

## Assessment Of Sinatrial Node Function In Patients With Persistent And Long-Standing Persistent Forms Of Atrial Fibrillation After Maze III Procedure Combined With Mitral Valve operation

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### Abstract

**Research objective:** Assessment of sinoatrial node function after Maze III procedure combined with a mitral valve operation.

**Methods:** 100 patients were included in the research with persistent and long-standing persistent forms of atrial fibrillation (AF) and need of operative treatment concerning valve disease.

The following preoperative preparation methods were executed to all patients: 1. Electrocardiogram in 12 standard assignments; 2. Two-dimensional echocardiographic with assessment of systolic and diastolic functions of the left ventricle, size of the left atrium and grade of valve disease; 3. Transesophageal echocardiography for exclusion of blood clots in the left atrium and left atrial appendage; 4. Coronary angiography for exclusion of coronary heart disease; 5. Computer tomography for examination of cardiac chambers and anatomic characteristics of pulmonary veins.

Electric cardioversion in X-ray operating room conditions was performed on all patients. After successful restoration of sinus rhythm, electrophysiological examination (EP) of heart was carried out. Then, on the first or second day after EP study, Maze III procedure combined with a mitral valve operation was performed.

**Results:** Following the results of Maze III procedure combined with correction of valve disease, disposal of AF was observed in 95% of patients. 46% of patients had stable sinus rhythm to the moment of discharge from the hospital. 24% of patients had atrial rhythm with the maximum heart rate of 80-110 bpm (according to results of 24-hour Holter monitoring). For 25% of patients, it was necessary to implant a pacemaker. According to results of EP study, 13% of these patients suffered from sick sinus syndrome before operation. For 9% of the remaining 12% of patients, the indications for pacemaker implantation were atrioventricular nodal rhythm with low heart rate and pauses more than 3 sec long. For 1% of patients the indication was second degree AV block (type 2) and second degree SA block (type 2); for 1% the indication was complete heart block, and for 1% it was atrial rhythm and pauses more than 3 sec long.

13% of patients with an atrial rhythm and normal heart rate developed typical atrial flutter (AFL) in the early postoperative period. For all of them the RF catheter ablation with linear ablation of the right atrial isthmus and creation of isthmus block was effective, and further recurrence of AFL was not observed.

**Conclusions:** In the early postoperative period Maze III procedure combined with a mitral valve operation proved to be an effective surgical technique of treatment of persistent and long-standing persistent forms of AF. Only 12% of patients had dysfunction of sinus node work due to iatrogenesis.

### Introduction

For treatment of persistent and long-standing persistent forms of atrial fibrillation combined with mitral valve operation several surgical techniques are used. The Maze procedure is based on the principle of prevention of atrial fibrillation by interruption of all potential re-entry ways. To direct an impulse from sinus node to AV-node multiple cuts are made in such a way, that do not allow the critical volume

of atrial tissue to support fibrillation process, thus preserving atrial contraction. This procedure has several major functional advantages over other surgical techniques, allowing to reach almost at all patients four therapeutic objectives: control of heart rate, restoration and maintenance of sinus rhythm, thromboembolic complications risk decreasing and restoration of normal heart hemodynamics. In our research we used operation modification - cryomodification of Maze III procedure by means of the Atricure device in combination with RFA of the right atrium. It is a method of choice in treatment of atrial fibrillation refractory to medicamentous therapy.<sup>1, 2, 3, 4, 5, 6, 7</sup> Despite of the use of the combined technic, at several patients dysfunction of sinus node (SND) was observed. It manifested itself by a wide range of electrophysiological anomalies. On a surface ECG dysfunction of sinus node shown itself as a severe form of sinus bradycardia, sinus pauses or a sinus arrest, sinoatrial exit block, atrial tachyarrhythmias, the alternating episodes of bradiarrhythmias and tachyarrhythmias

### Key Words:

Sinoatrial, Atrial Fibrillation, Maze III Procedure.

### Disclosures:

None.

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**Table 1: Patient characteristics**

Characteristics	Values
Number	100
Men (%)	48
Age (years)	59,3±10,2
AF duration (years)	4±4,2
Antiarrhythmic therapy (drugs/patient)	3±0,45
Electrical cardioversion (n)	15
Valvular affection (years)	21,8±12,8
Tricuspid valve insufficiency (n)	80, (80)
NYHA class	
I (n)	14, (14)
II (n)	20, (20)
III (n)	66, (66)
F-waves (mV)	0,15±0,09
Left ventricular ejection fraction (%)	61±8,6
Size of the left atrium (cm)	5,1±1,5
Cardiothoracic index (%)	58,6±4,7
Thromboembolic anamnesis (n)	12, (12)
Aorto-coronary artery bypass graft surgery (n)	9, (9)
Arterial hypertension (n)	16, (16)
Diabetes (n)	5, (5)

Note. Values are means ± SD or % unless otherwise is indicated

and the inadequate response of heart rate to emotional or physical activity.

The main aims of this long prospective research were: 1) to identify the type and frequency of postoperative electrophysiological manifesting of sinus node dysfunction; 2) to estimate dynamics of sinus node function in postoperative period; 3) to estimate the possible reasons of these pathological changes after Maze III procedure at patients with valve pathologies and lack of electrophysiological symptoms of sinus node dysfunction at a preoperative stage.

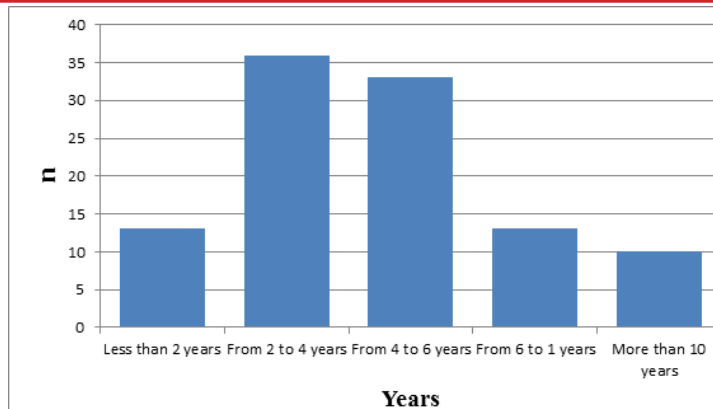
Invasive electrophysiology study is commonly used for a sinus node function assessment. However, there are only few reports about the use of this method at a significant amount of patients with mitral and tricuspid valve disease and persistent and long-standing persistent forms of atrial fibrillation before Maze III procedure combined with mitral valve operation.

On the basis of the conducted research the complex assessment of the sinus node function, function of the atrioventricular conduction system (atrioventricular node and His-Purkinje system) and electrophysiological parameters of atriums at patients with mitral and tricuspid valve disease and persistent and long-standing persistent forms of atrial fibrillation is given.

## Material And Methods

100 patients were included in the research with persistent and long-standing persistent forms of atrial fibrillation (AF) and need of operative treatment concerning valve disease.

The following preoperative preparation methods were executed to all patients: 1. Electrocardiogram in 12 standard assignments; 2. Two-dimensional echocardiography with assessment of systolic and diastolic functions of the left ventricle, size of the left atrium and grade of valve disease; 3. Transesophageal echocardiography for exclusion of blood clots in the left atrium and left atrial appendage; 4. Coronary angiography for exclusion of coronary heart disease; 5. Computer tomography for examination of cardiac chambers and

**Figure 1: Distribution of AF duration (n=100)**

anatomic characteristics of pulmonary veins.

Electric cardioversion in X-ray operating room conditions was performed on all patients. After successful restoration of sinus rhythm, electrophysiological examination (EP) of heart was carried out. Then, on the first or second day after EP study, Maze III procedure combined with a mitral valve operation was performed.

## Electrical Cardioversion

Electrical cardioversion was performed in a X-ray operating room, fully equipped for tracking the vital functions of a patient (an electrocardiogram, measurements of arterial blood pressure, frequencies of breath and saturation of blood by oxygen) and for carrying out resuscitation actions (a defibrillator, artificial respiration unit and an electropacemaker in case of development of heart blockades).

Two electrodes on a thorax surface were imposed, one electrode was located to the right of the chest under a clavicle, and the second — in the area of the apex of the heart, centered in the sixth — seventh intercostal space on the anterior axillary line.

The defibrillator generating a bipolar impulse was used. Electric discharge was begun with 200 J, and if necessary, the force of each following discharge was increased on 50 J.

After cardioversion sinus rhythm was successfully restored to all patients.

## Electrophysiological Examination (EP)

All antiarrhythmic drugs were cancelled for 5 half-lives before EP. Usually, under local anesthesia of 0,5 % Novocain solution the left or right femoral vein and the left subclavian vein were punctured. Through them four electrodes for carrying out the EP study were positioned.

The first quadripolar electrode was positioned in the high right atrium (HRA). Thus, the distal couple of poles could be used for stimulation, and proximal - for registration of activity of HRA.

The second electrode (quadripolar) was established in the apex of the right ventricle for diagnostic stimulation and recording EG of the right ventricle.

The third quadripolar electrode was placed in a projection of His bundle.

The fourth ten-polar electrode was set in the coronary sinus (CS) for registration of activity of right and left atriums.

The refractory periods of atriums were studied from three points: HRA, AV-node area and CS.

After positioning the catheters we registered patient's own heart rhythm for 5-10 minutes. Then we began with stimulation of HRA

**Table 2: EP study results**

	Data	Normal values
P-P (msec)	1000,4±300,3	600-1000
P (msec)	128,0±24,2	<120
PQ (msec)	220,1±36,5	140-210
QRS (msec)	118,6±20,1	70-110
QT (msec)	435,2±98,3	350-440
AH (msec)	88,2±34,8	60-125
HV (msec)	48,3±15,5	35-55
Atrial conduction time (msec)	84,7±27,3	24-50
Intra-atrial conduction time (msec)	106,3±18,4	
SNRT (msec)	1426,2±346,4	<1500
CSNRT (msec)	425,7±147,1	350-525
Sinoatrial Conduction Time (msec)	174,4±72,8	<215
Atrial FRP (HRA) (msec)	290,0±45,4	
Atrial RRP (HRA) (msec)	360,3±24,0	
Atrial ERP (HRA) (msec)	258±33,6	180-330
Atrial FRP (CS) (msec)	278±24,2	
Atrial RRP (CS) (msec)	323±25,6	
Atrial ERP (CS) (msec)	231,5±37,1	180-330
AV node FRP (msec)	256±33,7	
AV node RRP (msec)	380,9±130,4	
AV node ERP (msec)	225,6±25,2	250-400
Antegrade Wenckebach point (msec)	365,0±86,5	350-460

Normal values are given according to Mark E. Josephson ["Clinical Cardiac Electrophysiology: Techniques and Interpretations", 1979]

with a frequency of 5-10 bmp. higher than patient's own rhythm. After 1 min. we stopped pacing and registered post-stimulation activity of sinus node. Then resumed stimulation with a frequency of 10 bpm exceeding the previous, and had all the procedure repeated. Thus, the increasing stimulation of atriums was led up to the frequency of 150-160 bpm. If at that time no paroxysm of tachycardia or second-degree atrioventricular block was registered, the frequency of stimulation continued to be increased until atrioventricular block is reached.

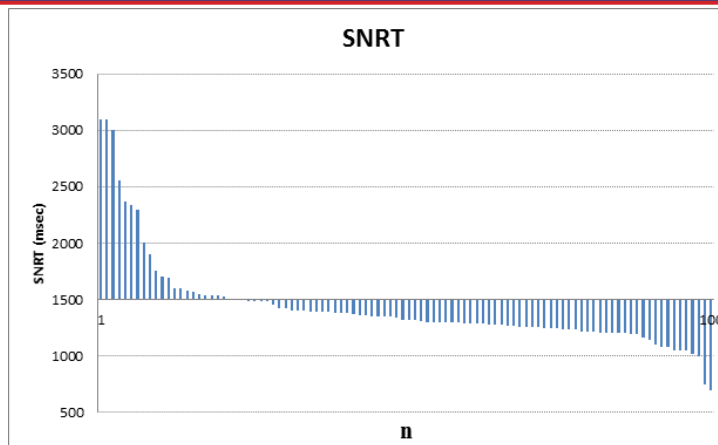
Afterwards we carried out single extrastimul pacing of atriums. Two frequencies of pacing were used (100 and 120 bpm.). The coupling interval of extrastimul was reduced by 10 msec each time, before reaching the refractory period of atriums.

The sinus node function was estimated by definition of sinus node recovery time (SNRT) - measurement of the duration of a post-stimulation pause between the last stimulated complex and the first atrium complex caused by a spontaneous impulse from the sinus node. Pacing began with a frequency exceeding a sinus rhythm for 10-20% and continued for 60 sec. The maximum value of a post-stimulation pause was assumed as SNRT. Also corrected sinus node recovery time (CSNRT) as difference between SNRT and sinus cycle length was calculated. The sinus node function was considered normal if the maximum SNRT didn't exceed 1500 msec, and CSNRT — 525 msec.

The sinoatrial conduction time (SACT) was measured as a difference of a value of an incomplete compensatory pause as a result of discharge of sinus node from a premature atrial beat and a value of a spontaneous atrial cycle.

#### Cryomodification Of Maze III Procedure In Combination With Rfa Of The Right Atrium During Mitral Valve Surgery

For the surgical treatment of atrial fibrillation at all patients cryomodification of the operation Maze III procedure on a classical



**Figure 2: Distribution of SNRT values in the research. The normal value is supposed to be less than 1500 msec**

technique was executed. Several of the surgical incisions were replaced with linear ablation using bipolar radiofrequency energy by Atricure device.

Operation was combined with valve surgery. At all patients correction of mitral valve defect was made (at 44 patients – valve replacement and at 56 – valve repair) and at 80% of patients tricuspid valve repair was executed.

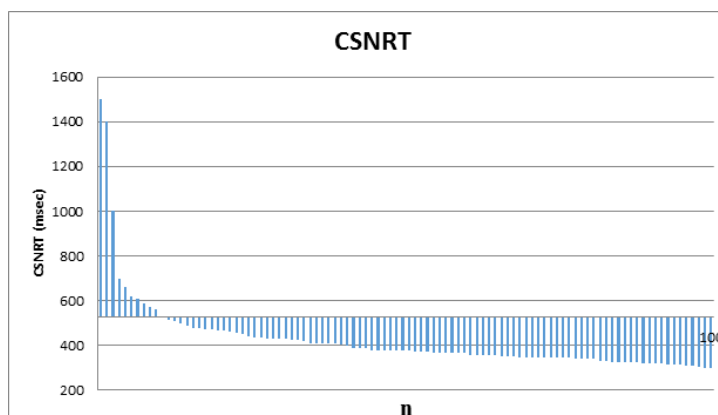
#### Statistical Analysis

Statistical analysis was carried out by nonparametric methods. When comparing constant figures the Mann-Whitney test was applied, and in the analysis of reliability of reactions of these figures in dynamic supervision in each of groups Wilcoxon's test was used. When comparing dichotomizing figures the bilateral test of Fischer was applied. In all cases of the comparative analysis of figures were considered reliable at  $p < 0,05$ . At multiple comparisons the Bonferonni adjustment on number of the groups included in comparison was considered. The correlation analysis between variables was carried out on Spearman's method.

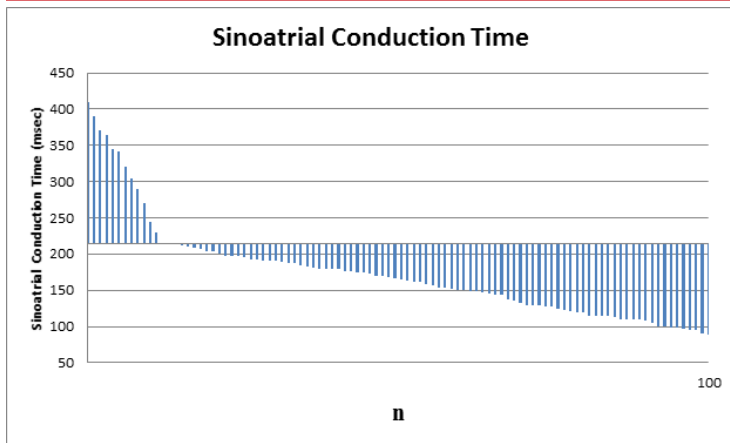
#### Results

##### Patient Characteristics

Research included 100 adult patients (48 men (48%) and 52 women (52%)) with persistent and long-standing persistent forms of atrial fibrillation and valve pathologies (see tab. 1). Average age of patients – 59,3±10,2 years with dispersion from 21 to 77 years. Existence of AF was confirmed by a surface electrocardiogram in 12 standard assignments or 24-hour Holter ECG monitoring.



**Figure 3: Distribution of CSNRT values in the research. The normal value is supposed to be less than 525 msec**



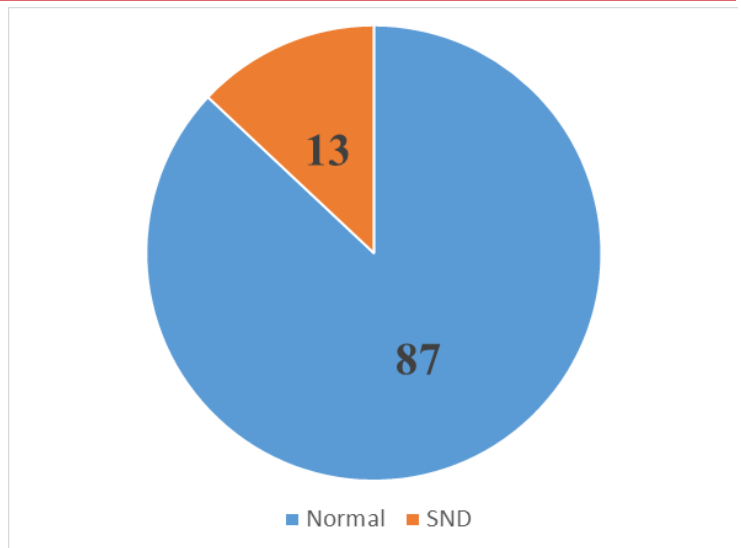
**Figure 4:** Distribution of Sinoatrial Conduction Time values in the research. The normal value is supposed to be less than 215 msec

Duration of AF from 1 year to 17 years, with average  $4\pm4,2$  years (see fig. 1). To all patients antiarrhythmic therapy was tried out, but proved to be ineffective. At 15% of patients attempts of restoration of a sinus rhythm by means of the electric cardioversion were applied, however it was not possible to control a normal sinus rhythm in long perspective. All patients had an organic pathology of the mitral valve with an average duration in  $21,8\pm12,8$  years. Also at 80% of patients tricuspid valve insufficiency was revealed. The functional class of heart failure on NYHA  $2,7\pm0,75$ . The average size of the left atrium was  $5,1\pm1,5$  cm, average left ventricular ejection fraction -  $61\pm8,6\%$ , and a cardiothoracic index -  $58,6\pm4,7\%$ . 12% of patients had the anamnesis of thromboembolic complications. 9% of 100 patients had aorto-coronary artery bypass graft surgery earlier, 16% of patients had arterial hypertension and 5% - diabetes.

**Electrophysiological Examination Results**

During the research all the patients retained normal sinus rhythm with a frequency from 45 to 94 bpm (see tab. 2). The average duration of P wave  $128,0\pm24,2$  ms, PQ interval -  $220,1\pm36,5$  ms, QRS complex width -  $118,6\pm20,1$  ms. The time of carrying out an impulse from sinus node to His bundle (AH interval) and from His bundle to ventricles (HV interval) made  $88,2\pm34,8$  ms and  $48,3\pm15,5$  ms respectively. Average atrial conduction delay was  $84,7\pm27,3$  ms. Average intra-atrial conduction delay was  $106,3\pm18,4$  ms. Average sinus node recovery time (SNRT) was  $1426,2\pm346,4$  ms, corrected sinus node recovery time (CSNRT) -  $425,7\pm147,1$  ms, and sinoatrial conduction time -  $174,4\pm72,8$  ms. The value of the functional refractory period (FRP) of the right atrium made  $290,0\pm45,4$  ms. The average relative refractory period (RRP) of the right atrium -  $360,3\pm24,0$  ms. And the average effective refractory period (ERP) of the right atrium -  $258\pm33,6$ . For the left atrium indicators of refractory periods were: FRP -  $278\pm24,2$  ms, RRP -  $323\pm25,6$  ms and ERP -  $231,5\pm37,1$  ms. Average values of a refractory periods of AV-node: FRP -  $256\pm33,7$  ms, RRP -  $380,9\pm130,4$  ms and ERP -  $225,6\pm25,2$  ms. Antegrade Wenckebach point was  $365,0\pm86,5$  ms. Average retrograde ERP of AV-node -  $316,2\pm76,4$  ms.

At 11% of patients pathological lengthening of CSNRT -  $900,3\pm300,6$  msec was revealed. And at 13% - pathological lengthening of sinoatrial conduction time (SACT) -  $340,2\pm80$  msec (see fig. 2-4). At 11% of patients pathological lengthening of SACT was followed by pathological lengthening of CSNRT, but



**Figure 5:** Distribution of SND

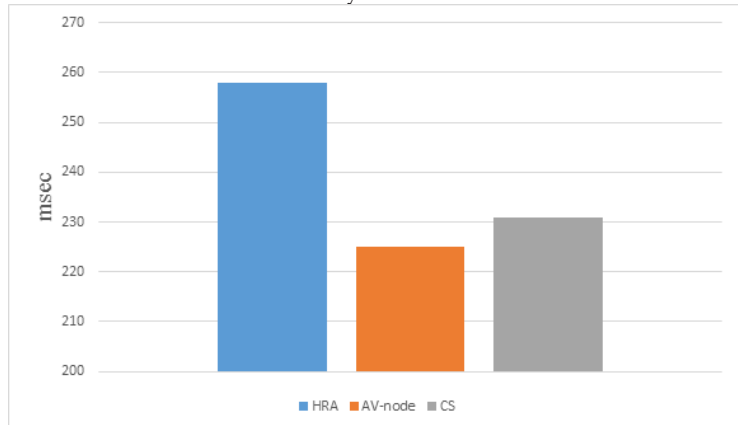
at 2% of patients other signs sinus node dysfunction (SND), except lengthening of SACT was not discovered.

Thus, total 13% of patients with AF and sinus node dysfunction (SND) were initially diagnosed (see figure 5).

The study of refractivity of various areas of the atria has shown that the ERP of AV-node was minimum in comparison with other areas and had mean value  $225,6\pm25,2$  msec. The longest ERP was found in the HRA area -  $258\pm33,6$  msec, that is significantly higher, than in the AV-node ( $p<0,01$ ). In the area of the coronary sinus the ERP had intermediate value, on average  $231,5\pm37,1$  msec. This is significantly lower, than the ERP in HRA ( $p<0,01$ ), but no statistically significant differences were found from the value of ERP of the AV-node (see figure 6).

The mean duration of PQ interval was  $220,1\pm36,5$  mm. The mean atrial conduction time was  $84,7\pm27,3$  msec, the mean AV-node conduction in the antegrade direction (AH) and the mean time of conduction of His-Purkinje system (HV) -  $88,2\pm34,8$  msec and  $48,3\pm15,5$  msec respectively. Thus, the lengthening of PQ interval was a consequence of the impulse conduction delay through the atria and AV-node.

Therefore, it is possible to draw a conclusion that patients with AF had decrease in functional ability of the AV-node.



**Figure 6:** Duration of the effective refractory periods of various areas of atria. HRA - high right atrium, CS - coronary sinus, AV-node - atrioventricular node

### Cryomodification Of Maze III Procedure In Combination With Rfa Of The Right Atrium During Mitral Valve Surgery Results

Consequently, by results of Maze III procedure with valve disease correction disposal of AF was observed at 95% of patients. At 46% of patients at the moment of discharge from the hospital the stable sinus rhythm remained. At 24% of patients the atrial rhythm with the maximum heart rate 80-110 bpm was observed (by the results of 24-hour Holter ECG monitoring). 25% of patients needed permanent pacemaker implantation. At the same time, by results of EP-study, initially before surgical treatment 13% of patients suffered from sinus node dysfunction. From the remained 12% at 9% of patients the indication for pacemaker implantation were the nodal rhythm with low heart rate and pauses more than 3 sec long, one patient had episodes of transient AV block (second degree, second type) and SA block (second degree, second type), one patient had a complete heart block and at the last one – atrial rhythm with pauses more than 3 sec long.

At 13% of patients with the atrial rhythm and normal heart rate in the early postoperative period typical atrial flutter has developed. To all of them the radio-frequency ablation of cavo-tricuspid isthmus with creation of the bidirectional block was performed, and further recurrence of atrial flutter wasn't observed.

#### Discussion

The mechanisms involved in development of sinus node dysfunction after Maze III procedure are: 1) direct consequence of the surgical treatment; 2) the general postoperative complications of the open-heart surgery. Anyway, sinoatrial node can be either directly damaged or its function can be lowered because of the external reasons, without direct damage of the sinus node tissue. The surgical factors directly changing anatomy and functional ability of sinoatrial node or an adjacent myocardium (or all together), include a mechanical trauma, injury of the sinoatrial node arteries, ischemia or necrosis.<sup>8,9,10,11</sup>

Influence of the surgical cuts applied during Maze III procedure on the atrial innervation, humoral homeostasis and the subsequent rhythm effect is still not fully studied. The main concern is caused by changes of integrative ability of sinus node area, autonomous nervous regulation and blood supply. Arterial supply of sinus node can be more variable, than it was supposed earlier, that makes critical all the area of the vena cava superior.<sup>12</sup>

Anyway, violation of a blood supply of the sinus node artery can contribute to its dysfunction, but most likely does not take essential part in pathogenesis, especially in case of cryomodification of Maze III procedure, which allows protecting the anatomic region of sinus node. Nevertheless, the process of generation of an electric impulse in the atria is difficult and is connected not only with one center of automatism. Experimental and clinical evidences force us to assume that the functional part of sinus node isn't so well defined as it was supposed earlier.<sup>8,13-15</sup>

#### Conclusions

In our research after cryomodification of Maze III procedure in combination with RFA of the right atrium during mitral valve surgery 46 (46%) patients have been discharge from the hospital with the stable sinus rhythm and 24 more (24%) had the atrial rhythm with adequate chronotropic characteristics.

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