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Ejection Fraction Recovery after Coronary Artery Bypass Grafting for Ischemic Cardiomyopathy

Vasileios Ntinopoulos[1] Nestoras Papadopoulos[1] Dragan Odavic[1] Achim Haeussler[1] Omer Dzemali[1]

[1] Department of Cardiac Surgery, Municipal Hospital Triemli, Zurich, Switzerland

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Address for correspondence Vasileios Ntinopoulos, MD, MSc, Department of Cardiac Surgery, Municipal Hospital Triemli, Birmensdorferstrasse 497, Zurich 8063, Switzerland (e-mail: vasileios.ntinopoulos@triemli.zuerich.ch).

Abstract

Background Controversy exists about left ventricular systolic function recovery after coronary artery bypass grafting in patients with ischemic cardiomyopathy. The aim of this study is to evaluate the temporal evolvement of left ventricular systolic function after coronary artery bypass surgery in patients with ischemic cardiomyopathy.

Patients and Methods A total of 50 patients with coronary artery disease and left ventricular ejection fraction (LVEF) ≤35% underwent isolated coronary artery bypass grafting in a single center in the period 2017 to 2019. We performed a retrospective analysis of the echocardiographic and clinical follow-up data at 3 months and 1 year postoperatively.

Results Median LVEF preoperatively was 25% (20–33%), mean patient age was 66 ± 8.2 years, 33 (66%) patients were operated off-pump, and 22 (44%) procedures were non-elective. There was no in-hospital myocardial infarction, stroke, and repeat revascularization. Three (6%) patients underwent re-exploration for bleeding or tamponade. In-hospital mortality was 8% and 1-year mortality was 12%. At 1 year postoperatively, there was no repeat revascularization, no myocardial infarction, 1 (2.6%) patient had a transient ischemic attack, and 10 (20%) patients required an implantable defibrillator. There was a statistically significant median ejection fraction increase at 3 months (15% [5–22%], $p < 0.0001$) and 1 year (23% [13–25%], $p < 0.0001$) postoperatively, with an absolute increase ≥10% in 32 (74.4%) and 30 (78.9%) patients at 3 months and 1 year, respectively.

Conclusion Patients with ischemic cardiomyopathy undergoing coronary artery bypass surgery show continuous recovery of left ventricular systolic function in the first postoperative year.

Keywords
- coronary artery bypass grafting
- CABG
- off-pump surgery
- heart failure

Introduction

Coronary artery disease (CAD) is the leading cause of death in the United States and accounted for 13% of deaths nationwide in 2018.[1] Ischemic cardiomyopathy, with left ventricular dysfunction and heart failure may develop over time, leading to even higher morbidity and mortality. Coronary artery bypass grafting (CABG) has been shown to be superior to medical therapy alone or percutaneous coronary intervention for the treatment of ischemic cardiomyopathy.[2,3]

Several studies have shown a recovery of left ventricular ejection fraction (LVEF) postoperatively, attributed to increased myocardial blood flow of the revascularized areas after CABG.[4–9] However, controversy exists about the temporal evolvement of LVEF recovery postoperatively and some of the published data have shown a benefit limited only to

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the early postoperative period.[10,11] Aim of this study is the evaluation of left ventricular systolic function recovery in the first postoperative year in patients with ischemic cardiomyopathy undergoing CABG.

Patients and Methods

A total of 50 patients with CAD and severe left ventricular dysfunction, defined as an LVEF ≤35%, underwent isolated CABG in a single center in the period 2017 to 2019. We performed a retrospective analysis of the echocardiographic and clinical follow-up data at 3 months and 1 year postoperatively. The study was approved and individual informed consent was waived by the local ethics committee (BASEC number: 2021-00625).

The procedure was performed over a median sternotomy in 46 (92%) patients and over a left anterolateral minithoracotomy in 4 (8%) patients. Cardiopulmonary bypass (CPB) was used in 17 (34%) patients, with 3 (6%) of the patients being non-electively converted from off-pump to on-pump CABG because of intraoperative hemodynamic instability. A total of 15 (30%) patients were operated on-pump beating-heart, without the use of cardioplegia and 2 (4%) patients with the use of cardioplegia. Bretschneider solution was used for myocardial protection and applied antegrade and indirectly to the ascending aorta. Patients were cooled to 34°C in case of CABG with cardioplegic arrest, whereas no cooling was performed in case of on-pump beating-heart CABG. CPB was established with arterial cannulation of the ascending aorta and venous cannulation of the right atrium. The procedure was performed without CPB (off-pump) in 33 (66%) patients.

The following patient data were collected: preoperative and intraoperative (age, gender, arterial hypertension, dyslipidemia, smoking status, diabetes mellitus, number of diseased coronary vessels, previous myocardial infarction, previous percutaneous coronary intervention, chronic obstructive pulmonary disease, previous stroke, peripheral arterial disease, chronic renal disease, use of CPB, surgery urgency, number of coronary anastomoses, LVEF, additive EuroSCORE), in-hospital postoperative (intubation duration, intensive care unit stay, postoperative stay, re-exploration for bleeding or tamponade, postoperative renal replacement therapy, implantable cardioverter defibrillator [ICD] or cardiac resynchronization therapy defibrillator [CRT-D] implantation, myocardial infarction, stroke, and repeat revascularization), and follow-up (LVEF at 3 months and 1 year postoperatively, ICD or CRT-D implantation, myocardial infarction, stroke, and repeat revascularization at 1 year postoperatively). The baseline data of the patients are presented in ►**Table 1**. LVEF was assessed preoperatively, at 3 months and 1 year postoperatively by transthoracic echocardiography.

The statistical analyses were performed with IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp, Armonk, New York, United States). Categorical variables are presented as counts (percentages) and continuous variables as mean ± standard deviation by normally distributed data and median (first and third quartile) by non-normally distributed data. Assessment of the normality of data distribution was performed using mainly Q–Q plot and histogram inspection and secondarily with the Shapiro–Wilk test and the Kolmogorov–Smirnov test. The Wilcoxon signed-rank test was used to assess for LVEF improvement at 3 months and 1 year postoperatively. Student's *t*-test, Mann–Whitney's *U*-test, Pearson's, and Spearman's correlation were used to identify factors leading to LVEF improvement postoperatively. All tests were two-sided and the level of statistical significance was set at 0.05.

Table 1 Baseline characteristics of the patient population ($n = 50$)

Age, years	66 ± 8.2
Female gender	7 (14)
Arterial hypertension	46 (92)
Dyslipidemia	37 (75.5)
Smoker, active or ex	37 (75.5)
Diabetes mellitus	21 (42)
Coronary artery disease	50 (100)
One-vessel	0
Two-vessel	5 (10)
Three-vessel	45 (90)
Previous myocardial infarction	30 (60)
Previous PCI	12 (24)
COPD	4 (8)
Previous stroke	10 (20)
Peripheral arterial disease	8 (16)
Chronic renal disease	20 (40.8)
OPCAB	33 (66)
Non-elective surgery	22 (44)
Number of coronary anastomoses	3 (3–4)
LVEF, %	25 (20–33)
Additive EuroSCORE, points	8.04 ± 3.3

Abbreviations: COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; OPCAB, off-pump coronary artery bypass; PCI, percutaneous coronary intervention.
Note: Continuous variables are reported as mean ± standard deviation or median (first and third quartile) and categorical variables as counts and percentages, *n* (%).

Results

In-hospital Outcomes

The median intubation duration was 6 (4–12) hours, the median intensive care unit stay was 2 (1–3) days, and the median postoperative stay was 9 (8–11) days. Three (6%) patients underwent re-exploration for bleeding or cardiac tamponade and one (2%) patient required postoperative renal replacement therapy. A total of four (8%) patients died during the index hospitalization. There was no myocardial infarction, stroke, or repeat revascularization. One patient with postoperative symptomatic ventricular tachycardia, persistent LVEF ≤35%, and non–left bundle branch block (LBBB) with QRS duration >120 milliseconds received a CRT-D for primary prevention of sudden cardiac death on the sixth postoperative day (epicardial left ventricular electrode already implanted during CABG).

Follow-up Outcomes

The 3-month and 1-year follow-up data of the patients are presented in ►**Table 2**. There was a statistically significant median LVEF increase from baseline to 3 months (15% [5–22%], $p < 0.0001$) and 1 year (23% [13–25%], $p < 0.0001$) postoperatively as well as from 3 months to 1 year (4% [0–10%], $p < 0.0001$) postoperatively. An LVEF increase ≥10% was shown in 32 (74.4%) patients at 3 months and 30 (78.9%) patients at 1 year postoperatively. There was no myocardial infarction and no repeat revascularization at 1 year postoperatively. A total of six (12%) patients died in the first postoperative year. Overall, six (12%) patients received a CRT-D, one patient during the index hospitalization and five at follow-up. Indications for CRT-D implantation at follow-up were primary prevention of sudden cardiac death by persistent symptomatic LVEF ≤35% and LBBB with a QRS duration >130 milliseconds or non-LBBB with a QRS duration >120 milliseconds (four patients with LBBB and one patient with non-LBBB). Four (8%) patients received an ICD for primary prevention of sudden cardiac death by persistent LVEF ≤35%. The mean implantation time point for all devices was 0.44 ± 0.33 years postoperatively. One (2%) patient had a questionable case of transient ischemic attack, presenting with hemiparesis and hypoesthesia of the left upper extremity, 2 days after the ipsilateral implantation of a CRT-D, with normal findings in cranial computed tomography and almost complete regression of the symptoms over the next 5 days and before hospital discharge.

The results of the analysis for factors affecting LVEF improvement at 3 months and 1 year postoperatively are presented in ►**Tables 3** and **4**. None of the assessed factors was found to be statistically significantly associated with LVEF improvement at 3 months postoperatively. Preoperative LVEF ($p = 0.033$), previous percutaneous coronary intervention ($p = 0.027$), normal kidney function ($p = 0.020$), and off-pump surgery ($p = 0.036$) were found to be statistically significantly negatively associated with LVEF improvement at 1 year postoperatively.

Table 2 Follow-up data of the patient population ($n = 50$)

LVEF at 3 mo postoperatively, %	40 (33–48)
LVEF increase ≥10% at 3 mo postoperatively	32 (74.4)
LVEF at 1 y postoperatively, %	45 (40–51)
LVEF increase ≥10% at 1 y postoperatively	30 (78.9)
ICD or CRT-D implantation at 1 y postoperatively	10 (20)
Myocardial infarction at 1 y postoperatively	0
Stroke at 1 y postoperatively	1 (2)
Repeat revascularization at 1 y postoperatively	0
Mortality at 1 y postoperatively	6 (12)

Abbreviations: CRT-D, cardiac resynchronization therapy defibrillator; ICD, implantable cardioverter defibrillator; LVEF, left ventricular ejection fraction.
Note: Continuous variables are reported as median (first and third quartile) and categorical variables as counts and percentages, *n* (%).

Table 3 Univariate analysis for factors affecting LVEF improvement at 3 months postoperatively

Variables	*p*-Value
Age	0.507
Female gender	0.987
Arterial hypertension	0.098
Dyslipidemia	0.489
Smoker, active or ex	0.135
Diabetes mellitus	0.677
Three-vessel coronary disease	0.283
Previous myocardial infarction	0.911
Previous PCI	0.378
COPD	0.981
Previous stroke	0.223
Peripheral arterial disease	0.692
Chronic renal disease	0.736
OPCAB	0.436
Non-elective surgery	0.737
Number of coronary anastomoses	0.718
LVEF	0.314
Additive EuroSCORE	0.386

Abbreviations: COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; OPCAB, off-pump coronary artery bypass; PCI, percutaneous coronary intervention.

Discussion

Our data show that patients with ischemic cardiomyopathy undergoing CABG exhibit a significant LVEF increase both in the first 3 months as well as the first year after revascularization. LVEF recovery was markedly higher in the first 3 postoperative months but continued further on during the first postoperative year. Previous studies have also shown an LVEF recovery in patients with ischemic cardiomyopathy after CABG, though the temporal trend of LVEF recovery was analyzed by only a few authors with contradicting results. Roberts et al. have shown a transient depression of LVEF in the first 2 postoperative hours, followed by recovery to preoperative levels at 24 hours and significant improvement at 7 days but no further change in LVEF from 7 days to 8 months postoperatively.[11] Similarly, Lorusso et al. have shown a significant LVEF improvement prior to hospital discharge after CABG, with gradual offset at 3 and 12 months postoperatively.[10] Other research groups were able to find a significant LVEF improvement at 1, 6, and 12 months

Table 4 Univariate analysis for factors affecting LVEF improvement at 1 year postoperatively

Variables	*p*-Value
Age	0.304
Female gender	0.763
Arterial hypertension	0.606
Dyslipidemia	0.642
Smoker, active or ex	0.110
Diabetes mellitus	0.976
Three-vessel coronary disease	0.385
Previous myocardial infarction	0.154
Previous PCI	0.027
COPD	0.272
Previous stroke	0.180
Peripheral arterial disease	0.680
Chronic renal disease	0.020
OPCAB	0.036
Non-elective surgery	0.803
Number of coronary anastomoses	0.356
LVEF	0.033
Additive EuroSCORE	0.816

Abbreviations: COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; OPCAB, off-pump coronary artery bypass; PCI, percutaneous coronary intervention.

postoperatively,[7,9,12,13] while some others were able to find a significant LVEF improvement postoperatively, though no exact follow-up time point was specified.[4–6]

The myocardial blood flow of revascularized areas increases significantly after CABG, driving the recovery of regional and global left ventricular function and leading to the observed postoperative LVEF improvement.[14] However, left ventricular function cannot recover in cases of irreversible myocardial damage, thus recovery of contractile function can only be achieved by revascularization of viable ischemic myocardium. Using preoperative dynamic positron emission tomography (PET) and transmural myocardial biopsy, some authors were able to show that higher levels of myocardial blood flow, higher myocardial glucose uptake, less tissue fibrosis, and specific alterations of cardiomyocytes (loss of myofilaments and accumulation of glycogen) were associated with reversible left ventricular dysfunction.[7,9,15,16] Other authors were able to identify patients with viable ischemic myocardium and predict myocardial recovery by using dobutamine echocardiography, magnetic resonance tomography with late gadolinium enhancement, and single photon emission computed tomography (SPECT).[17–20] No data about preoperative myocardial viability were available in our study; therefore, no relevant analysis could be performed.

Even though the assessment of preoperative myocardial viability with the abovementioned imaging methods helps the prediction of left ventricular function recovery after CABG, not all patients with evidenced viability exhibit the expected LVEF recovery. Mandegar et al. have shown that patients with higher left ventricular end-systolic volume and fewer viable myocardial segments in preoperative dobutamine echocardiography had a lower likelihood of postoperative LVEF recovery.[21] Consequently, patients with poor left ventricular systolic function, severe left ventricular dilation, and low proportion of viable myocardium are not expected to show significant LVEF recovery after CABG. No data about preoperative left ventricular dilation were available in our study; therefore, no relevant analysis could be performed.

Despite the overall significant LVEF improvement at 3 months and 1 year postoperatively, every fifth patient received an ICD or CRT-D postoperatively, with an indication for implantation based on the recommendations of international society guidelines.[22] This is a considerable proportion of patients and most probably reflects a subgroup with a large amount of nonviable myocardium and/or severe left ventricular dilation, who did not profit from the surgical revascularization.

This study has limitations associated with the retrospective data analysis and the inherent patient selection bias of these analyses. Additionally, no preoperative data about myocardial viability and left ventricular dilation were available, factors associated with reversibility of myocardial dysfunction after CABG, which might have been able to explain the absence of LVEF recovery in some patients.

Conclusion

In conclusion, the strengths of this study must be emphasized. Using echocardiographic follow-up data at 3 months and 1 year postoperatively, we were able to perform an analysis of the postoperative LVEF evolvement in patients with ischemic cardiomyopathy. Only a few previous studies have assessed the temporal evolvement of LVEF after CABG, with contradicting results. Our study shows a significant increase of LVEF at 3 months and 1 year after CABG, providing more data about a continuous LVEF recovery over the first postoperative year.

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Conflict of Interest
None declared.

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