mainly in patients with

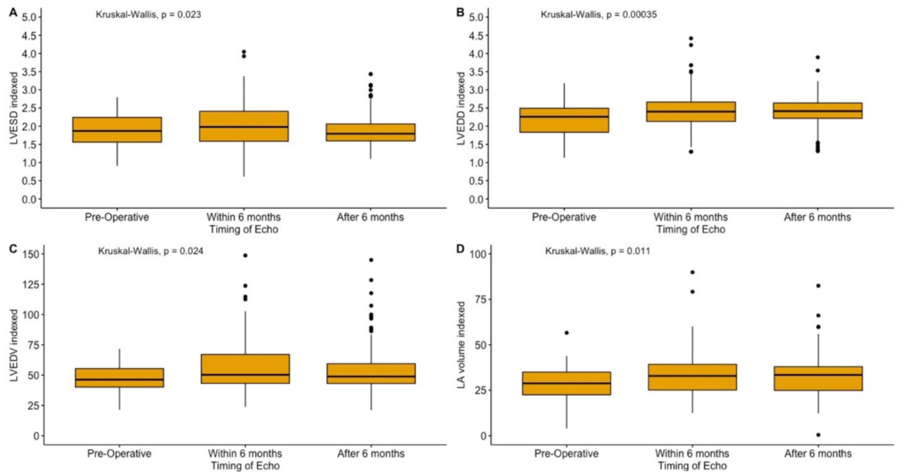

Figure 3. Indexed echocardiographic measurements for patients who underwent CABG. A = LVESD, left ventricular end systolic dimension measured in cm/m^2; B = LVEDD, left ventricular end diastolic dimension measured in cm/m^2; C = LVEDV, left ventricular end diastolic dimension measured in ml/m^2; D = LA volume, left atrial volume measured in ml/m^2

Table 2. Echocardiography data

Variable	Pre-op ECHO (*N* = 287, 96.3%)	ECHO within 6 months of surgery (N = 81, 27.2%)	ECHO after 6 months of surgery (N = 125, 42%)	P-value
LV ESD (cm), median (IQR)	3.4 (3-4.1)	3.7 (3-4.4)	3.4 (2.9-4)	0.029*
LV ESD Indexed (cm/m^2), median (IQR)	1.87 (1.56-2.24)	1.98 (1.59-2.41)	1.8 (1.6-2.1)	0.023*
LV EDD (cm), median (IQR)	4.5 (4-4.9)	4.6 (4.1-5)	4.6 (4.1-5)	<0.001*
LV EDD Indexed (cm/m^2), median (IQR)	2.26 (1.83-2.49)	2.4 (2.13-2.66)	2.64 (2.22-2.64)	0.0004*
LV EDV Indexed (ml/m^2), median (IQR)	48.3 (41.6-59.1)	49.8 (43.1-68.7)	47.3 (43.1-57.6)	0.024*
LV EF (%), median (IQR)	51 (44.1-57.9)	53.1 (41-58.6)	50.3 (43.5-57.3)	0.454
LA Volume Indexed (ml/m^2), median (IQR)	31 (23.4-36.6)	32.7 (25.2-39.7)	34.2 (26.3-39.1)	0.011*
MR Vena contracta (cm), median (IQR)	0.44 (0.37-0.54)	0.47 (0.38-0.52)	0.45 (0.39-0.52)	0.53
MR ERO area (cm^2), median (IQR)	0.22 (0.16-0.25)	0.2 (0.17-0.29)	0.18 (0.14-0.2)	0.061
MR Regurgitant volume (ml), median (IQR)	37.7 (33.5-45.9)	33.3 (33-33.6)	37 (23.2-42.9)	0.68
MV inflow e/a ratio, median (IQR)	0.92 (0.75-1.3)	1.1 (0.78-1.4)	1.1 (0.77-1.3)	0.16
MV e/é ratio, median (IQR)	10.6 (8.52-14.4)	11.4 (8.95-16.1)	10.2 (8.3-13.7)	0.065

LV, left ventricle; ESD, end systolic dimension; EDD, end diastolic dimension; EDV, end diastolic volume; LA, left atrium; MR, mitral regurgitation; ERO, effective regurgitant orifice; IQR, interquartile range; Pre-op, preoperative; Echo, echocardiography; MV, mitral valve

chronic renal failure and were not on preoperative dialysis and all of these patients had mild MR. Finally, postoperative mortality was the least prevalent outcome and was found in two (0.9%) patients; both had mild MR.

Status of MR after CABG: Figure 4 depicts the change in MR from pre-CABG to post-CABG. (Figure 4) Twenty-six patients had unknown preoperative status of their MR (most either emergency surgery or had echocardiograms in another institutions). Twenty-one patients had no MR preoperatively. In the postoperative report of these patients, 66.1% had mild or no MR, only 4.8% had moderate MR, and 28.6% were either not assessed postoperatively or underwent only limited studies. Almost one-third of patients had trace MR preoperatively. For these patients, 54% of these patients had mild or less MR on the postoperative echocardiograms, and 6% had more than mild MR. However, 40.6% were either not assessed postoperatively or underwent only limited studies. Ninety-two patients (31%) had mild MR preoperatively. In the postoperative report of these patients, one (1.1%) had no MR, and only one (1.1%) progressed to moderate-severe MR. Twenty-seven patients had mild-moderate MR preoperatively, of whom three (11.1%) had a decrease in MR severity

Table 3. Outcomes by Preoperative MR Status

Variable	All (N = 234)	Mild MR (*N* = 214, 91.5%)	Moderate to severe MR (*N* = 20, 8.5%)	*P*-value
Postoperative wound infection = Yes, n (%)	40 (17.1)	37 (17.3)	3 (15)	0.795
Postoperative pneumonia = Yes, n (%)	7 (3)	6 (2.8)	1 (5)	0.471
Postoperative UTI = Yes, n (%)	14 (6)	12 (5.6)	2 (10)	0.344
Postoperative stroke = Yes, n (%)	9 (3.8)	8 (5)	1 (3.7)	0.779
Postoperative new dialysis = Yes, n (%)	6 (2.6)	6 (2.8)	0 (0)	NA
Postoperative mortality, n (%)	2 (0.9)	2 (0.9)	0 (0)	NA

BMI, body mass index; HTN, hypertension; DM, diabetes mellitus; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; UTI, urinary tract infection; IQR, interquartile range; n, number of patients

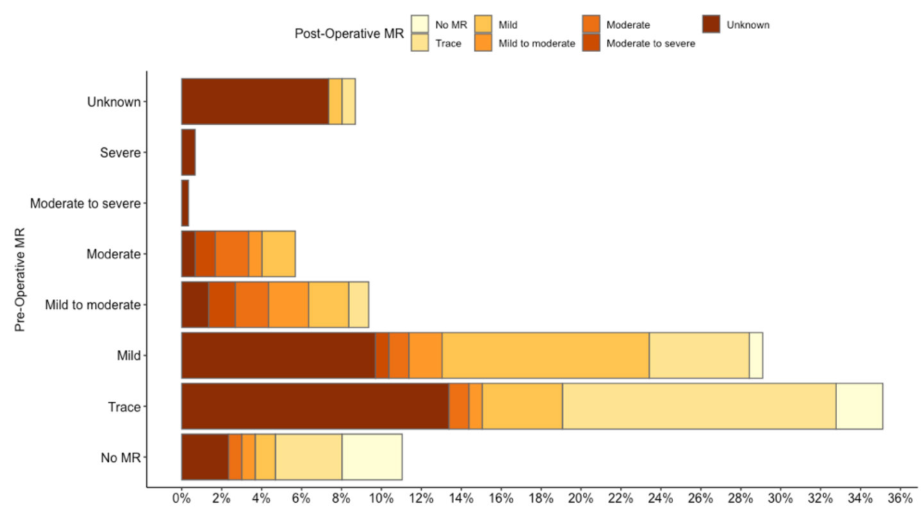

Figure 4. Status of Mitral Regurgitation after CABG. MR, mitral regurgitation

to trace on postoperative echocardiography and two (12.5%) had progression of the MR to moderate-severe. Only three patients had a moderate to severe or severe MR before surgery (1%) (Figure 4). The decision of not intervening on these MRs was not clear, however we assume it was to minimize the cardio-pulmonary bypass time because of the frailty of these three patients (all above the age of 80 years with EF around 30% with multiple comorbidities and it was felt addressing the MR will significantly increase the surgical risk). Based on our cohort, incomplete revascularization had no significant impact on the status of postoperative MR in patients with or without LM disease (P = 0.523 and P = 0.742, respectively).

DISCUSSION

Data on the assessment of pre- and postoperative changes in LV systolic function and MR after CABG are scarce. This might be due to a lack of routine echocardiography after isolated CABG. Annular dilatation secondary to LV cavity dilatation is the most accepted cause of mitral regurgitation in the setting of myocardial ischemia [Wang 2014]. In the setting of moderately depressed LV function, it is expected that revascularization will restore myocardial function, at least partially, in the presence of viable myocardium. Theoretically, this will help restore normal LV geometry, which will decrease the MR without the need for surgical repair [Virk 2017]. This has been demonstrated in several large trials, and based on their findings, the guidelines have dismissed the need for mitral valve repair unless MR is severe [Virk 2017]. Several studies have demonstrated the positive effects of revascularization in the setting of CAD with depressed LV function with viable myocardium and focused mainly CABG, which is more cost effective and associated with a better improvement of quality of life and a reduction in symptoms [Fanari 2013].

There are a limited number of studies that have compared preoperative and postoperative cardiac echocardiography after CABG. Koene et al. examined 838 patients who underwent isolated CABG [Koene 2017]. They noticed an increase in the LVEDD and a decrease in LVEF, especially in patients with near-normal preoperative EF. In our study, we had similar findings; although the EF change was not statistically significant, the indexed LVEDD was significantly increased. However, this was not associated with an increase in postoperative complications or mortality at follow up. One of the major limitations of the study by Koene et al. is that it included only men, as it was conducted at a Veterans Affairs center.

In our study, most patients had mild MR, with a small proportion having moderate-severe MR before surgery. Of all the patients with moderate MR (12.4%), almost 42% showed improvement of their MR to mild or even trace on follow-up echo. Cardiac function in our cohort did not differ between groups with early or late follow up, although this might be secondary to the high EF in our cohort. The low mortality rate after revascularization in our study may be mainly due to factors not related to the improvement of ejection fraction. This may be the result of either electrical stabilization preventing fatal arrhythmias or a reduction in ischemic burden leading to better functional capacity. In a study by Michler et al., which we considered to be the largest randomized controlled trial that addressed this issue, the authors examined 301 patients who underwent only surgical revascularization versus surgical revascularization with mitral valve annuloplasty to downsize the mitral annulus [Michler 2016]. They followed the patients for 2 years, and the primary end point was the degree of left ventricular reverse remodeling, as measured by means of the left ventricular end systolic volume index (LVESVI) on transthoracic echocardiography at 1 year after enrollment. The secondary end points included findings on transthoracic echocardiography, mortality rate, MACCEs (defined as a composite of death, stroke, subsequent mitral valve surgery, hospitalization for heart failure, or worsening New York Heart Association (NYHA) class), serious adverse events, degree of postoperative mitral regurgitation, quality of life, and rehospitalization. The authors concluded that adding an annuloplasty to CABG decreased MR and provided a more durable repair; it did not improve left ventricular remodeling or survival in patients with moderate MR and was associated with an increased risk of stroke and arrythmias [Wang 2014].

We acknowledge that the incidence of wound infection in our cohort is quite high, however our institutional definition of wound infection follows the World Health Organization of postoperative wound infection that will include all wound related infections (from simple superficial all the way to complex deep sternal infections). That might contribute to the fact that our incidence is quite high. However, the rate of deep sternal wound infection requiring surgical intervention of advanced therapy (like vacuum assisted closure) is around 2%. This is consistent with published literature locally and internationally [Jonkers 2003; Mufti 2020].

The most important findings of the current study can be summarized as follows. First, improvement in the severity of MR is expected after surgical revascularization without the need for mitral valve intervention. Second, the beneficial effects of surgical revascularization will take some time to show on the echocardiogram, and the test should be repeated 3 or even 6 months after surgery to allow sufficient time for the expected benefits of surgery to take effect. Third, in this high-risk population, we demonstrated very low mortality comparable to international standards and high-volume centers. Fourth, incomplete revascularization had no influence on the status of post-operative MR if the LAD territory is revascularized.

Limitations: We acknowledge that there are several limitations of our study to be highlighted. First, the study has the inherent disadvantage of its retrospective design. This means that it is more of a hypothesis-generating study. Second, echocardiograms are not routinely obtained after CABG unless there is an issue, which might induce selection bias. Third, echocardiography was obtained only two times for each patient, and not all the echocardiograms were obtained at the same point during follow-up, which might induce measurement bias, as we cannot be sure whether these changes would remain consistent if the study were repeated later. Fourth, it is well known that echocardiography has approximately 6–10% interobserver variability in several parameters, especially EF [Wood 2014]. Fifth, the unconditional definition of complete revascularization used in our study is subjective and inherently susceptible to observer bias. We have used the unconditional anatomical definition as we felt it will enable us to be more objective and capture as many patients as we can. In future studies that would like to address the question for the fate of MR after CABG, we strongly recommend the use of a more functional definition as it is more objective and re-producible. Some other limitations of this work include: the quality of the acquired data might profoundly impact the models and their interpretation, the small sample size, being a single-center study might limit the generalization of this results. Also, around 13% of our patients had an unknown MR status prior to surgery, which might impact the results of our data. However, most these patients had mild or less MR post-CABG. Although the numbers are small (around 4% of the whole cohort), we cannot explain the progression of some of the patients with mild or less MR to a more severe regurge. Finally, patients who didn't follow up in our center were also not included in our cohort as we don't know what happened to them and the outcome of interest (EF and IMR). Unfortunately, regional wall motion abnormalities, ventricular wall thickness in the preoperative TTE are inconsistently reported or just reported at normal versus abnormal and for that reason we were not able to use this information because we felt it is unreliable.

CONCLUSION

Based on international guidelines and best evidence, surgical revascularization alone is sufficient for patients with CAD that is associated with IMR that is not severe, which is associated with improvement of LVEF and IMR severity. Complete revascularization might have an influence on ventricular recovery that might improve or stabilize IMR. The results of our cohort are consistent with those of larger studies with very low postoperative mortality of this group of high-risk patients.

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