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ATRIAL REMODELLING COMPARISON AFTER MAZE-3 AND CRYO-MAZE PROCEDURES IN COMBINED CARDIAC INTERVENTIONS: A RETROSPECTIVE STUDY

Georgy N. Antipov[1,*], Anzhelika S. Postol[1], Sergey N. Kotov[1], Marina O. Makarova[2], Yuriy A. Shneider[1]

[1] Federal Centre for High Medicine Technologies
Kaliningradskoe Shosse, 4, Rodniki stlmt., 238312, Russia

[2] Immanuel Kant Baltic Federal University
Nevskogo str., 14, Kaliningrad, 236041, Russia

ABSTRACT

Background. The maze procedure aims to eliminate atrial fibrillation (AF), restore sinus rhythm (SR) and atrial contractility. However, conflicting evidence exists regarding the extent of atrial remodelling in various techniques, which directed the focus of our study.

Objectives. An atrial remodelling comparison after a cut-and-sew maze-3 surgery and its biatrial cryo-maze modification using 2D echocardiography.

Methods. The study is a retrospective uncontrolled interrupted two-cohort time-series trial, with patients selected by pseudorandomisation according to a normal sinus rhythm-maintaining AF surgery method. A total of 217 maze-3 and 113 cryo-maze combined cardiac interventions have been performed within 2012–2021. The interventions included valve repair, coronary artery bypass grafting and their combination. Due to differences in long-term follow-up, the cohorts were pseudorandomised to select by 50 restored vs. maintained sinus rhythm patients using a nearest-neighbour classifier coupled with logistic regression. Mean follow-up period was 6 (1–17) months. The patients had paroxysmal, persistent and longstanding persistent AF. Echocardiography values prior to and long-term post-surgery were further analysed to determine the atrial remodelling dynamics.

Results. A statistically significant atrial volume reduction is evident in a long-term within-cohort comparison. Meanwhile, a statistically more pronounced remodelling is observed between cohorts after maze-3 procedure. The cohort 1 vs. 2 estimates are: mean left atrial volume 120/125 mL^3 (p = 0.011), left atrial size in apical view 52/53 mm (p = 0.023), right atrial size in apical view 58/62 mm (p = 0.004), right atrial size in parasternal short axis view 43/45 mm (p = 0.004), right atrial area in apical 4-chamber view 25/28 cm^2 (p = 0.007). Maintained atrial pacing patients had positive systolic atrial function recovery rates (E/A ratio increased to average 1.5) in the long-term in both comparison cohorts.

Conclusion. Remodelling is biatrial after all the maze procedures compared. A more pronounced atrial volume reduction occurs after maze-3 surgery. The presence of sinus rhythm is facilitated by cardiac conduction leading to mechanical and electrical remodelling of the atria.

Keywords: atrial fibrillation, maze surgery, atrial remodelling.

Conflict of interest: the author declares no conflict of interest.

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СРАВНЕНИЕ РЕМОДЕЛИРОВАНИЯ ПРЕДСЕРДИЙ ПОСЛЕ ПРОЦЕДУР «ЛАБИРИНТ-3» И «КРИОЛАБИРИНТ» ПРИ СОЧЕТАННЫХ ВМЕШАТЕЛЬСТВАХ НА СЕРДЦЕ: РЕТРОСПЕКТИВНОЕ ИССЛЕДОВАНИЕ

Г.Н. Антипов[1,*], А.С. Постол[1], С.Н. Котов[1], М.О. Макарова[2], Ю.А. Шнейдер[1]

[1] Федеральное государственное бюджетное учреждение «Федеральный центр высоких медицинских технологий» Министерства здравоохранения Российской Федерации Калининградское шоссе, д. 4, п. Родники, Калининградская область, 238312, Россия

[2] Федеральное государственное автономное образовательное учреждение высшего образования «Балтийский федеральный университет имени Иммануила Канта» ул. А. Невского, д. 14, г. Калининград, 236041, Россия

АННОТАЦИЯ

Введение. Процедура «лабиринт» направлена на устранение фибрилляции предсердий (ФП), восстановление синусового ритма (СР) и восстановление сократительной функции предсердий. При этом имеются противоречивые данные относительно степени ремоделирования предсердий в зависимости от использованной методики. Исходя из этого определилась цель нашего исследования.

Цель исследования — сравнение ремоделирования предсердий после операции «лабиринт-3» (“cut-and-sew”) и ее варианта — двухпредсердного криолабиринта с помощью двухмерной эхокардиографии.

Методы. Дизайн исследования — ретроспективное неконтролируемое исследование с прерванным временным рядом двух групп пациентов, отобранных с помощью метода псевдорандомизации в зависимости от варианта хирургического лечения ФП с удерживаемым регулярным ритмом сердца. В период с 2012 по 2021 год выполнено 217 сочетанных вмешательств на сердце по методике «лабиринт-3» и 113 по методике «криолабиринт». Сочетанные вмешательства включали клапанную коррекцию, шунтирование коронарных артерий и их комбинацию. Ввиду различий по срокам отдаленного наблюдения группы подверглись псевдорандомизации с отбором по 50 пациентов с восстановленным и удерживаемым синусовым ритмом в каждой по принципу «ближайший сосед» с использованием метода логистической регрессии. Средний период наблюдения составил 6 (1–17) месяцев. Пациенты имели пароксизмальную, персистирующую и длительно персистирующую формы ФП. Далее был выполнен анализ эхокардиографических показателей до и после операции в отдаленные сроки наблюдения с целью определения динамики ремоделирования предсердий.

Результаты. В отдаленные сроки наблюдения происходит статистически значимое уменьшение объемов предсердий при внутригрупповом сравнении. При этом при межгрупповом сравнении статистически более выраженное ремоделирование происходит после процедуры «лабиринт-3». Полученные значения группы 1 против группы 2: средний объем левого предсердия 120 и 125 мл^3 (p = 0,011), размер левого предсердия

в апикальной позиции 52 и 53 мм (p = 0,023), размер правого предсердия в апикальной позиции 58 и 62 мм (p = 0,004), размер правого предсердия в парастернальной позиции по короткой оси 43 и 45 мм (p = 0,004), площадь правого предсердия из апикальной 4-камерной позиции 25 и 28 см^2 (p = 0,007). Пациенты с удерживанием регулярного предсердного ритма, по данным долговременных наблюдений, имели позитивные показатели восстановления систолической функции предсердий (отношение E/A увеличивалось в среднем до 1,5) в обеих группах сравнения.

Заключение. После исследованных нами вариантов операций «лабиринт» процессы ремоделирования происходят в обоих предсердиях. Более выраженное уменьшение объемов предсердий происходит после процедуры «лабиринт-3». Наличие синусового ритма характеризуется физиологическим проведением по проводящей системе сердца, что приводит к механическому и электрическому ремоделированию предсердий.

Ключевые слова: фибрилляция предсердий, операция лабиринт, ремоделирование предсердий

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INTRODUCTION

The maze procedure was developed in order to eliminate atrial fibrillation (AF) and restore normal sinus rhythm and atrial contractility [1, 2, 3]. Many authors point to the recovery of atrial contractility in most patients following surgical AF treatment, especially in maintaining regular sinus rhythm [3, 4, 5, 6, 7, 8]. However, there is contradictory evidence concerning the efficacy of various techniques to accomplish atrial remodelling and repair [9, 10]. According to some views, fibrous changes in the atria following the “cut-and-sew” procedure prohibit a restoration of their contractility due to the lack of remodeling, which leads to a decrease in the contribution of the atria during their systole (normally up to 20%) [11, 12, 13].

In order to assess the extent of atrial remodelling via estimating the pre — and post-operative ultrasound parameters at variant follow-up terms, Doppler echocardiography is employed[1] [14, 15, 16]. Here, the major parameters comprise: left atrium (LA) size in apical view; LA volume; right atrium (RA) size in parasternal short axis view; RA size in apical view; RA area in apical 4-chamber view; atrial emptying fractions. Atrial contractility is measured by the presence and ratio of E/A waves. Although single peak flow is defined by a sole E peak, atrial contraction is effective when an A peak of interval-vular flow is detected. The A wave is not detected in non-restored atrial transport; moreover, the advantages of surgical AF treatment may diminish since, on the one hand, the risk of thrombosis remains at persisting atrial blood stasis and, on the other hand, cardiac haemodynamics continues to deteriorate due to a lack of atrial contribution to cardiac output.

Atrial contractility can be most accurately measured with speckle-tracking echocardiography, comprising a quantitative ultrasound imaging technique for accurately analysing the myocardial function by interpreting the speckle motion pattern in conventional 2D sonograms [11, 17, 18]. Although this novel technique was developed exclusively for controlling the left ventricular function, several studies have recently extended it onto other heart chambers, including the left atrium [19]. Since conservative AF treatment is generally ineffective or has an unstable short-lived impact, surgical treatment of this pathology has gained the most research attention. We set out to study postoperative atrial remodelling in a retrospective uncontrolled interrupted two-cohort time-series trial, in which the patients were selected by pseudorandomisation according to a normal sinus rhythm-maintaining AF surgery method.

Objectives. The study aimed to investigate atrial remodelling comparison following cut-and-sew

[1] Balakhonova T.V., Gorokhova S.G., Saidova M.V., Smolyaninova N.G., Aleksandrova-Tebenkova E.S., Arakelyants A.A., Popova E.Yu., Rodionova L.V. *Ultrasonography of heart and vessels: a practical manual. 2nd edition, revised and extended*. Moscow: Eksmo, 2015. 456 pp. ISBN 978-5-699-55204-7.

maze-3 surgery vs. its biatrial cryo-maze modification using 2D echocardiography.

METHODS

Experimental design

A retrospective uncontrolled interrupted two-cohort time-series trial, in which patients were selected by pseudorandomisation according to a normal sinus rhythm-maintaining AF surgery method.

Eligibility criteria

Inclusion criteria

Since atrial remodelling and contractility restoration are analysed by interpreting data on patients with restored and maintained sinus rhythm, these comprised the main inclusion criterion for retrospective cohort construction.

Non-inclusion criteria

All patients not selected by pseudorandomisation.

Exclusion criteria

The follow-up terms differed because the first intervention was performed in 2012–2016 and the second from 2020 onwards. In the interim, from 2017 to 2019, only left atrial maze-3 was performed; accordingly, this cohort was excluded from the trial as featuring no right atrial (RA) intervention.

Facilities

The work was carried out at the Federal Centre for High Medicine Technologies, Ministry of Health of the Russian Federation (Kaliningrad). The average follow-up period was 6 (1–17) months.

Trial duration

The patients were enrolled from 2012 to 2021. The follow-up period was 6 (1–17) months.

Intervention description

Surgical aspects of interventions

Standard normothermic bicaval cannulation was followed by aortic clamping and cold del Nido cardioplegia. Both atria were opened to perform either a classic cut-and-sew maze-3 (2012–2016) or biatrial cryo-maze as described by McCarthy (2020–2021). In maze-3, ablations were performed with a cryoprobe on the mitral valve (MV) fibrous ring with transverse application onto the coronary sinus from the outside and inside of the LA and tricuspid valve (TV). After applying cryolines using a CryoIce Cryoablation Probe (Isolator Synergy, AtriCure Inc., Mason OH, USA), a combined cardiac intervention was carried out. In most cases, MV reduction plasty was performed to correct mitral defect. De Vega tricuspid valve annuloplasty was conducted using 2–0 Ethibond sutures and spacers. MV and TV plasty was considered satisfactory at grade I regurgitation in control transoesophageal echocardiography (TEE). In most patients, bilateral internal thoracic artery grafting with a bypass ratio of 2.1 was attempted. The operation was completed with the standard cardiac surgery completion technique.

Postoperative period

All patients received saturation and Cordarone maintenance therapy at 1200 mg/24 h intravenously on postoperative day 1, followed by 200 mg orally every 8 h until hospital discharge and then 200 mg daily for 3–6 months.

In patients with sinus or ectopic atrial rhythm <70 beats/min, temporary 80 beats/min pacemaking was implemented to prevent supraventricular ectopic contractions, AF and promoted atrial conduction restore. Electro-pulse therapy was employed in cases where recurrent postoperative atrial tachyarrhythmias were unresponsive to medication treatment.

Trial outcomes

Main trial outcome

A comparison of atrial remodelling after maze-3 and cryo-maze procedures in combined cardiac interventions.

Complementary trial outcome

No complementary outcomes were envisaged.

Methods of outcome registration

All patients had paroxysmal, persistent and long-standing persistent AF before surgery. Mean preoperative AF period was 27.4 (1–200) months in cohort 1 and 32 (1–540) months in cohort 2. The indications for maze-3 surgery were ineffective antiarrhythmic therapy and the need for combined cardiac procedures, in accordance with the latest AF treatment guidelines (ACC/AHA Guidelines 2019) [20].

Early postoperative cardiac rhythm was monitored with standard 12-channel electrocardiography (ECG). ECG was supplemented at variant follow-up terms with 24-hr Holter monitoring by indication. All patients had standard 2D transthoracic echocardiography with a Philips EpiQ 7 ultrasound system (Cambridge MA, USA). Structural atrial change, contractility and remodelling dynamics were evaluated at variant long-term follow-up terms. The transmitral flow velocity was measured at MV in apical 4-chamber view by determining the early — (E) and atrial (A) filling wave peak velocities. The obtained E/A ratio reflects the atrial contribution to ventricular diastolic filling. Each measurement was obtained at average 6 to 8 consecutive beats, with a ≥10 cm/s

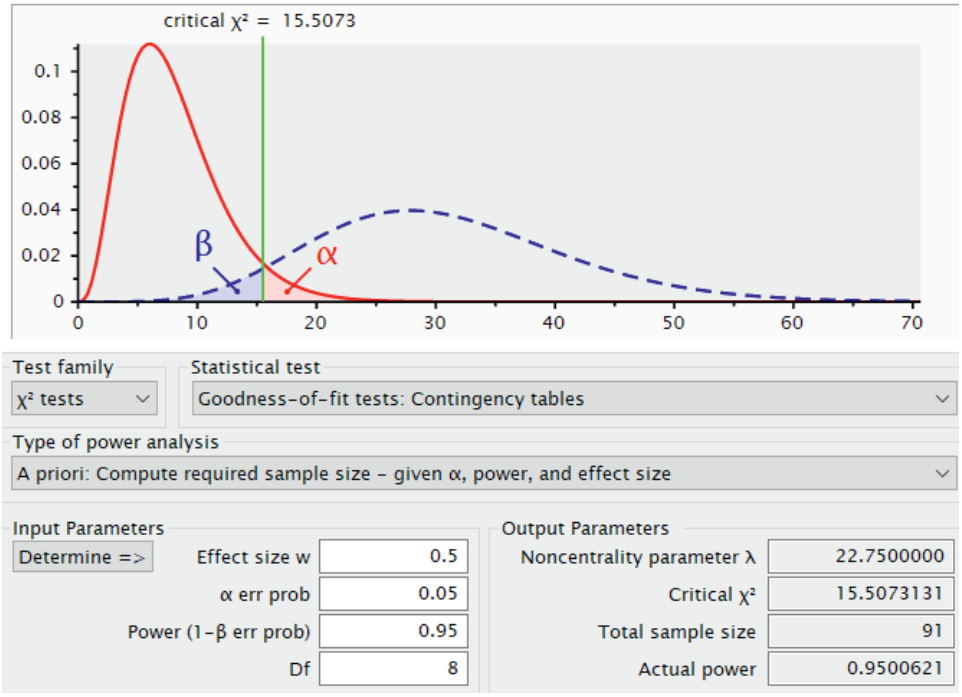

Рис. 1. Определение объема выборок по группам.
Fig. 1. Sample determination in cohorts.

A wave peak indicating effective atrial contraction in echocardiography.

Cohort construction

Due to variations in long-term follow-up, pseudorandomisation (propensity score matching) was performed using the nearest-neighbour classifier coupled with logistic regression. The trial enrolled patients who had an open cardiac surgery (for valve correction and/or CHD) combined with AF surgery of a classic cut-and-sew biatrial maze-3 (217 patients) or McCarthy cryo-maze modification (113 patients) from 2012–2021. The GPower v.3.1 software was used to determine the sample sizes of both comparison cohorts, allowing for χ^2-based corrections for a non-normal distribution of all ultrasound measurements (Fig. 1). Each cohort was thus assigned with 50 individuals.

Statistical data processing

Sample size determination

The sample size was calculated based on pseudorandomisation using the GPower v. 3.1 statistical package.

Methods of statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 21.0 (Chicago IL, USA). The samples were tested for normality using exploratory analysis, including the Shapiro-Wilk, Kolmogorov-Smirnov criteria, histograms and Q-Q plots. Normally distributed parameters are presented as sample mean with standard deviation ($\bar{x}$ ± sd), while non-normally distributed parameters are given as median with min–max range (Me, (min–max)).

Student's paired t-criterion for dependent and independent samples was used for null hypothesis (H0) testing with normally distributed variables. With non-normally distributed samples, the χ^2 (chi square) test was used to estimate statistical significance; the Mann–Whitney U-test was used for independent samples, while the Wilcoxon W-test was used for dependent samples. Pearson's correlation coefficient (r) was used to infer correlation dependencies (significance was assumed at p <0.05) with parametric distributions, while Spearman's correlation coefficient was used with nonparametric data (or if two variables were ranked).

Inter-cohort differences were assumed statistically significant at p <0.05.

RESULTS

Patient data

The patients' clinical metrics and functional status are detailed in Table 1. The cohorts were comparable by age, gender, comorbidity and other parameters. At baseline, most patients had NYHA functional class III cardiac failure (in the New York Heart Association Functional Classification), with male patients predominating and no class I patients.

Key findings

The majority (about 60%) comprised patients with isolated valve defects, 26–28% cases involved isolated coronary heart disease (CHD), while the remaining 14% of patients experienced CHD-comorbid valve pathology. The range of combined interventions and intraoperative data are detailed in Table 2.

Intra — and postoperative findings evinced the following statistically significant differences: longer myocardial ischaemia time in cohort 1 (p = 0.015), more frequent use of inotropic support in cohort 1 (p = 0.046) and higher blood loss on follow-up day 1, also in cohort 1 (p = 0.005) (Table 3).

Since all operations were combined surgeries, AF was treated surgically when antiarrhythmic therapy was ineffective and combined cardiac procedures had been recommended in accordance with the ACC/AHA Guidelines 2019. Table 4 presents a preoperative echo findings comparison in two cohorts.

The intra-cohort comparison yielded statistically significant echocardiographic variances before vs. after surgery in both cohorts, which suggests that remodelling occurs in both atria after maze-3, as well as following a cryo-maze procedure. At the same time, our inter-cohort echo data comparison revealed a more significant long-term atrial remodelling after maze-3 (Table 5).

The inter-cohort comparison suggests a statistically more pronounced remodelling after the maze-3 procedure. The cohort 1 vs. 2 estimates are: mean left atrial volume — 120/125 mL^3 (p = 0.011); left atrial size in apical view — 52/53 mm (p = 0.023); right atrial size in apical view — 58/62 mm (p = 0.004); right atrial size in parasternal short axis view — 43/45 mm (p = 0.004); right atrial area in apical 4-chamber view — 25/28 cm^2 (p = 0.007). Maintained atrial pacing patients had long-term positive systolic atrial function recovery rates (E/A ratio increased to average 1.5) in both comparison cohorts.

Table 1. Preoperative patient values
Таблица 1. Предоперационные данные пациентов

	Cohort 1 (n = 50)	**Cohort 2 (n = 50)**	**p-value**
Age, Me, years	64 (35–79)	65 (27–81)	0.700
Males, n, %	30 (60.0)	31 (62.0)	0.759
Height, $\bar{x}$ ± sd, m	1.68 ± 0.1	1.69 ± 0.1	0.578
Weight, $\bar{x}$ ± sd, kg	80.8 ± 12.5	82.1 ± 15.5	0.345
BMI, Me	28.3 (19.6–40.7)	28.4 (18.4–44.4)	0.583
AF period, Me, months	27.4 (1–200)	32 (1–540)	0.309
AH, n	36 (72%)	37 (74%)	0.623
Diabetes mellitus, n	4 (8%)	5 (10%)	0.788
Thromboembolism, n	1 (2%)	1 (2%)	1.000
NYHA functional class, n	41 (82%)	39 (78%)	0.618

Note: АГ — arterial hypertension, ИМТ — body mass index, ФП — atrial fibrillation.
Примечание: АГ — артериальная гипертензия, ИМТ — индекс массы тела, ФП — фибрилляция предсердий.

Table 2. Combined interventions
Таблица 2. Спектр сочетанных вмешательств

	Cohort 1 (n = 50)	**Cohort 2 (n = 50)**
Acquired heart disease corrections, n	30 (60%)	29 (58%)
CABG, n	13 (26%)	14 (28%)
CABG + AHD, n	7 (14%)	7 (14%)
- MV interventions, n (total)	28	27
- AV replacement, n	4	5
- TV interventions, n	17	19
- LV plasty, n	2	1
- Ascending aorta interventions, n	2	2

Note: АК — aortic valve, АКШ — aorto-coronary bypass, ЛЖ — left ventricle, МК — mitral valve, ППС — acquired heart disease, ТК — tricuspid valve.
Примечание: АК — аортальный клапан, АКШ — аорто — коронарное шунтирование, ЛЖ — левый желудочек, МК — митральный клапан, ППС — приобретенные пороки сердца, ТК — трикуспидальный клапан.

Table 3. Intra — and postoperative patient values
Таблица 3. Интра — и послеоперационные данные пациентов

	Cohort 1 (*n* = 50)	Cohort 2 (*n* = 50)	*p*-value
Extracorporeal circulation time, Me, min	106 (56–292)	98 (55–364)	0.679
Myocardial ischaemia time, Me, min	82 (35–156)	74 (12–250)	**0.015**
Inotropic support, *n*	31 (62%)	21 (42%)	**0.046**
Drainage discharge on post-surgery day 1, Me, mL^3	650 (230–2000)	552 (230–1770)	**0.005**
Bleeding, *n*	4 (8%)	1 (2%)	0.169
Temporary pacemaker, *n*	35 (70%)	30 (60%)	0.295

Note: ВЭКС — temporary pacemaker, ОНМК — acute cerebrovascular accident, ОССН — acute cardiovascular failure, СПОН — multiple organ failure syndrome.
Примечание: ВЭКС — временный электрокардиостимулятор, ОНМК — острые нарушения мозгового кровообращения, ОССН — острая сердечно — сосудистая недостаточность, СПОН — синдром полиорганной недостаточности.

Table 4. Preoperative echocardiography comparison between cohorts.

Таблица 4. Сравнение данных эхокардиографии у пациентов обеих групп до операции.

Parameter	Cohort 1 (*n* = 50)	Cohort 2 (*n* = 50)	*p*-value
LA EDV, Me, mL^3	131 (50–450)	143 (55–560)	0.231
LA size in apical view, mm	60 (34–113)	61 (34–120)	0.407
RA size in apical view, Me, mm	60 (34–97)	63 (37–93)	0.117
RA size in parasternal short axis view, Me, mm	45 (29–73)	47 (35–72)	0.099
RA area in apical 4-chamber view, Me, cm^2	27 (9.86–70.8)	29 (13–69.8)	0.199
LV EF, Me, %	45 (29–73)	48 (35–72)	0.762

Примечание: ЛП — левое предсердие, ПП — правое предсердие, ФВ ЛЖ — фракция выброса левого желудочка.
Note: LA — left atrium; RA — right atrium; LF EF — left ventricular ejection fraction

Table 5. Long-term postoperative echocardiography comparison between cohorts
Таблица 5. Сравнение данных эхокардиографии у пациентов обеих групп после операции в отдаленные сроки наблюдения

Parameter	*Cohort 1 (n = 50)*	*Cohort 2 (n = 50)*	*p*-value
LA volume, Me, mL^3	120 (50–230)	125 (60–380)	**0.011**
LA size in apical view, mm	52 (34–96)	53 (34–113)	**0.023**
RA size in apical view, Me, mm	58 (35–77)	62 (42–95)	**0.004**
RA size in parasternal short axis view, Me, mm	43 (29–65)	45 (31–72)	**0.004**
RA area in apical 4-chamber view, Me, cm^2	25 (10–54.8)	28 (13–68.4)	**0.007**
LV EF, Me, %	43 (29–65)	45 (31–72)	0.527

Note: LA — left atrium; RA — right atrium; LF EF — left ventricular ejection fraction
Примечание: ЛП — левое предсердие, ПП — правое предсердие, ФВ ЛЖ — фракция выброса левого желудочка.

Complementary findings

The complementary findings include the statistically significant variations in myocardial ischaemia time (p = 0.015), the need for early postoperative inotropic support (p = 0.046) and greater drainage losses in the first 24 h post-surgery (p = 0.005) in the maze-3 cohort.

Adverse events

Not registered

DISCUSSION

Key findings summary

Our study reveals the remodelling processes developing in both atria after maze-3 as well as cryo-

maze procedure. However, changes are more pronounced following maze-3 surgery due to the atrial incisions specifically enabling surgical remodelling (atrioplasty for large and giant LA sizes, including auto-transplantation) [27]. Nevertheless, the maintained atrial pacing patients had positive systolic atrial function recovery rates (E/A ratio increased to average 1.5) in the long term in both comparison cohorts at no statistical difference.

Inter-cohort comparison uncovered certain negative aspects of the maze-3 procedure, including statistically significant variations in myocardial ischaemia time ($p = 0.015$), the need for early postoperative inotropic support ($p = 0.046$) and greater drainage losses in the first 24 h post-surgery ($p = 0.005$). Novel less invasive maze application techniques are emerging to compensate for the disadvantages of classic maze-3. Furthermore, in an earlier study we showed the importance of opting for the biatrial maze surgery due to the significant difference observed in the time to permanent pacemaker implantation compared to the isolated left-atrial technique [28]. These findings supported the conclusion that a right-atrial intervention facilitates preserved spontaneous heart rhythm regulation before permanent pacemaker is needed [28]. In our opinion, this constitutes a decisive factor to warrant an intervention of some type on both atria.

In our study, we investigated the remodelling of both atria following two variants of biatrial interventions. Since atrial contractility recovery requires regular atrial rhythm improvements to be preserved over a long period of time, it is necessary to carry out long-term monitoring of the patient's atrial rhythm and clinical status. Importantly, the regular atrial rhythm control determines the terms of withdrawal in anticoagulant and antiarrhythmic therapies.

Since LA contractility probably has a secondary nature and generally follows SR restoration, it can be seen as contributing to SR preservation, whereas earlier SR may constitute a temporary event that does not necessarily imply rhythm stability. In this case, the extent of structural atrial remodelling in the form of fibrotic stranding in the atrial myocardium appears a major factor. The stranding reduces the likelihood of atrial transport recovery.

Limitations of the study

A significant limitation is the limited sample size, which precludes definitive conclusions. Therefore, we believe that our preliminary results require confirmation from broader studies in order to better describe the negative impact of longstanding arrhythmias on the efficacy of surgical AF treatment.

Discussion of key findings

The surgical AF treatment has gone through a series of modifications over the past decades, and the maze-3 procedure hac become its current gold standard, despite the longer myocardial ischaemia time and significant risks of bleeding [7, 21, 22]. This situation warrants research into alternative ablation techniques (like cryoablation and radiofrequency ablation) towards simplifying the whole procedure [23–25]. All maze modifications pursue the common major goal of eliminating arrhythmias in order to restore atrial contractility and improve the atrial transport function. Positive atrial remodelling at preserved sinus rhythm increases stroke volume and affects thrombus formation, thus minimising the occurrence thromboembolic events [6, 24, 26,].

The left atrium contributes to the left ventricle filling via three phases: reservoir during systole, conduit in early diastasis and active contraction in late diastole [7]. The booster function of enlarged LA is among the mechanisms that compensate for the earlier reduced filling, while the loss of atrial contribution reduces cardiac output by 15–20% [2, 3, 7].

Conclusion

Based on the notion that SR recovery and LA contractility comprise integral parts of one process, we have attempted an in-depth study of plausible predictors of the atrial transport function recovery and long-term maintenance. We believe that further research into the predictors of sinus rhythm maintenance and atrial transport function recovery will help to personalise patient screening. Future endeavours will focus on interpreting the atrial malformation and spatial contractility using the promising approach of speckle-tracking ultrasound imaging of cardiac cavities, possibly combined with genetic and neurohumoral approaches, in order to obtain preoperative indications for a particular surgical AF treatment corresponding to excellence in terms of outcomes [3].

COMPLIANCE WITH ETHICAL STANDARDS

No expert evaluation of the trial protocol has been requested. The research compliance with ethical standards has been approved by the Committee for Ethics of the Federal Centre for High Medicine Technologies, Ministry of Health of the Russian Federation (Kaliningrad) (Kaliningradskoe Shosse str., 4), Minutes No. 4 of 01.11.2021.

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AUTHOR CONTRIBUTIONS

Antipov G.N.

Conceptualisation — concept statement; statement and development of key goals and objectives.

Conducting research — data analysis and interpretation.

Text preparation and editing — critical revision of the manuscript draft with a valuable intellectual investment; contribution to the scientific layout; creation of final manuscript.

Approval of the final manuscript — acceptance of responsibility for aspects of the work, integrity of all parts of the article and its final design.

Statistical analysis — application of statistical, mathematical, computing or other formal methods for data analysis and synthesis.

Postol A.S.

Conceptualisation — statement and development of key goals and objectives.

Conducting research — data analysis and interpretation.

Text preparation and editing — drafting of the manuscript; contribution to the scientific layout.

Approval of the final manuscript — acceptance of responsibility for aspects of the work, integrity of all parts of the article and its final design.

Kotov S.N.

Conceptualisation — statement and development of key goals and objectives.

Conducting research — data analysis and interpretation.

Text preparation and editing — drafting of the manuscript; contribution to the scientific layout.

Approval of the final manuscript — acceptance of responsibility for aspects of the work, integrity of all parts of the article and its final design.

Makarova M.O.

Conceptualisation — concept statement; statement and development of key goals and objectives.

Conducting research — data analysis and interpretation.

Text preparation and editing — critical revision of the manuscript draft with a valuable intellectual investment; contribution to the scientific layout; creation of final manuscript.

Approval of the final manuscript — acceptance of responsibility for aspects of the work, integrity of all parts of the article and its final design.

Statistical analysis — application of statistical, mathematical, computing or other formal methods for data analysis and synthesis.

Shneider Yu.A.

Conceptualisation — statement and development of key goals and objectives.

Conducting research — data analysis and interpretation.

Text preparation and editing — drafting of the manuscript; contribution to the scientific layout.

Approval of the final manuscript — acceptance of responsibility for aspects of the work, integrity of all parts of the article and its final design.

ВКЛАД АВТОРОВ

Антипов Г.Н.

Разработка концепции — формирование идеи; формулировка и развитие ключевых целей и задач.

Проведение исследования — анализ и интерпретация полученных данных.

Подготовка и редактирование текста — критический пересмотр черновика рукописи с внесением ценного замечания интеллектуального содержания; участие в научном дизайне; создание окончательного варианта рукописи.

Утверждение окончательного варианта статьи — принятие ответственности за все аспекты работы, целостность всех частей статьи и ее окончательный дизайн.

Проведение статистического анализа — применение статистических, математических, вычислительных или других формальных методов для анализа и синтеза данных исследования.

Постол А.С.

Разработка концепции — формулировка и развитие ключевых целей и задач.

Проведение исследования — анализ и интерпретация полученных данных.

Подготовка и редактирование текста — составление черновика рукописи; участие в научном дизайне.

Утверждение окончательного варианта статьи — принятие ответственности за все аспекты работы,

целостность всех частей статьи и ее окончательный дизайн.

Котов С.Н.

Разработка концепции — формулировка и развитие ключевых целей и задач.

Проведение исследования — анализ и интерпретация полученных данных.

Подготовка и редактирование текста — составление черновика рукописи; участие в научном дизайне.

Утверждение окончательного варианта статьи — принятие ответственности за все аспекты работы, целостность всех частей статьи и ее окончательный дизайн.

Макарова М.О.

Разработка концепции — формирование идеи; формулировка и развитие ключевых целей и задач.

Проведение исследования — анализ и интерпретация полученных данных.

Подготовка и редактирование текста — критический пересмотр черновика рукописи с внесением ценного замечания интеллектуального содержания; участие в научном дизайне; создание окончательного варианта рукописи.

Утверждение окончательного варианта статьи — принятие ответственности за все аспекты работы, целостность всех частей статьи и ее окончательный дизайн.

Проведение статистического анализа — применение статистических, математических, вычислительных или других формальных методов для анализа и синтеза данных исследования.

Шнейдер Ю.А.

Разработка концепции — формулировка и развитие ключевых целей и задач.

Проведение исследования — анализ и интерпретация полученных данных.

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INFORMATION ABOUT THE AUTHORS / СВЕДЕНИЯ ОБ АВТОРАХ

Georgy N. Antipov* — Cand. Sci. (Med.), Head of Department of Cardiac Surgery No. 2, Federal Centre for High Medicine Technologies.

Contact information: e-mail: enzo17@mail.ru, tel. +7(981) 461-69-17;

Kaliningradskoe Shosse, 4, Rodniki stlmt., 238312, Russia.

https://orcid.org/0000-0002-7704-2669

Anzhelika S. Postol — Cand. Sci. (Med.), Physician, Department of Complex Heart Rhythm Disturbance and Pacing Surgery, Federal Centre for High Medicine Technologies.

https://orcid.org/0000-0003-0983-3773

Sergey N. Kotov — Head of the Department of Functional Diagnostics, Federal Centre for High Medicine Technologies.

https://orcid.org/0000-0002-4027-4159

Антипов Георгий Николаевич* — кандидат медицинских наук, заведующий кардиохирургическим отделением № 2 федерального государственного бюджетного учреждения «Федеральный центр высоких медицинских технологий» Министерства здравоохранения Российской Федерации.

Контактная информация: e-mail: enzo17@mail.ru, тел. +7(981) 461-69-17;

Калининградское шоссе, д. 4, п. Родники, Калининградская область, 238312, Россия.

https://orcid.org/0000-0002-7704-2669

Постол Анжелика Сергеевна — кандидат медицинских наук, врач отделения хирургического лечения сложных нарушений ритма сердца и электрокардиостимуляции федерального государственного бюджетного учреждения «Федеральный центр высоких медицинских технологий» Министерства здравоохранения Российской Федерации.

https://orcid.org/0000-0003-0983-3773

Котов Сергей Николаевич — заведующий отделением функциональной диагностики федерального государственного бюджетного учреждения «Федеральный центр высоких медицинских технологий» Министерства здравоохранения Российской Федерации.

https://orcid.org/0000-0002-4027-4159

Marina O. Makarova — Cand. Sci. (Med.), Assoc. Prof., Chair of Therapy, Immanuel Kant Baltic Federal University.

https://orcid.org/0000-0001-9007-5273

Yuriy A. Shneider — Dr. Sci. (Med.), Prof., Chief Physician, Federal Centre for High Medicine Technologies.

https://orcid.org/0000-0002-5572-3076

Макарова Марина Осеевна — кандидат медицинских наук, доцент; доцент кафедры терапии федерального государственного автономного образовательного учреждения высшего образования «Балтийский федеральный университет имени Иммануила Канта».

https://orcid.org/0000-0001-9007-5273

Шнейдер Юрий Александрович — доктор медицинских наук, профессор; главный врач федерального государственного бюджетного учреждения «Федеральный центр высоких медицинских технологий» Министерства здравоохранения Российской Федерации.

https://orcid.org/0000-0002-5572-3076

* Corresponding author / Автор, ответственный за переписку