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Right Ventricular Function in Surgical Treatment of Left Heart

Aim	The aim of this study was to evaluate right ventricular (RV) function during left chamber surgery.
Material and methods	This was a single-site prospective cohort study. The study included 197 patients with valvular pathology of heart left chambers. Mean age of patients was 58 [47; 65] years. Precordial echocardiography was performed preoperatively and within one week after surgery.
Results	Decreased parameters of the right ventricular (RV) longitudinal function and global contractile function were observed postoperatively in the majority of patients. More noticeable decreases were observed in parameters of the longitudinal function (p<0.001). Analysis of the changes in RV contractility depending on the underlying pathology revealed the greatest changes in the contractile function in the mitral insufficiency group. In the mitral stenosis group, the greatest difference was observed in the tricuspid annular systolic excursion (TAPSE) (p=0.027). In the groups with aortic defects, all parameters of RV contractile function, except for the fractional area change (FAC), showed statistically significant decreases after correction of the underlying defect (p<0.05).
Conclusions	Surgical intervention for left heart valvulopathy can result in a decrease in RV function unrelated with systolic deficit of the left ventricle. Modern technologies allow multi-vector assessment of the RV contractile function. To assess the RV function, it is advisable to use a combination of parameters that reflect both global and longitudinal function.

Keywords	Transthoracic echocardiography; right ventricular function; TAPSE; RV FAC; RV EF; RV-fwLS; left heart valvulopathy; cardiac surgery; valvular heart disease; aortic stenosis; aortic insufficiency; mitral stenosis; mitral regurgitation
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Introduction

Pulmonary hypertension (PH) caused by left heart disease is more common than other categories of PH according to the World Health Organization classification [1].

Despite the evidence of the association between elevated pulmonary artery pressure and right ventricular (RV) dysfunction [2, 3], PH may not be the only marker of RV performance [4]. Despite the potential reversibility of RV dysfunction after the elimination of the underlying disease, there is evidence that a considerable proportion of postoperative patients have RV dysfunction [5–8].

Therefore, the objective of this study was to analyze the echocardiography parameters of RV function in cardiac surgery patients with left heart valve disease at the perioperative stage, both in the heterogeneous cohort and depending on the underlying disease.

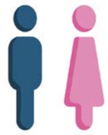
Material and methods

Study design and subject profile

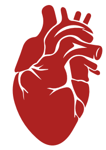
This study is a single-center prospective cohort study conducted at the Bakulev Scientific Center of Cardiovascular Surgery in 2022. The local ethics committee reviewed and approved the design of this study in accordance with the Declaration of Helsinki (Minutes No. 3/2022). All patients signed voluntary informed consent to be included in the study.

Patients were examined before and after cardiac surgery. Inclusion criteria were age over 18 years, presence of PH – pulmonary artery systolic pressure (PASP)≥30 mm Hg. Exclusion criteria were inadequate imaging that did not allow collecting data before and after surgery, history of cardiac surgery, combined mitral and aortic valve disease, coronary artery disease (history of myocardial infarction; revascularization, including endovascular revascularization), infective endocarditis, mini-invasive inter-

Central illustration. Right Ventricular Function in Surgical Treatment of Left Heart



- ✓ 197 patients without significant differences in the sex composition
- ✓ Median age 58 [47; 65] years



Underlying disease:

- ✓ MVI – 74 patients (37.6 %)
- ✓ AS – 71 patients (36 %)
- ✓ AVI – 35 patients (17.8 %)
- ✓ MS – 17 patients (8.6 %)

Analysis of the echocardiography parameters of RV function in cardiac surgery patients with left heart valve disease at the perioperative stage, both in the heterogeneous cohort and depending on the underlying disease.

RESULTS

- ✓ In the postoperative period, TAPSE (2D)↓ indicators were detected in 95.4% (n=188) of patients, FW LS RV (2D Ste) in 84.3% (n=166), FAC RV (2D) and EF RV (3D) in 62.4% (n=123).
- ✓ With the exception of FAC RV (2D), all indicators showed a statistically significant ↓ in the aortic malformation groups.
- ✓ In the MS group, TAPSE (2D) had the greatest differences.
- ✓ The analysis showed statistically significant changes in all RV contractile function indicators of interest in the MVI group in the early postoperative period.
- ✓ The analysis of the relationship between baseline LVEF and changes in the RV functional parameters in a heterogeneous cohort of patients showed that no RV contractile function parameter had a statistically significant dependence on the LV contractility

MVI, mitral valve insufficiency; AS, aortic stenosis; AVI, aortic valve insufficiency; MS, mitral stenosis; RV, right ventricle; TAPSE, tricuspid annular plane systolic excursion; FW LS RV, right ventricular free wall longitudinal strain; FAC RV, right ventricular fractional area change; EF RV, right ventricular ejection fraction; PASP, pulmonary artery systolic pressure; LVEF, left ventricular ejection fraction.

ventions, organic right heart disease, severe chest wall deformity. The chosen surgical technique for cardiac valve surgery was not an exclusion criterion. The final analysis included 197 patients.

Echocardiogram analysis

Patients underwent precordial echocardiography before surgery and within 1 week after surgery using the PHILIPS EPIQ CVx ultrasound system and the X5–1 transducer. All echocardiographic examinations were performed by two cardiac radiologists experienced in evaluating cardiac surgery patients. Quantitative measurements were made in accordance with the 2015 ASE/EACVI guidelines [9]. Volumetric and functional parameters of the left ventricle (LV) were analyzed using the Simpson biplane method.

The peak tricuspid regurgitation (TR) velocity was measured in the continuous-wave Doppler mode in the apical four-chamber view (A4C). TR flow was ranked as insignificant, moderately severe, and severe. PASP was calculated by adding the right atrial pressure to the peak TR velocity. The diameter and inspiratory collapse of the inferior vena cava was measured in the subcostal view. The estimated right atrial pressure was 5–20 mm Hg depending on the combination of parameters [10].

Quantitative echocardiographic analysis of the right ventricle

The following echocardiography parameters were used to assess the RV function: FAC RV (2D), TAPSE (2D), FW LS RV (2D STE), EF RV (3D).

Tricuspid annular plane systolic excursion (TAPSE) was calculated as the systolic amplitude of the lateral tricuspid annulus (M-mode).

Right ventricular fractional area change (FAC RV) was calculated by the formula:

$$\text{FAC RV (\%)} = (\text{EDA RV} - \text{ESA RV}/\text{EDA RV}) \times 100\%,$$

where EDA RV is right ventricular end-diastolic area and ESA RV is right ventricular end-systolic area.

Automatic 3D RV segmentation provides primary image alignment and contouring with the possibility of manual corrections. Volumetric data were calculated based on a dynamic surface model and used to calculate right ventricular end-diastolic volume (EDV RV), right ventricular end-systolic volume (ESV RV) and their indexes, right ventricular ejection fraction (EF RV), and right ventricular stroke volume (SV RV).

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Table 1. Characteristics of cardiac surgery patients included in the study

Parameters		Before surgery
Age, Me [IQR], full years		58 [47; 65]
Sex:	– Male, n (%)	107 (54.3)
	– Female, n (%)	90 (45.7)
BSA, Me [IQR], m^2		1.92 [1.80; 2.05]
BMI, Me [IQR], kg/m^2		26.1 [23.7; 29.7]
Heart rhythm at admission:	– Sinus, n (%)	166 (84.3)
	– AF, n (%)	31 (15.7)
Underlying disease		
Aortic stenosis, n (%)		71 (36.0)
Aortic valve insufficiency, n (%)		35 (17.8)
Mitral stenosis, n (%)		17 (8.6)
Mitral valve insufficiency, n (%)		74 (37.6)
Comorbidities		
COPD, n (%)		25 (12.7)
Bronchial asthma, n (%)		4 (2.0)
Diabetes mellitus, n (%)		9 (4.6)
Chronic kidney disease, n (%)		6 (3.0)
History of CVA, n (%)		3 (1.5)
Varicose veins of lower extremities, n (%)		43 (21.8)
Cervical atherosclerosis, n (%)		34 (17.3)
Arterial hypertension	Grade I, n (%)	4 (2.0)
	Grade II, n (%)	32 (16.2)
	Grade III, n (%)	80 (40.6)
CHF grade 2a, n (%)		189 (95.9)
CHF grade 2b, n (%)		8 (4.1)
CHF class II (NYHA), n (%)		52 (26.4)
CHF class III (NYHA), n (%)		138 (70.1)
CHF class IV (NYHA), n (%)		7 (3.6)
EuroScore II, Me [IQR], %		1 [1; 2]

HR, heart rate; BP, blood pressure; AF, atrial fibrillation; BSA, body surface area; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; NYHA, New York Heart Association.

The RV longitudinal strain was quantified in AutoStrain. When the RV endocardial border was automatically placed, the correct placement and tracking of the borders was verified. Borders could be edited manually if necessary. Automatic speckle tracking was performed throughout the cardiac cycle. Right ventricular free wall longitudinal strain (FW LS RV) was expressed as absolute values [9].

Statistical analysis

Statistical analysis was performed in SPSS Statistics v. 26 (IBM Corporation, USA) and StatTech v. 2.8.8 (OOO Stattekh, Russian Federation).

Quantitative indicators were evaluated for normal distribution using the Shapiro-Wilk test (if less than 50 subjects) or the Kolmogorov-Smirnov test (if more than 50 subjects). Non-normally distributed quantitative data were described using the medians (Me) and the lower and upper quartiles [Q1 – Q3]. The categorical data were expressed by the absolute values and percentages.

Two groups were compared by a non-normally distributed quantitative indicator using the Mann-Whitney U-test.

Three or more groups were compared by a non-normally distributed quantitative indicator using the Kruskal-Wallis test, and post-hoc comparisons were performed using Dunn's test with Holm correction.

Non-normally distributed quantitative indicators were compared in two dependent groups using the Wilcoxon test.

The relationship between the two quantitative indicators was assessed using a correlation analysis with the calculation of Spearman's rank correlation coefficient ρ, and the closeness of the relationship was evaluated by the Chaddock scale. The differences or relationship were statistically significant with $p<0.05$.

Results

The study included 197 patients with median age of 58 [47; 65] years and had no significant difference in sex composition. Mitral valve insufficiency (MVI) and aortic stenosis (AS) prevailed in the structure of the underlying diseases of the left heart. Main patient characteristics are provided in Table 1.

Surgical technique

Conventional complete median sternotomy was conducted in all patients and was followed by aortic bicaval cannulation. A cardioplegic solution was administered after starting cardiopulmonary bypass and clamping the aorta. Antegrade, retrograde, and combined cardioplegia was used in 54.8%, 1.5%, and 43.7% of cases, respectively. Custodiol solution was used in all cases to protect the myocardium. There were no significant differences between patients in the amount of cardioplegic solution administered. The median temperature was 30 [28; 30] °C. The median duration of cardiopulmonary bypass was 142 [120; 166] min. The median duration of aortic clamping was 92 [78; 116] min.

106 and 91 surgeries were performed for aortic malformation and mitral malformation, respectively. De Vega annuloplasty was performed on the tricuspid valve in all cases. Surgical parameters are described in Table 2.

Echocardiogram analysis

The analysis of TAPSE (2D), FW LS RV (2D STE), EF RV (3D), and FAC RV (2D) in the general patient cohort before and after surgery showed statistically significant changes ($p<0.001$) (Table 3, Figure 1, and Figure 2).

Echocardiographic data of various perioperative stages are presented in Table 3.

Figure 1 and Figure 2 show changes in global and longitudinal RV functional indicators before surgery and in the early postoperative period. The vast majority of patients had deterioration of the RV longitudinal function after surgical treatment. Decrease in TAPSE (2D) was observed in 95.4% (n=188) of patients and FW LS RV (2D STE) in 84.3% (n=166) of patients. There was reduction in parameters of the RV global contractile function FAC RV (2D) and EF RV (3D) – in 62.4% (n=123) of patients in both cases.

We analyzed changes in the indicators of RV contractility depending on the underlying disease. With the exception of FAC RV (2D), all indicators showed a statistically significant decrease in the aortic malformation groups (Table 4, 5) after the correction of the leading defect. The RV longitudinal function showed a more pronounced decrease ($p<0.001$).

In the mitral stenosis (MS) group, TAPSE (2D) had the greatest differences (Table 6). The remaining parameters showed no statistically significant differences.

The analysis showed statistically significant changes in all indicators of the RV contractile function in the MVI group

Table 2. Intraoperative characteristics

Surgical technique		n (%)
Aortic valve replacement		77 (39.1)
Bentall-de Bono		16 (8.1)
Ozaki		7 (3.6)
Manouguian-Seybold-Epting		4 (2.0)
David V		2 (1.0)
Supracoronary replacement of the ascending aorta		12 (6.1)
Robicsek reduction ascending aortoplasty		2 (1.0)
Morrow myoectomy		5 (2.5)
Mitral valvuloplasty		48 (24.4)
Mitral valve replacement		43 (21.8)
De Vega tricuspid valve annuloplasty		197 (100.0)
Left atrial appendage closure		2 (1.0)
Patent foramen ovale closure		4 (2.0)
Cardioplegia		
Custodiol solution cardioplegia	– Antegrade	108 (54.8)
	– Retrograde	3 (1.5)
	– Combined	86 (43.7)
Surgical parameters		Me [IQR]
Duration of cardiopulmonary bypass, min		142 [120; 166]
Duration of aortic clamping, min		92 [78; 116]
Body temperature, °C		30 [28; 30]

Figure 1. Analysis of changes in the global right ventricular contractile function.
A – right ventricle wall motion in the transverse plane,
B – FAC RV (2D), C – EF RV (3D)

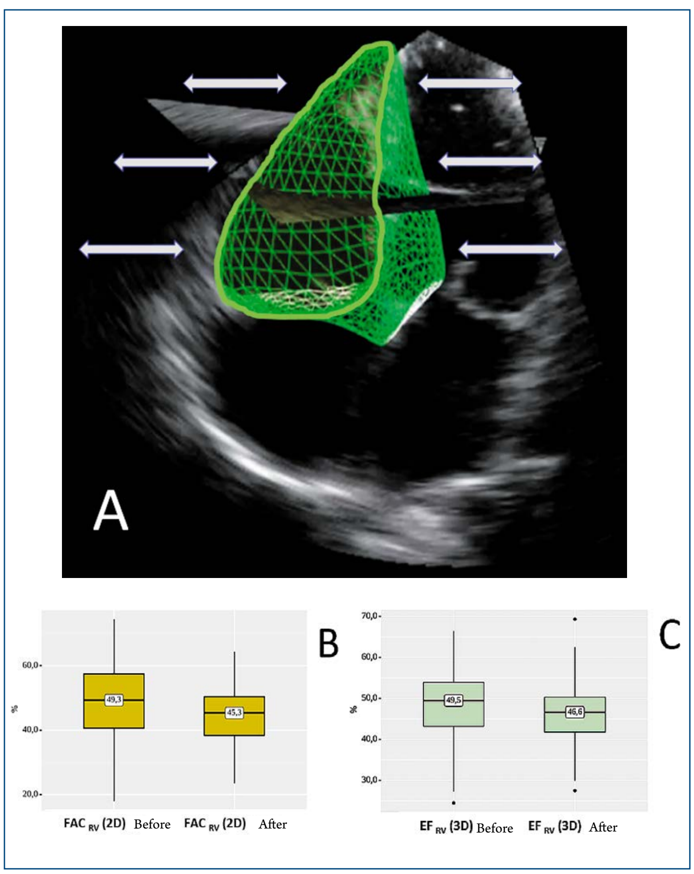
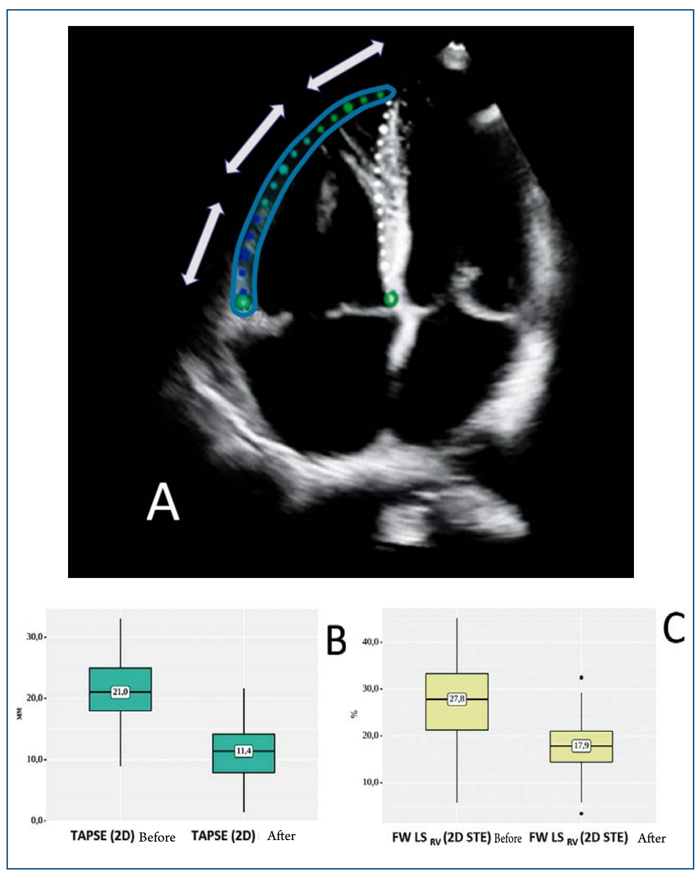


Figure 2. Analysis of changes in the longitudinal right ventricular contractile function.
A – right ventricle wall motion in the longitudinal plane,
B – TAPSE (2D), C – FW LS RV (2D STE)



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(Table 7); of note is that this group was most numerous (n=74).

According to the data obtained, the smallest changes in the RV contractile function parameters were observed in the MS group. Figure 3 shows that preoperative PASP was highest in the MS group. Differences in baseline PASP depending on the pathology were statistically significant ($p<0.001$). Posterior comparisons showed that PASP for were statistically significantly higher in MS and MVI (median values 55 [42– 57] mm Hg and 44 [38–53] mm Hg, respectively) than in AS and AVI (median values 37 [33–44] mm Hg and 35 [32.5–39] mm Hg, respectively).

The relationship between baseline LVEF and changes in the RV functional parameters was then studied in a heterogeneous cohort of patients (Table 8). As shown in the table, no parameter of the RV contractile function had a statistically significant relationship with the LV contractile function.

Discussion

Various factors can influence the development of intra-operative RV dysfunction: hypothermia, duration, and injury of the operation, hypoperfusion, etc. Several hypotheses were proposed, for example, inadequate protection of the RV myocardium during cardiopulmonary bypass that cause intraoperative ischemia and a decrease in the longitudinal RV function. The longitudinal RV function can also be affected by extra-myocardial factors, such as geometric changes in the RV after tricuspid valve surgery, paradoxical movement of the interventricular septum, or loss of pericardial support [11]. Decreased RV function can also be observed in patients after off-pump cardiac surgery [12], which does not allow distinguishing the etiological priority of the RV dysfunction.

Moreover, cardiopulmonary bypass surgery worsens the initial RV contraction pattern and may further predispose to the development of open dysfunction, which clinically manifests as RV insufficiency [13, 14]. We should keep in mind, that the preoperative functional reserve of the RV contractile function can also contribute to the development of postoperative dysfunction [15].

Decreased echocardiographic longitudinal indicators (TAPSE and RV S′) is a well-known phenomenon after cardiac surgery, although the correlation with decreased RV performance is still controversial [5, 7, 16, 17]. According to Maffessanti et al. [11], there is a significant postoperative decrease in the RV free wall strain and LV septal strain after MV repair. Other studies also reported similar RV dysfunction after various types of surgeries [14, 16]. At the same time, the decrease in the RV strain function was associated neither with the duration of aortic clamping and cardiopulmonary bypass, the duration of surgery, mechanical ventilation, nor duration of hospital stay, nor PH or LVEF [18].

Figure 3. Preoperative echocardiographic values of pulmonary artery systolic pressure depending on the underlying disease

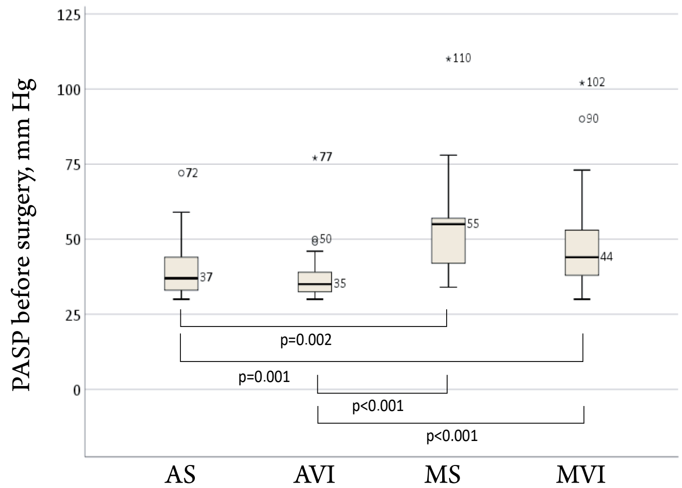

Table 3. Comparison of pre-operational and postoperational echocardiographic data

Parameter, Me [IQR]	Stages		p
	Before surgery	After surgery	
LAVI (2D), mL/m²	35.6 [25.6; 49.3]	32.8 [22.6; 43.7]	0.048*
RAVI (2D), mL/m²	22.6 [17.0; 34.3]	22.4 [16.5; 32.3]	0.108
RVEDD, basal, mm	42.1 [36.7; 47.0]	39.2 [35.9; 45.3]	0.061
RVEDD, middle, mm	37.8 [32.2; 42.1]	35.8 [31.8; 40.6]	0.158
RV longitudinal dimension, mm	75.8 [66.8; 86.2]	76.3 [68.7; 83.2]	0.423
EDI LV (2D), mL/m²	67.6 [52.2; 83.3]	51.0 [42.0; 68.0]	<0.001*
ESI LV (2D), mL/m²	26.0 [19.8; 35.7]	24.5 [19.8; 32.2]	0.538
EF LV (2D), %	65.0 [56.2; 68.0]	56.5 [50.0; 65.0]	0.002*
FAC RV (2D), %	49.3 [40.5; 57.3]	45.3 [38.4; 50.3]	< 0.001*
EF RV (3D), %	49.5 [43.2; 53.9]	46.6 [41.8; 50.3]	< 0.001*
TAPSE (2D), mm	21.0 [18.1; 25.1]	11.4 [7.9; 14.2]	< 0.001*
FW LS RV (2D STE), %	27.8 [21.2; 33.3]	17.9 [14.4; 21.0]	< 0.001*
RV systolic pressure, mm Hg	41 [35; 51]	35 [30; 40]	< 0.001*

LAVI, left atrial volume index; RAVI, right atrial volume index; RVEDD, right ventricular end-diastolic dimension; EDI LV, left ventricular end-diastolic dimension index; ESI LV, left ventricular end-systolic dimension index; EF LV, left ventricular ejection fraction; FAC RV, right ventricular area fractional change; EF RV, right ventricular ejection fraction; TAPSE, tricuspid annular plane systolic excursion; FW LS RV, right ventricular free wall longitudinal strain. * Statistically significant differences ($p<0.05$).

Table 4. Analysis of changes in the contractile function parameters in the aortic stenosis group

Category	Stages		Difference, Me [IQR]	$p_{before-after}$
	Before surgery, Me [IQR]	After surgery, Me [IQR]		
FAC RV (2D), %	49.5 [41.0; 58.2]	47.0 [39.1; 50.1]	-3.2 [-14.0; 4.8]	0.058
EF RV (3D), %	49.3 [43.4; 53.6]	46.5 [40.0; 49.8]	-2.8 [-10.5; 3.1]	0.050*
TAPSE (2D), mm	20.0 [18.0; 21.1]	13.0 [9.2; 15.3]	-8.5 [-10.6; -4.7]	< 0.001*
FW LS RV (2D STE), %	27.0 [21.8; 32.7]	17.9 [14.6; 21.0]	-9.6 [-13.7; -3.8]	< 0.001*

* Statistically significant differences (p<0.05).

Table 5. Analysis of changes in the contractile function parameters in the aortic valve insufficiency group

Category	Stages		Difference, Me [IQR]	$p_{before-after}$
	Before surgery, Me [IQR]	After surgery, Me [IQR]		
FAC RV (2D), %	46.7 [38.9; 56.4]	40.9 [35.9; 50.7]	-7.0 [-13.3; 2.1]	0.063
EF RV (3D), %	53.0 [46.5; 54.6]	45.5 [40.8; 48.5]	-5.9 [-13.8; 1.1]	0.007*
TAPSE (2D), mm	23.1 [20.5; 24.5]	9.5 [6.1; 12.7]	-12.5 [-16.6; -7.3]	< 0.001*
FW LS RV (2D STE), %	30.1 [22.5; 33.7]	18.2 [14.5; 21.1]	-12.2 [-16.6; -5.3]	< 0.001*

* Statistically significant differences (p<0.05).

Table 6. Analysis of changes in the contractile function parameters in the mitral stenosis group

Category	Stages		Difference, Me [IQR]	$p_{before-after}$
	Before surgery, Me [IQR]	After surgery, Me [IQR]		
FAC RV (2D), %	48.6 [43.1; 50.9]	49.6 [43.6; 53.5]	-0.5 [-3.0; 5.1]	0.898
EF RV (3D), %	45.6 [41.0; 48.4]	48.6 [47.0; 52.5]	3.0 [0.0; 8.9]	0.123
TAPSE (2D), mm	18.2 [16.2; 19.0]	13.9 [10.9; 15.0]	-4.3 [-7.0; -1.4]	0.027*
FW LS RV (2D STE), %	23.4 [19.6; 28.2]	19.3 [16.7; 22.1]	-3.2 [-8.7; -2.3]	0.092

* Statistically significant differences (p<0.05).

Table 7. Analysis of changes in the contractile function parameters in the mitral valve insufficiency group

Category	Stages		Difference, Me [IQR]	$p_{before-after}$
	Before surgery, Me [IQR]	After surgery, Me [IQR]		
FAC RV (2D), %	50.4 [42.9; 58.3]	43.2 [38.5; 49.2]	-8.4 [-13.4; 2.9]	0.003*
EF RV (3D), %	50.9 [43.1; 54.1]	46.8 [42.3; 51.2]	-4.0 [-9.6; 2.1]	0.003*
TAPSE (2D), mm	24.0 [21.1; 26.2]	11.2 [6.4; 13.9]	-12.2 [-15.0; -9.3]	< 0.001*
FW LS RV (2D STE), %	28.7 [22.8; 33.6]	16.2 [14.3; 20.7]	-8.4 [-16.4; -5.2]	< 0.001*

* Statistically significant differences (p<0.05).

However, decreased RV function may be observed in patients after cardiac surgery without conventional sternotomy. A retrospective study (n=158) conducted by Orde et al. (2020) demonstrated a significant decrease in the RV function after MV surgery by a minimally invasive technique (Da Vinci) and an open-heart technique [18]. There was a significant postoperative decrease in the RV systolic function (STE method) in both the robotic surgery group and the open MV repair group: FW LS RV 22.2±7% to 16.2±6% and 23.5±8% to 13.4±5% (p<0.001 for both). A gradual functional recovery of the RV was demonstrated during the first year after MV surgery, but the parameters never reached the preoperative levels. In is still unclear whether this RV dysfunction is transient or may become irreversible. As noted by Bootsma et al. (2017), reduced RV systolic function can persist for a long time after cardiac surgery, and it can expectedly be a strong independent long-term predictor of mortality [19]. Therefore, identifying patients at risk of developing postoperative RV dysfunction would allow performing more thorough perioperative monitoring or even preventive drug treatment [20].

Table 8. Results of the correlation analysis of the relationship between the baseline LVEF and changes in of the RV contractile function parameters

Difference between RV parameters	Correlation parameters, Spearman's ρ	p
	LVEF	
FAC_{RV}	-0.121	0.25
EF_{RV}	-0.192	0.064
TAPSE	-0.105	0.442
$FW\ LS_{RV}$	-0.025	0.797

LVEF, left ventricular ejection fraction; RV, right ventricle.

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Moreover, according to Rong et al. (2019) [6], the assessment of the detected intraoperative RV dysfunction (in 38% of patients) showed no differences in baseline volumetric characteristics and LVEF. Interestingly, systolic RV deficiency is not always correlated with a similar LV function loss [11]. We studied the correlations between changes in the parameters of the RV contractile function and baseline LVEF. According to our data, there was no statistically significant relationship with LV contractile function. This finding supports the idea that intraoperative RV dysfunction can develop regardless of LV performance. At the same time, intraoperative or postoperative RV dysfunction can develop into a complicated clinical case leading to longer stay in the intensive care unit, the use of more medical resources, and increased mortality [19, 21–23].

According to the results of our comparative analysis of the dependent variables, the parameters of the RV longitudinal function had the greatest differences. Decreased longitudinal function TAPSE (2D) resulting from surgical treatment was found in the vast majority of patients (95.4%). Another indicator characterizing the RV longitudinal function (FW LS RV) also showed a decrease in 84.3% after surgery. Reduced global RV function (FAC RV and EF RV) was less frequent after valve repair – in 62.4% in both cases. This is probably due to its decrease after surgery, but with greater preservation of radial function, which is partially reflected by the indicators of the global RV function. At the same time, many researchers also noted changes in longitudinal indicators with preserved global RV function [20, 24–26].

The more pronounced decrease in the parameters of the longitudinal RV function, especially TAPSE, shown in or study may be due to a change in the basal RV geometry caused by the restricted systolic excursion of the tricuspid annulus after suture annuloplasty. A less pronounced effect on the radial function may be due to the elimination of volumetric overload of the heart after the correction of the underlying disease, except for MS.

There is no universal parameter that correctly reflects the RV function [27], which is why it is advisable to use a combination of parameters, for example, TAPSE and FAC RV, to describe the RV function, which allows simultaneously assessing such multidirectional characteristics as longitudinal or transverse RV contraction [28, 29].

The right ventricle is overloaded in the increased pulmonary artery pressure due to the high chamber compliance [5], which often leads to structural and functional deterioration and reduced contractility of the RV. It is generally accepted that PH is the main and most common cause of RV dysfunction in patients with heart valve disease [4, 22], but the relationship of these phenomena is not always linear. For example, pulmonary artery pressure may decrease when RV dysfunction progresses [22].

Hyllén et al. (2014) observed a postoperative decrease in global RV strain only in patients with high PH (42% of patients with PASP > 50 mm Hg) [3], the RV strain characteristics did not change in patients with PASP<50 mm Hg. The authors suggested that elevated PASP had a negative effect on the RV functional state and the reversibility of abnormalities was due to the regression of PH following surgical repair of mitral malformation. Hyllén et al. also showed that 61% of patients had postoperative RV dysfunction shown by STE 6 months after MV repair.

According to our data, the smallest perioperative differences in the parameters of the RV contractile function were observed in the MS group despite the highest baseline PASP values. The highest potential for reversibility of the RV functional changes can be suggested in these patients.

Moreover, MS is the least prevalent valve malformation worldwide, which makes our experience unique.

Patients with mitral or aortic incompetence mostly have normal LV contractile function in the preoperative period, which to a certain extent may be due to volumetric overload of the LV with the present shunt, thus leading to an artificial increase in LVEF. Underestimation of systolic dysfunction does not allow correctly stratifying the risk of postoperative heart failure. The greatest postoperative changes in the parameters of the systolic RV function were observed in groups with left heart valve insufficiency (MVI, AVI). The RV functional parameters possibly may be the indicators of LV systolic dysfunction in these patient groups despite normal baseline LVEF.

Limitations

First, this is a single-center, non-randomized study. Second, the pathology was heterogeneous. It should be noted that the majority of surgeries were performed in patients with AS or MVI, and MS was the smallest group (n=17).

Moreover, patients with coronary artery disease and active infective endocarditis were excluded due to the possible negative effect on the RV myocardium (toxic, ischemic). Thus, the inclusion of such patients in the study may change the final results.

Also, the analysis of dependent variables included only patients with data available for all stages of follow-up. If there is a technical possibility of intraoperative assessment of the RV function and examination of patients on mechanical ventilation, other results could be expected, which may be more indicative.

The follow-up period covering only the perioperative stage is also a limitation of the study. It is necessary to increase the duration of the study to verify the trends in later follow-up periods.

The above comparisons should be interpreted given the presence of PH in patients undergoing surgeries for left heart valve diseases.

Assessment of the RV contractility is complicated, as well as by its anatomical features, by the pronounced dependence of the data obtained on afterload and preload, sensitivity to changes in the inotropic state, and dependence on the heart dimensions. Despite these limitations, a comprehensive assessment of the RV can be an additional information resource regarding the patient's condition after surgery.

Conclusion

Surgical intervention for left heart valve disease is associated with a significant – but transient in some cases – decrease in the RV function. It is not possible to prioritize the causes given the complex interactions of extramyocardial and intramyocardial factors, which determine the RV function. Moreover, the versatility of RV dysfunction mechanisms does not allow relying solely on generally recognized indicators of dysfunction, such as PH and/or tricuspid insufficiency. Modern technologies give an opportunity to assess the RV contractile function and can affect the outcomes in routine practice, which undoubtedly requires further research. It is advisable to use a combination of parameters, for example, TAPSE and FAC RV, to describe the RV function, which allows simultaneously assessing such multidirectional characteristics as longitudinal or transverse RV contraction.

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