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RESEARCH ARTICLE

Left Ventricular Function and Morphology after Cardiac Surgery for Severe Mitral Insufficiency - A Single Center Experience

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Introduction: Mitral insufficiency is a common valvular disease affecting 10% of the general population. The main treatment of the severe mitral regurgitation is surgical. We have analyzed the impact of cardiac surgery on the left ventricular performance and morphology, in patients treated for severe mitral insufficiency accordingly to the type of intervention, ischemic time and type of cardioplegia. **Methods**: Ninety patients diagnosed with isolated severe mitral insufficiency that benefited from mitral valvular replacement or mitral valvuloplasty were retrospectively enrolled. The left ventricle, the left atrium, the right ventricle diameters and the left ventricle ejection fraction were measured by two-dimensional (2D) echocardiography before and after surgery. The influence of the myocardial ischemia time and the type of cardioplegia administered on the ventricular systolic function were also analyzed. **Results**: Regardless the surgical technique chosen, after surgery we noticed a decreased size of the left ventricle (preoperative mean 54.91mm ±8.18 vs postoperative mean 51.94mm±8.15, p=0.035), right ventricle (preoperative mean 33.49mm±5,87 vs postoperative mean 32.41mm±6.03, p=0.0001), as well as the ejection fraction (preoperative mean 51.29%±8.51 vs postoperative mean 46.57%±8.71, p=0.0001). **Conclusions**: Immediately after surgery, a decrease in the size of cardiac cavities as well as a decrease of the left ventricle ejection fraction is noticed.

Keywords: mitral regurgitation, surgery, reverse-remodeling, cardioplegia

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Introduction

Mitral insufficiency is one of the most frequent valvulopathies, affecting 10% of the whole population [1]. It is the second most frequent reason for valvular surgery after aortic stenosis [2].

In the case of mitral insufficiency, some blood from the left ventricle passes backwards into the left atrium due to a deficiency of the mitral valve apparatus which comprises the anterior and posterior mitral valves, the mitral ring and the sub-valvular apparatus. Deficiency of any part of the mitral valvular apparatus causes a degree of regurgitation depending on the area of the regurgitant orifice and the pressure gradient between the left ventricle and the left atrium. In the case of chronic mitral insufficiency, a ventricular remodeling occurs with time, which modifies the geometry of the cavities, their diameters, volumes and the left ventricle's ejection fraction [3].

Surgical treatment of mitral insufficiency involves mitral valvular replacement with a metallic or tissue prosthesis or, if possible, mitral valvuloplasty [4].

In our article, we have analyzed the severe mitral insufficiency cases surgically treated in the Cardiovascular Surgery Clinic of the Emergency Institute for Cardiovascular Diseases and Transplantation of Târgu Mureș from January to December 2019.

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The purpose of this study is to assess the early response in terms of left cardiac chamber size and left ventricular ejection fraction for the surgery method chosen.

Materials and Methods

We completed a retrospective observational study of 90 patients diagnosed with isolated severe mitral insufficiency, which benefited from mitral valvular replacement or mitral valvuloplasty in the Emergency Institute for Cardiovascular Diseases and Transplantation (IuBCvT) of *Târgu Mureș* from January to December 2019. The study included the patients who had pre- and postoperative echocardiographic assesment. We excluded from the study patients who had a history of cardiac surgery or who required other simultaneous cardiac surgical procedures. We also excluded patients with epicardial coronary artery stenosis ≥50% and patients with a history of coronary intervention. We analyzed the diameters of the left ventricle (LV), the left atrium (LA), the right ventricle (RV) and the LV ejection fraction (EF), before and after surgery. We also analyzed the influence of the myocardial ischemic time and the type of cardioplegia (Custodiol or Calafiore) administered on the ventricular systolic function.

Echocardiographic Assessment

The two-dimensional-guided measurement of LV end-diastolic diameter was made just distal to the mitral leaflets' tips, perpendicular to the long axis of the LV, normal range: 42–59mm in men and 39–53mm in women [5]. The LA was also measured in long axis view, from the posterior aortic wall to the posterior left atrial wall in a plane parallel to the mitral annulus in end-systole, normal range <40mm [5]. The RV diameter was measured in four chambers view at mid-chamber level in end-diastole, normal range < 35mm, to estimate the intravascular volume status of the patient. The EF was calculated with Simpson's biplane method, normal range: >52% in men and >54% in women [5].

Two measurements were made: 1 day before surgery and 7 to 10 days after surgery, on the day before discharge. By the time the echocardiographic evaluations were made, the patients were clinically stable and no inotropic support was needed.

Surgical Technique

Cold crystalloid Custodiol cardioplegia (CCP) was administered at a temperature of 4°C, with re-administration after 90 minutes of aortic cross-clamping.

With intermittent warm blood cardioplegia Calafiore (IWBC), the initiation of cardiac arrest was achieved using a high dose of potassium [K+] 18–20 mEq/l infusion and maintained by repetitive supply every 20 minutes with reducing concentrations [6]. All patients received anterograde cardioplegia.

Metallic or tissue prostheses were used. The mitral valvuloplasty techniques used were the Alfieri technique, mitral annuloplasty with ring and respectively complex mitral valvuloplasty.

Statistical Analysis

Data were considered as nominal or quantitative variables. Nominal variables were characterized using frequencies. Quantitative variables were tested for normality of distribution using Kolmogorov-Smirnov test and were characterized by median and percentiles (25–75%) or by mean and standard deviation (SD), if appropriate. A chi-square test was used to compare the frequencies of nominal variables. Quantitative variables were compared using paired t-tests. The correlation between quantitative variables was assessed using Pearson correlation. The level of statistical significance was set at $p<0.05$. Statistical analysis was performed using SPSS for Windows version 23.0 (SPSS, Inc., Chicago, IL).

For this study, we obtained the agreement of the Ethics Committee of the Emergency Institute for Cardio-Vascular Diseases and Transplantation, Romania (993/31.01.2020).

Results

The mean age of the patients was 60.26 years old +/- 11, with a small variation between genders; 46 (51.1%) were female and 44 (48.9%) male.

The most frequent surgical intervention chosen was valvular replacement with mechanical prosthesis (71.1%), followed by mitral valvular replacement with tissue valve (24.4%). Among the mitral valvuloplasty procedures, the Alfieri technique was used in 2.2% of patients, mitral annuloplasty with ring in 1.1% and respectively complex mitral valvuloplasty in 1.1%.

Paired t-tests were used to compare the pre- and post-surgery parameter averages and identified significant differences, the values being higher before surgery than after the surgery (Table I).

In relation to the mitral valvular replacement with mechanical prosthesis, decreases in the sizes of the LV and LA were observed after the surgical intervention (pre-surgery LV mean 54.92 mm±0.99, post-surgery LV mean 52.25±1.01; p=0.003; pre-surgery LA mean 51.92 mm±1.27, post-surgery LA mean 51.3 mm±1.09; p=0.40). EF decreased after mitral replacement with prosthesis (pre-surgery EF mean 53.04 %±0.96, post-surgery EF mean 47.93%±1.006; p=0.0001). The RV response was similar in the case of mitral valve replacement with mechanical prosthesis (pre-operative RV mean 33.11mm ± 0.75, post-operative RV mean 31.87mm ± 0.74; p=0.024).

The same results were found for the mitral valvular replacement with tissue valve: a reduced diameter of the left cavities after surgical intervention (pre-surgery LV mean 52.54 mm±1.68, post-surgery LV mean 49.45 mm±1.72; p=0.047; pre-surgery LA mean 52.63mm±2.15, post-surgery LA mean 50.4 mm±1.859; p=0.20) and decrease in EF (pre-surgery EF mean 48.54%±1.63, post-surgery EF mean 45.68%±1.7; p=0.033). The results are similar in the case of the RV (pre-surgery RV mean 34.45 mm±1.27, post-surgery RV mean 32.86 mm±1.25; p=0.30).

In our study only four cases of mitral valvuloplasty were included: two cases of valvuloplasty using Alfieri technique, one annuloplasty with a prosthetic ring and one complex valvuloplasty. In all cases the diameter of LV and LA and EF were reduced post-surgery. The number of patients was too small for statistical analysis.

CCP was used in 35 cases (18 women and 17 men) representing 39.8% and IWBC was used in 53 cases (27 women and 26 men) representing 60.2% of the cases.

The diameters of the cavities and the EF by type of cardioplegia are presented in Table II.

The mean ischemic time was higher for the group receiving CCP than for those receiving IWBC, but the difference was statistically insignificant: 58.74min±2.19. vs.

Table I. Paired Sample Statistics to Compare Pre- and Post-operatory Parameter Averages.

		Mean	Std. Deviation	P value
Pair 1	LV preoperative	54.91	8.18	0.0001
	LV postoperative	51.94	8.15	
Pair 2	RV preoperative	33.49	5.87	0.035
	RV postoperative	32.41	6.03	
Pair 3	LA preoperative	52.02	9.91	0.165
	LA postoperative	51.20	8.62	
Pair 4	EF preoperative	51.29	8.51	0.0001
	EF postoperative	46,57	8,71	

LV left ventricle, LA left atrium, RV right ventricle, EF ejection fraction

Table II. Paired Samples Statistics to Compare the Difference Between the Pre- and Post-surgery parameter averages by type of Cardioplegia.

		Calafiore			Custodiol		
		Mean	**Std. Deviation**	**P value**	**Mean**	**Std. Deviation**	**P value**
Pair 1	LV preoperative	55.00	8.21	0.001	54.20	7.86	0.057
	LV postoperative	51.81	8.77		51.86	7.34	
Pair 2	RV preoperative	33.62	6.19	0.19	32.89	5.09	0.11
	RV postoperative	32.81	6.49		31.54	5.34	
Pair 3	LA preoperative	49.79	8.003	0.74	54.37	11.26	0.20
	LA postoperative	49.53	6.94		53.31	10.42	
Pair 4	EF preoperative	51.29	8.20	0.001	51.51	9.25	0.001
	EF postoperative	47.21	8.88		46.00	8.55	

LV left ventricle, LA left atrium, RV right ventricle, EF ejection fraction.

57.25min±2.80, (unpaired t-test with Welch's correction, p=0.70).

Initial EF values below or above 52% (the minimum normal value according to the American Society of Echocardiography and the European Association of Cardiovascular Imaging) are presented in Table III.

We observed that when the pre-operative EF was over 52%, EF decreased more than if the initial value was less than 52% and this difference was statistically significant. However, mean post-operative EF only reduced slightly.

A partial correlation analysis using the post-operative EF as the dependent variable, the ischemic time as the independent variable and pre-operative EF as a co-variate was performed. (Table IV). It was observed a statistically insignificant and negative correlation (p=0.770. r= -0.031).

Discussions

With chronic mitral insufficiency, the end-diastolic volume of the LV grows, which leads to the expansion of the mitral ring. There is, therefore, a vicious circle in which the mitral insufficiency aggravates the mitral insufficiency [7,8].

Table III. Paired Samples Statistics to Compare the Differences Between the Pre- and Post-surgery EF by initial value of EF. EF ejection fraction.

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**P value**
EF < 52%	EF preop.	45.75	40	6.37	0.18
	EF postop.	44.13	40	9.19	
EF >52%	EF preop.	57.79	43	3.66	0.0001
	EF postop.	50.70	43	4.95	

Table IV. Correlation between the ischemic time and preoperative/postoperative EF. Correlation is significant at the 0.01 level (2-tailed).

Correlations					
Control Variables			**Ischemic time**	**EF postop.**	**EF preop.**
-none-a	Ischemic time	Correlation	1	-0.031	-0.154
		P value	.	0.770	0.150
	EF postop.	Correlation	-0.031	1	0.659
		P value	0.770	.	0.001
	EF preop.	Correlation	-0.154	0.659	1
		P value	0.150	0.001	.
EF preop.	Ischemic time	Correlation	1	0.094	
		P value	.	0.383	
	EF postop.	Correlation	0.094	1	
		P value	0.383	.	

EF of the LV is maintained normal and symptoms are delayed because afterload drops through the presence of mitral regurgitation. This means that a slightly reduced EF (40–50%) apparent from ultrasound does not have a hemodynamic significance in the clinic, although there is a moderate decrease of contractility, for which the prognosis may become unfavorable post-surgery. For an EF under 30% pre-surgery, the prognosis post-surgery certainly becomes unfavorable [3,7].

The surgical intervention for fixing the mitral valvular lesion determines the reverse-remodeling of the left cavities of the heart, leading to improved heart performance, even if the EF of the LV drops post-surgery. The mitral valvular replacement leads to a decrease in the end-diastolic volume without a decrease in the end-systolic volume with improved afterload determined by a competent mitral valve [9].

According to a study that followed the ventricular response to surgery to the mitral valve, replacement or valvuloplasty and assessed the left ventricular and atrial diameters and EF, a reduction in the size of the left cavities was observed in the first year after surgery, with a decrease in EF immediately after surgery. After one year, the EF was slightly improved regardless of the surgical technique [10]. Similar short-term results can be found in the present study.

In our study, we observed a decreased size of the left ventricle after the mitral valvular replacement with mechanical prosthesis (p=0.003) or tissue valve (p=0.047) and respectively complex mitral valvuloplasty, but without the improvement of the ventricular systolic function post-surgery and a small statistically significant decrease in EF (p=0.0001). The long-term results are to be studied by our team.

According to data in the literature, the mitral valvuloplasty or the mitral valvular replacement is associated with an improvement in the size of the left cavities and a regression of left ventricular hypertrophy. In some patients, especially those with decreased EF post-surgery, ventricular systolic function may not improve immediately after surgical intervention [11].

In the study performed by Imasaka, which compared the effects of mitral valvuloplasty with mitral valvular replacement on left ventricular performance, no superior effect of mitral valvuloplasty was noticed compared to mitral valvular replacement with the partial preservation of cording in the immediate post-surgery period [12].

Instead, according to the study made by Tischler, a decrease in EF was observed after mitral valvular replacement. However, in the patients subjected to mitral valvuloplasty, the EF improved due to better preservation of the left ventricular geometry [13,14].

In our study, the left cavity diameters were reduced after cardiac surgery but also the EF dropped slightly.

Myocardial ischemia during cardiopulmonary bypass is recognized for its role in post-operative ventricular dysfunction. In addition to the inflammatory response caused by the extracorporeal circulation, in more than half of the cases, during cardiac arrest, areas of myocardial hibernation with reperfusion injury after aortic decompression are inevitable. In our study, a longer intraoperative ischemia time was associated with reduced post-operative EF but this finding was not statistically significant. Although myocardial ischemia during cardiopulmonary bypass affects post-operative ventricular function to a certain extent, factors such as cardiac injury due to extracorporeal circulation, surgical injury and pre-operative cardiac function status should be considered [11,15].

According to the study by Hoyer et al., which compared the efficiency of CCP with IWBC, no significant differences were found regarding myocardial protection in mitral surgery [16,17]. In the present study, the mean time of myocardial ischemia during the cardiopulmonary bypass was higher but statistically insignificant for the group receiving CCP than for those receiving IWBC: 58.74min±2.19. vs. 57.25min±2.80 (p=0.70). It does not seem to influence the evolution of the EF after mitral valve replacement, in line with data in the literature. The left cavity diameters decreased statistically significantly in patients where IWBC was used (p=0.001). The EF dropped regardless of the cardioplegia solution used (p=0.001).

Limits of our study: There might be an inter-observer variability regarding the echocardiography assessment. Another cause of bias might be the different experience of the cardiac surgeons who performed the operations.

Conclusions

After cardiac surgery for severe isolated mitral regurgitation, the dimensions of the left cavities decrease. The influence of surgery on the LVEF is multifactorial and very complex. Short-term following surgery, the EF decreases but further study is required to assess the long-term outcomes.

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Conflicts of interest

No declared conflicts.

Author contributions

OC performed the clinical investigations, as cardiologist, and drafted the manuscript.

OCo, SA and HM had a substantial contribution to conception, acquisition, and interpretation of data.

VS realized the statistical analysis in our study.

SH has revised critically for important intellectual content, contributed to manuscript drafting and allowed the final version of the paper. All authors approved the final version of the paper.

OC and SA have equal contribution to the paper.

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