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ASSESSMENT OF THE RISK OF ATRIAL FIBRILLATION AFTER MITRAL VALVE RECONSTRUCTION USING VARIOUS TYPES OF SUPPORT RINGS UP TO 12 MONTHS AFTER OPERATION

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Aim. To evaluate the effect of mitral valve (MV) reconstruction using rigid and superelastic support rings for up to one year in patients with mitral regurgitation (MR) II according to A. Carpentier on the development of atrial fibrillation (AF).

Methods. The study included 62 patients with indications for surgical correction of MR and sinus rhythm (SR): group I (n=31) - with implantation of the biological semi-rigid saddle closed ring NeoRing and II (n=31) - with implantation of the rigid open ring RIGID. The average age of patients was 56.6±11.2 years and 58.0±10.2 years in groups I and II. Both groups were comparable in gender (men - 67.7% and 61.3%), age, comorbidity, functional class of chronic heart failure according to NYHA. The rhythm in patients was assessed by Holter monitoring at control points after 9 days and 12 months.

Results. The duration of artificial circulation, aortic occlusion, and the incidence of isolated P2-segment prolapse did not differ in the comparison groups. A positive effect on the reverse remodeling of the left heart was revealed: the end-diastolic dimension of the left ventricle ($p<0.001$), the left atrium ($p<0.001$), a decrease in the overload of the pulmonary circulation and a decrease in pressure in the pulmonary artery ($p<0.001$). According to the Holter monitoring data, all patients had SR. Both groups showed a satisfactory result at the hospital stage in the form of restoration of the locking function of the MV ($p<0.001$) and a low frequency of the revealed maximum MR up to grade 1 in group I - 9.7% and II - 29% ($p=0.292$). However, patients with RIGID had higher values of transvalvular diastolic gradient on MV and transvalvular flow velocity ($p < 0.001$). In group II, the values of transvalvular diastolic gradient on MV were Pcp 3.34±1.01 mm Hg, versus 2.39±0.62 mm Hg in group I ($p < 0.001$), transvalvular flow velocity in group II was Vcp 79±15 cm/sec versus 66±12 cm/sec in group I, respectively ($p < 0.001$). After 12 months, the RIGID group more often showed a change from SR to AF - 11 cases (35.5%), in NeoRing - 4 (12.9%). According to echocardiography data after 12 months, freedom from MR ≥ grade 2 in group I was 93.5%, versus 77.4% in group II ($p=0.076$). In addition, patients in group II maintained higher values of transvalvular diastolic gradient on MV - Pcp 3.70 [3.00; 4.40] mmHg, versus 2.3 [2.05; 2.85] mmHg ($p<0.001$), as well as higher transvalvular flow velocity - Vcp 79 [71; 94] cm/sec versus 70 [64; 79] cm/sec ($p=0.017$). AF developed 12 months after surgery in those patients whose transvalvular diastolic gradient on the MV exceeded 2.7 mm Hg, as well as in patients with developed MR ≥ grade.

Conclusions. The development in the medium term, after reconstruction of the mitral valve with a support ring, of an increased transmitral diastolic gradient and MR ≥ grade 2 is the cause of the development of AF, while the implantation of a rigid ring is accompanied by a high risk of developing AF within 12 months after surgery ($p=0.029$).

Key words: mitral regurgitation; atrial fibrillation; mitral valve reconstruction; support ring

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Mitral regurgitation (MR) is a common form of acquired heart valve disease, affecting approximately 24.2 million people worldwide. Primary or degenerative MR is most often a consequence of myxomatous degeneration of the mitral valve (MV). Mitral valve prolapse is the most prevalent cardiac pathology globally, occurring in 2-3% of the general population [1-3], and is primarily classified as type II MR according to A.Carpentier's classification [6, 7]. The gold standard for the treatment of dysplastic MR is reconstructive surgery [8]. Mitral annuloplasty is the primary method of MR correction, performed alongside leaflet and subvalvular apparatus repair. This technique helps restore the size and shape of the mitral fibrous annulus and reduces the risk of progressive dilation of both the ventricles and atria [9].

Atrial fibrillation (AF) is the most common cardiac arrhythmia and significantly increases the risk of ischaemic stroke and severe heart failure. This arrhythmia is present

in 30-50% of patients undergoing MV surgery [4, 5]. The development of open surgical ablation techniques for AF has led to their widespread use in mitral valve procedures. Numerous studies have focused on surgical correction of MV pathology in patients with pre-existing AF. However, there is a paucity of research tracking newly emerging arrhythmias after open-heart surgery, particularly following MR correction in patients who had sinus rhythm preoperatively. Most clinicians emphasise that the initial onset of AF after open-heart surgery is of particular clinical significance [10]. A recent study [11] demonstrated that postoperative AF is a frequent complication of cardiac surgery, occurring in 10-63% of cases, including 33-37% of patients after valve repair or replacement. Among this patient cohort, those undergoing mitral annuloplasty require particular attention, given the combination of the most common valve pathology with the most prevalent arrhythmia. However, there is a distinct lack of studies assessing the mid-term incidence of AF following MV repair.

This study aimed to evaluate the effect of mitral valve reconstruction using rigid and superelastic support rings for up to 12 months in patients with type II MR according to A. Carpentier on the development of AF.

METHODS

A prospective, randomised study was conducted at the Department of Cardiovascular Surgery-1 of the Research Institute for Complex Problems of Cardiovascular Diseases (Kemerovo, Russia) to assess the impact of MV repair using two types of support rings. The study included 62 patients with severe MR that developed against the background of MV dysplasia. All patients were randomly assigned to two groups using a two-envelope randomisation method: Group I (n=31) underwent implantation of a biological semi-rigid saddle-shaped closed ring, NeoRing (CJSC NeoKor, Kemerovo, Russia), while Group II (n=31) received a rigid open ring, RIGID (CJSC R&D Enterprise MedInzh, Penza, Russia). All participants signed a standard informed consent form.

Table 1.

General preoperative characterization of patients

Indicator	NeoRing (n=31)	RIGID (n=31)	p
Age, years	56.6±11.2	58.0±10.2	0.564
Men, n (%)	21 (67.7)	19 (61.3)	0.241
BSA, m²	1.97±0.23	1.88±0.20	0.057
Barlow's disease, n (%)	6 (19.4)	7 (22.6)	0.325
FED, n (%)	25 (80.6)	24 (77.4)	
NYHA FC I, n (%)	0 (0.0)	0 (0.0)	0.195
NYHA FC II, n (%)	19 (61.3)	18 (58.1)	
NYHA FC III, n (%)	11 (35.5)	11 (35.5)	
NYHA FC IV, n (%)	1 (3.2)	2 (6.5)	
CAD, n (%)	10 (32.3)	11 (35.5)	0.742
AIS, n (%)	7 (22.6)	9 (29.0)	0.528
MAC, n (%)	1 (3.2)	2 (6.5)	0.647
COPD, n (%)	4 (12.9)	3 (9.7)	0.498
CKD, n (%)	4 (12.9)	4 (12.9)	0.891
DM, n (%)	2 (6.5)	1 (3.2)	0.597

Note: BSA - body surface area; FED - fibroelastine degeneration; NYHA FC - functional class; CAD - coronary artery disease; AIS - acute ischaemic stroke; COPD - chronic obstructive pulmonary disease; CKD - chronic kidney disease; DM - diabetes mellitus.

Table 2.

Echocardiographic parameters at 12 months of follow-up

Indicator	Before surgery		p	In 12 months		p
	NeoRing	RIGID		NeoRing	RIGID	
LV EDD, cm	6,29±0,70	6,24±0,73	0,773	5,31±0,44	5,57±0,55	0,031
LV ESD, cm	4,01±0,56	3,89±0,70	0,429	3,70 [3,40; 3,90]	3,60 [3,45; 4,15]	0,354
LV EDV, ml	209 [167; 220]	194 [160; 220]	0,978	135,71±27,36	155,46±37,28	0,008
LV ESV, ml	66 [51; 90]	62 [44; 83]	0,242	55 [46; 63]	61 [50,50; 75,25]	0,071
LVEF, %	65 [63; 68]	67 [65; 71]	0,072	61 [57; 62]	62 [58,50; 65,00]	0,105
LA, cm	5,2 [4,8; 5,75]	5,0 [4,5; 5,6]	0,334	4,30 [4,10;5,05]	4,50 [4,28; 4,90]	0,594
RA, cm	4,8 [4,1; 5,4]	4,5 [4,0; 5,1]	0,401	4,40 [3,95; 4,95]	4,25 [3,80; 4,60]	0,256
Vena contracta, cm	0,8 [0,65;0,80]	0,85 [0,74; 0,90]	0,015	0,1 [0,00; 0,2]	0,3 [0,00; 0,4]	0,102
MR Gr 1, n (%)	-	-	0,528	3 (9,7)	3 (9,7)	0,281
MR Gr 2, n (%)	-	-		2 (6,5)	7 (22,6)	
MR Gr 3, n (%)	7 (22,6)	6 (17,0)		-	-	
MR Gr 4, n (%)	24 (77,4)	25 (83,0)		-	-	
ERO, cm²	0,42 [0,35; 0,55]	0,50 [0,40 ;0,60]	0,095	0,05 [0,00; 0,1]	0,1 [0,00; 0,2]	0,070
Vmean, cm/s	-	-	-	70 [64; 79]	79 [71; 94]	0,017
Pmean, mmHg	-	-	-	2,3 [2,05; 2,85]	3,70 [3,00; 4,40]	<0,001

Note: LV - left ventricle; EDD - end-diastolic dimension; ESD - end-systolic dimension; EDV - end-diastolic volume; ESV - end-systolic volume; LVEF - left ventricular ejection fraction; LA - left atrium; RA - right atrium; MR - mitral regurgitation; Gr - grade; ERO - effective regurgitation orifice

Patients aged over 18 years were eligible for inclusion. The primary inclusion criterion was the presence of severe dysplastic MR classified as type II according to A.Carpentier, with an indication for surgical correction in accordance with the 2017 guidelines of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) [12], and a history of sinus rhythm. Exclusion criteria included prior open-heart surgery, indications for concomitant aortic valve replacement or coronary artery bypass grafting, significantly reduced left ventricular (LV) contractile function (ejection fraction <40%), and a history of AF. The study was conducted in accordance with the principles of the Declaration of Helsinki. Data were analysed at three time points: preoperatively, postoperatively, and at 12 months after surgery.

The mean age of patients in Group I was 56.6±11.2 years, while in Group II, it was 58.0±10.2 years. Both groups were comparable in terms of sex, age, and comorbidities. Coronary angiography revealed haemodynamically insignificant coronary artery stenoses in all patients. The baseline preoperative characteristics of the study population are presented in Table 1.

The primary endpoints in the mid-term period were newly detected arrhythmias. Secondary endpoints included stroke, systemic embolism, and anticoagulant-related bleeding.

Surgical procedure

As the first step, before the surgical intervention, all patients underwent transesophageal echocardiography to assess the morphology of MR. The surgical procedures were performed under normothermic cardiopulmonary bypass. To prevent embolic complications, CO_2 insufflation was performed into the surgical field, and myocardial protection was provided using Custodiol solution (Köhler Chemie, Germany). All surgical procedures were performed via median sternotomy by a single surgeon. Intraoperative differential diagnosis between Barlow's disease and fibroelastic deficiency was conducted according to the A. Anyanwu algorithm [13].

Access to the MV was achieved through a left atriotomy. Based on intraoperative assessment of the MV and identification of the prolapse zone, the following reconstructive techniques were performed: chordal replacement, resection (triangular, quadrangular), translocation of second-order chords to the free edge, and leaflet plication. MV reconstruction was completed with annuloplasty using either the NeoRing or RIGID ring.

Statistical Analysis

Statistical analysis was performed using the StatTech v. 2.8.8 software (StatTech LLC, Russia). Quantitative variables were assessed for normality using the Shapiro-Wilk test. In cases where the data did not follow a normal distribution, they were described using the median (Me) and interquartile range (Q1-Q3). Comparisons between two groups for non-normally distributed quantitative variables were conducted using the Mann-Whitney U test.

Categorical variables were presented as absolute values and percentages. Comparisons of percentage distributions in 2×2 contingency tables were performed using Pearson's chi-square test, provided that the expected frequency in each cell exceeded 10. Statistical differences were assessed using the Kaplan-Meier method with a log-rank test.

A 5% level of Type I error ($\alpha = 0.05$) was adopted, meaning that differences were considered statistically significant at $p < 0.05$.

RESULTS

Intraoperatively, the duration of cardiopulmonary bypass and aortic occlusion time were assessed and did not differ significantly between the comparison groups. In the vast majority of cases in both groups, isolated prolapse of the P2 segment was observed. In the early postoperative period, the need for prolonged mechanical ventilation was noted in the RIGID group.

At the time of hospital discharge, both groups exhibited a reduction in left ventricular ejection fraction (LVEF) compared to preoperative values: in the NeoRing group, the median LVEF decreased from 65% to 55%, while in the RIGID group, it declined from 67% to 60%. However, after 12 months, LVEF recovered in both groups to levels close to baseline, with no significant intergroup differences at this stage (p=0.105). A statistically significant positive effect on reverse remodeling of the left heart chambers was observed, including reductions in left ventricular end-diastolic dimension (p<0.001), left atrial size (p<0.001), pulmonary circulation overload, and pulmonary artery pressure (p<0.001). No significant intergroup differences were identified at the time of discharge. The echocardiographic results for both groups over the study period are presented in Table 2.

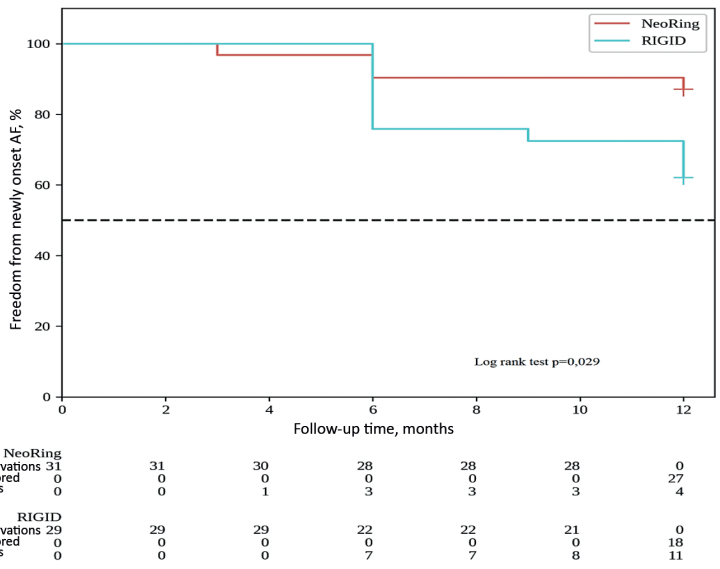

Figure 1. Kaplan-Meier curve for freedom from newly onset atrial fibrillation in the mid-term period.

At 12 months postoperatively, patients in the RIGID group maintained the remodeling parameters achieved during hospitalization, while those in the NeoRing group demonstrated further remodeling improvements, including a reduction in left ventricular end-diastolic diameter (p=0.031) and volume (p=0.008). Both support rings provided satisfactory clinical outcomes at the hospital stage, evidenced

by restoration of MV competency (p<0.001) and a low frequency of residual MR up to grade 1, observed in 9.7% of patients in the NeoRing group and 29% in the RIGID group, though the difference was not statistically significant (p=0.292).

However, patients with the RIGID ring exhibited significantly higher transvalvular diastolic gradient values (p<0.001) and increased transvalvular flow velocity (p<0.001). Echocardiographic assessment at 12 months revealed that freedom from MR ≥ grade 2 was observed in 93.5% of patients in the NeoRing group, compared to 77.4% in the RIGID group (p=0.147). Additionally, patients in the RIGID group continued to exhibit significantly higher transvalvular diastolic gradients (mean: 3.70 [3.00; 4.40] mmHg vs. 2.3 [2.05; 2.85] mmHg, p<0.001) and higher transvalvular flow velocity (mean: 79 [71; 94] cm/s vs. 70 [64; 79] cm/s, p=0.017) compared to those in the NeoRing group.

At the 12-month follow-up, implantation of either support ring did not show a significant impact on the incidence of thromboembolic complications or the need for permanent pacemaker implantation. The most common complaint during follow-up was dyspnoea with moderate physical exertion, reported by approximately one-third of the patients.

Holter ECG monitoring revealed that 11 patients (35.5%) in the RIGID group experienced a transition from sinus rhythm to AF, compared to 4 patients (12.9%) in the NeoRing group, necessitating antiarrhythmic and anticoagulant therapy in the mid-term period. These results were statistically significant (p=0.037). Kaplan-Meier analysis and the log-rank test demonstrated significant statistical differences (p=0.029) (Figure 1).

Further analysis revealed that AF development occurred in patients with transvalvular diastolic gradients exceeding 2.7 mmHg in the mid-term period. Additionally, the onset of paroxysmal AF was associated with the progression of MR to grade ≥2, which had not been previously documented in these patients.

DISCUSSION

Mitral valve reconstruction is recognised as the gold standard for the correction of type II MR according to A. Carpentier's classification [14, 15]. A fundamental requirement for reconstruction is the restoration of the size and shape (resizing, reshaping) of the mitral annulus using support rings. In our study, both support rings effectively reduced MR, with no statistically significant difference in the recurrence of MR within 12 months postoperatively. It is noteworthy that annuloplasty with the superelastic NeoRing was associated with lower transvalvular diastolic gradient (TDG) values compared to the RIGID group.

The durability and effectiveness of MV reconstruction is primarily assessed by the freedom from recurrent MR in the postoperative period. No cases of MR recurrence ≥ grade 3 were recorded in either group within the mid-term follow-up period. Echocardiographic analysis at 12 months showed that freedom from MR ≥ grade 2 was 93.5% in the NeoRing group, compared to 77.4% in the RIGID group (p=0.076). Univariate analysis identified residual MR as a significant factor contributing to MR recurrence ≥ grade 2 (OR 98.0, 95% CI: 9.68-992.5; p<0.001). Our findings are supported by D. Benedetto et al., who concluded that residual MR ≥ grade 1 at discharge was the sole independent predictor of repeat surgery and late MR recurrence [16]. Similarly, A.V. Bogachev-Prokofiev et al. identified residual MR, coronary artery disease, and residual systolic pulmonary artery pressure as major contributors to MR recurrence [17].

In the mid-term follow-up, the incidence of atrial fibrillation (AF) was significantly higher in the RIGID group (11 cases, 35.5%) compared to the NeoRing group (4 cases, 12.9%) (p=0.037). Kaplan-Meier analysis and the log-rank test revealed statistically significant differences (p=0.029). This was likely related to increased intra-atrial pressure due to MV repair failure, which was associated with a higher mean transvalvular diastolic gradient in the rigid ring group.

The primary predictors of AF onset in the mid-term period were: a mean transvalvular diastolic gradient (TDG) > 2.7 mmHg (OR 0.861±0.064, 95% CI: 0.736-0.987; p <0.001); MR recurrence ≥ grade 2.

W.Ma conducted a retrospective analysis of MV reconstruction in 390 patients using closed and C-shaped rings. After a median follow-up of 46 months, AF developed in 31.2% of patients, which was strongly associated with an elevated TDG (OR 3.93; p=0.004). Using minimum p-value analysis, the authors identified a mean gradient ≥4.5 mmHg as the threshold for predicting late-onset AF (χ^2=40.704; p<0.001) [18]. Their study also reported higher TDG values in patients with closed rings compared to open rings.

In our study, AF development in the postoperative period was influenced not only by elevated TDG, but also by MR recurrence ≥ grade 2 and the type of support ring implanted.

CONCLUSION

The development of elevated transvalvular diastolic gradient (TDG) and MR ≥ grade 2 in the mid-term period following MV reconstruction with a support ring is a significant factor contributing to the onset of atrial fibrillation (AF). The implantation of a rigid ring is associated with a higher risk of AF development within 12 months postoperatively (p=0.029). This necessitates modification of patient management strategies, including the initiation of antiarrhythmic and anticoagulant therapy, and increases the risk of adverse events.

The findings of this study highlight the need for further research to identify predictors of AF development in patients following MV reconstruction with a support ring.

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