**VILNIUS UNIVERSITY**

**Paulius Jurkuvėnas**

# COMPARISON OF EFFECTIVENESS THE RADIOFREQUENCY MODIFIED MAZE PROCEDURE AND MITRAL VALVE SURGERY USING TRANSSEPTAL OR SEPTAL-SUPERIOR APPROACHES THE FOR THE TREATMENT OF ATRIAL FIBRILLATION

Summary of doctoral dissertation

Biomedical science, Medicine (07B)

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Scientific Advisor:
Prof. Dr. Audrius Aidietis (Vilnius University, Biomedical sciences, Medicine – 07B)

**Doctorate Committee**:

Chairman:

Prof. Dr. Janina Tutkuvienė (Vilnius University, Biomedical science, Medicine – 07B)

Members:
Prof. Dr. Marija Rūta Babarskienė (Kaunas University of Medicine, Biomedical science, Medicine – 07B).
Assoc. Prof. Dr. Aras Puodžiukynas (Kaunas University of Medicine, Biomedical science, Medicine – 07B)
Prof. Dr. Jolanta Dadonienė (Vilnius University, Biomedical science, Medicine – 07B)
Dr. Gintaras Kalinauskas (Vilnius University, Biomedical science, Medicine – 07B)

Opponents:
Assoc. Prof. Dr. Žaneta Petrulionienė (Vilnius University, Biomedical science, Medicine – 07B)
Prof. Habil. Dr. Algimantas Kirkutis (Klaipėda University, Biomedical science, Medicine – 07B)

Maintaining of the Dissertation is scheduled at the open Doctorate Committee Meeting on January 22, 2010 at 1 p.m. at the Conference Hall of Vilnius University Hospital Santariškių Klinikos.

Address: Santariškių str. 2, LT-08661, Vilnius, Lithuania
tel. (+370) 5 236 5216
fax. (+370) 5 236 5210

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VILNIAUS UNIVERSITETAS

Paulius Jurkuvėnas

# MODIFIKUOTOS RADIODAŽNINĖS LABIRINTO PROCEDŪROS IR MITRALINIO VOŽTUVO YDOS KOREKCIJOS, ATLIEKAMOS PER TARPPRIEŠIRDINĖS PERTVAROS IR VIRŠUTINĮ PERTVAROS PJŪVIUS EFEKTYVUMO PALYGINIMAS GYDANT PRIEŠIRDŽIŲ VIRPĖJIMĄ

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Mokslinis vadovas:

Prof. dr. Audrius Aidietis (Vilniaus universitetas, biomedicinos mokslai, medicina – 07B)

**Disertacija ginama Vilniaus universiteto medicinos mokslo krypties taryboje**:

Pirmininkas:
Prof. dr. Janina Tutkuvienė (Vilniaus universitetas, biomedicinos mokslai, 07B – medicina)

Nariai:
Prof. habil. dr. Marija Rūta Babarskienė (Kauno medicinos universitetas, biomedicinos mokslai, 07B – medicina,),
Prof. dr. Jolanta Dadonienė (Vilniaus universitetas, biomedicinos mokslai, 07B - medicina,),
Doc.dr. Aras Puodžiukynas (Kauno medicinos universitetas, biomedicinos mokslai, 07B – medicina),
Dr. Gintaras Kalinauskas (Vilniaus universitetas, biomedicinos mokslai, 07B - medicina,).

Oponentai:
Doc. dr. Žaneta Petrulionienė (Vilniaus universitetas, biomedicinos mokslai, 07B – medicina)
Prof. habil. dr. Algimantas Kirkutis (Klaipėdos universitetas, biomedicinos mokslai, 07B – medicina,).

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Adresas: Santariškių 2, LT-08661, Vilnius
tel. (+370) 5 236 5216
faks. (+370) 5 236 5210

Disertacijos santrauka išsiųsta 2009 m. gruodžio d.

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**Abbreviations**

AAI – atrial pacing
AAIR – adaptative atrial pacing
AAD – anti-arrhythmic drugs
CABG – coronary artery by-pass grafting
AoVP – aortic valve prosthesis implantation
AV – atrioventricular
DDD – consecutive (dual-chamber) atrial and ventricular pacing
DDDR – adaptative dual-chamber atrial pacing
CPB – cardiopulmonary by-pass
RA– right atrium
EchoCG – echocardiography
EP – electrophysiology
EPE – electrophysiology examination
EG – electrogram
EIT – electro impulse therapy (cardioversion)
ECG – electrocardiogram
PM – pace maker
EHS – electric heart stimulation
EF – ejection fraction
LA – left atrium
LV – left ventricle
LVdd – left ventricle diastolic diameter
LVH – left ventricle hypertrophy
MVI – mitral valve insufficiency
MV – mitral valve
NYHA – *New York Heart Association*
TOES – trans-oesophageal stimulation
CI – confidence interval
Pl – plasty
AFL – atrial flutter
TA – trans-septal approach
fig. – figure

PT – paroxysmal tachycardia

AF – atrial fibrillation

RF – radiofrequency

RFA – radiofrequency ablation

SN – sinus node

SSNS – sick sinus node syndrome

SR – sinus rhythm

HF – heart failure

IVS – interventricular septum

SSA – superior septum approach

TV – tricuspid valve

VVI – ventricular pacing

VVIR – adaptative ventricular pacing

TVpl - tricuspid valve plasty

AoVP - aortic valve prosthesis

MVP - mitral valve prosthesis

MVpl - mitral valve plasty

ASD - atrial septal defect

TOEPE – trans-oesophageal electrophysiology examination

CONTENT

## 1. INTRODUCTION

Atrial fibrillation (AF) is one of the most common heart rhythm disturbances. The prevalence of this disorder in general population is 0.4 – 0.9%. AF incidence depends on the age of the patient: the incidence of AF in patients older than 60 years increases two-fold every decade and in patients over 65 years this rhythm disorder is diagnosed for 6% of the patients; the incidence of AF in subjects over 80 years is as high as 6 – 10%. Frequently, AF is related to cardiovascular diseases and disorders of metabolism, (e.g., coronary heart disease, arterial hypertension, heart failure, heart valve malformations, hyperthyroidism and diabetes mellitus). The increase of patients suffering from these diseases results in an increase of AF cases. It is widely accepted, that this arrhythmia requires a substrate and trigger mechanism. Structural heart disease results in progress of pathophysiology mechanisms causing anatomical atrial re-modelling (i.e., inflammatory and autoimmune processes, changes of angiotensin – aldosterone and functioning of autonomic nervous systems). The processes of electrical re-modelling (ectopic activity, single and multiple circles of re-entry excitation) cause and maintain AF. AF disturbs ventricular filling because of atrial arrhythmia and increased heart; this, in turn, influences blood flow and affects prognosis of a patient suffering from structural heart disease. Hart publication analyzing cardio-embolism strokes and AF indicates that AF causes a condition of hyper-coagulation. Long-term AF results in an increase of plasma D-dimer and beta-thromboglobulin levels; impairment of nitrous oxide metabolism and disturbances of plasminogen activator inhibition are reported as mechanisms of thrombogenesis impairment, also. Increasing understanding of AF pathophysiology mechanisms resulted in development of surgical methods of treatment of AF. In 1987, James L. Cox proposed MAZE procedure; atrial incisions create an atrial maze allowing excitation generated in sinus node to spread towards atrioventricular node by a certain path, only. While suppressing arrhythmogenic impulses, this method in 90 % of cases prevents from atrial fibrillation caused by various mechanisms. Therefore, medicamental treatment and different methods of non-medicamental (e.g., electro impulse therapy, catheter ablation, heart pacing), as well as hybrid, treatment are being attempted to be combined to cure AF. During the recent years, maze procedure modified by various authors is being applied more and more frequently; these procedures include creation of atrial conductivity blockade lines using not only incisions but radiofrequency (RF) energy or other types of energy (microwaves, laser and ultrasound), also. These procedures significantly decrease duration of the procedure, risk of bleeding and increase the rate of good results. Therefore, methods of surgical ablation may be successfully combined together with different heart surgery interventions (correction of congenital and acquired heart malformations, coronary surgery) as it is unwise not to cure AF when it is possible to do it.

AF is frequently present in cases of mitral valve (MV) malformations. In accordance with data from epidemiological studies, 30 – 50 % patients undergoing MV correction suffer from AF, also. AF persists in 60 -80 % of the patients after surgical correction of MV malformation, even when medicamental treatment is being performed. AF worsens patient's quality of life and decreases life duration of patients after operation. It is related to significantly (from five- to fifteen-fold) increased risk of thromboembolism complications, even when anticoagulation therapy is being applied.

The maze procedure performed with MV or other valve correction is nearly as effective as in event of isolated AF. Incision of atrial septum via trans-septal approach (TA) or superior atrial incision, also known as superior septal approach (SSA) (when MV exposure is difficult), are being performed during correction of MV malformation at Vilnius University Santariškių Klinikos Clinic of Angiology and Cardiology. In other centres, a longitudinal LA incision parallel to inter-atrial groove is chosen when modified RF maze procedure is performed. Databases contain very sparse information regarding atrial incisions during maze procedures. TA in bi-atrial RFA (mono and bipolar) was reported by Levy (2004); the study included 60 patients; the duration of follow-up was 3 months. In 2009, Kainuma S.et al. analyzed the data of patients for whom SSI for correction of MV malformation and RFA, cryoablation were performed; the group included 10 patients and follow-up duration was $\leq$ 18 months. At our centre, Cox maze III procedure using atrial incisions is being performed since 2000, and RFA modified maze procedure with MV correction – since 2001.

## 2. PURPOSE OF THE STUDY

To evaluate efficacy and safety of modified radiofrequency maze procedure, while treating atrial fibrillation and using mono-polar irrigated (cooled with liquid) radiofrequency ablation catheters in patients who undergo correction of mitral valve malformations via atrial septum incisions.

### 2.1 Study tasks

1. To compare radiofrequency maze procedures using trans-atrial approach and superior septal approach.
2. To evaluate clinical factors of prognosis of treatment.
3. To evaluate influence of different septal incisions on treatment of atrial fibrillation in patients who underwent radiofrequency maze procedure and correction of mitral valve malformation.
4. To evaluate influence of radiofrequency maze procedure on mechanic atrial function in postoperative patients with sinus rhythm.
5. To assess factors influencing treatment efficacy in patients who underwent radiofrequency ablation procedure and correction of mitral valve correction.
6. To evaluate the role of electrophysiology methods of treatment (implantation of heart pace maker, per-catheter radiofrequency ablation) after modified maze procedure and correction of mitral valve malformation.

## 2.2 Scientific novelty of the study

1. A modified maze procedure was developed and applied in operations of MV with atrial incision.
2. Influence of two types of atrial incisions (TA and SSA) and RF maze procedure on treatment of AF was investigated.
3. Comparison of these methods was performed.
4. It was stated, that localization of electrode of permanent stimulation at coronary sinus is optimal for the patients suffering from sinus node (SN) dysfunction.

# 3. METHODS OF THE STUDY

## 3.1. Study subjects

The data of 143 patients suffering from persistent or chronic AF, who since 2002 to 2008 underwent correction of mitral valve malformation and modified radiofrequency maze procedure at Vilnius University Hospital Santariškių Klinikos were retrospectively collected, analyzed and evaluated. The patients were informed about the procedure and their written consent was obtained.

The majority of the data concerning anamnesis, clinical status and intra-cardiac or trans-oesophageal EPE was collected from out-patient cards, case histories, intensive care documents and hospital computer database. The follow-up after the operation was performed in out-patient manner.

*(Kur kitos 4 lent.?)* ***Table 5***.

| Type of operation | N (%) | |
|---|---|---|
| AoVP, MVP, TVpl | 1 (0.7 %) | 72.7(%) |
| MVP | 13 (9.5 %) | |
| AoVP, MVP, TVpl | 25 (18.2 %) | |
| MVP,TVpl | 62 (45.3 %) | |
| MV pl, TVpl | 13 (9.5 %) | 28.3(%) |
| AoVP, MVpl, TVpl | 4 (2.9 %) | |
| MVpl | 4 (2.9 %) | |
| MVpl, ASD suture | 9 (6.6 %) | |
| MVpl, TVpl, ASD suture | 4 (2.9 %) | |
| MVpl, correction of anomalous pulmonary vein drainage | 1 (0.7 %) | |
| MVpl, TVpl + CABG | 1 (0.7 %) | |

Total number of surgical procedures - 214

* - MVP – mitral valve prosthesis, AoVP- aortic valve prosthesis, MVpl – mitral valve prosthesis, ASD – atrial septal defect, TVpl – tricuspid valve plasty.

Patients' clinical and functional condition, rhythm disturbances, medicamental treatment and complications were evaluated by means of questioning and clinical examination.

### 3.2 Study methods

AF type, duration and further dynamics, efficacy of AAD, functional status, echocardiography data, Holter monitoring findings were evaluated for all patients prior operation, post-operatively or after other procedures (oesophageal electrophysiology examination, heart pace maker implantation, electrical cardioversion, per-catheter RF ablation). Histology examination of RA and LA auricles, removed during operations was performed in accordance with standard methods for a group of the patients.

Electrocardiogram. Standard 12-leads ECG was registered using Hellige, Shiller or Philips electrocardiographs. AF was diagnosed when ECG showed f-waves of irregular form, amplitude, duration and R-R intervals of irregular duration. All ECG were recorded using standard speed (25 mm/s) and sensitivity (1 mV corresponds 10 mm). The largest f-wave was measured in V1 lead in not less than 10 R-R intervals. The amplitude of the wave was measured in millimetres and AF was considered to be a "large wave", when amplitude was > 1 mm (> 0.1mV) and "small wave", when amplitude was < 1 mm (<0.1 mV) [83].

ECG's were registered after operation, during postoperative hospitalization and 1, 3, 6 months, 1 year after the procedure and during the last visit. The superficial ECG is often not informative enough; therefore we used to perform trans-esophageal ECG registration in order to differentiate the rhythm of the heart.

Trans-oesophageal electrophysiology examination (TOEPE). The trans-oesophageal EPE was performed for patients prior implantation of heart pace maker in order to choose the mode of constant electrical heart stimulation. An electrode containing 4 – 6 contacts was inserted through the nose into oesophagus. One pair of contacts was used to record an electrogram (EG) and another one was used for atrial stimulation. EG was registered and LA stimulation performed using computerized electrophysiology system *CardioComp -2*. Oesophageal EG signal was recorded using bipolar mode and filtration of the signal in 0.3 – 50 Hz frequency range. While changing the position of the electrode, the site of atrial electrical potential of largest size was detected. The examination included evaluation of the rhythm (SR, AFL/AF) and AV conductivity. In event of organized atrial arrhythmia, the mechanism of this arrhythmia was analyzed and restoration SR attempted using rate increasing stimulation. AV conductivity was assessed using rate increasing stimulation and was considered to be decreased when it was < 130 beats per minute.

AF assessment. Patients who pre-operatively had symptomatic chronic or persistent AF (≥ 6 months) were selected for assessment. Persistent AV type was defined as AF with duration till SR restoration more than 7 days; chronic AF was defined as AF resistant to cardioversion (or relapsing in 24 hours after cardioversion). The results were assessed as positive when AF or AF-AFL did not reoccur 1 year after the operation. The results were assessed as negative in event of chronic AF or episodes of AF – AFL after treatment procedures or on AAD.

Functional condition of the subjects. The condition was evaluated in accordance with NYHA classification (I, II, III and IV functional classes).

Methods of echocardiography examination. Ultrasound heart examinations were performed using *KONTRON Sigma 440* with 3.5 MHz superficial sector frequency transducer, *TOSHIBA Power Vision 7000* with 3.7 MHz electronic sector superficial transducer, *VIVID 7 Dimention* (*GE Healthcare*) and *VIVID 4 Expert* (*GE Healthcare*) electronic phase multi-frequency transducers using standard methods. Diastolic LV diameter, diastolic diameters of interventricular septum (IVS) and LV posterior wall (LVPW) were measured in one-dimension echocardiograms using two dimensional para-sternal long axis sections. Diastolic LV diameter was measured during the final phase of the diastole before the beginning of QRS complex from IVS endocardium surface to the surface of LVPW endocardium. Normal size of diastole LV ranged from 37-56 mm. IVS thickness was measured at the end of diastole from the right endocardium surface to the surface of the left endocardium. The thickness of IVS during diastole was considered to be normal when it ranged from 6 to 9 mm. The thickness of LVPW was measured at the end of the diastole from endocardium to visceral layer of pericardium. The thickness of LVPW during diastole was considered to be normal when it ranged from 6 to 9 mm. An increased diastolic size of IVS and LVPW was assessed as hypertrophy of LV (LVH). LV ejection fraction (EF) was evaluated visually in apical four, three and two chamber, para-sternal long and short axis sections. The function of the ventricle was considered as good, when EF was >50%. The size of LA was measured at the end of the systole in four chamber apical section when MV was completely closed. LA size was measured in two perpendicular plains: the vertical measurement (long) was determined – by joining MV annulus and basal part of LA, another measurement (short) was determined by joining atrial septum with free wall of LA. LA was considered to be not enlarged when neither of these measurements was larger than 50 mm; grade I enlargement was diagnosed when either of these measurements ranged from 51 to 60 mm, grade II – 61 – 80 mm, grade III – 81 – 100 mm, grade IV – when either of the measurements was larger than 100 mm. The size of RA was measured in two perpendicular plains. The size of RA was measured in apical four chamber section at the end of the systole, when TV was completely closed. The vertical measurement (long) was determined by joining TV and basal part of RA. Another (horizontal) measurement (short) was measured by joining atrial septum with free wall of LA. The size of LA was considered to be normal when neither of these measurements was larger than 40 mm, grade I enlargement was diagnosed when either of these measurements ranged from 41 to 60 mm, grade II – 61 – 80 mm, grade III – 81 – 100 mm, grade IV – when either of these measurements was larger than 100 mm. MV insufficiency (MVI) grade was evaluated taking into account pulse wave and findings of colour Doppler echocardiography. MVI grade was determined by the length of regurgitation flow from MV annulus in apical four, two and three chamber sections and para-sternal long and short axis sections. Grade I MVI was diagnosed when regurgitation flow was registered at MV annulus only, grade II – when regurgitation flow was registered from MV annulus to the third of LA, grade III – from MV annulus to the middle of LA, and grade IV – when the flow was larger.

Holter 24 h ECG monitoring. This examination was performed in order to evaluate sinus node (SN) function, AV conductivity, mechanism causing arrhythmia and efficacy of treatment. The examinations were performed using *OXFORD Medilog MR63* and *DATRIX XR-300 Holter Recorder* equipment and data were analyzed using *Premier IV Holter* system software.

### 3.3 Surgical technique

After middle sternotomy, ascending aorta and both v. cava were cannulated, cardiopulmonary by-pass (CPB) was started for all patients (standard technique). Myocardium protection was performed using lukewarm (28$^{o}$C) blood cardioplegia and antegrade intermittent cardioplegia. Retrograde cardioplegia (32$^{o}$C) was performed for eight patients.

While on CPB, the following incisions were performed: 1) excision of RA auricle (fig. 7?, *a incision*); 2) 4 cm incision of RA from removed auricle downwards to inferior vena cava (*b*); 3) arched RA longitudinal-lateral incision to open RA (*c*); the incision was begun at the margin of inter-atrial septum and continued towards atrioventricular groove. In the group of TA patients the left atrium was opened by means of incision (d1) of atrial septum (fig. 8 A). In SSA group LA was opened using incision (d2) when the incision of the septum was continued upwards through the roof of LA and in other direction towards the stump of RA auricle (fig. 8 B). RF maze procedure was performed prior correction of mitral valve malformation or other surgical procedures.

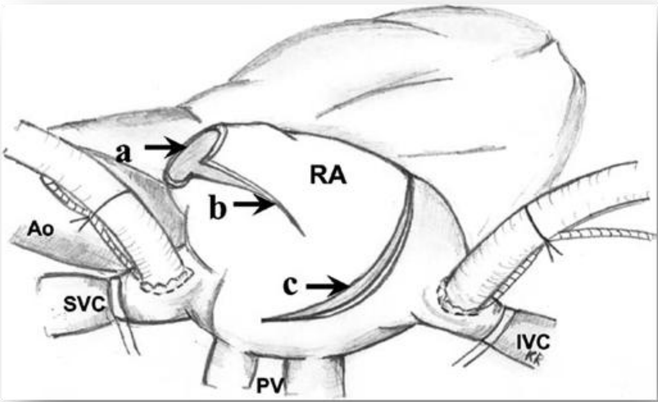
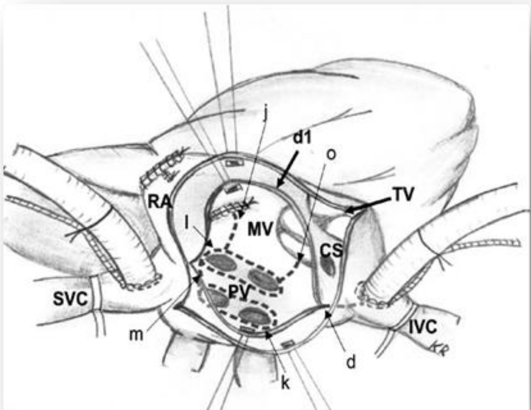



***Fig. 7.*** Layout of right atrium incisions

The incisions are marked by arrows (a – removal of the auricle; b – incision form auricle stump towards inferior vena cava; c- arched longitudinal-lateral incision to open the right atrium;). Ao – aorta, SVC – superior vena cava, IVC – inferior vena cava, RA – right atrium, PV – pulmonary veins.



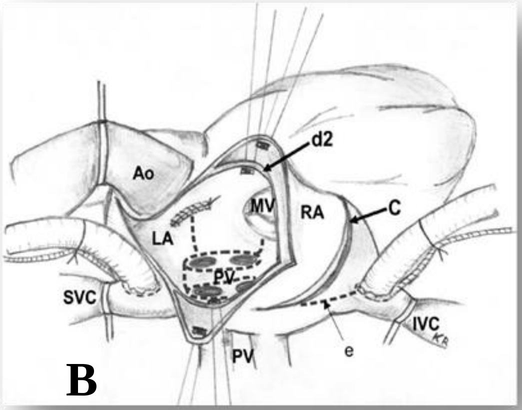



**Fig 8.** Layout of maze procedure

Lines of radiofrequency ablation are shown by doted lines (*d, f, g, e, j, k, l, m, o*). The incisions are marked by arrows (a, b, c, d1,d2). Ao – aorta, CS – coronary sinus, RA – right atrium, SVC – superior vena cava, IVC – inferior vena cava, PV – pulmonary veins, TV – tricuspid valve.

### 3.4 Radiofrequency maze procedure

RF energy applications were performed using *HAT 200S (Sulzer-Osypka GmbH)* RF energy generator and electrode catheters with special inner channels for cooling liquid and openings in the end of the catheter *Sprinklr (Medtronic)* and *Celsius ThermoCool (Biosense Webster)* (fig. 3.A). We used infusion pump *SP-12S Pro* (*UAB „Viltechmeda", Vilnius*) for infusion of cooling solution (Na Cl 0.9%); the speed of infusion during ablation was 20 ml/min.

A

B

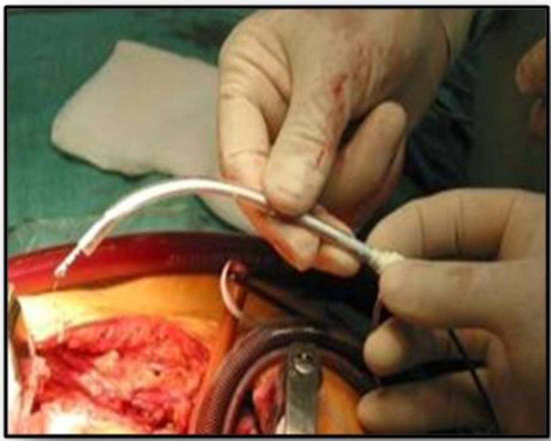


***Fig.9.*** Catheter used in modified RF procedure.

In order to achieve proper handling and catheter's shape desired, we used to insert electrode catheters into vascular 7-8 F introducers (used in interventional cardiology) and to cover these catheters with polyethylene cannulae containing metal wire in the wall (fig.9 B). While creating maze lines we performed slow oscillating movements of electronic catheter placed on atrial myocardium. The duration of each radiofrequency application procedure was individual and based on thickness and visible changes of the tissue (developing pallor). The capacity of radiofrequency energy was limited to 25 – 45 W. At first, LA maze was formed (fig.7) and then we used to perform RA maze creation. (fig. 8). For the patients who underwent trans-atrial incision the line of ablation *(d1)* was continued from incision of atrial septum to inferior vena cava (*d*) (fig.8 B).

In patients for whom superior septal incision was performed (d) line was not created, but they underwent formation of (e) line. After this, corrections of mitral valve malformations and other surgical procedures, excision of LA auricle were performed. Temporary epicardial stimulation electrodes were fixed on the heart for atrial and ventricular pacing prior discontinuation of cardiopulmonary by-pass. After connection of temporary pacing system we checked whether both atrial and ventricular stimulation was effective.

### 3.5. Follow-up

The duration of follow-up ranged from 12 months to 6.5 years (mean duration 21.2±7.4 months). In event the patient developed constant atrial or sinus rhythm postoperatively, anti-arrhythmic drugs were not administered. The patients with episodes of AF or AFL were administered amiodarone, metaprolol, sotalol or amiodarone with propaphenone. If the treatment with the drugs mentioned above failed to restore SR, electric impulse therapy was performed. Anti-arrhythmic drugs were administered for the patients with atrial rhythm disturbances for further 3-6 months and, in event AF/AFL did not reoccur, treatment with these drugs was discontinued. Treatment with warfarin was administered in accordance with European Society of Cardiology Guidelines. Warfarin was administered for life for patients who underwent implantation of MV prosthesis and patients after successful MV plasty received this drug for 3-6 months; then warfarin was discontinued if AF/AFL did not reoccur.

### 3.6. Statistical analysis

The data were analyzed using statistical analysis software package SPSS 16.0. For quantitative variables descriptive statistics was used and mean value ± mean square deviation was presented. For qualitative variables absolute and percentage rates were presented. Hypotheses concerning the difference between quantitative variables in two groups were checked using Sudent ($t$) criterion of independent samples. In event data normality premise was not met, non-parametrical Mann – Whitney – Wilcoxon test was used. While comparing groups regarding qualitative variables, chi-square ($\chi^2$) or exact Fisher's tests were used. Marginal homogeneity or McNemar tests were used to compare short-term and final results. In analysis of relationship between results of procedures and findings of echocardiography, age and different qualitative parameters univariate and multivariate models of logistic regression were applied. In order to evaluate characteristics of model quality ROC curves were used. Significance level was considered to be equal to 0.05.

## 4. RESULTS AND JUSTIFIED RELIABILITY

### 4.1. General characteristics of study subjects, short-term post-operative results and complications

The analysis included data of 143 patients. For 90 (62.9%) patients maze procedure was performed using TA and 53 (37.1%) patients underwent maze procedure with SSA. The age of the patients ranged from 27 to 76 (mean age 55.35 years, standard deviation 9.52 years); there were 97 (67.8 %) female and 46 (32.3%) male patients (see Table 6).

***Table 6.*** General characteristic of the patients

| Variable* | Characteristic |
|---|---|
| Age (years) | **55.35 ± 9.52** |
| Gender: | |
| Male | **46 (32.2%)** |
| Female | **97 (67.8%)** |
| Re-operation | **24 (16.8%)** |
| **Type of AF:** | |
| Chronic | **106 (74.6%)** |
| Persistent | **36 (25.4%)** |
| Left ventricle ejection fraction | **49.44 ± 6.21** |
| Size of f-waves in V1 lead (mm) | **1.44 ± 0.81** |
| Size of f-waves in V1 lead (≤1 mm) | **65 (47.8%)** |
| Duration of preoperative AF (months) | **24.80 ± 32.92** |
| Total duration of AF (months) | **53.30 ± 47.05** |
| Longitudinal measurement of the left atrium (cm) | **6.75 ± 0.85** |
| Transversal measurement of the left atrium (cm) | **5.90 ± 0.82** |
| Longitudinal diameter of the left atrium (cm) | **6.67 ± 1.19** |
| Longitudinal measurement of the right atrium (cm) | **5.95 ± 0.75** |
| Transversal measurement of the right atrium (cm) | **6.39 ± 7.59** |
| **NYHA functional class:** | |
| No heart failure | **0 (0.0%)** |
| I | **0 (0.0%)** |
| II | **1 (0.7%)** |

| | |
|---|---|
| III | **117 (81.8%)** |
| IV | **25 (17.5%)** |

In-hospital mortality rate was 3.5%: one patient died during re-thoracotomy because of bleeding from posterior wall of the left ventricle; 4 patients died during early (under 10 days) post-operative period (2 patients died of sepsis and 2 of multi-organ failure with low cardiac output syndrome). These patients not included in further analysis of atrial fibrillation treatment efficacy. Non-lethal complications that developed during 30 days after the operation included: bleeding requiring re-thoracotomy (3); fistula between the left ventricle and right atrium (1) (see fig. 10), suppuration of the wound (1); transitory impairment of brain circulation (1), bleeding from digestive tract requiring laparotomy (1).

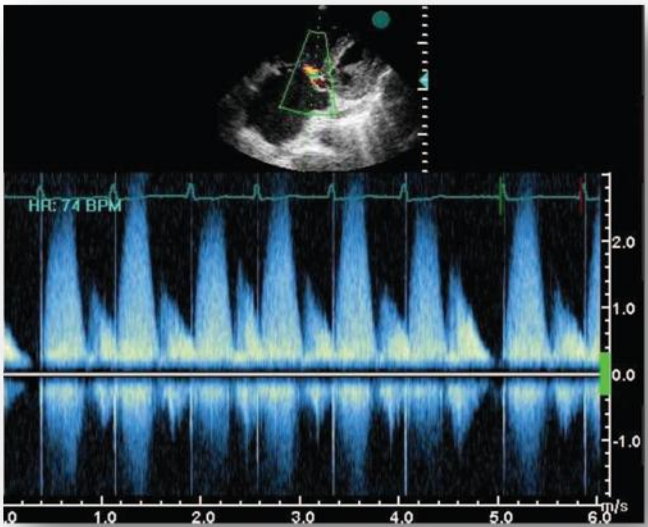



***Fig. 10.*** *Intracardiac connection found by means of echocardiogfraphy examination with Doppler flow evaluation (maximum systolic velocity – 3.5 m/s): fistula between the left ventricle and right atrium*

There was one thromboembolism complication (embolisation of a. femoralis) during further period of follow-up (after 6 months); no neurology complications were observed. One patient who had suffered from dilatative cardiomyopathy died because of progressing heart failure; two patients had died because of causes not related to cardiovascular pathology (one patient because of ovarian cancer 5 years after the operation and another patient – because of septic complications that developed after urgent removal of gall bladder 14 months following the operation). There were 5 cases of MV para-prosthetic fistulae with significant (grade 2 – 3) regurgitation; three patients underwent repeated operations; two patients refused re-operation; one of these patients currently has chronic AF and the other one suffers from persistent AF/AFL. For 4 patients primary plasty of MV was not effective; therefore these patients underwent repeated MV plasty or implantation of MV prosthesis.

### 4.2. Comparison of TA and SSA groups

There were two groups of patients according atrial incisions performed. The baseline data in these groups did not differ (see Table 7). Analysis of operative data showed that the groups did not differ, also (see Table 8), except duration of temporary postoperative stimulation.

***Table 7***. Characteristics of patients in TA and SSA groups

| **Variable*** | **TA (n=90)** | **SSA (n=53)** | ***p* value** |
|---|---|---|---|
| Age | 55.39 ± 9.62 | 55.28 ± 9.44 | 0.949 |
| Gender: | | | |
| Male | 26 (28.9%) | 20 (37.7%) | 0.274 |
| Female | 64 (71.1%) | 33 (62.3%) | |
| Repeated operation | 18 (20.0%) | 7 (13.2%) | 0.302 |
| AF type: | | | |
| Chronic | 63 (70.8%) | 43 (81.1%) | 0.170 |
| Persistent | 26 (29.2%) | 10 (18.9%) | |
| LV ejection fraction | 49.61 ± 5.28 | 49.16 ± 7.56 | |
| Size of f waves in V1 lead | 1.43 ± 0.85 | 1.47 ± 0.74 | 0.486 |
| Duration of AF prior operation (months) | 26.33 ± 38.04 | 22.19 ± 21.74 | 0.916 |
| Total duration of AF (months) | 57.16 ± 53.30 | 46.75 ± 33.36 | 0.455 |
| LA longitudinal measurement (cm) | 6.79 ± 0.84 | 6.67 ± 0.87 | 0.388 |
| LA transversal measurement (cm) | 5.96 ± 0.80 | 5.79 ± 0,85 | 0.240 |
| LA longitudinal diameter (cm) | 6.81 ± 1.19 | 6.42 ± 1.15 | 0.060 |
| RA longitudinal measurement (cm) | 6.03 ± 0,77 | 5.83 ± 0.69 | 0.133 |
| RA transversal measurement (cm) | 5.20 ± 0.99 | 5.03 ± 0.80 | 0.306 |
| NYHA functional class: | | | |
| No heart failure | 0 (0.0%) | 0 (0.0%) | 0.533 |
| I | 0 (0.0%) | 0 (0.0%) | |
| II | 0 (0.0%) | 1 (1.9%) | |
| III | 74 (82.2%) | 43 (81.1%) | |
| IV | 16 (17.8%) | 9 (17.0%) | |

* - mean value and standard deviation (mean ± SD) are presented for quantitative variables and rate (number and %) is presented for qualitative variables.

***Table 8***. Characteristics of surgical treatment in TA and SSA groups

| **Variable*** | **TA (n=90)** | **SSA (n=53)** | ***p* value** |
|---|---|---|---|
| CPB (min.) | 150.11 ± 44.19 | 152.09 ± 40,70 | 0.790 |
| Duration of Ao cross-clamping | 98.46 ± 26.47 | 101.55 ± 27.85 | 0.509 |
| Temporary post-operative stimulation (days) | 3.40 ± 5,20 | 6.08 ± 6,44 | 0.005 |
| Incidence of temporary post-operative stimulation ** | 40 (44.4%) | 35 (66.0%) | 0.013 |
| Total duration of operation (min.) | 248.03 ± 59.79 | 255.70 ± 52.76 | 0.441 |
| Duration of left side maze procedure (min.) | 10.34 ± 2.32 | 9.91 ± 2.26 | 0.312 |
| Duration of right side maze procedure (min.) | 7.21 ± 2.55 | 6.49 ± 1.67 | 0.090 |
| Total duration of maze procedure (min.) | 17.64 ± 4,00 | 16.65 ± 2,92 | 0.125 |
| Implantation of permanent pace maker | 16 (17.8%) | 11 (20.8%) | 0.818 |
| f-wave size in V1 lead (mm) | 1.44 ± 0.86 | 1.50 ± 0,75 | 0.438 |

* - mean value and standard deviation (mean ± SD) are presented for quantitative variables and rate (number and %) is presented for qualitative variables ** CPB – cardiopulmonary by-pass.

We also analyzed post-operative characteristics of the groups. Summary of short-term results is presented in Table 9 and Tables 10 – 13 shows the changes of results and rhythm found during the final visit (Table 12). One can see that there are no differences between the groups.

***Table 9***. Comparison of short-term results

| | | **TA** | **SSA** | ***p* value** |
|---|---|---|---|---|
| Rhythm immediately after operation* | Normal sinus | 46 (54.1%) | 27 (55.1%) | 0.610 |
| | Sinus bradycardia | 33 (38.8%) | 20 (40.8%) | |
| | AF | 0 (0.0%) | 1 (2.0%) | |
| | AV rhythm | 4 (4.7%) | 1 (2.0%) | |
| | AV block | 2 (2.4%) | 0 (0.0%) | |
| Rhythm during the first 14 post-operative days | Normal sinus | 42 (53.2%) | 19 (45.2%) | 0.380 |
| | Bradycardia requiring pace maker | 13 (16.5%) | 6 (14.3%) | |
| | 1 AF paroxysm without EIT | 7 (8.9%) | 4 (9.5%) | |
| | >1 AF paroxysm without EIT | 4 (5.1%) | 5 (11.9%) | |
| | 1 AF paroxysm without EIT | 1 (1.3%) | 2 (4.8%) | |

| | | | | |
|---|---|---|---|---|
| | >1 AF paroxysm with EIT | 5 (6.3%) | 0 (0.0%) | |
| | AF, rhythm not restored | 1 (1.3%) | 2 (4.8%) | |
| | AFL without EIT | 3 (3.8%) | 3 (7.1%) | |
| | AFL with EIT | 3 (3.8%) | 1 (2.4%) | |

*Atrial stimulation was checked prior transferring the patient to the post-operative ward; the presence of response was considered as absence of AF at the moment.

AF – atrial fibrillation; AFL with EIT or TOES – atrial flutter with trans-oesophageal stimulation or electro impulse therapy (cardioversion).

***Table 10.*** Dynamics of results: post-operative rhythm

| | | **TA** | **SSA** | ***p* value** |
|---|---|---|---|---|
| Rhythm 1 month after operation | Normal sinus | 52 (65.8%) | 30 (63.8%) | 0.590 |
| | Bradycardia requiring pace maker | 9 (11.4%) | 2 (4.3%) | |
| | 1 AF paroxysm without EIT | 3 (3.8%) | 1 (2.1%) | |
| | >1 AF paroxysm without EIT | 3 (3.8%) | 5 (10.6%) | |
| | 1 AF paroxysm with EIT | 4 (5.1%) | 5 (10.6%) | |
| | >1 AF paroxysm with EIT | 3 (3.8%) | 2 (4.3%) | |
| | AF, rhythm not restored | 1 (1.3%) | 0 (0.0%) | |
| | AFL without EIT | 1 (1.3%) | 0 (0.0%) | |
| | AFL with EIT or TOES * | 3 (3.8%) | 2 (4.3%) | |
| Rhythm 3 months after operation | Normal sinus | 55 (69.6%) | 29 (61,7%) | 0.118 |
| | Bradycardia requiring pace maker | 11 (13,9%) | 3 (6.4%) | |
| | 1 AF paroxysm without EIT | 0 (0.0%) | 1 (2.1%) | |
| | >1 AF paroxysm without EIT | 3 (3.8%) | 4 (8.5%) | |
| | 1 AF paroxysm with EIT | 3 (3.8%) | 5 (10.6%) | |
| | >1 AF paroxysm with EIT | 0 (0.0%) | 2 (4.3%) | |
| | AF, rhythm not restored | 2 (2.5%) | 1 (2.1%) | |
| | AFL without EIT | 3 (3.8%) | 0 (0.0%) | |
| | AFL with EIT or ES | 2 (2.5%) | 2 (4.3%) | |
| Rhythm 6 months after operation | Normal sinus | 50 (70.4%) | 29 (64.4%) | 0.180 |
| | Bradycardia requiring pacemaker | 11 (15.5%) | 5 (11.1%) | |
| | 1 AF paroxysm without EIT | 1 (1.4%) | 0 (0.0%) | |
| | >1 AF paroxysm without EIT | 2 (2.8%) | 3 (6.7%) | |
| | 1 AF paroxysm with EIT | 3 (4.2%) | 3 (6.7%) | |
| | >1 AF paroxysm with EIT | 0 (0.0%) | 4 (8.9%) | |
| | AF, rhythm not restored | 3 (4.2%) | 1 (2.2%) | |
| | AFL with EIT or TOES | 1 (1.4%) | 0 (0.0%) | |
| Rhythm 12 months after | Normal sinus | 43 (70.5%) | 34 (77.3%) | 0.014 |
| | Bradycardia requiring pace | 9 (14.8%) | 2 (4.5%) | |

| | | | | |
|---|---|---|---|---|
| operation | maker | | | |
| | 1 AF paroxysm without EIT | 0 (0.0%) | 3 (6.8%) | |
| | >1 AF paroxysm without EIT | 5 (8.2%) | 0 (0.0%) | |
| | 1 AF paroxysm with EIT | 1 (1.6%) | 3 (6.8%) | |
| | AF, rhythm not restored | 3 (4.9%) | 1 (2.3%) | |
| | AFL with EIT or ES | 0 (0.0%) | 1 (2.3%) | |
| Rhythm 24 months after operation | Normal sinus | 44 (62.0%) | 8 (88.9%) | 0.924 |
| | Bradycardia requiring pace maker | 10 (14.1%) | 1 (11.1%) | |
| | 1 AF paroxysm without EIT | 6 (8.5%) | 0 (0.0%) | |
| | >1 AF paroxysm without EIT | 6 (8.5%) | 0 (0.0%) | |
| | 1 AF paroxysm with EIT | 3 (4.2%) | 0 (0.0%) | |
| | AF, rhythm not restored | 2 (2.8%) | 0 (0.0%) | |
| **Rhythm at the last visit** | Normal sinus | 51 (58.0%) | 29 (59.2%) | 0.429 |
| | Bradycardia requiring pace maker | 13 (14.8%) | 5 (10.2%) | |
| | AF paroxysms | 15 (17.0%) | 5 (10.2%) | |
| | Chronic AF, rhythm not restored | 6 (6.8%) | 7 (14.3%) | |
| | AFL | 3 (3.4%) | 3 (6.1%) | |

AF – atrial fibrillation; AFL with EIT or TOES – atrial flutter with trans-oesophageal stimulation or electro impulse therapy (cardioversion)

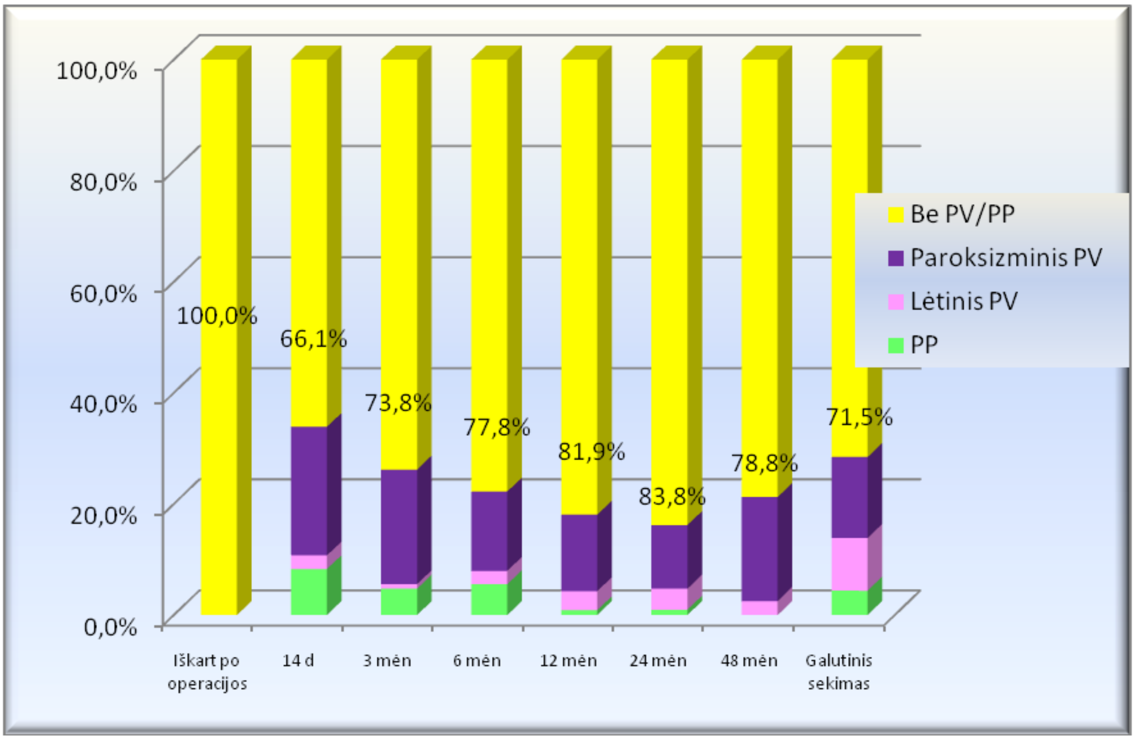



***Fig 11.*** Dynamics of the results; rhythm after operation, during follow-up and at the last visit.

/Įrašai pav.: „Be PV/PP“ - without AF/AFL; „Paroksizminis PV“ – paroxysmal AF; „Lėtinis PV“ – chronic AF; „PP“ – AFL. “Galutinis sekimas” – last follow-up/

**Dynamics of echocardiography data**

***Table 11.*** Dynamics of the results: measurements of the atriums after operation

| | **TA** | **SSA** | ***p* value** |
|---|---|---|---|
| Longitudinal measurement of LA after 3 months (cm) | 5.79 ± 0.77 | 5.54 ± 0.90 | 0.351 |
| Transversal measurement of LA 3 months after operation (cm) | 5.10 ± 0.67 | 5.16 ± 0.48 | 0.598 |
| Longitudinal measurement of RA 3 months after operation (cm) | 5.01 ± 1.02 | 5.03 ± 0.61 | 0.906 |
| Transversal measurement of RA 3 months after operation (cm) | 4.42 ± 0.84 | 4.24 ± 0.57 | 0.248 |
| Longitudinal measurement of LA 6 months after operation (cm) | 5.65 ± 1.03 | 5.18 ± 1.25 | 0.034 |
| Transversal measurement of LA 6 months after operation (cm) | 5.05 ± 0.66 | 5.06 ± 0.46 | 0.714 |
| Longitudinal measurement of RA 6 months after operation (cm) | 4.82 ± 0.97 | 4.91 ± 0.56 | 0.293 |
| Transversal measurement of RA 6 months after operation (cm) | 3.94 ± 1.21 | 3.92 ± 1.07 | 0.868 |
| Longitudinal measurement of LA 12 months after operation (cm) | 5.19 ± 0.69 | 5.30 ± 0.41 | 0.493 |
| Transversal measurement of LA 12 months after operation (cm) | 4.96 ± 0.62 | 5.11 ± 0.48 | 0.431 |
| Longitudinal measurement of RA 12 months after operation (cm) | 4.69 ± 0.68 | 4.84 ± 0.55 | 0.417 |
| Transversal measurement of RA 12 months after operation (cm) | 4.05 ± 0.78 | 4.22 ± 0.59 | 0.582 |

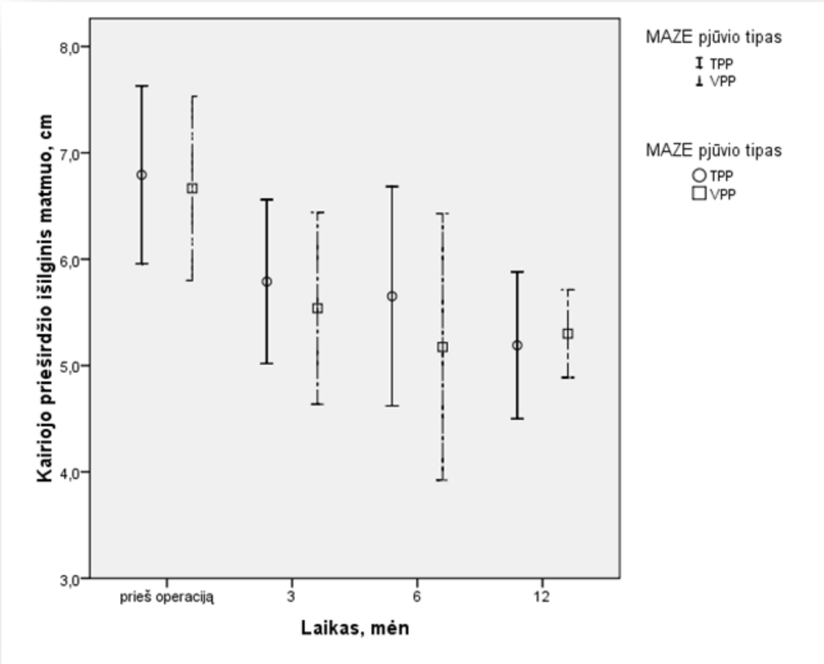



***Fig. 12***. Dynamics of the results: longitudinal measurement of the left atrium /Įrašai pav.: "Kairiojo prieširdžio išilginis…" – longitudinal measurement of the left atrium (cm); "prieš operaciją" – preoperatively; "Laikas, mėn," – time (months); "Maze pjūvio tipas" – type of maze approach; "TTP" – TA; "VPP" – SSA/.

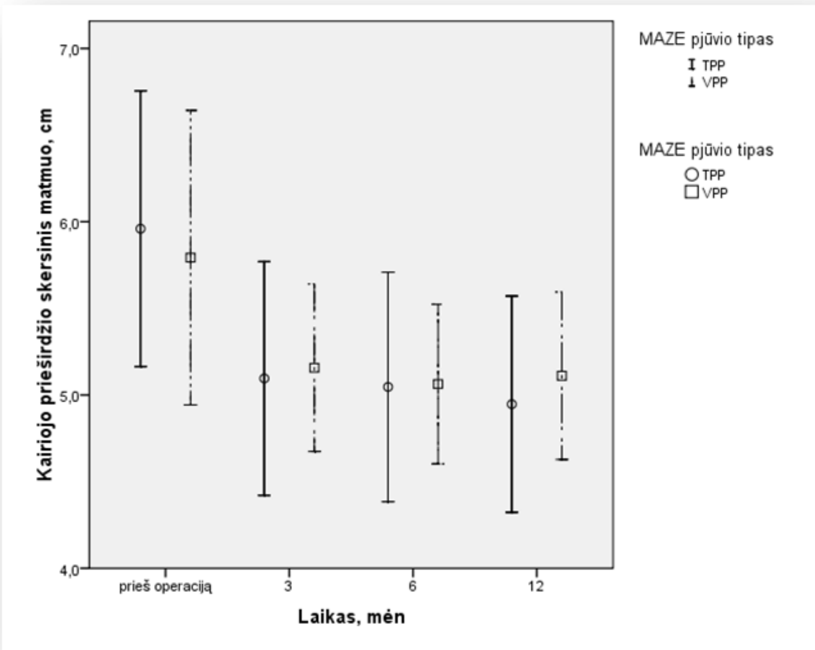



***Fig 13.*** Dynamics of the results: transversal measurement of the left atrium (mean ± SD)

/Įrašai pav.: „Kairiojo prieširdžio"...- transversal measurement of the left atrium (cm)/

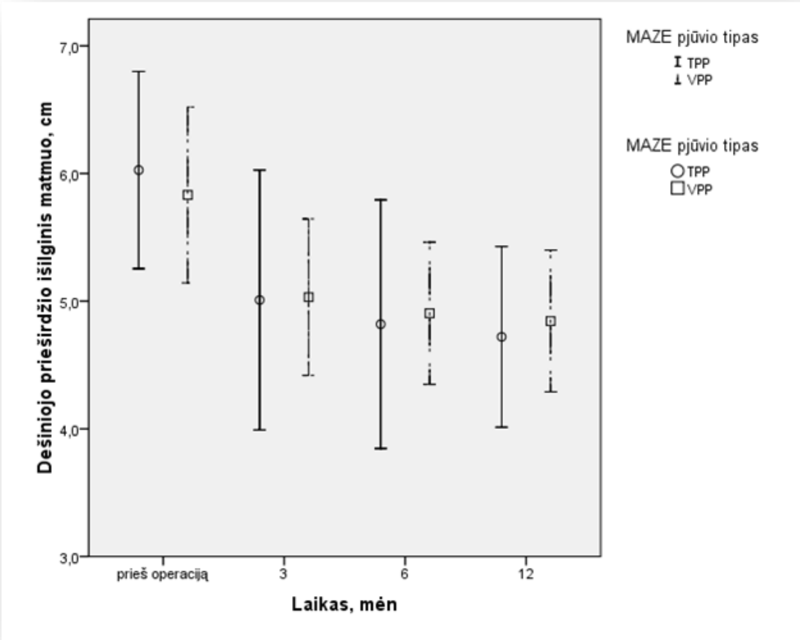



***Fig. 14 pav***. Dynamics of the results: longitudinal measurement of the right atrium (mean ± SD) /Įrašai pav.: "Dešiniojo prieširdžio išilginis matmuo…" – longitudinal measurement of the right atrium (cm)/

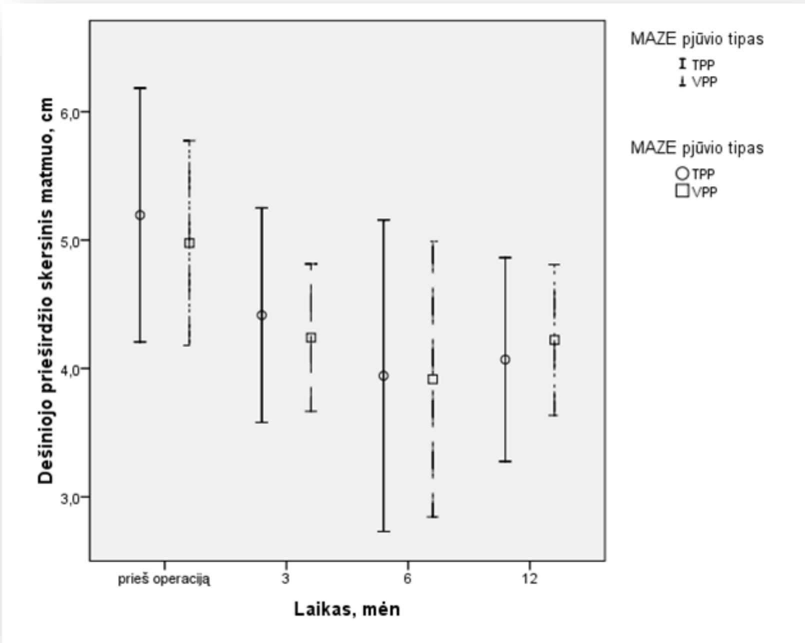



***Fig. 15.*** Dynamics of the results: transversal measurement of the right atrium (mean ± SD). /Įrašas pav.: "Dešiniojo prieširdžio…" – transversal measurement of the right atrium (cm)/

***Table 12.*** Changes of atrial measurements in TA and SSA groups

| | | **Preoperatively** | **After 12 months.** | ***p* value** |
|---|---|---|---|---|
| **TA** | Longitudinal measurement of the left atrium (cm) | 6.79 ± 0.84 | 5.19 ± 0.69 | <0.001 |
| | Transversal measurement of the left atrium (cm) | 5.96 ± 0.80 | 4.96 ± 0.62 | <0.001 |
| | Longitudinal measurement of the right atrium (cm) | 6.03 ± 0.77 | 4.69 ± 0.68 | <0.001 |
| | Transversal measurement of the right atrium (cm) | 7.23 ± 9.49 | 4.05 ± 0.78 | 0.013 |
| **SSA** | Longitudinal measurement of the left atrium (cm) | 6.67 ± 0.87 | 5.30 ± 0.41 | <0.001 |
| | Transversal measurement of the left atrium (cm) | 5.79 ± 0.85 | 5.11 ± 0,48 | 0.072 |
| | Longitudinal measurement of the right atrium (cm) | 5.83 ± 0.69 | 4.84 ± 0.55 | 0.005 |
| | Transversal measurement of the right atrium (cm) | 4.98 ± 0.80 | 4.22 ± 0.59 | 0.182 |

***Table 13.*** Dynamics of the results: mitral valve blood flow velocity

| | **TA** | **SSA** | ***p* value** |
|---|---|---|---|
| MV blood flow velocity (m/s) after 3 months | 1.67 ± 0,48 | 1.77 ± 0,64 | 0.426 |
| MV blood flow velocity (m/s) , A-wave (mechanic function of the atrium) after 3 months | 0.27 ± 0.31 | 0.50 ± 0.48 | 0.056 |
| MV blood flow velocity (m/s) after 6 months | 1.50 ± 0.65 | 1.47 ± 0.57 | 0.922 |
| MV blood flow velocity (m/s) , A-wave (mechanic function of the atrium) after 6 months | 0.55 ± 0.28 | 0.48 ± 0.31 | 0.288 |
| MV blood flow velocity (m/s) after 12 months | 1.58 ± 0.51 | 1.78 ± 0.43 | 0.397 |
| MV blood flow velocity (m/s) , A-wave (mechanic function of the atrium) after 12 months | 0.52 ± 0.30 | 0.59 ± 0.05 | 0.792 |

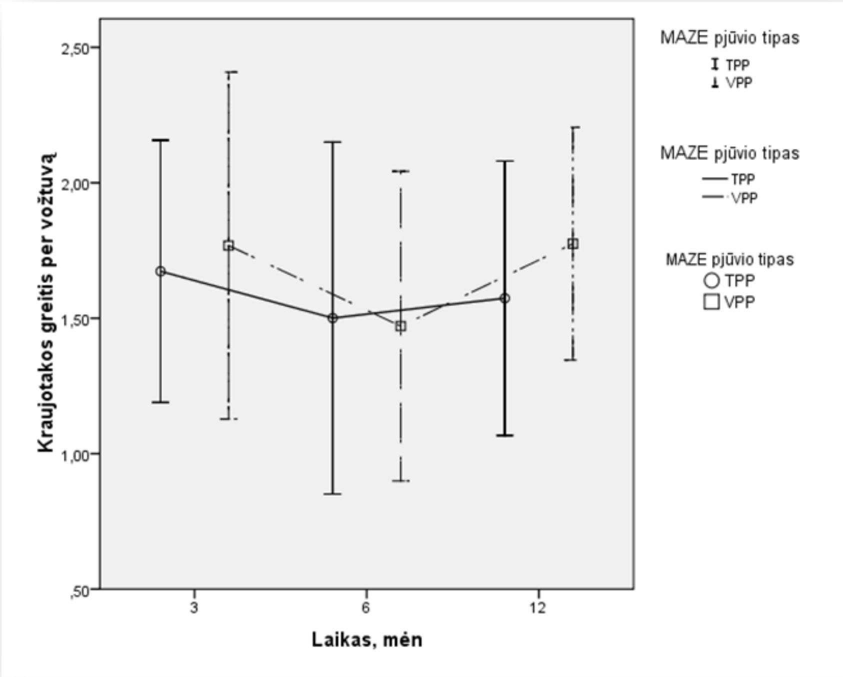



***Fig.16.*** Dynamics of the results: MV blood flow velocity (mean ± SN; the lines link mean values) /Įrašai pav.: "Kraujotakos greitis…" – MV blood flow velocity; "Laikas, mėn" – time (months); "Maze pjūvio tipas" – type of maze approach; "TTP" – TA; "VPP" – SSA/

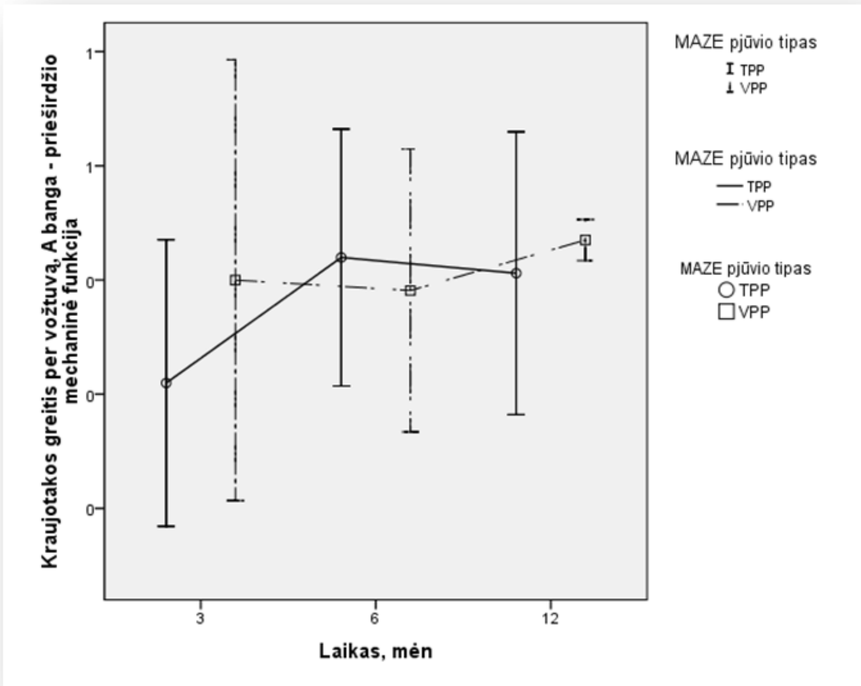



***Fig. 17 pav.*** Dynamics of the results: MV blood flow velocity,
A-wave (mechanic function of the atrium) (mean ± SD; the lines link mean values)

/Įrašai pav.: “Kraujotakos greitis…” – MV blood flow velocity, A-wave (mechanic function of the atrium); “Laikas, mėn” – time (months); “Maze pjūvio tipas” – type of maze approach; “TTP” – TA; “VPP” – SSA/

***Table 14***. Changes of blood flow velocity in TA and SSA groups

| | | **3 months** | **12 months** | ***p* value** |
|---|---|---|---|---|
| **TA** | MV blood flow velocity (m/s) | 1.67 ± 0.48 | 1.58 ± 0.51 | 0.293 |
| | MV blood flow velocity (m/s) , A-wave (mechanic function of the atrium) | 0.27 ± 0.31 | 0.52 ± 0.30 | <0.001 |
| **SSA** | MV blood flow velocity (m/s) | 1.77 ± 0.64 | 1.78 ± 0.43 | 0.461 |
| | MV blood flow velocity (m/s) , A-wave (mechanic function of the atrium) | 0.50 ± 0.48 | 0.59 ± 0.05 | 0.056 |

***Table 15***. Dynamics of the results: changes of atrial longitudinal and transversal measurements 3 and 12 months after operation

| **Measurement** | **Mean ± SD** | ***p* value*** |
|---|---|---|
| Relative change of longitudinal measurement of the left atrium (3 months vs. 12 months) | 8.97 ± 10,43 | <0.001 |
| Relative change of transversal measurement of the left atrium (3 months vs. 12 months) | 1.80 ± 15.80 | 0.393 |
| Relative change of longitudinal measurement of the right atrium (3 months vs. 12 months) | 3.61 ± 14.58 | 0.067 |
| Relative change of transversal measurement of the right atrium (3 months vs. 12 months) | 5.07 ± 20.72 | 0.070 |

* - *p* value was calculated in order to check the hypothesis, stating that relative change differ significantly from 0.

***Table 16***. Dynamics of the results: relative changes of atrial longitudinal and transversal measurements comparing preoperative data and data 12 months after operation

| **Measurement** | **mean ± SD (mm)** | ***p* value*** |
|---|---|---|
| Relative change of the left atrium longitudinal measurement (measured preoperatively and 12 months after operation) | 23.85 ± 10.3 | <0.001 |
| Relative change of the left atrium transversal measurement (measured preoperatively and 12 months after operation) | 14.32 ± 15,63 | <0.001 |
| Relative change of the right atrium longitudinal measurement (measured preoperatively and 12 months after operation) | 19.19 ± 16.27 | <0.001 |

| | | |
|---|---|---|
| Relative change of the right atrium transversal measurement (measured preoperatively and 12 months after operation) | 17.64 ± 27.89 | <0.001 |

* - *p* value was calculated in order to check the hypothesis, stating that relative change differ significantly from 0.

The size of atrium (diameters were measured in four chamber apical view) decreased statistically significantly after 6 months in patients without AF/AFL. Doppler examination showed that mechanic function (detected A wave) was restored after 6 months in 79/94 (84%) of the patients without AF/AFL.

### 4.3. Relationship between baseline findings and prognosis of treatment results

Among other aims of this study, we tried to asses factors influencing the prognosis of the treatment. Therefore, the patients were allocated to two groups: the *first group* included patients with good or satisfactory results (defined as normal sinus rhythm or bradycardia because of sinus node dysfunction, corrected by implantation of a pace maker); the *second group* included patients with negative results (paroxysmal AF, chronic AF or AFL). Then logistic regression models allowing to predict one of outcomes mentioned above (good or satisfactory results vs. negative results) were created taking into account 11 parameters, including age, gender, type of AF at the baseline (i.e. prior operation), duration of AF prior operation, NYHA functional class, LV EF, type of approach (TA or SSA), measurements (longitudinal and transversal) of the right and left atriums, longitudinal measurement of the left atrium in M-mode, size of f waves in V1 lead.

At first, univariate logistic regression models were created for each factor (i.e. a model with one independent variable, see Table 18); then, significant variables were selected and multivariate logistic model was created (Table 20).

***Table18***. Univariate logistic regression models for prognosis of the treatment*

| Independent variable | Regression coefficient (error) | *p* | Odds ratio (95 % CI) |
|---|---|---|---|
| Gender (male vs. female) | -0.040 (0.409) | 0.922 | 0.961 (0.431;2.143) |
| Age | -0.009 (1.117) | 0.647 | 0.991 (0.953;1.031) |
| AF type (persistent vs. chronic) | -0.199 (0.444) | 0.653 | 0.819 (0.343;1.955) |

| | | | |
|---|---|---|---|
| Duration of AF prior operation (months) | 0.003 (0.005) | 0.644 | 1.003 (0.992;1.013) |
| NYHA** | 1.253 (0.482) | 0.009 | 3.500 (1,361;9,004) |
| LV EF | 0.012 (0.032) | 0.700 | 1.012 (0.915;1.078) |
| Type of maze approach (TA vs. SSA) | -0.163 (0.392) | 0.678 | 0.850 (0.395;1.831) |
| Longitudinal measurement of the left atrium (cm) | 0.410 (0.238) | 0.084 | 1.507 (0.946;2.401) |
| Transversal measurement of the left atrium (cm) | -0.204 (0,238) | 0.391 | 0.815 (0.511;1.300) |
| Longitudinal measurement of the right atrium (cm) | 0.298 (0.259) | 0.249 | 1.348 (0.811;2.239) |
| Transversal diameter of the right atrium (cm) | -0.329 (0.216) | 0.127 | 0.720 (0.471;1.098) |
| Longitudinal diameter of the left atrium (cm) | 0.717 (0,195) | <0.001 | 2.048 (1.397;3.003) |
| Size of f-waves in V1 lead (mm) | -0.142 (0.239) | 0.552 | 0.867 (0.542;1.387) |
| Size of f waves in V1 lead (mm) (≤1 mm vs. >1 mm)*** | 0.123 (0.382) | 0.749 | 1.130 (0.534;2. 392) |

*Negative outcome was considered to be an event; *p* value presented was calculated in order to check the hypothesis, stating that coefficient of independent variable differed from zero statistically significantly; i.e. the independent variable could be used to predict the outcome of the treatment.
** NYHA functional class was regarded as quantitative variable.
*** Two models were used for f - waves: in the first model absolute findings of measurements were used and the second model included discrete findings (≤1 or >1 mm).

It obvious that there are two significant independent variables in univariate regression models that can be used to predict the outcome of the treatment: NYHA functional class and transversal diameter of the left atrium. NYHA functional class is regarded as quantitative variable. The increase of NYHA functional class in one class increases probability of negative result of the treatment approximately 3.5-fold (inferior margin of confidence interval 1.361 – see Table 18). The size of the left atrium diameter in M-mode allows to achieve sensitivity of 74.4% and specificity of 60.2% (see Table 19 and fig. 21); in other words, the 1 cm increase of the left atrium longitudinal diameter in M-mode increases probability of AF/AFL 2.04-fold.

***Table 19***. Threshold values of the left atrium longitudinal diameter and estimated sensitivity/specificity.

| Negative result of the treatment, if the values is ≥ than threshold value | Sensitivity | Specificity |
|---|---|---|
| 6.0500 | 94.9% | 37.8% |

| | | |
|---|---|---|
| 6.1500 | 89.7% | 43.9% |
| 6.2500 | 87.2% | 44.9% |
| 6.3500 | 84.6% | 46.9% |
| 6.4500 | 82.1% | 53.1% |
| 6.5500 | 82.1% | 57.1% |
| 6.6500 | 74.4% | 60.2% |
| 6,7500 | 61.5% | 62.2% |
| 6.8500 | 59.0% | 63.3% |

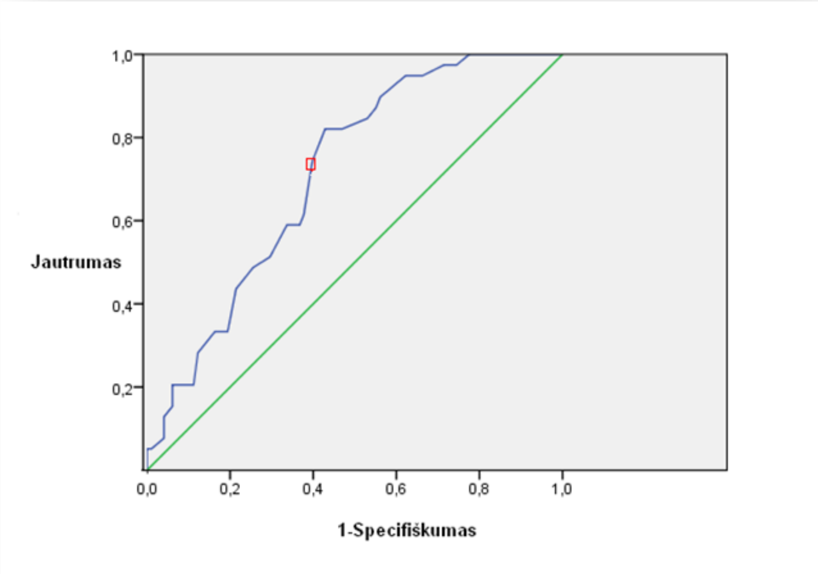



***Fig. 21 pav.*** ROC curve presenting predictive value of the left atrium transversal diameter (area under the curve 0.71)
/Įrašai grafike: „Jautrumas“ – sensitivity; „Specifiškumas“ – specificity/

***Table 20***. Multivariate logistic regression models for prognosis of the treatment*

| **Independent variable** | **Regression coefficient (error)** | ***p*** | **Confidence interval (95 % PI)** |
|---|---|---|---|
| NYHA** | 1.213 (0,528) | 0.021 | 3.365 (1.196;9.465) |
| Longitudinal diameter of the left atrium | 0.712 (0.202) | <0.001 | 2.038 (1.373;3.027) |

* Negative outcome was considered to be an event; *p* value presented was calculated in order to check the hypothesis, stating that coefficient of independent variable differed from zero statistically significantly; i.e. the independent variable could be used to predict the outcome of the treatment.

** NYHA functional class was regarded as quantitative variable.

The complex model including both variables (NYHA functional class and LA longitudinal diameter) may show slightly higher predictive value (fig. 24); however, this value is almost similar to that of the left atrium diameter.

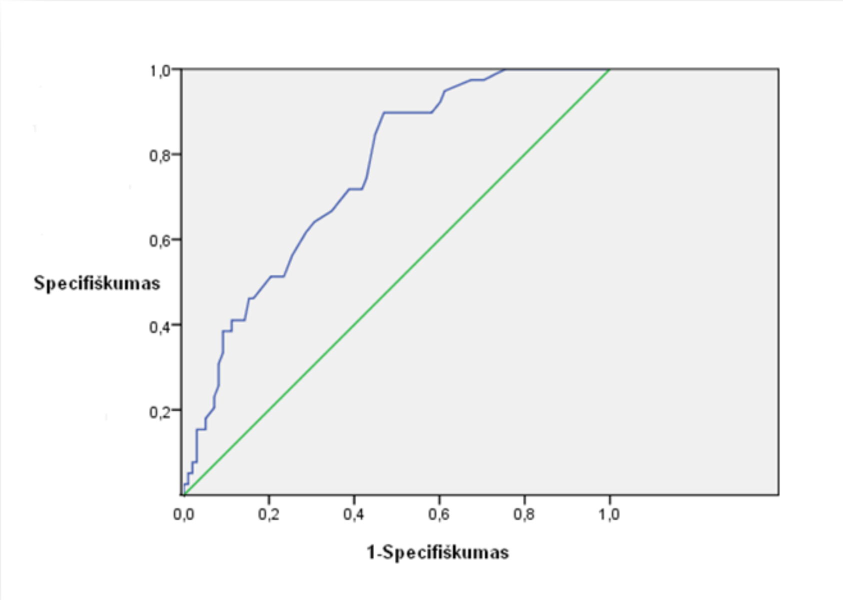



***Fig. 22.*** ROC curve showing combined predictive value of LA longitudinal diameter and NYHA functional class (area under the curve 0.75).

### 4.4 Mitral valve prosthesis vs. plasty and final result of the treatment

The implantation of mitral valve prosthesis was performed for 101 (72.7%) patients (for details see Table 21). One of the aims of the study was to assess, whether the mode of correction of MV malformation (MV plasty or implantation of prosthesis) had an influence on final result. As the parameters of the patients in TA and SSA groups were almost similar, we analyzed general group of the patients. The group included two sub-groups: the patients for whom implantation of mitral valve prosthesis was performed and patients who underwent MV plasty. We compared these subgroups in accordance with final results of the treatment (see fig. 23) and found out no statistically significant difference.

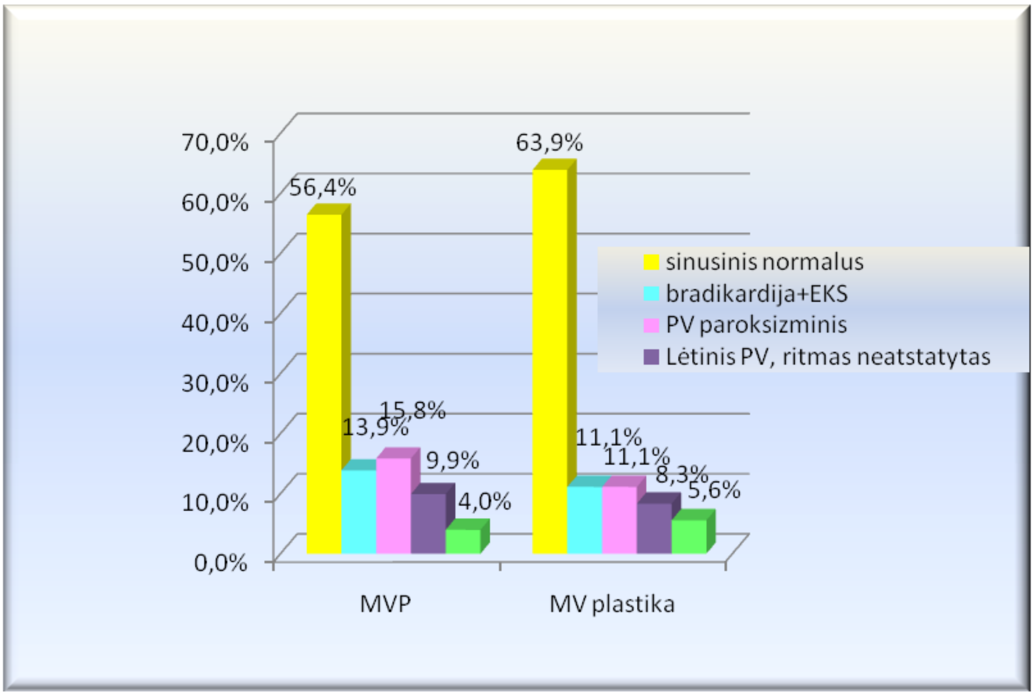



***Fig.23***. Type of operation and final result of the treatment
/Įrašai pav.: "MVP" – MV prosthesis; "MV plastika" – MVpl; "sinusinis normalus" – normal sinus; "bradikardija + EKS" – bradycardia requiring pace maker; "PV paroksizminis" – paroxysmal AF; "Lėtinis PV, ritmas neatstatytas" – chronic AF, rhythm not restored/

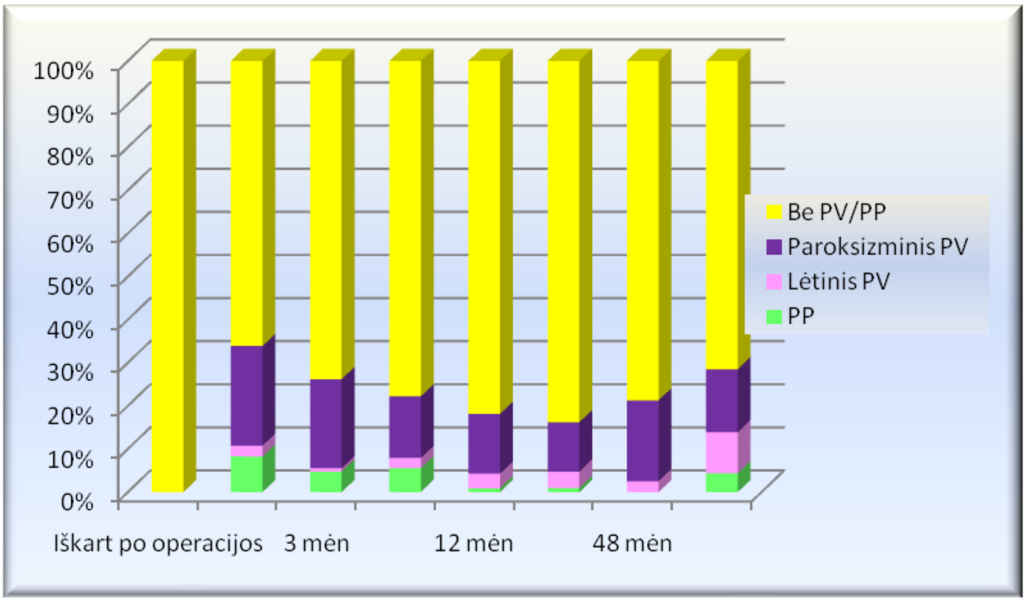



***Fig. 24***. Dynamics of the results in general group of patients
/Įrašai pav.: „Iškart po operacijos" – immediately after operation; „mėn." – months; „Be PV/PP" – without AF/AFL; „Paroksizminis PV" – paroxysmal AF; „Lėtinis PV" – chronic AF; „PP" – AFL/

### 4.5 Comparison of short-term and long-term results of the treatment

In practise, it is very important to know the relationship between the short-term and long-term results; i.e. to realize, whether the results achieved in the beginning of the treatment are not too optimistic when compared with the results that are present several months after the procedure. In order to clarify this, we compared the rhythm of the patients one year after the treatment with long-term results. Similar analysis was performed with 3-month results. We analyzed the data of general group because, as shown above, no significant differences between the groups of TA and SSA had been found. The comparison is presented in Tables 23-24. Of course, the were some differences between the sub-groups (as some of the patients worsened and some improved); however, the total percentage of the patients without AF/AFL in the beginning of the treatment was similar to the percentage of the patients with positive results at the end of follow-up (see fig. 25, also)

***Table 23.*** Comparison of short-term and long-term results of the treatment

| | | **Final result*** | | | | |
|---|---|---|---|---|---|---|
| | | Normal sinus | **Bradycardia requiring pace maker** | Paroxysmal AF | Chronic AF | AFL |
| **Rhythm 1 month after operation** | Normal sinus | 56 (68.3%) | 4 (4.9%) | 13 (15.9%) | 5 (6.1%) | 4 (4.9%) |
| | **Bradycardia requiring pace maker** | 1 (9.1%) | 7 (63.6%) | 2 (18.2%) | 1 (9.1%) | 0 (0.0%) |
| | **Paroxysmal AF** | 15 (57.7%) | 5 (19.2%) | 3 (11.5%) | 3 (11.5%) | 0 (0.0%) |
| | Chronic AF | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 1 (100.0%) | 0 (0.0%) |
| | AFL | 5 (83.3%) | 0 (0.0%) | 0 (0.0%) | 1 (16.7%) | 0 (0.0%) |
| **Rhythm 3 months after operation** | Normal sinus | 64 (76.2%) | 4 (4.8%) | 10 (11.9%) | 4 (4.8%) | 2 (2.4%) |
| | **Bradycardia requiring pace maker** | 1 (7.1%) | 8 (57.1%) | 2 (14.3%) | 2 (14.3%) | 1 (7.1%) |
| | **Paroxysmal AF** | 7 (38.9%) | 4 (22.2%) | 4 (22.2%) | 2 (11.1%) | 1 (5.6%) |
| | Chronic AF | 0 (0.0%) | 0 (0.0%) | 1 (33.3%) | 2 (66.7%) | 0 (0.0%) |
| | AFL | 5 (71.4%) | 0 (0.0%) | 1 (14.3%) | 1 (14.3%) | 0 (0.0%) |

* Percentage rates are presented in the groups of short-term results; p value was calculated in order to compare the results after 1 month with final results (i.e. to answer, whether the changes are marked); this value is equal to 0.539; p value calculated to compare the results after 3 months with final results is equal to 0.382.

***Table 24.*** Comparison of short-term and final results of the treatment

| | | **Final results*** | | |
|---|---|---|---|---|
| | | Rhythm restored | Rhythm not restored | **Total** |
| **Rhythm after 1 month** | Rhythm restored | 68 | 25 | 93 (73.8%) |
| | Not restored | 25 | 8 | 33 (26.2%) |
| | **Total** | 93 (76.8%) | 33 (26.2%) | – |
| **Rhythm after 3 months** | Rhythm restored | 77 | 21 | 98 (77.8%) |
| | Not restored | 16 | 12 | 28 (22.2%) |
| | **Viso** | 93 (76.8%) | 33 (26.2%) | |

* *p* value was calculated in order to compare treatment results after 1 month and final results (i.e. to answer, whether the changes were marked); this value is equal to 1.000; p value calculated to compare the results of treatment after 3 months with final results is equal 0.511. The group "Rhythm restored" includes diagnoses "normal sinus rhythm" and "bradycardia requiring pace maker"; the group "rhythm not restored" includes the remaining diagnoses.

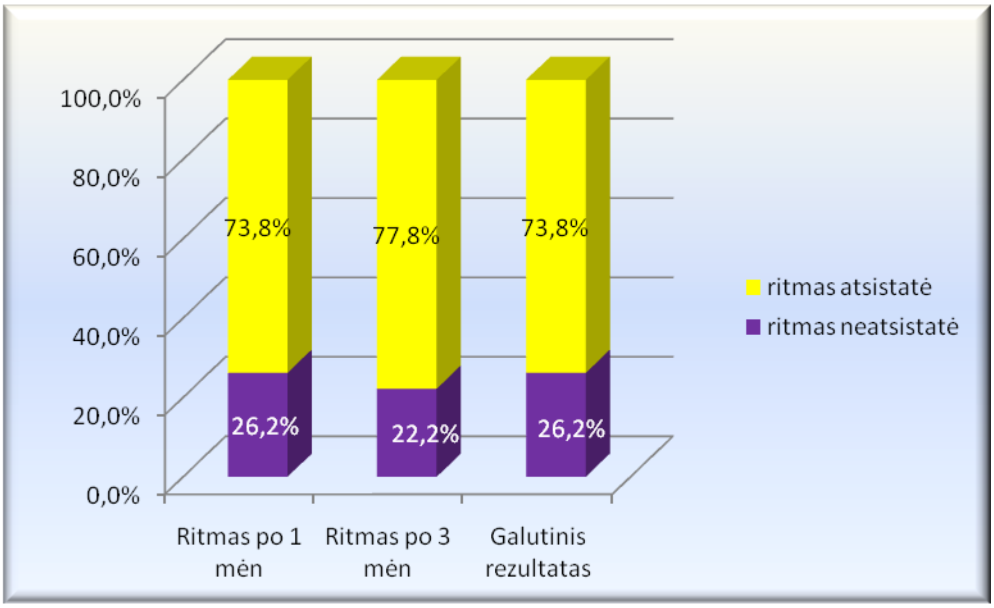



***Fig.25.*** Results of the treatment in the beginning of the treatment and during the last visit /Įrašai pav.: „Ritmas po..." – rhythm after 1 month; rhythm after 3 months; „ritmas atsistatė" – rhythm restored; „ritmas neatsistatė" – rhythm not restored; „galutinis rezultatas" – final result/.

Possible changes in sub-groups (some patients developed no rhythm disturbances and some developed AF/AFL) may be related to medicamental treatment. Therefore, we checked the hypothesis whether administration of amiodarone during the first months could be related to long-term results of the treatment (Table 25). One can see that there is no relationship (see fig. 25, also).

***Table 25.*** Administration of dugs and final result of the treatment*

| **Period** | | Rhythm restored | Rhythm not restored | |
|---|---|---|---|---|
| **Amiodarone after 1 month** | Administered | 45 (73.8%) | 16 (26.2%) | 0.992 |
| **Amiodarone after 3 months** | Not administered | 49 (76.6%) | 15 (23.4%) | 0.442 |
| | Administered | 43 (70.5%) | 18 (29.5%) | |

* The group "Rhythm restored" includes diagnoses "normal sinus rhythm" and "bradycardia requiring pace maker"; the group "rhythm not restored" includes the remaining diagnoses.

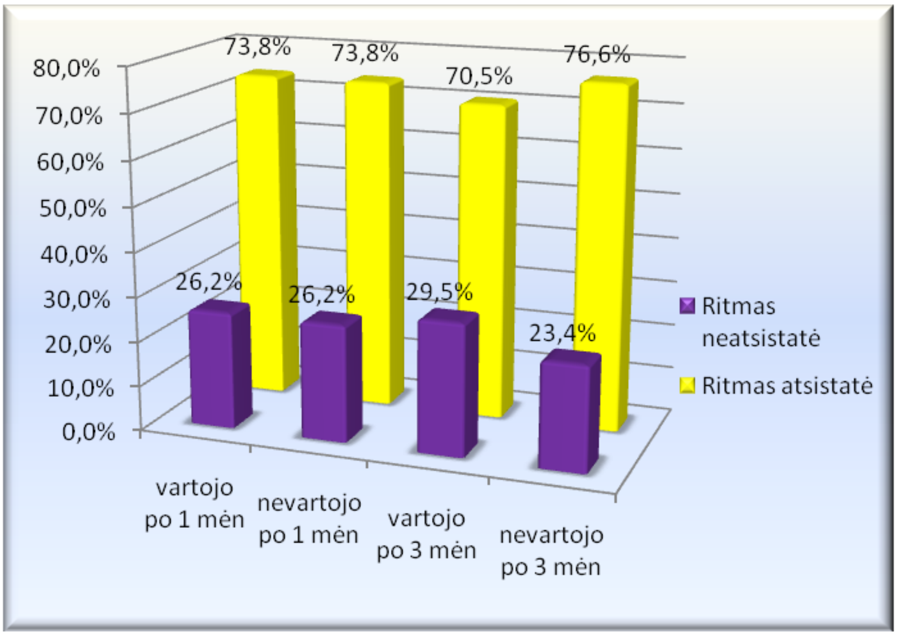



***Fig. 26***. Administration of the dugs and final results
/Įrašai pav: "vartojo po 1 mėn." – used after 1 month; "nevartojo po 1 mėn." – not used after 1 month; "vartojo po 3 mėn." – used after 3 months; "nevartojo po 3 mėn." – not used after 3 months; "ritmas atsitatė" – rhythm restored; "ritmas neatsistatė" – rhythm not restored/

### 4.6 Other factors possibly influencing outcomes of MV malformation correction and maze procedure

We additionally investigated influence of anatomy of pulmonary veins on final result of the treatment. Anatomy was considered as normal when 2 left (with common collector) and 2 right veins were visualized; other variants of pulmonary veins were very different (from 1 to 3 left pulmonary veins and from 1 to 4 right pulmonary veins). We suppose that even in this case there were no marked differences (see Table 26). The final incidence of rhythm types in subjects with normal pulmonary vein anatomy was similar to that of subjects with other variants of pulmonary vein anatomy (see fig. 32).

***Table 26***. Variants of pulmonary vein anatomy and final result of the treatment

| | **Normal** | **Other variants of anatomy** | ***p* value** |
|---|---|---|---|
| Normal sinus | 46 (59.7%) | 21 (58.3%) | 0.611 |
| Bradycardia requiring pace maker | 11 (14.3%) | 4 (11.1%) | |
| Paroxysmal AF | 9 (11.7%) | 7 (19.4%) | |
| Chronic AF, rhythm not restored | 6 (7.8%) | 4 (11.1%) | |
| AFL | 5 (6.5%) | 0 (0.0%) | |

Histology examination of removed RA and LA auricles was performed for 64/143 patients (46.6%); 48 (75%) of these patients were free of AF/AFL. We examined the influence of myocyte hypertrophy, lymphocyte infiltration, fibrosis and fat dystrophy on final result of the treatment. The hypertrophy of myocytes was diagnosed in 62/64 (97%), fibrosis in 60/64 (94%), lymphocyte infiltration in 58/64 (91%) and fat dystrophy 61/64 (95%) of the patients, so we supposed that there was no differences regarding changes of auricles examined. We also did not find statistically significant relationship between histology changes and final results of the treatment.

### 4.7 Sinus node dysfunction, temporary and permanent heart pacing

In the group of TA patients the incidence of temporary heart pacing because SN dysfunction during the early post-operative period was statistically reliably lower: 40(44%) vs. 35(66%) in SSA group ($p = 0.013$). The duration of temporary heart pacing was higher in SSA group than in TA group (6.1 vs. 3.4 days, respectively). In more than a half of the patients in both groups brady-arrhythmia caused by SN dysfunction during post-operative period disappeared or were clinically insignificant. Analysis of ECG and Holter monitoring data of 56 patients for whom temporary heart pacing was performed, showed that sinus rhythm with clearly visible P-wave in lead II was restored at the first out-patient visit (during 1 – 3 months) in 30 (53%) patients; atrial rhythm with low-voltage P-waves, negative or absent in lead II was observed in other 21 patient. Implantation of permanent heart pace maker because of SN node dysfunction was required for 16 (18%) and 10 (19%) patients of TA and SSA group, respectively. Twenty two pace makers were implanted during 4 – 14 postoperative days. Another 4 patients required implantation of pace maker 140±27 days after operation; for 3 of them bradycardia developed because of AAD (fig.28). One patient on Holter monitoring showed pauses > 5 s.; the patient used no AAD. While implanting a pace maker, we used electrodes of active fixation (Tendril, St. Jude Medical, Sylmar, CA). Two pace makers were implanted because of complete AV block after aortic valve replacement by prosthesis. Four AAIR and 26 DDDR type pace makers were implanted. While implanting a pacemaker, it was noted that it was difficult to find an optimal site for stimulation in the right atrium (because of incisions, ablation lines, removal of RA auricle). The sites of electrode implantation were as follows: inferior part of RA - 5, region of RA auricle - 2, inter-atrial septum - 3, orifice of coronary sinus (CS) – 16. The threshold of atrial stimulation during implantation of pace maker system was 1±0.48V. For 12 of 16 patients for whom atrial electrodes were fixed in the region of CS orifice AV intervals were measured and compared while stimulating other sites of RA. The shortest AV intervals were found at the orifice of CS (180 ± 50 ms) and 230 ± 147 ms at the other sites. The voltage of P-wave at the orifice of CS was 2.07±1.14mV and 1.4±1.2 mV at other sites of stimulation. The following complications were observed after implantation of pace maker: 1 haematoma of the pace maker site (removed) and one patient after 6 months developed prosthetic endocarditis of MV. During follow-up after 24 months 14 patients (70%) were free of AF/AFL; 7 patients are observed 5 years and 6 (86%) of them are free of AF/AFL.

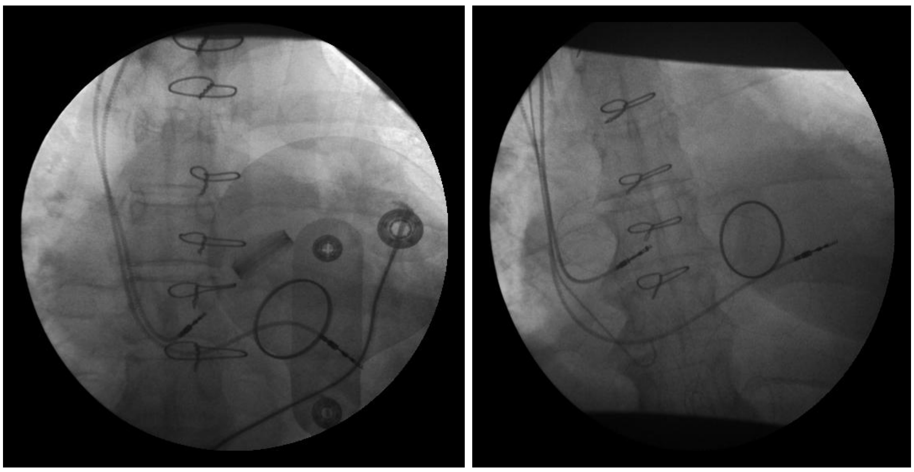


***Fig. 29.*** Atrial electrode implanted at the site pf coronary sinus (anterior view).

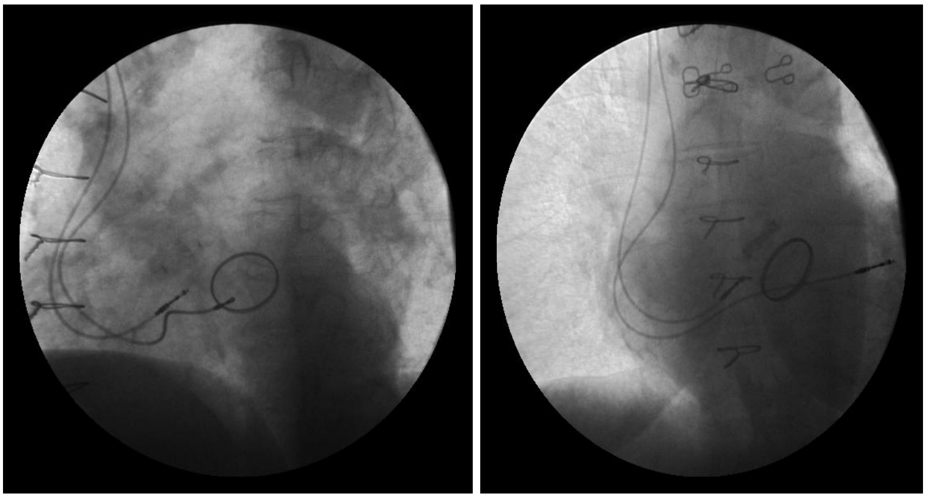


***Fig.30.*** ECG recording electric stimulation in different sites of RA. A- electrode of electric stimulation fixed at inferior part of RA (AV interval 254 ms); B – electrode of electric stimulation fixed at the orifice of coronary sinus (AV interval 170 ms).

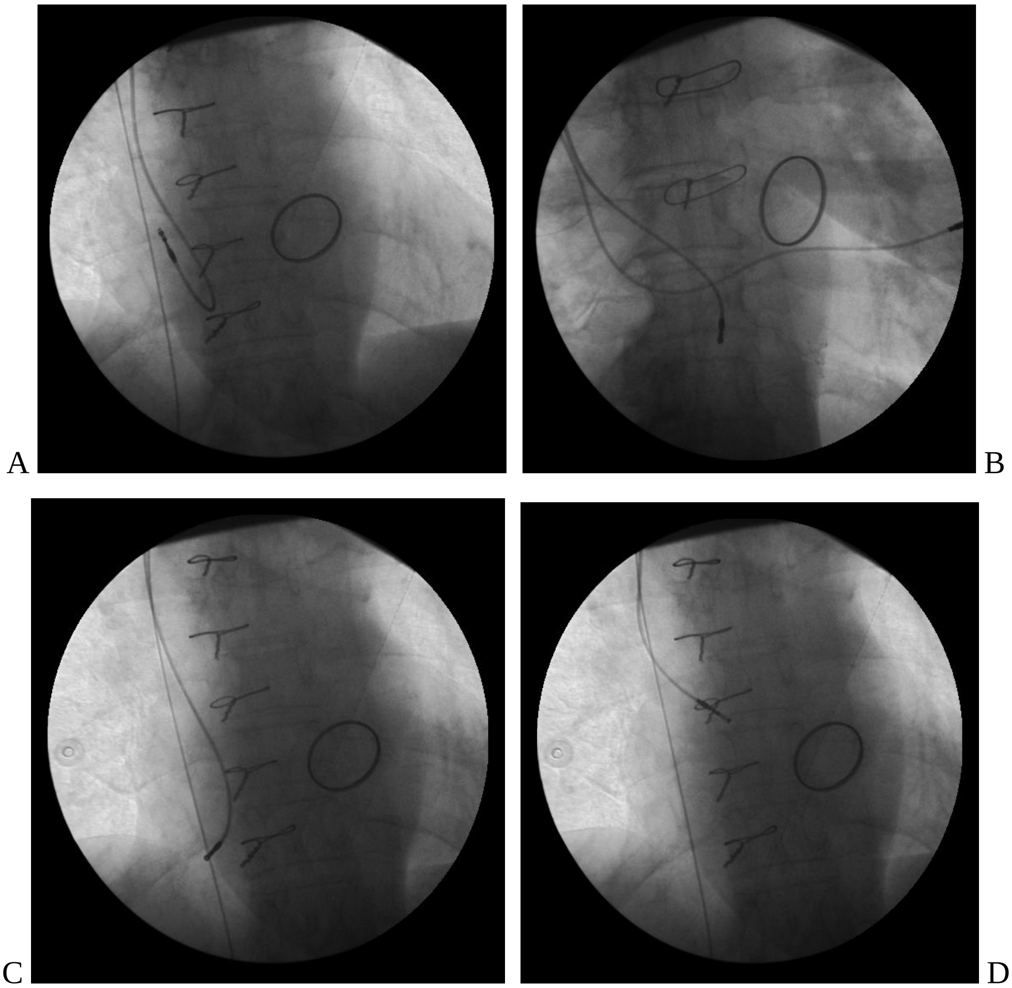



***Fig.31.*** Other sites of atrial electrode position. A- superior part of RA at the site of removed auricle; B, C- inferior part of RA; D – atrial septum (anterior view)

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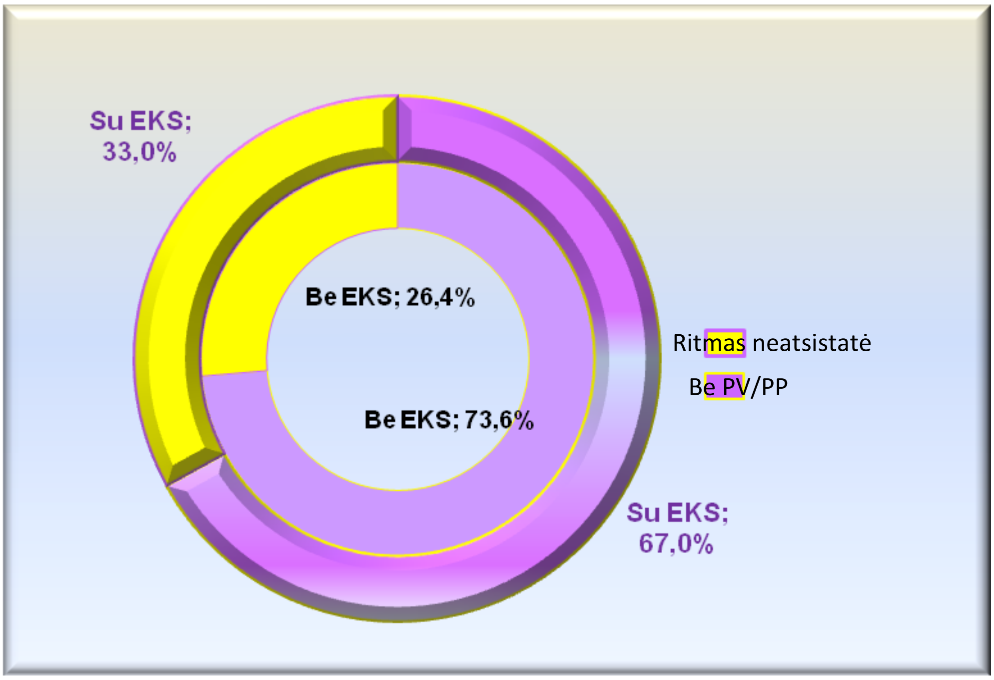


***Fig. 32.*** Rhythm disturbances observed during the last follow-up visit in groups of patients with and without heart pace maker.

/Įrašai pav.: "su EKS" – with pace maker; "be EKS' – without pace maker; "ritmas neatsistatė" – rhythm not restored; "Be PV/PP" - without AF/AFL/

### 5.9. Other post-operative arrhythmias and treatment of these rhythm disturbances

Different forms of AFL were observed in 10 patients during 2 – 12 postoperative day. In three patients on amiodarone and after discontinuation of AFL paroxysm by means of trans-oesophageal stimulation, these arrhythmias did not relapse after 3 – 6 months (fig. 33).

A


B


***Fig. 33***. A – atrial tachycardia registered during post-operative trans-oesophageal electrophysiology examination; B- AFL 2:1 registered after connection of electrodes of temporary heart pacing to a system of electrophysiology examination.

Five patients because of persistent symptomatic AFL underwent EPE and RFA using CARTO system. For one patient AFL with re-entry circle in cavo-tricuspidal isthmus was diagnosed; the patient underwent 24 RF applications and, when conductivity block was obtained in isthmus of IVC, AFL was discontinued and did not reoccur (fig. 34). Other 2 patients had “rotation” of PP in RA; the patients underwent linear RFA in critical zones of arrhythmia and AFL was discontinued.

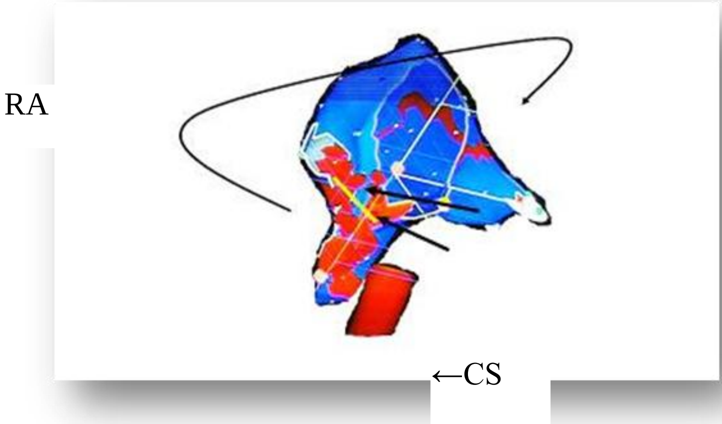


***Fig. 34.*** RFA of atrial flutter – green line and black arrows show the line of RFA  in cavo-tricupsidal isthmus, rounded line shows spreading of AFL in RA.

For two patients atypical AFL was diagnosed of LA electrophysiology examination (fig. 34, 35). For another two patients multiform AFL degenerating to AF relapsed despite per-catheter ablation; these patients underwent AV node modification because of tachysystolia and for one patient VVIR pace maker was implanted (for another patient DDDR pace maker has been implanted previously).

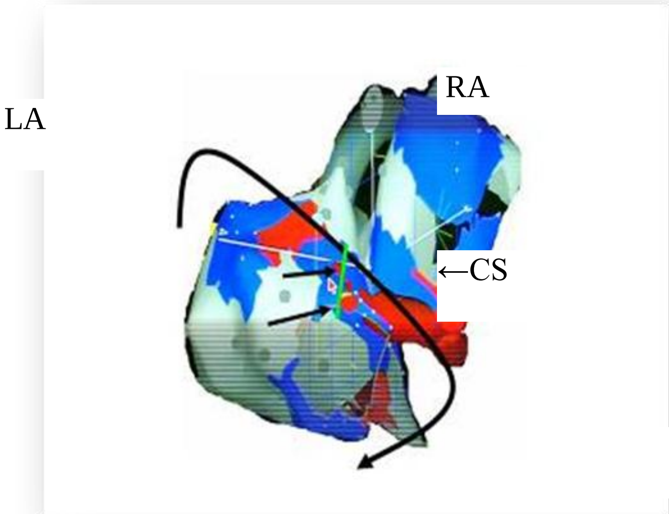


***Fig. 35***. RFA of atrial flutter in the left atrium.

Green line and black arrows show the line of ablation connecting scars (grey zones) in the site of LA roof; circle line shows spreading of AFL in LA

## 5. CONCLUSIONS

1. Modified radiofrequency liquid cooled maze procedure using trans-septal and superior septal approaches is safe and restores sinus rhythm effectively when operations of mitral valve malformation correction are being performed together with other operations to correct heart malformations or create coronary artery by-passes.
2. Comparison of the results and complications in both approach groups showed that in the group of superior atrial approach duration and requirement of temporary heart pacing was higher; other statistically reliable differences were not found between these groups.
3. The type of mitral valve correction (i.e. implantation of mitral valve prosthesis or plasty of mitral valve) had no statistically reliable influence on the results of atrial fibrillation treatment.
4. Higher NYHA functional class and increased longitudinal diameter of the left atrium had statistically reliable influence on less effective results of treatment of atrial fibrillation after surgical correction of mitral valve.
5. Symptomatic sinus node dysfunction treated by means of implantation of heart pace maker showed that atrioventricular intervals were shorter when atrial electrode was fixed near coronary sinus orifice in comparison with other sites of stimulation.

## 6. RECOMMENDATIONS FOR PRACTISE

1. Maze procedure together with correction of mitral valve malformation is recommended using trans-septal and superior septal approaches, as it is safe surgical method of treatment of patients suffering form symptomatic atrial fibrillation and mitral valve (or other valves) malformations.
2. In cases of complicated operations we recommend to use superior septal approach, as it is easier to inspect the mitral valve and to correct mitral valve malformation. This incision may be the only way to reach mitral valve when due to anatomical conditions or in event of repeated operation it is difficult to expose the left atrium.
3. We recommend to perform intensive treatment of postoperative rhythm disturbances (atrial fibrillation or atrial flutter) as this treatment allows to increase the rate of successful

procedures after modified maze procedure with surgical correction of mitral valve malformation using trans-septal incisions.

4. It is recommended to secure the membrane part of oval fossa while performing septal incisions, for it will be more convenient and safer to perform catheter ablation of the left atrium flutter or tachycardia, if needed in future.
5. While correcting symptomatic dysfunction of sinus node after modified maze procedure by means of implantation of electric cardiostimulation system, it is advisable to fix atrial electrode near the orifice of coronary sinus.

## LIST OF SCIENTIFIC PUBLICATIONS RELATED TO DOCTORAL THESIS


1. Aidietis A., Ručinskas K., Sirvydis V., Jurkuvėnas P., Grebelis A., Marinskis G.,Uždavinys G. Modifikuota radiodažninė labirinto procedūra ir mitralinio vožtuvo ydos korekcija: vidutinės trukmės pooperacinio stebėjimo rezultatai . MEDICINA, 2004; 40, Nr.1. P. 1-6. (*Medline, Index Copernicus*)
2. Aidietis A., Ručinskas K., Sirvydis V., Grebelis A., Marinskis G., Jurkuvėnas P., Aidietienė S., Uždavinys G. Mitral valve surgery with trans-septal or septal-superior approaches combined with the intra-operative radiofrequency modified Maze procedure for the treatment of atrial fibrillation . Seminars in Cardiology, 2005; 11(1): 30–37. (*Index Copernicus*)
3. Aidietis A., Ručinskas K., Sirvydis V., Grebelis A., Marinskis G., Jurkuvėnas P., Aidietienė S., Uždavinys G. Left ventricle-to-right atrium fistula after the radio-frequency modified Cox-Maze procedure combined with mitral valve replacement. Seminars in Cardiology, 2005; 11(2): 78–80. (*Index Copernicus*)

THESES

1. Aidietis A., Rucinskas K., Sirvydis V., Grebelis A., Marinskis G., Jurkuvenas P., Aidietiene S., Uzdavinys G. Comparison of trans-septal and septal-superior approaches during mitral valve surgery combined with intra-operative radiofrequency modified Maze procedure. 15 World Congress WSCTS, Vilnius, Lithuania. Abstr. J Cardiovasc Surg 2005; 46 Suppl. 1:56.
2. Aidietis A., Marinskis G., Jurkuvenas P., Sirvydis V., Grebelis A., Marinskis G. Rucinskas K., Laucevičius A. Optimal atrial lead position for permanant pacing after mitral valve surgery combined with modified MAZE procedure. 18 World Congress WSCTS. Cardiothoracic Multimedia Journal 2008; 11-Supl.1: 17. (poster presentation).

INFORMATION ABOUT THE AUTHOR

**Paulius Jurkuvėnas**

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**Birth place** 1972.09.21 Vilnius, Lithuania

**Education** 1990 - 1996 Vilniaus University, Faculty of Medicine, Medicine

**Primary residentship**

1996 - 1997 Red Cross Hospital, Vilnius

1996 - 1997 Cardiology intensive care department, VUH Santariškių klinikos

**Assistant physician**

1997-1999 Clinic of internal diseases, VUH Santariškių klinikos

**Residentship in internal medicine**

1999.08.05 – 2001.08.05 Clinic of cardiology, VUH Santariškių klinikos

**Residentship in cardiology**

Centre of cardiology and angiology, Vilnius University Hospital

Since 2001.09.01 Santariškių klinikos, Santariškių 2, 2021

**Cardiologist**

(Licence for specialized medicine practice, issued by the Ministry of Health of the Republic of Lithuania. Licence No.18465)

**Refresher courses and fellowships**

1996.09.09 -10.09 Vilnius University Physician Refresher Courses' Centre
Courses of clinical echocardiography

1997.03.17 - .04.02 Vilnius University Physician Refresher Courses' Centre
Courses of secondary prophylaxis of arterial atherosclerosis

1997.10 -1998.04 Essen University Clinic, department of cardiology
echocardiography examinations (two-dimensional, Doppler and coloured tissue Doppler examinations)

2002.01.07-2002.02.17 Vilnius University Physician Refresher Courses' Centre
Courses of interventional cardiology

2005.03 – 2005.05 Kiel University Clinic, department of cardiology
non-medicamental methods of treatment of heart arrhythmias

2008.11.25 – 11.27, 2009.06.10 – 06.14 Denmark, Varde Clinic
Three-dimensional electrophysiology anatomy cartography system CARTO and most modern electrophysiology system AXIS'sss"STEREOTAXIS"

**Membership**

Member of Lithuanian Heart Association since 1998

Member of Lithuanian Society of Cardiologists since 2000.

**Social activities**

1996 - 2009 Voluntary support for seminars, public events and publishing organized by Lithuanian Heart Association and Lithuanian Society of cardiology.

**Scientific work**

While being a resident, the author worked in Vilnius University Cardiology Clinic group of non-invasive cardiology examinations (echocardioscopy). Under supervision of assist. Prof V.Grabauskiene, studied restoration of the left ventricle function after reperfusion therapy.

While working as a cardiologist at VU Cardiology and angiology centre, under guidance of Prof. A. Aidietis studies application of modern methods of heart arrhythmia treatment. Currently works in the group of arrhythmology specialists and heart surgeons implementing modified radiofrequency maze procedure for treatment of atrial fibrillation and developing new methods of non-medicamental treatment of heart arrhythmias. The results were published in "Medicina" and "Kardiologijos seminarai" journals, the author delivered reports at scientific conferences.

Author of 17 published articles.