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Research Article

Recurrence of Arrhythmias after Thoracoscopic MAZE procedure

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BACKGROUND: Thoracoscopic version of the MAZE operation alone or in combination with catheter ablation (hybrid approach) has become widespread in the treatment of atrial fibrillation (AFib). However, recurrences of arrhythmias after such operations, in particular recurrence of AFib, remain unresolved problem.

AIM: The aim of this study was to establish the structure of arrhythmia recurrence in patients with long-standing persistent AFib after primary epicardial ablation using the Dallas lesion set technique, as well as determining the optimal RFA strategy for recurrence.

METHODS: 138 catheter ablation procedures for 100 patients, who applied with recurrence of various atrial arrhythmias after thoracoscopic MAZE. 34 patients had 2 or more RFA (31 pts — 2, 2 pts — 3, 1 pts — 4).

RESULTS: After Dallas lesion set thoracoscopic ablation in the structure of recurrences dominated: 1 — AFib recurence; 2 — incisional left atrial flutter. After the operation, a potential arrhythmogenic substrate remains, which must be fully eliminated by RFA (in addition to ablation the main cause of recurrence). This minimally necessary intervention implies: control and reisolation of the pulmonary veins; control and reisolation of the posterior wall; septal line from the mitral valve to the right superior pulmonary vein with Y-shaped branch to the left superior pulmonary vein; cava-tricuspid isthmus-blockade. This will eliminate and prevent in the future potentially possible incisional arrhythmias in fragmentary scars after thoracoscopic MAZE procedure. The return of AFib represents the most difficult group of patients. Restoration of sinus rhythm in recurrent AFib after epicardial ablation is possible, but may require extensive ablations in both atriums, as a result of repeated procedures, until all potential arrhythmia mechanisms, present in a particular patient, are eliminated.

CONCLUSIONS: Catheter ablation remains the only method of effective treatment of recurrences after thoracoscopic MAZE procedure. The complexity and multicomponent nature of long-standing AFib causes the frequent need for repeated procedures, especially in cases of recurrence of atrial fibrillation.

Keywords: radiofrequency catheter ablation; atrial fibrillation; thoracoscopic MAZE; Dallas lesion set; hybrid approach; recurrence of atrial fibrillation; treatment of long-standing persistent atrial fibrillation.

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Научная статья

Рецидивы аритмий после торакоскопической процедуры MAZE

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Актуальность. Торакоскопический вариант операции MAZE изолированно или в сочетании с катетерной абляцией (гибридный подход) получил широкое распространение в лечении фибрилляции предсердий. Однако рецидивы аритмий после таких операций, в особенности, рецидивы фибрилляции предсердий, остаются нерешенной проблемой.

Цель — изучение структуры рецидивов аритмий у пациентов с длительно-персистирующей фибрилляцией предсердий (ФП) после первичной эпикардиальной абляции по методике Dallas lesion set, а также определение оптимальной стратегии радиочастотной абляции (РЧА) при рецидивах.

Материалы и методы. Выполнены 138 процедур катетерной абляции 100 пациентам, обратившимся с рецидивами различных предсердных аритмий после торакоскопической модификации операции MAZE (34 пациентам — 2 и более; 31 человеку — 2, 2 пациентам — 3, 1 человеку — 4). У пациентов с 3 и более процедурами после торакоскопической операции рецидивирующей аритмией была фибрилляция предсердий.

Результаты. После торакоскопического варианта операции MAZE (по методике Dallas lesion set) в структуре рецидивов преобладают: 1 — возврат ФП, 2 — инцизионные левопредсердные трепетания, а также остается потенциально аритмогенный субстрат, который необходимо полностью устранять при катетерной РЧА (помимо работы с основной причиной рецидива). Такое минимально необходимое вмешательство подразумевает: контроль и реизоляцию легочных вен; контроль и реизоляцию задней стенки левого предсердия; септальную линию от митрального клапана до правой верхней легочной вены с Y-образным ответвлением к левой верхней легочной вене; кавотрикуспидальный истмус-блок. Это позволит устранить и предотвратить в будущем потенциально возможные инцизионные нарушения ритма по фрагментарным рубцам после торакоскопического MAZE. Пациенты с возвратом ФП представляют наиболее сложную группу. Восстановление синусового ритма при рецидивах ФП после торакоскопического варианта операции MAZE возможно с помощью повторных вмешательств, но может требовать обширных РЧА в обоих предсердиях в результате неоднократных процедур до устранения всех потенциальных механизмов ФП, присутствующих у конкретного пациента.

Выводы. Катетерная абляция остается единственным методом эффективного лечения рецидивов после торакоскопической процедуры MAZE, а сложность и многокомпанентность длительно-персистирующей ФП обусловливает частую необходимость повторных процедур, особенно при рецидивах ФП.

Ключевые слова: радиочастотная абляция; фибрилляция предсердий; торакоскопическая абляция; гибридный подход; рецидив фибрилляции предсердий; лечение длительно-персистирующей фибрилляции предсердий.

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BACKGROUND

The development of hybrid surgery for atrial fibrillation (AF) has opened up new prospects for its treatment. Despite the experience gained and increased efficiency, some patients still have refractory and recurrent forms of arrhythmia. Among the modern methods of primary surgery for long-existing AF, MAZE surgeries under cardiopulmonary bypass can be highlighted, including their thoracoscopic variants, and various non-standardized catheter ablation schemes. In recent years, the thoracoscopic MAZE procedure (TM) surgery has gained great popularity in Russia, and the most common method for this approach is the isolation of the pulmonary veins (PVs) with bipolar clamps in combination with the linear effects that isolate the posterior wall of the left atrium — "Dallas lesion set", DLS, and modifications [1, 2]. This study presents the results of reinterventions in patients who initially had exceptionally long-term persistent AF (LPAF) and initially underwent surgery according to the DLS scheme. However, regardless of how AF surgery was started, repeated procedures due to relapse after the primary surgery remain the exclusive prerogatives of catheter techniques. Moreover, only a few studies have focused on specific mechanisms of recurrence after TM surgery [3, 4] and described a few cases. No multicenter studies, long-term follow-ups, and a standard scheme for repeated catheter ablations after DLS surgery have been conducted.

The aim of this study was to establish the structure of arrhythmia recurrence in patients with long-standing persistent AFib after primary epicardial ablation using the Dallas lesion set technique, as well as determining the optimal RFA strategy for recurrence.

MATERIALS AND METHODS

The study included 100 patients with recurrence of various atrial arrhythmias after thoracoscopic ablation (DLS) who underwent surgery in our clinic between 2020 and 2022.

PVs were isolated initially with bipolar clamps, and a monopolar electrode (AtriCure) was used for the lines that isolate the left atrial posterior wall (LAPW). The line along the roof was made after preliminary skeletonization of the atrial wall from fat and fibrous structures, as wide as possible, with special attention to the area closer to the left PV, left atrium (LA) appendage and the exit site of the ligament of Marshall; in addition, the line was expanded along the roof to the aorta. Exit block testing by pacing was not routinely performed. The LA appendage was ligated by the tourniquet technique in all patients [5]. If atrial arrhythmias persisted, cardioversion through the short axis of the heart was performed at the end of the procedure with restoration of sinus rhythm (SR).

Men predominated in this group (68/100). All patients initially had LPAF, and its duration ranged from 1 to 10 years (35.8 ± 10.5 months) before treatment initiation. The LA volume was increased and was 180 ± 48 mL according to computed tomography (CT) findings before epicardial ablation. The left ventricular ejection fraction according to the initial echocardiography (echoCG) was moderately reduced (48 ± 10%).

Catheter ablation was performed depending on the timing of arrhythmia recurrence, ranging from the early postoperative period to 5 years after the primary surgery, with most reinterventions in terms of up to 6 months. In addition to mapping and eliminating the main cause of recurrence, the protocol for endocardial radiofrequency ablation (RFA) included monitoring the isolation of PVs and LAPW.

All patients were informed about the approach of treatment and research and provided informed consent. Not later than 48 h before surgery, all patients underwent transesophageal echoCG or LA CT to rule out thrombosis of the LA appendage and coronary angiography to rule out pathology of the coronary vessels.

Antiarrhythmic and anticoagulant therapy

Postoperative antiarrhythmic therapy (AAT, mainly with amiodarone) after repeated catheter procedures during the first month was performed in all patients. Subsequently, while maintaining SR, AAT was canceled. Before planning endocardial RFA, AAT was canceled, considering the timing of excretion of the drug used. Patients admitted for catheter ablation received anticoagulants continuously without discontinuation in the perioperative period; in the case of warfarin, the international normalized ratio was monitored. During the endocardial procedure, a standard anticoagulation protocol was used (bolus of heparin 100 IU/kg + infusion through transseptal sheath introducers 1,000 IU/h and control of the activated clotting time of >300 s).

Endocardial electrophysiological heart test and radiofrequency ablation

The scenarios for RFA to eliminate the recurrence of arrhythmia were as follows:

1) If atrial arrhythmia (excluding AF) was in progress, mapping and elimination of the mechanism of this arrhythmia were applied;

2) If the procedure was performed in SR (except for paroxysm), an attempt was made to induce arrhythmia;

3) All patients underwent verification (if necessary, additional RFA) of previously performed lines, control of PV and LA posterior wall isolation;

4) If the patient was admitted in AF rhythm (as well as in cases of SR), PV isolation, LAPW isolation, and RFA of the posteroinferior parts of the left atrium were monitored (from the lower line of the LAPW "box" to the coronary sinus (CS) and along the CS, a wide septal line from the mitral valve (MV) to the right superior PV with a branch line to the left superior PV). While AF was maintained, cardioversion was performed. In the case of AF relief in atrial tachycardia or atrial flutter, appropriate ablations were performed until SR

was restored (in some cases, active zones in the right atrium were excluded);

5) In addition, all patients underwent cavotricuspid isthmus (CTI) block.

Of the 138 repeated procedures, 106 were performed on the EnSite Precision navigation system (Abbot Inc.), whereas the remaining 32 procedures were performed on Carto 3 (Biosense-Webster Inc., CA, USA). All patients underwent double transseptal access using unguided introducers. The electrode used for high-density automatic mapping was a multi-pole HD-Greed electrode (Abbot Inc.) and a Lasso electrode (Abbot Inc., Biosense-Webster Inc.), and mapping and ablation were also performed with FlexAbility D, CoolFlex M, and TactiCath (Abbot Inc.) electrodes when using EnSite and a ThermoCool SmartTouch electrode (Biosense-Webster Inc.) for Carto procedures.

Control monitoring in the postoperative period

Patients' condition was monitored during visits to the clinic and through remote monitoring [6]. Cardiac rhythm was assessed 1, 3, 6, 9, and 12 months after RFA according to daily ECG monitoring data or according to the data of implanted devices. Antiarrhythmic therapy was canceled at the first visit 1 month after the endocardial procedure in the absence of sustained atrial arrhythmias.

RESULTS

Between 2020 and 2022, 138 catheter ablation procedures were performed in 100 patients who presented with recurrences of various atrial arrhythmias after TM surgery in the clinic. At the time of writing this article, 34 patients required ⩾ 2 RFAs (2 RFA for 31 patients, 3 RFA for 2 patients, and 4 RFA for 1 patient). In patients with ⩾ 3 RFAs after TM, AF was the recurrent arrhythmia (Fig. 1). The history of the patient with 4 RFAs after TM is described below. The recovery of SR during ablation without defibrillation was associated with a longer arrhythmia-free period in the multiple reintervention group.

Initially, all 100 patients had LPAF. RFA for relapses was performed in terms from early ablations after TM without discharge from the hospital to up to 5 years. More than half of the relapses and repeated RFAs (54/100) occurred in the first 6 months, and in 37 of 54 patients a stable SR was not restored after primary TM before RFA, despite repeated attempts at defibrillation and antiarrhythmic therapy (Fig. 2).

Complications of catheter ablations after TM

Complications of the vascular approach because of unintentional punctures of the arteries such as arteriovenous fistulas were the most common, including two requiring

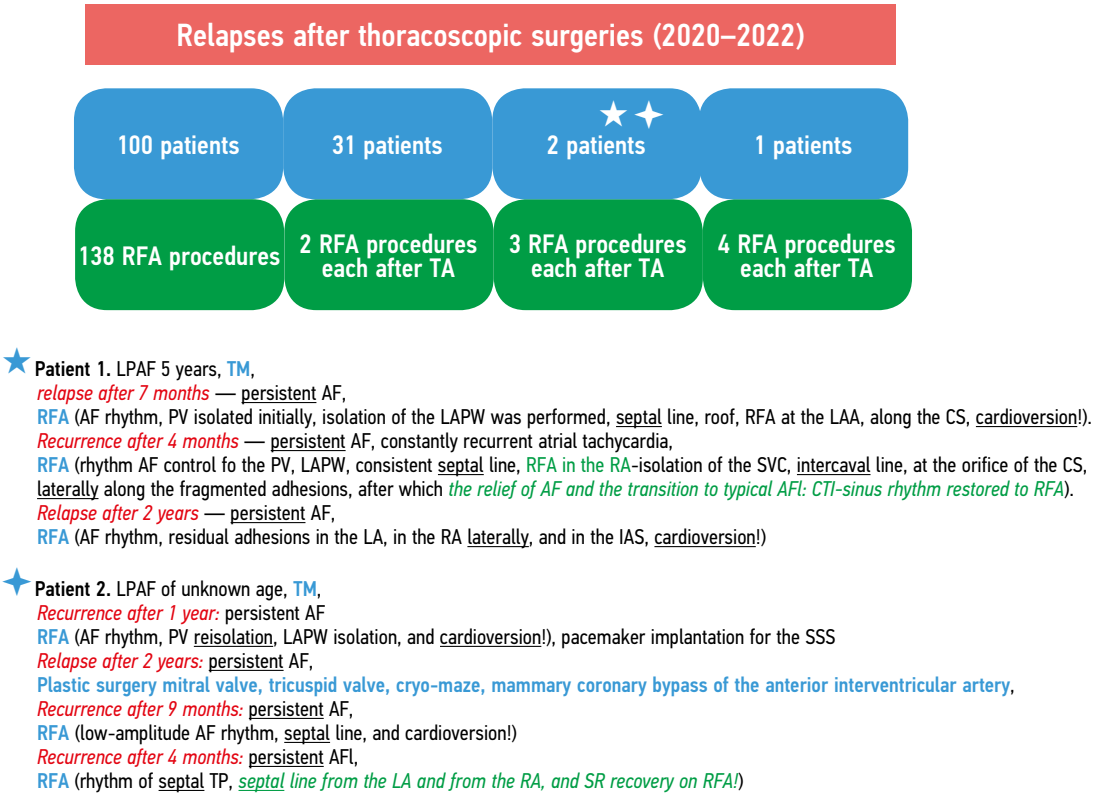

Fig. 1. Patients with recurrent arrhythmias after thoracoscopic surgery: 34 patients had ⩾ 2 RFA after thoracoscopic MAZE surgery (TM) and 2 patients had 3 consecutive radiofrequency ablations (RFA) (described in detail under links). Both patients had atrial fibrillation as the main recurrent arrhythmia. One patient had four RFAs after TM. The restoration of sinus rhythm on RFA was associated with a longer arrhythmia-free period. AFl — atrial flutter; CS — coronary sinus; CTI — cavotricuspid isthmus; IAS — interatrial septum; LAA — left atrial appendage; LAPW — left atrium posterior wall; LPAF — long-term persistent atrial fibrillation; PV — pulmonary veins; RA — right atrium; SR — sinus rhythm; SSS — sick sinus syndrome; SVC — superior vena cava; TA — thoracoscopic ablation

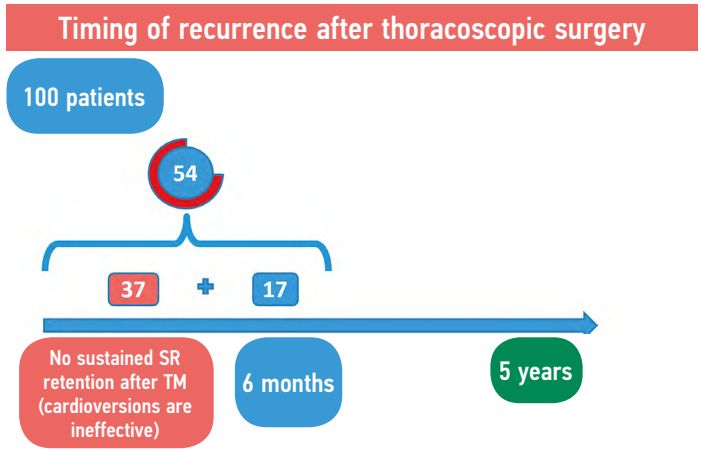

Fig. 2. Timing of the recurrence of arrhythmias after TM. A total of 100 patients (for several cases radiofrequency ablations after TM, the time of the first recurrence is presented in the scheme). During the first 6 months, 54/100 recurrences had occurred, 37 of them had not maintained a stable sinus rhythm after TM, despite repeated attempts at defibrillation. SR — sinus rhythm; TM — thoracoscopic MAZE surgery

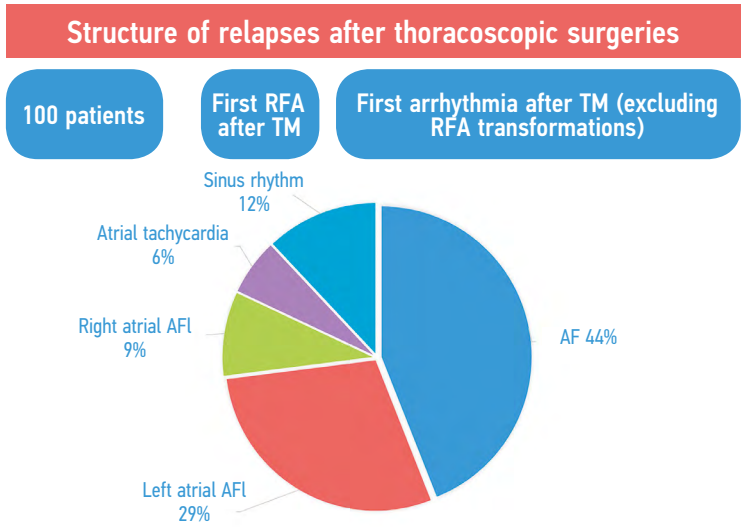

Fig. 3. Structure of relapses during the first radiofrequency ablations after TM. Data on the first rhythm disturbance are presented without taking into account transformations during ablation. "Sinus rhythm" in the diagram means that the patient had sinus rhythm at the start of the radiofrequency ablations procedure and underwent induction, or the standard anatomical ablation scheme after TM (described in the "Materials and Methods"). AF — atrial fibrillation; AFl — atrial flutter; SR — sinus rhythm; TM — thoracoscopic MAZE surgery

surgical treatment. In three patients, control radiography in the early postoperative period revealed paresis of the right phrenic nerve (after ablations in the right atrium and isolation of the superior vena cava — SVC); it was asymptomatic and resolved conservatively. In these patients, no hemopericardium or tamponade occurred. However, one case of bilateral hemothorax developed intraoperatively (perforation of the LA roof with an ablation electrode during RFA of continuous recurrent atrial tachycardia in the early period after TM) [7].

Electrophysiological results

At the start of the initial RFA after TM, 44 patients had AF rhythm, 29 had a LA flutter rhythm with a stable cycle, 12 were admitted with SR (documented paroxysmal arrhythmias), 9 had a typical right atrial flutter rhythm, and 6 had focal continuously recurrent atrial tachycardia (Fig. 3).

Patients without recovery of SR after TM were of particular interest (n = 37). The structure of rhythm disorders in this group is presented in Fig. 4. Non-isolated PVs were registered in these patients atypically frequently for RFA after TM (6/37), particularly in cases of left PV collectors, and LAPW isolation was consistent in only one case (1/37). The total number of arrhythmias significantly exceeded the number of patients (46 types of atrial arrhythmias per 37 patients) due to transformations during ablation or re-induction of different atrial arrhythmias in one procedure. Persistent AF and LA flutter were the most frequent among rhythm disorders, and 8 out of 37 patients had continuously recurrent atrial tachycardias (localizations are detailed in Fig. 4). All 37 patients restored intraoperatively a stable SR as a result of RFA, which was not obtained as a result of TM.

The analysis of amplitude maps after TM, plotted by high-density mapping before RFA, confirms in numerous

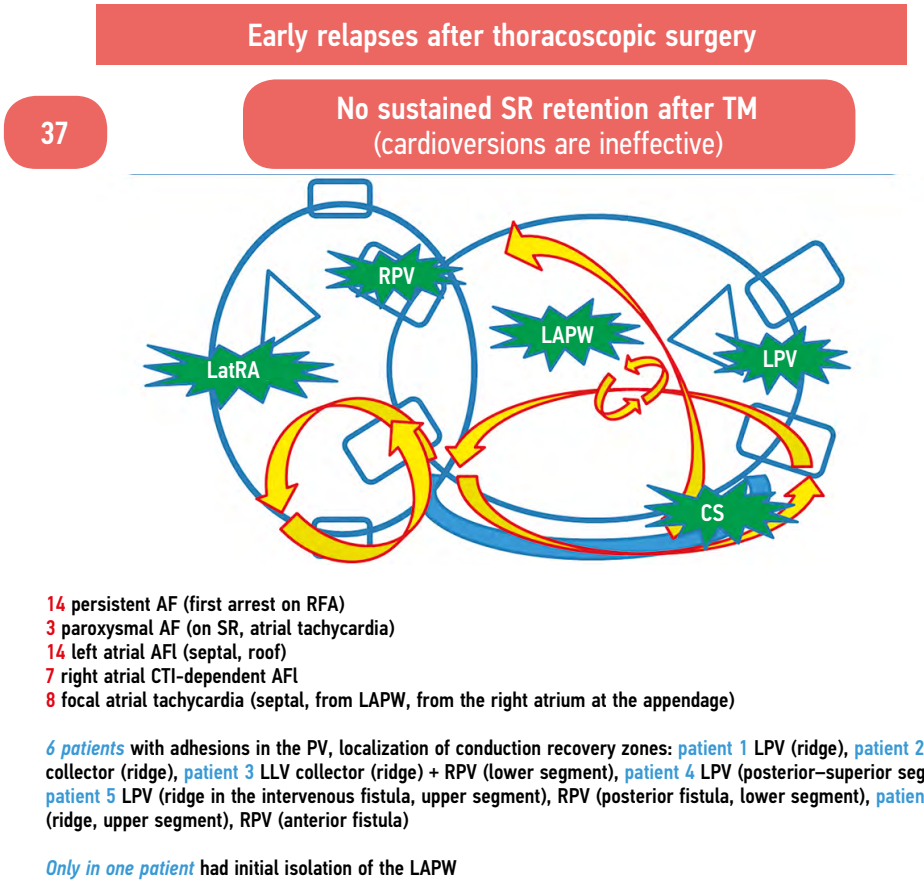

Fig. 4. Results of radiofrequency ablation (RFA) of patients whose TM did not lead to the restoration of a stable sinus rhythm. In this group, non-isolated pulmonary veins were more common, which is generally not typical for patients after TM. AF — atrial fibrillation; AFl — atrial flutter; CS — coronary sinus; CTI — cavotricuspid isthmus; LAPW — left atrium posterior wall; LatRA — lateral segments of the right atrium; LPV — left pulmonary veins; RPV — right pulmonary veins; SR — sinus rhythm; TM — thoracoscopic variant of MAZE surgery

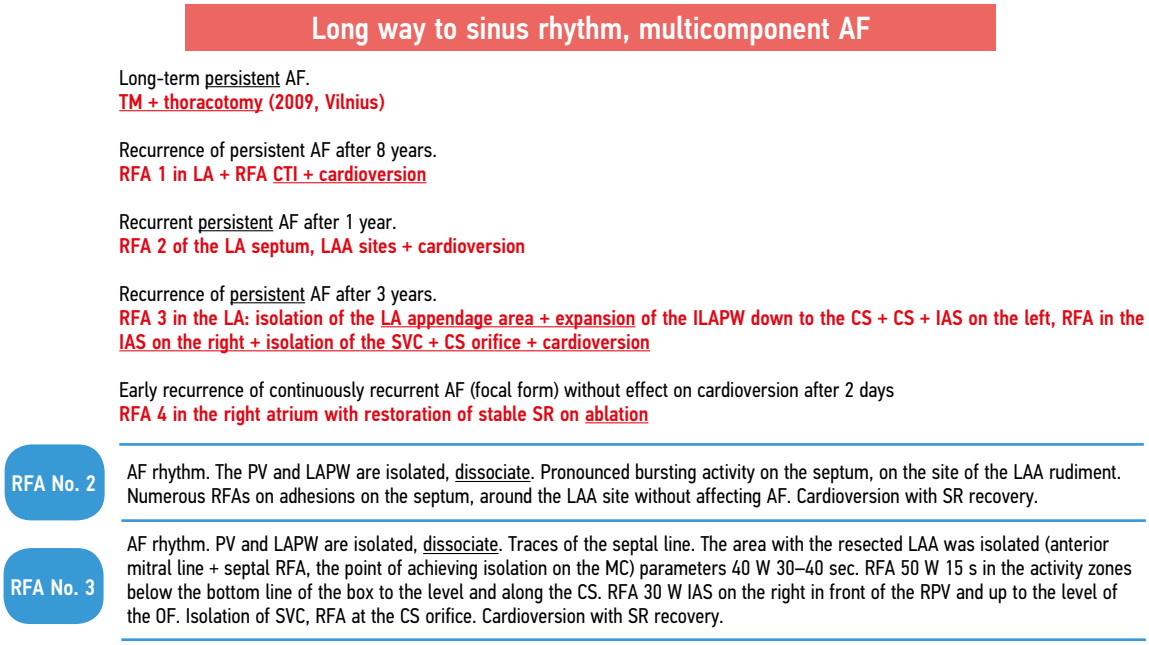

Fig. 5. Multiple radiofrequency ablation (RFA) after TM in the treatment of long-term persistent AF. AF — atrial fibrillation; AFl — atrial flutter; CS — coronary sinus; CTI — cavotricuspid isthmus; IAS— interatrial septum; ILAPW — isolation of the left atrium posterior wall; LA — left atrium; LAA — left atrial appendage; OF — oval fossa; RA — right atrium; RPV — right pulmonary veins; SR — sinus rhythm; SVC — superior vena cava; TM — thoracoscopic MAZE surgery

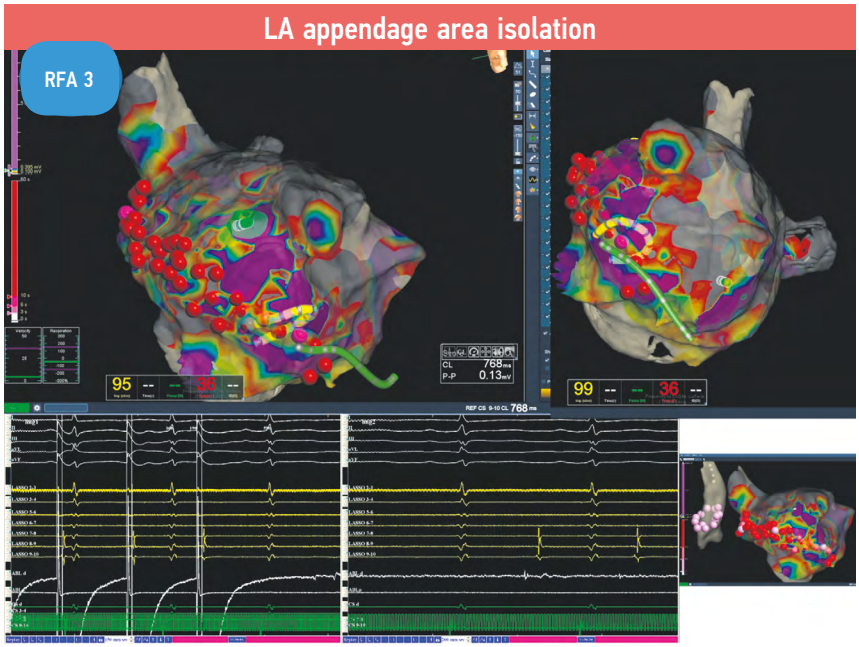

Fig. 6. Multiple radiofrequency ablations (RFA) after thoracoscopic MAZE surgery in the treatment of long-term persistent atrial fibrillation. History of patient A. RFA 3. Stimulation from an ablation electrode with dissociated local capture of the site of the rudiment of the left atrial appendage and spontaneous activity within the blocked zone. Ablation points of the mitral line and on the septum on the right are hidden. LA — left atrium

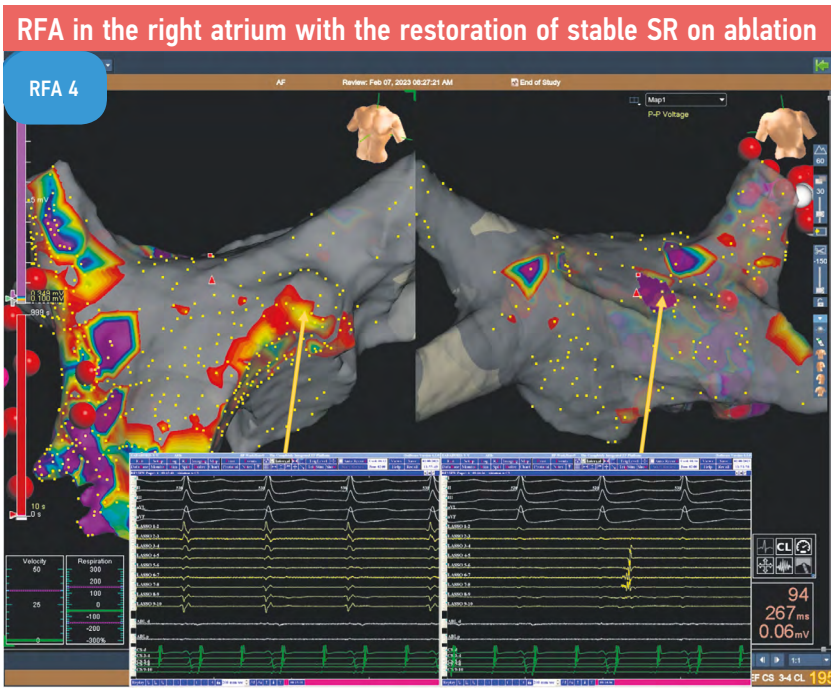

Fig. 7. Multiple radiofrequency ablations (RFA) after thoracoscopic MAZE surgery in the treatment of long-term persistent atrial fibrillation. History of patient A. RFA 4. Left atrial control. Persistent isolation of the left atrial appendage rudiment site with spontaneous dissociated activity. Purple areas on the posterior wall of the left atrium indicate dissociated activity of the block of pulmonary veins – posterior wall of the left atrium

patients the weak points of TM that we have previously described [7, 8]. A typical zone of residual conduction of signals on the LAPW after TM was the bottom line at the right inferior PV and LA roof. A typical cycle of LA flutter is perimitral and septal re-entries caused by the formation of an inhomogeneous cicatricial field not reaching the MV annulus following TM.

The experience of repeated RFAs at intervals of several years until an arrhythmia-free condition was achieved indicated understanding of the mechanisms of maintenance and recurrence of LPAF. In this group, a patient underwent four RFAs after TM (Fig. 5–8). His story sheds light on the causes of the lack of efficiency of existing methods of LPAF surgery and should be described in detail.

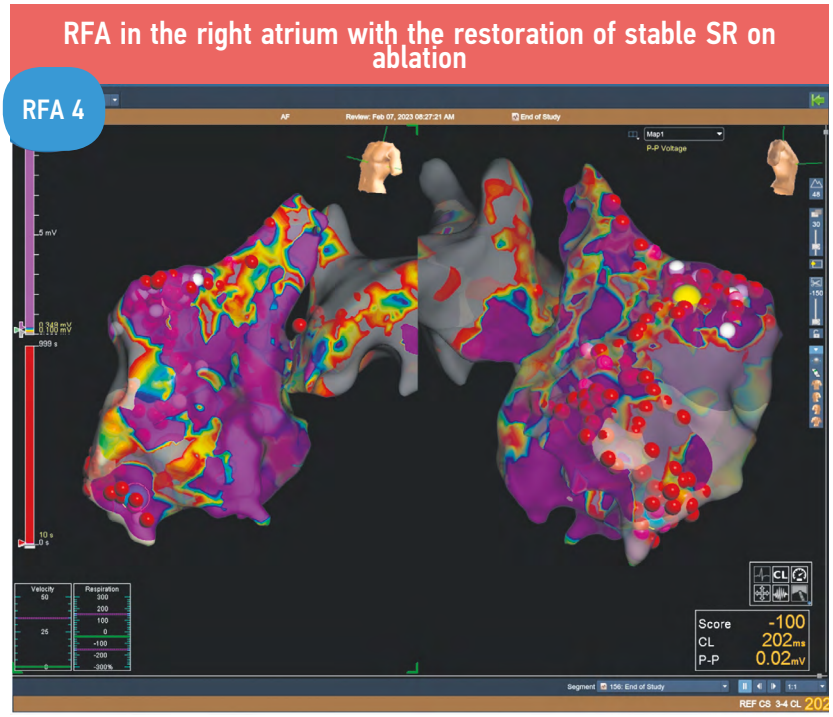

Fig. 8. Multiple radiofrequency ablations (RFA) after thoracoscopic MAZE surgery in the treatment of long-term persistent atrial fibrillation. History of patient A. RFA 4. Amplitude map of the right atrium is presented at the end of the surgery. On the yellow dot at the base of the right atrial appendage, there is cycle switching of atrial tachycardia, and the restoration of sinus rhythm is on the blue dot

The treatment of long-term AF of unknown duration in patient A started with TM in 2009. After 8 years with a recurrence of persistent AF, he visited our center. In 2018, RFA 1 was performed, namely, in the left atrium, and a consistent LAPW isolation with PVs was confirmed (activity dissociates). An additional CTI block and electrical impulse therapy with SR recovery were performed. Persistent AF recurred after 1 year; therefore, RFA 2 was performed, where pronounced burst activity was detected on the interatrial septum and area of the rudiment of the LA appendage. RFA in these areas did not lead to AF relief; again, SR was restored by electrical impulse therapy (EIT), and CTI block was confirmed in SR. The normal rhythm lasted for 3 years after these interventions. RFA 3 for a recurrence of persistent AF was performed in the scope of mitral block in the left atrium + septal line with the achievement of isolation of the LA appendage rudiment (dissociating activity), expansion of RFA from the LAPW down to the level of the CS, along the CS. In RFA 3, work was started in the right atrium with ablation of the interatrial septum to the right of the level of projection of the right PVs up to the oval fossa + isolation of the SVC + ablation of the CS orifice. Despite the large amount of RFA, EIT was again required to stop AF. On day 2 after RFA 3, arrhythmias recurred early, but in the form of continuously recurrent focal tachycardia, turning into AF. After 3 months, the patient was admitted for RFA 4, where at the start of the surgery in the left atrium, complete isolation of the block PV – LAPW + LA appendage site was confirmed (activity dissociates), and RFA was then performed in the right atrium. At RFA 4, the patient no longer had AF, and regular tachycardia was recorded with a cycle of 250 ms. After RFA at the base of the right atrial appendage, the rhythm transformed into atrial tachycardia with a cycle of 270 ms, which was stopped by RFA in the lower lateral parts of the right atrium. Areas with activity much faster than the tachycardia cycle were found in the right atrium, and the activity in them gradually slowed down and stopped during RFA (Fig. 9). After the restoration of a stable SR, these zones demonstrated dissociating isolated bursts (Fig. 10), similar to those recorded on the LAPW and LA appendage area. This finding indicates the existence of areas of burst activity that can act as potential triggers for AF not only in the LA but also, as in the patient presented, in the right atrium. Until all such areas are isolated, arrhythmia recurs. After recovery of SR in RFA 4, the patient is under close follow-up. Data on arrhythmias were not received during the year.

DISCUSSION OF THE RESULTS

In recent years, the development of hybrid surgery has led to the accumulation of experience in repeated catheter interventions. However, only a few studies were conducted, and the number of cases described is not large. When RFA was performed regardless of arrhythmia recurrence, it is often referred to as a planned-implemented hybrid approach. Patients in nearly all studies are heterogeneous and include both paroxysmal and LPAF [9–11]. All these factors lead to scattered data on the causes of relapse of arrhythmias. In this study, only patients with a recurrence of arrhythmias

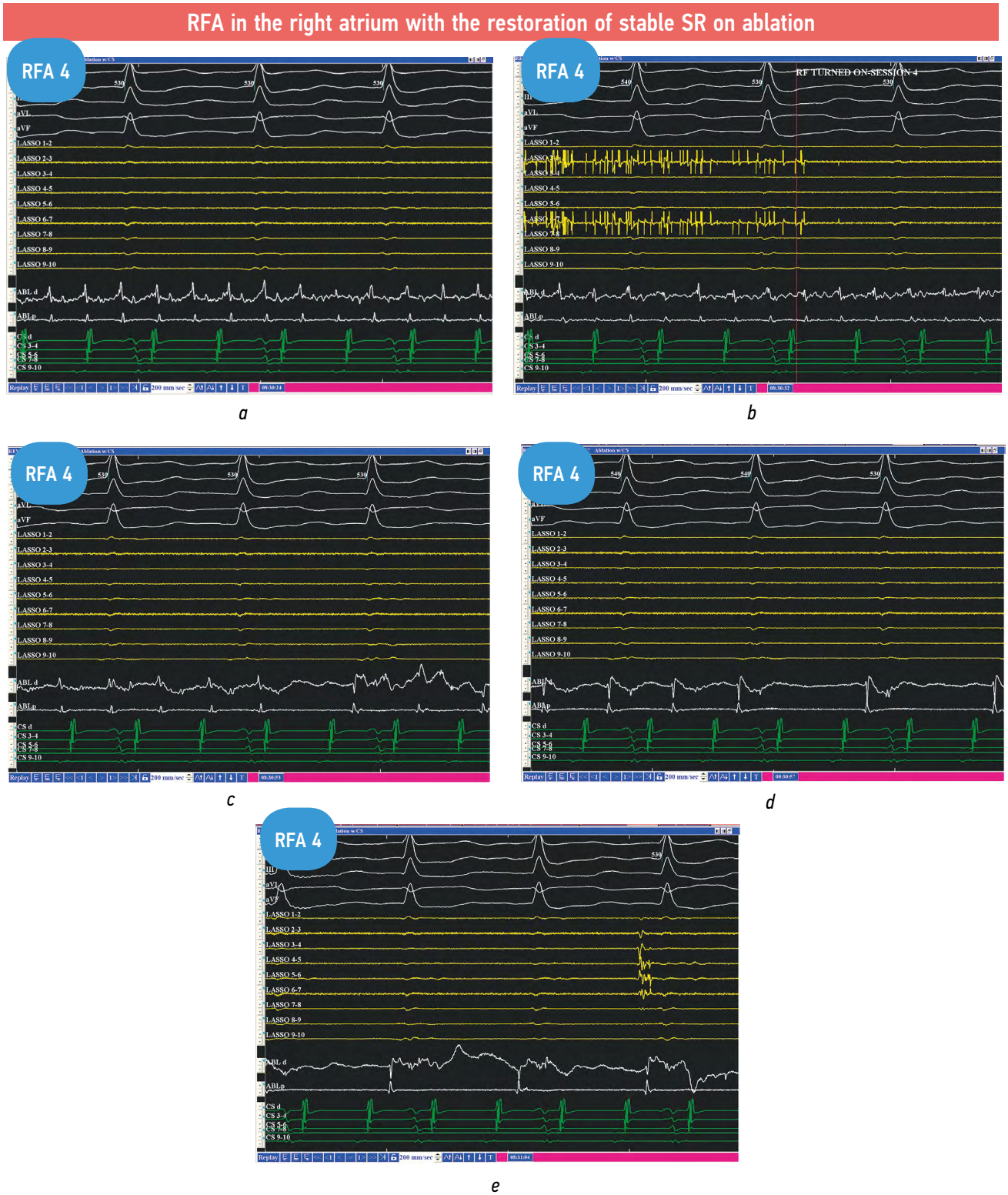

Fig. 9. Multiple radiofrequency ablations (RFA) after thoracoscopic MAZE surgery in the treatment of long-term persistent atrial fibrillation. History of patient A. RFA 4. Active area in the right atrium (a series of images in chronological order, reflecting the change in the activity of the arrhythmogenic zone under the influence of ablation: *a* — frequent bursting activity before the start of RFA; *b–d* — slowing of the cycle and arrest of spontaneous activity during RFA; *e* — rhythm of this area after RFA)

after TM surgery using the DLS method were included. They initially had a LPAF. In our earlier study [7], the main aspects and "weak points" of epicardial ablation were already described, namely, the application of lines with a monopolar electrode does not guarantee the transmurality of damage; as a result, a potentially arrhythmogenic inhomogeneous scar is formed. When the line expands to the aorta, an area of intact myocardium is preserved between the cicatricial

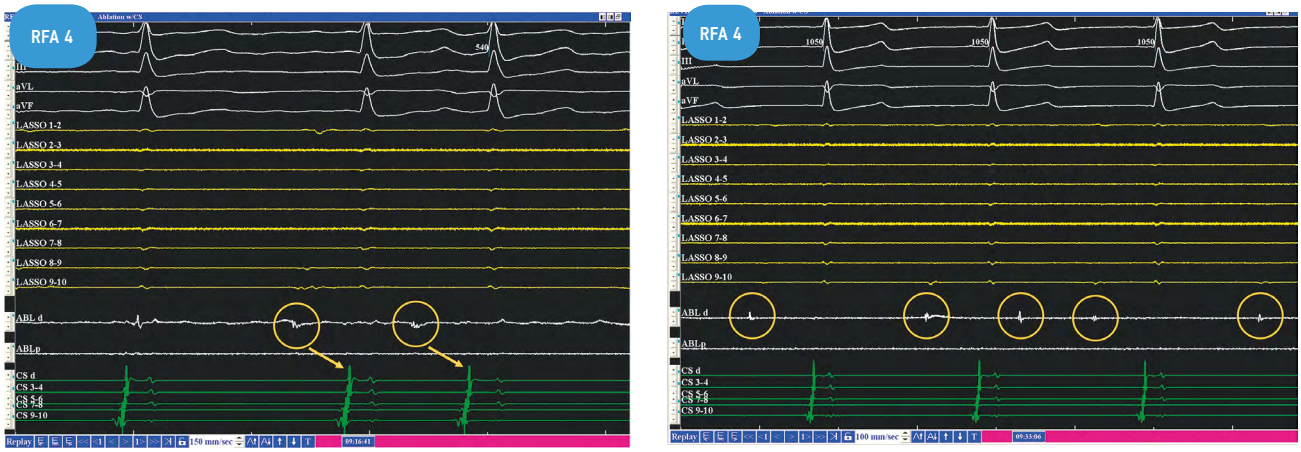

Fig. 10. Multiple radiofrequency ablations (RFA) after thoracoscopic MAZE surgery in the treatment of long-term persistent atrial fibrillation. History of patient A. RFA 4. *a* — spontaneous activity of a non-isolated area in the right atrium after the restoration of sinus rhythm; *b* — dissociating spontaneous bursting activity of an isolated area in the right atrium in the presence of sinus rhythm

field and the annulus fibrosis of the MV, which creates a substrate for perimitral flutter. The technique advantage is bipolar ablation of the PVs, which allows almost guaranteed isolation of all PVs. In addition to the restoration of LAPW conduction, focal atrial tachycardias of various localizations can cause the relapse. Further study of these patients in this trial confirms the aspects already described in numerous cases. These are data of long-term monitoring and multiple repeated procedures for the recurrence of arrhythmias, which demonstrates clearly the multicomponent nature of LPAF. All mechanisms of recurrence after TM surgery can be divided into two groups, namely (1) an arrhythmogenic substrate formed as a result of the primary surgery and (2) individual mechanisms of AF, which remained beyond previous ablations. If the first reason is stereotyped and determined, initially, by the peculiarities of the epicardial ablation technique, then the need arises for a stereotypical set of catheter RF effects that eliminate all potentially arrhythmogenic consequences of TM during the repeated procedures. Such intervention should include control and reisolation of the PVs, control and reisolation of the LA posterior wall, septal line from the MV to the right superior PV with a Y-shaped branch to the left superior PV, and CTI block. This RFA set will eliminate and prevent future potential incisional arrhythmias in fragmentary scars after TM. Performing it immediately at the initial RFA in the case of relapse will serve as electrophysiologically substantiated prevention of relapses. The second reason for repeated procedures, individual mechanisms of AF, not affected by the previous surgery, is less standardized and includes atrial tachycardias of unpredictable localizations (often several mechanisms in one patient), which requires in each case a different set of extensive ablations in both the left and right atrium to eliminate all active zones that support and trigger AF.

CONCLUSIONS

The study revealed that after TM surgery (according to the DLS method), relapses, return of AF, and incisional arrhythmias are predominant. In addition to the correction of the underlying cause of arrhythmia recurrence, epicardial ablation creates a potentially arrhythmogenic substrate that must be eliminated by catheter RFA. AF recurrence represents the most difficult cases. The restoration of SR in recurrent AF after TM is possible but may require extensive RFA in both atria as a result of repeated procedures until all potential AF mechanisms present in a patient have been eliminated.

ADDITIONAL INFORMATION

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