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Enhanced Cardiac Reverse Remodeling after Pulmonary Artery Denervation Combined with Mitral and Maze Surgery

Trofimov NA*; Nikolskiy AV; Rodionov AL; Egorov DV; Surkova TV

Chuvash State University, 15 Moskovskiy Prospekt, 428015 Cheboksary, Russia.

Abstract

Background: The study evaluates the effectiveness of cardiac reverse remodeling in patients after surgical treatment of high pulmonary hypertension (PH) in patients with mitral valve disease and Atrial Fibrillation (AF).

Methods: An analysis of the surgical treatment of 202 patients with mitral valve disease complicated by PH (with more than 40 mmHg) and AF was performed. Surgical intervention consisted in surgical correction of mitral dysfunction (valve replacement or repair) – the first group of patients (n = 62). In patients of the second group (n = 89), the Maze IV procedure was additionally performed due to concomitant AF using the AtriCure bipolar radiofrequency ablator. Patients of the third group (n = 51) underwent a comprehensive surgical intervention consisting in the mitral valve intervention, Maze IV surgical correction of AF, and circular radiofrequency denervation of the trunk and orifices of bilateral pulmonary arteries (Pulmonary Artery Denervation - PADN).

Results: PADN can significantly reduce the level of PH in the postoperative period ($p\chi 2 = 0.018$ compared to the other groups) and promotes reverse remodeling by reduction in cardiac cavities. Complex surgical correction of patients with mitral dysfunction, AF, and high PH can significantly reduce heart failure ($p\chi 2 = 0.023$ compared to the group without PADN).

Conclusion: The circular PADN procedure is effective and safe. Further analysis of the PADN effectiveness with grouping of a larger number of patients, analysis of long-term results, as well as determining the feasibility of this technique in patients with non-valve forms of PH is necessary.

Keywords: Secondary pulmonary hypertension; Pulmonary arteries denervation; Mitral valve disease; Atrial fibrillation.

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Correspondance: *Trofimov NA, Chuvash State University, 15 Moskovskiy Prospekt, 428015 Cheboksary, Russia.*

Tel: +7-903-3227950; Email: nikolai.trofimov@mail.ru

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Introduction

Increased pressure in the pulmonary circulation in patients with damage to the valvular apparatus of the heart reduces the effectiveness of surgical intervention, reduces the topic of postoperative reverse remodeling of the cardiac cavities, and also increases the risk of recurrence of AF after radiofrequency atrial ablation according to the Maze IV scheme [1]. The feasibility of correcting PH was discussed in S. Briongos Figuero et al., Where it was demonstrated that a preoperative high degree of PH is closely correlated with the preservation of PH even after surgical treatment of mitral valve disease (odds ratio 1.761; p = 0.03) [2].

The location of the sympathetic nerve plexuses in the adventitia of the trunk and the orifices of the pulmonary arteries responsible for spasm of the pulmonary arterioles and an increase in PH was first reported in the works of J. Osorio in 1962 [3]. These data were subsequently confirmed in B.G. Baylenet. al. [4] and C.E. Juratschet. al. [5].

Currently, conservative treatment of high PH does not allow for a steady decrease in pressure in the pulmonary circulation, and associated with the use of expensive drugs [6].

The first surgical interventions for high PH were first proposed by S.L. Chen in 2013, in the form of endovascular catheter ablation of the trunk and the orifices of the pulmonary arteries, which, according to the authors, allowed to significantly reduce the pressure in the pulmonary artery [7].

In recent years, several works on the surgical correction of PH in patients with mitral dysfunction during extracorporeal circulation, simultaneously with surgical treatment of mitral disease, have been presented. A technique was proposed for radiofrequency ablation of the anterior wall of the trunk and the mouths of the pulmonary arteries using a monopolar electrode. Also currently used is the method of circular radiofrequency denervation of the pulmonary arteries using a bipolar RF clamps [8,9]. Despite the existing correction methods of PH, the problem of surgical treatment of high secondary PH is the most urgent, since there is no generally accepted algorithm for treating this pathology, further investigation of the problem with finding the optimal surgical technique for this category of patients is necessary.

Patients and methods

During the research work, an analysis of the surgical treatment of 202 patients with mitral valve disease complicated by high PH (mean pulmonary arterial pressure (mPAP) is more than 40 mmHg) and AF was performed. Patients underwent surgical correction of mitral valve disease – valve replacement or valve repair – the first group of patients (n = 62). In patients of the second group (n = 89), mitral valve disease correction was also performed, as well as the Maze IV procedure was performed in connection with concomitant AF using the AtriCure bipolar radiofrequency ablator. Patients of the third group (n = 51) underwent a comprehensive surgical intervention consisting in the mitral valve intervention, surgical correction of AF in the form of the Maze IV procedure, and circular PADN was performed. Inclusion criteria was mitral valve disease complicated by AF and high secondary PH. Exclusion criteria were history of pulmonary embolism, hemodynamically significant coronary artery lesions. The study has been approved by local ethical committee, register number 10/D-2019 from 05.26.2019. All the studied patients before the operation, without fail, were informed about the upcoming additional procedure PADN, which was planned to be performed with the main stage of surgical correction, signed informed voluntary, according to the principles of clinical practice (Good Clinical Practice - GCP), in accordance with the Helsinki Declaration.

Patients of all study groups were comparable for the main clinical and instrumental parameters (Table 1).

The presented data characterize patients of the 3rd group as more severe in age, EUROSCORE, left ventricle contractility, dilatation of the left ventricle and the right heart, and the severity of PH.

The PADN procedure was performed circularly with AtriCure's Isolator Synergy Bipolar Radiofrequency Clamps. After mobilization of the pulmonary trunk and orifices of bilateral pulmonary arteries, in conditions of beating heart with the concomitant use of cardiopulmonary bypass, 2 ablative circular lines were applied to the distal part of the pulmonary trunk, each line consisted of 3 applications (Figure 1A).

Later, the orifices of the right pulmonary artery were isolated and similar circular ablation lines were applied (Figure 1B).

In some cases, the isolation of the right pulmonary artery was performed through the subaortic access, to the right of the aorta, in the transverse sinus of the heart. Similarly, circular denervation was performed in the area of the orifice of the left pulmonary artery (Figure 1C).

Procedure in the final represents 6 ablation lines, 2 at the level of the distal part of the pulmonary trunk and 2 at the orifices of bilateral pulmonary arteries (Figure 1D).

Mean overall PADN procedure time was 5.5 minutes. After radiofrequency denervation of the pulmonary arteries antegrade custodiole cardioplegia was performed into the aortic root and, after the cardiac arrest, the main stage of the operation was performed - correction of valvular heart dysfunction and the Maze IV procedure. Mean overall aortic cross-clamp time was 85.2 minutes, cardiopulmonary bypass time was 114.1 minutes. Patients stayed in the intensive care unit for an average 2.4 days. Postoperative management of patients of the Denervation group did not differ from the management of patients in the others ones. All patients were followed with periodic visits through ECHO control in 3, 6, 12, 24 months after surgery.

Statistical processing of the results was carried out in the program "SPSS Statistics 26". Quantitative data were described as mean and standard deviation ($M \pm \sigma$), in the absence of a normal distribution, or rank data as the median and upper and lower quartiles - Me (Q1-Q3).

The statistical significance of the differences for the quantitative data in the normal distribution was estimated by the Student t-test, and in the absence of a normal distribution and for rank data, it was evaluated by the Mann–Whitney U-test. Normality of distribution was checked by the Shapiro-Wilk test. For qualitative data (relative values), the differences were evaluated using the Pearson's chi-squared test ($\chi 2$). If the number of observations, at least in one of the fields of Table 2, was less than 5, the calculation was performed using the Fisher's exact test.

If it was necessary to compare 3 groups at the same time, the Kruskal-Wallis test (for quantitative and rank data) and the chi-squared test (for qualitative data) were used. Error probability (p) was considered acceptable at $p < 0.05$. With the successive repeated application of the statistical criteria of Student, chi-square and Mann-Whitney (alternately comparing the groups among themselves), the probability of detecting differences, where there are none, increases by N times. Therefore, in the triple sequential comparison of the groups, the Bonferroni correction was used, an acceptable significance level (p) was calculated as $p = 0.05/n$, where $n = 3$, i.e., 0.0167.

The statistical significance of the dynamic differences was calculated for quantitative data by the Wilcoxon sign test, for qualitative data by the McNemar test with Yates correction. The statistical analysis was guided by the recommendations of Stanton A. Glantz [27].

Results

Fatal outcomes among patients occurred one in each group and were caused by acute progressive heart failure on the first day after surgery. There were no postoperative complications associated with the PADN procedure. According to the data of transthoracic ECHO, all patients showed improvement in the postoperative period (Table 2). There was no significant decrease in AF frequency only in group 1.

Since the main criteria for evaluating the effectiveness of treatment is the achievement of target indicators, the final results in the study groups are analyzed in the form of a share of the achieved indicators.

For indicators of ECHO, the range of normal values were taken (Table 3).

The table shows that with comparable initial indicators, the achievement of the target indicators in group 3 is significantly better, including in comparison with group 2, even taking into account the Bonferoni correction. Positive changing according to the McNemar criterion was noted for almost all indicators in groups 2 and 3. Group 1 did not achieve a statistically significant improvement in the sizes of LA and RA, normalization of mPAP, restoration of sinus rhythm.

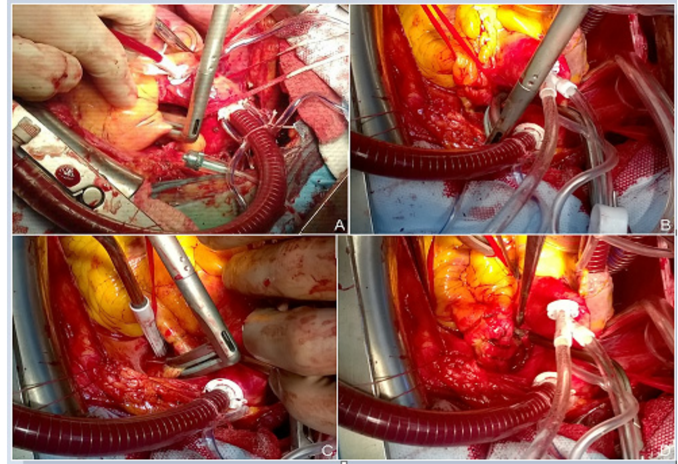

Figure 1: (A): Circular ablation of the pulmonary trunk. **(B):** Ablation of the orifice of the right pulmonary artery. **(C):** Ablation of the orifice of the left pulmonary artery. **(D):** The final view of the circular PADN procedure.

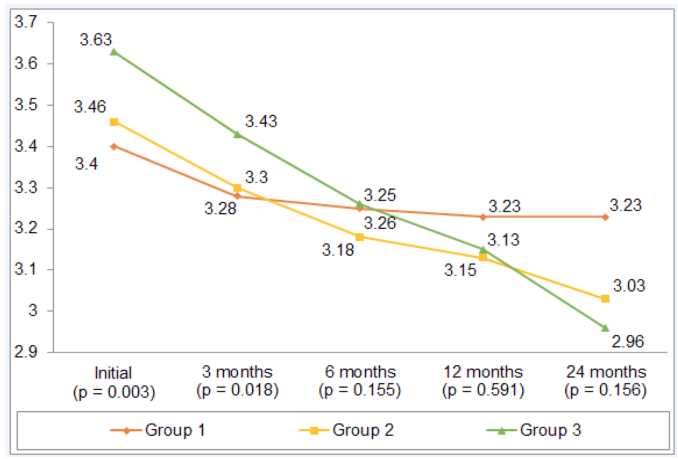

Figure 2: Dynamics of pulmonary hypertension in patients of the studied groups.

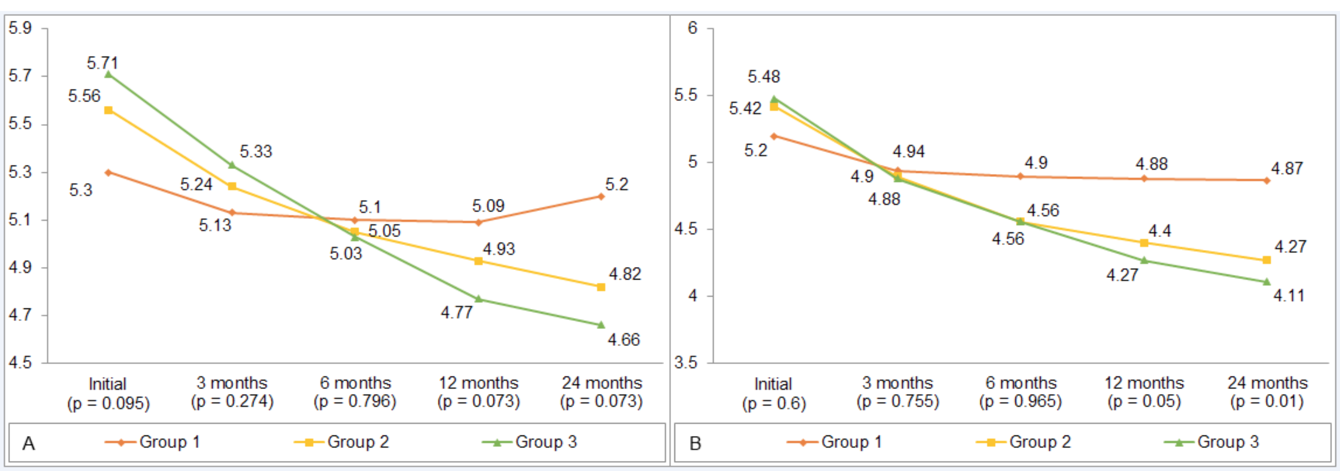

Figure 3: Dynamics of reverse remodeling of the right ventricular cavity in patients of the studied groups.

The presented ECHO data demonstrate significant positive changes in the group of complex surgical treatment for reverse remodeling of the cardiac cavities, lower mPAP, increase the left ventricular ejection fraction, restore and restoration of the sinus rhythm, in comparison with groups 1 and 2.

Circular denervation of the sympathetic ganglia in the trunk and mouth of the pulmonary arteries, after the PADN procedure, helps to relax smooth muscle fibers in the vascular wall, which leads to dilatation of arteries and arterioles, increasing the capacity of the vascular bed in the pulmonary circulation and reduces PH in the postoperative period.

In the course of the work, the dynamics of mPAP the was analyzed according to transthoracic ECHO (Figure 2).

Indicators of PH in group 3, initially significantly worse, were comparable with indicators of groups 1 and 2 already 3 months after the operation, and subsequently the best indicators among study groups. Normalization of PH contributed to a decrease in pressure in the right heart, primarily in the right ventricle, which had a beneficial effect on the reverse remodeling of the right ventricular cavity in the postoperative period (Figure 3).

Also, significant existing dilatation of the right ventricle after 6 months was comparable in terms of average values to groups 1 and 2, and by 24 months it occupied a leading position among all study groups. Concomitant tricuspid valve insufficiency, which was observed in almost all patients and was eliminated during the operation through repair, also had a positive trend in the postoperative period (Figure 4A).

The positive effect of surgical correction also affected the reduction of heart failure according to the 6-minute walk test (Figure 4B).

The results presented in the diagram demonstrate the significant advantage of the complex surgical treatment applied in group 3 already 3 months after surgery, compared with groups 1 and 2.

The elimination of tricuspid insufficiency, against the background of a decrease in pressure in the right heart, contributed to a reduction in the right atrium cavity (Figure 5A).

The presented diagram shows the best dynamics of cardiac reverse remodeling in the group of complex surgical treatment (group 3) - a more pronounced dilatation of the right atrium before surgery, was comparable with the average values of groups 1 and 2, and from 12 months had the best performance among the study groups.

A comprehensive surgical approach in group 3 made it possible to increase the effectiveness of surgical treatment of AF, which significantly improved the results of restoration and preservation of sinus rhythm in the postoperative period compared with patients of groups 1 and 2 (Table 2). The restored sinus rhythm contributed to a better reverse remodeling of the left atrium cavity (Figure 5B).

The presented data demonstrate a significant reduction in heart failure in group 3 from 12 months after surgery, compared with patients of groups 1 and 2, which is due to positive changes in the hemodynamic and structural parameters of the myocardium.

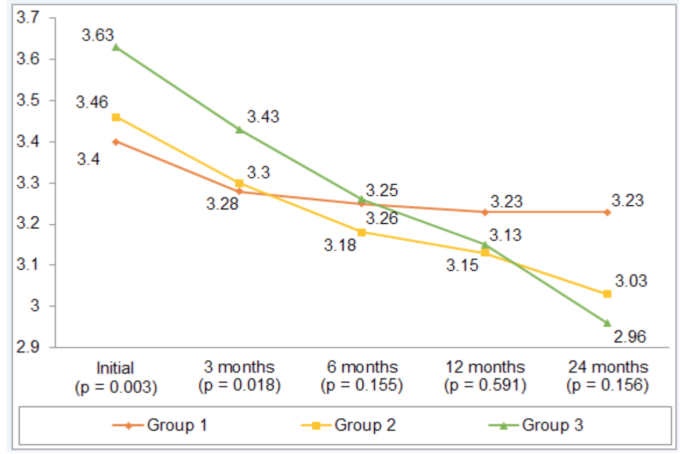

Figure 4: **(A):** The dynamics of achieving the target values of tricuspid valve insufficiency (0-1) in the study groups. Differences between the 3 groups were calculated using the chi-square (χ2) test. **(B):** The dynamics of achieving the target class of NYHA II heart failure in the study groups.

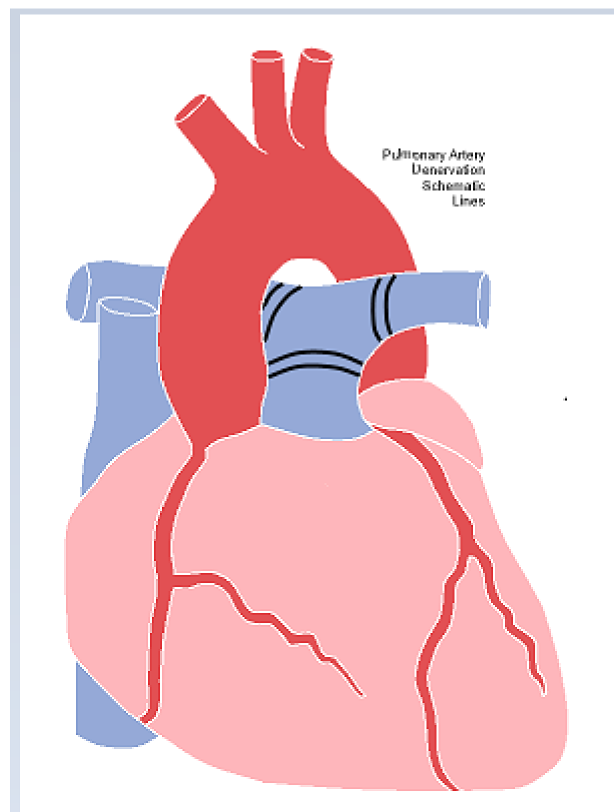

Figure 5: **(A):** The dynamics of reverse remodeling of the right atrium cavity in the studied groups. **(B):** The dynamics of reverse remodeling of the left atrium cavity in the study groups.

Table 1: Clinical and instrumental characteristics of the studied patients (n = 202).

	Group 1	Group 2	Group 3	p Value		
	(n = 62)	(n = 89)	(n = 51)	1-2	1-3	2-3
Gender (male/female)	19/43	28/61	23/28	0.916	0.116	0.108
Age at operation, years	56.3 ± 8.0	55.8 ± 8.3	59.4 ± 5.2	0.740	0.017#a	0.005#
Cause of mitral valve disease, %						
Rheumatic fever	82	85	76	0.604	0.447	0.184
Infective endocarditis	8	9	20	0.842	0.073	0.072
Degenerative	10	6	4	0.345	0.235	0.657
Type of AF						
Long-term persistent	77	84	86	0.167	0.321	0.749
Persistent	8	2	8	0.094	0.965	0.116
Paroxysmal	15	13	6	0.857	0.138	0.162
Arrhythmia history, years	2.7 ± 2.2	2.7 ± 1.7	2.6 ± 1.4	0.841	0.887	0.688
Atrial flutter, %	10	20	14	0.081	0.501	0.385
Carotid stenosis > 50%, %	27	17	18	0.118	0.219	0.904
Past medical history of a stroke, %	10	8	8	0.867	0.320	1
EuroSCORE	5 (3-6)	4 (3-6)	5 (4-8)	0.817	0.004#	0.004#
Cardiopulmonary bypass time, min	110 (90-136)	136 (118-151)	111 (87-130)	0.006#	0.511	<0.001#
Aortic cross-clamp time, min	84.5 (70-102)	107 (92-128)	79 (67-102)	<0.001#	0.359	<0.001#
TVI 2-4 degree, %	54.8	76.4	64.7	0.016#	0.533	0.095
NYHA III-IV class, %	27.4	28.1	43.1	0.953	0.082	0.058
LVIDd, cm	5.5 (5.2-6.3)	5.5 (5.2-5.7)	5.6 (5.4-6.4)	0.245	0.349	0.014#
LVIDs, cm	4.2 (3.7-4.8)	3.8 (3.6-4.1)	4 (3.8-4.8)	0.002#	0.925	<0.001#
LVEDV, cm	147.4 (129.5-201.2)	143.2 (130.4-160)	153.7 (135.3-208.5)	0.176	0.465	0.016#
LVESV, cm	76.4 (58.1-107.5)	62 (54.4-71.2)	70 (62.0-107.5)	0.001#	0.902	<0.001#
LVEF, %	51 (43.9-57.9)	56.3 (53.1-58)	52.2 (49.1-55.1)	<0.001#	0.080	<0.001#
RVD, cm	3.4 (3.2-3.6)	3.4 (3.2-3.7)	3.6 (3.4-4)	0.182	<0.001#	0.003#
LADs, cm	5.1 (4.8-5.7)	5.4 (5.2-5.6)	5.5 (5.3-5.7)	0.034	0.002#	0.600
RADs, cm	5.2 (5-5.7)	5.6 (5.2-5.9)	5.8 (5.6-6)	0.004#	<0.001#	0.095
PASP, mmHg	46 (43-49)	46 (44-50)	48 (45-60)	0.440	0.002#	0.018

[a]Hereinafter, for most cases (for the age of patients and AF, Student t-test was used), intergroup differences were calculated by the Mann–Whitney U-test due to the lack of a normal distribution (in this case, the data are presented as Me (Q1-Q3)), for qualitative values used the Pearson's chi-squared test or the Fisher's exact test. The # sign indicates the required level of statistical significance, taking into account the Bonferroni correction.

LADs: Left Atrium Anterior-Posterior Diameter In Systole; LVEDV: Left Ventricular End-Diastolic Volume; LVEF: Left Ventricular Ejection Fraction; LVESV: Left Ventricular End-Systolic Volume; LVIDd: Left Ventricular Internal Diameter In Diastole; LVIDs: Left Ventricular Internal Diameter In Systole; PASP: Pulmonary Artery Systolic Pressure; RADs: Right Atrium Anterior-Posterior Diameter In Systole; RVD: Right Ventricular Basal Diameter; TVI: Tricuspid Valve Insufficiency.

Table 2: Changing of echocardiographic parameters of the studied groups.

		Group 1	Group 2	Group 3	p Value		
		(n = 62)	(n = 89)	(n = 51)	1-2	1-3	2-3
TVI 2-4 degree, %	original	54.8	76.4	64.7	0.016#a	0.533	0.095
	24 Mo. after	32.80*b	20.5*	0*	0.044	<0.001#	<0.001#
NYHA III-IV class, %	original	100	98.9	100	0.953	0.082	0.058
	24 Mo. after	67.2	36.4*	18.0*	<0.001#	<0.001#	0.023

LVIDd, cm	original	5.5 (5.2-6.3)	5.5 (5.2-5.7)	5.6 (5.4-6.4)	0.245	0.349	0.014#
	24 Mo. after	5.3 (5-6)*	4.8(4.6-5.1)*	4.6 (4.5-5.3)*	<0.001#	<0.001#	0.896
LVIDs, cm	original	4.2 (3.7-4.8)	3.8 (3.6-4.1)	4 (3.8-4.8)	0.002#	0.925	<0.001#
	24 Mo. after	3.9 (3.4-4.3)*	3.3 (3.1-3.7)*	3.2 (3-3.6)*	<0.001#	<0.001#	0.625
LVEDV, cm	original	147.4 (129.5-201.2)	143.2 (130.4-160.0)	153.7 (135.3-208.5)	0.176	0.465	0.016#
	24 Mo. after	135.3 (118.2-180)*	105.9 (97.3-123.8)*	97.3 (93.8-135.3)*	<0.001#	<0.001#	0.858
LVESV, cm	original	76.4 (58.1-107.5)	62.0 (54.4-71.2)	70 (61.9-107.5)	0.001#	0.902	<0.001#
	24 Mo. after	65.9 (47.4-83.1)*	44.1 (36.5-57.7)*	42.6 (35-54.43)*	<0.001#	<0.001#	0.691
LFEV, %	original	51.0 (43.9-57.9)	56.3 (53.1-58.0)	52.2 (49.1-55.1)	<0.001#	0.08	<0.001#
	24 Mo. after	53.4 (47.6-57.0)*	57.9 (54.4-63.3)*	58.2 (56.3-60.1)*	<0.001#	<0.001#	0.857
RVD, cm	original	3.4 (3.2-3.6)	3.4 (3.2-3.7)	3.6 (3.4-4)	0.182	<0.001#	0.003#
	24 Mo. after	3.2 (3-3.4)*	3.0 (2.9-3.1)*	2.9 (2.8-3.2)*	<0.001	<0.001	0.156
LADs, cm	original	5.1 (4.8-5.7)	5.4 (5.2-5.6)	5.5 (5.3-5.7)	0.034	0.002#	0.600
	24 Mo. after	4.8 (4.5-5.3)*	4.3 (4-4.6)*	4.1 (3.8-4.3)*	<0.001#	<0.001#	0.010#
RADs, cm	original	5.2 (5-5.7)	5.6 (5.2-5.9)	5.8 (5.6-6)	0.004#	<0.001#	0.095
	24 Mo. after	5.1 (5-5.5)*	5.0 (4.4-5.3)*	4.5 (4.4-5)*	<0.001#	<0.001#	0.073
PASP, mmHg	original	46 (43-49)	46 (44-50)	48 (45-60)	0.44	0.002#	0.018
	24 Mo. after	32 (30-34)*	26 (23.5-29.4)*	23 (21-28)*	<0.001#	0.583	0.519
AF, %	original	100	100	100	1	1	1
	24 Mo. after	95	34*	16*	<0.001#	<0.001#	0.022

[a]Intergroup differences were calculated by the Mann–Whitney U-test due to the lack of a normal distribution (in this case, the data are presented as Me (Q1-Q3)), for qualitative values used the Pearson's chi-squared test or the Fisher's exact test. The # sign indicates the required level of statistical significance, taking into account the Bonferroni correction.

[b]The statistical significance of dynamic differences was indicated by the * sign in the data line after 24 months, for quantitative data it was evaluated by the Wilcoxon sign test, for analysis of repeated measurements of qualitative characteristics - by the McNemar test with Yates correction (changes in the percentage of TVI 0-1 degree, the NYHA II-IV share, AF percentage).

LADs: Left Atrium Anterior-Posterior olume; LVIDd: Left Ventricular Internal Diameter In Diastole; LVIDs: Left Ventricular Internal Diameter In Systole; PASP: Pulmonary Artery Systolic Pressure; RADs: Right Atrium Anterior-Posterior Diameter In Systole; RVD: Right Ventricular Basal Diameter; TVI: Tricuspid Valve Insufficiency.

Table 3: The share of target indicators 24 months after surgery in the study groups.

		Group 1	Group 2	Group 3	p Value		
		(n = 62)	(n = 89)	(n = 51)	1-2	1-3	2-3
TVI 0-1 degree, %	original	45.2	23.6	35.3	0.005#a	0.288	0.137
	24 Mo. after	67.2*b	79.5*	100*	0.089	<0.001#	<0.001#
TVI 0 degree, %	original	1.6	0	0	0.229	0.362	1
	24 Mo. after	0	3.4	88*	0.091	<0.001#	<0.001#
NYHA I-II class, %	original	0	1.1	0	0.402	1	0.447
	24 Mo. after	32.8*	63.6*	82*	<0.001	<0.001	0.023
Sinus rhythm preservation, %	original	0	0	0	1	1	1
	24 Mo. after	4.9	65.9*	84*	<0.001#	<0.001#	0.022
LVIDd, cm	original	38.7	47.2	31.4	0.301	0.417	0.067
	24 Mo. after	50.8*	87.5*	92.0*	<0.001#	<0.001#	0.414
LVIDs, cm	original	24.2	38.2	19.6	0.07	0.559	0.023
	24 Mo. after	44.3*	72.7*	98*	<0.001#	<0.001#	<0.001#

LVEDV, cm	original	21	21.3	11.8	0.955	0.193	0.154
	24 Mo. after	36.1*	64.8*	66*	<0.001#	<0.001#	0.884
LVESV, cm	original	14.5	19.1	11.8	0.463	0.668	0.26
	24 Mo. after	29.5*	64.8*	62*	<0.001#	<0.001#	0.745
LFEV, %	original	38.7	76.4	52.9	<0.001#	0.13	0.004#
	24 Mo. after	49.2*	81.8*	96*	<0.001#	<0.001#	0.018
RVD, cm	original	40.3	44.9	21.6	0.573	0.033	0.006#
	24 Mo. after	68.9*	83*	96*	0.044	<0.001#	0.03
LADs, cm	original	3.2	4.5	0	0.695	0.196	0.125
	24 Mo. after	1.6	23.9*	48*	<0.001#	<0.001#	0.004#
RADs, cm	original	4.8	2.2	0	0.381	0.111	0.281
	24 Mo. after	0	33*	54*	<0.001#	<0.001#	0.016#
PASP < 25 mmHg	original	0	0	0	1	1	1
	24 Mo. after	3.3	34.1*	62*	<0.001#	<0.001#	0.002#

[a]Intergroup differences were calculated by the Pearson's chi-squared test or the Fisher's exact test. The # sign indicates the required level of statistical significance, taking into account the Bonferroni correction.

[b]The statistical significance of repeated measurements of qualitative traits was evaluated by the McNemar test with Yates correction.

LADs: left atrium anterior-posterior diameter in systole; LVEDV: left ventricular end-diastolic volume; LVEF: left ventricular ejection fraction; LVESV: left ventricular end-systolic volume; LVIDd: left ventricular internal diameter in diastole; LVIDs: left ventricular internal diameter in systole; PASP: pulmonary artery systolic pressure; RADs: right atrium anterior-posterior diameter in systole; RVD: right ventricular basal diameter; TVI: tricuspid valve insufficiency.

Comment

The performed research work demonstrates the effectiveness of complex surgical correction in patients with mitral valve disease, AF, and severe secondary PH, which, in addition to the standard mitral valve dysfunction and Maze IV procedure, underwent the PADN circular procedure (group 3). The control groups were initially comparable according to the main clinical and instrumental data, they also underwent surgery for mitral disease (group 1) and simultaneous elimination of mitral dysfunction and AF (group 2), but patients of these groups did not undergo specific surgical treatment of secondary PH. Even with a small number of studied patients and the lack of data on the effectiveness of the PADN procedure in the long term, the presented results demonstrate the better reverse remodeling of the cardiac cavities, as well as a significant reduction in PH, restoration and preservation of the sinus rhythm in the postoperative period, which enhances the first effect. Ultimately, the regressing of heart failure in patients of the 3rd group of the study is more pronounced in comparison with the control groups. The achieved result was obtained not only due to mitral valve disease surgery correction and restoration of sinus rhythm after the Maze IV procedure, but also due to the circular PADN procedure. The proposed method for surgical correction of PH was simple in technical design, did not take much time and during the course of the research work proved to be absolutely safe.

The result of our work was a demonstration of the effectiveness, practical significance and safety of the proposed methodology. In addition, no additional consumables were required to perform the PADN procedure, since the same AtriCure radio frequency destructor, which was used for surgical correction of AF, was used. The use of a bipolar clamp-destructor allows radiofrequency exposure around the entire circumference of the pulmonary arteries, which is advantageous in comparison with the impacts of only the anterior wall of the trunk and the orifices of bilateral pulmonary arteries.

Based on the data obtained, the following conclusions can be drawn:

1. The circular PADN procedure is effective and safe, can significantly reduce the level of PH in the postoperative period ($p\chi2 = 0.018$ compared with the group without PADN) and promotes reverse remodeling of the cardiac cavities.

2. Comprehensive surgical correction of patients with mitral dysfunction, AF, and high PH can significantly reduce heart failure ($p\chi2 = 0.023$ compared with the group without PADN).

3. Further analysis of the effectiveness of radiofrequency denervation of the pulmonary arteries with the study of a larger number of patients, analysis of long-term results, as well as determining the feasibility of this technique in patients with non-valve forms of PH is needed.

Declarations

Conflict of interest: None declared.

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