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Catheter ablation of atrial arrhythmias in patients after thoracoscopic ablation of persistent atrial fibrillation

Artyukhina E. A., Taymasova I. A., Revishvili A. Sh.

Aim. To determine the mechanisms of development and approaches to interventional treatment of postoperative atrial tachycardia in patients after thoracoscopic ablation (TA) of atrial fibrillation (AF).

Material and methods. The results of thoracoscopic ablation of AF in 46 patients were analyzed, of which 19,5% (n=9) had atrial tachycardia after the procedure. Radiofrequency ablation (RFA) was conducted in these patients after a 3-month blanking period. Regardless of tachycardia type, the three-dimensional reconstruction including high-density right and left atrial (LA) voltage mapping was performed in order to visualize the lesions, pulmonary veins and LA posterior wall isolations. After RFA and sinus rhythm restoration, re-mapping was performed to assess conduction block and absence of electrical activity in the lesion zones.

Results. Complete pulmonary vein (PV) isolation was verified in 55,5% of patients (n=5). In 44,4% (n=4), there were residual PV fractionated potentials without conduction with LA. In 22,2% of subjects (n=2), we identified typical atrial flutter (AFL), which was terminated by RFA in cavotricuspid isthmus (CTI). There were 77,7% (n=7) of patients who were diagnosed with atypical LA flutter; 66,6% (n=6) of them had conduction reconnection at the thoracoscopic box-lesion line. Perimitral AFL with slow conduction zone which was located on the anterior wall of LA was verified in 11,1% of patients (n=1). The effective RFA was performed in these areas. Two main factors affecting failed ablation were LA volume and body mass index (BMI). In patients with arrhythmias after TA, LA volume was 180,2±35,6 ml vs 158,34±38,5 ml in patients with sinus rhythm. BMI was 30,8±3,1 kg/m^2 and 28,9±3,9 kg/m^2, respectively. The mean follow-up was 9,8±2,7 months. All patients after catheter ablation maintained a stable sinus rhythm.

Conclusion. Atrial tachycardia after TA is caused by the gaps in box-lesion lines. The main predictors of gaps are high values of LA volume and BMI. The high-density mapping increases the effectiveness of RFA. Combination of epicardial and endocardial accesses is the most effective approach to treatment of patients with persistent AF.

Key words: atrial fibrillation, thoracoscopic ablation, atrial tachycardia, high-density mapping, radiofrequency ablation.

Relationships and Activities: none.

Vishnevsky National Medical Research Center of Surgery, Moscow, Russia.

Artyukhina E. A. ORCID: 0000-0001-7065-0250, Taymasova I. A.* ORCID: 0000-0002-9280-9063, Revishvili A. Sh. ORCID: 0000-0003-1791-9163.

*Corresponding author:
irina-tame@yandex.ru

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Atrial fibrillation (AF) is the most common type of arrhythmia. Due to the progressive increase in the incidence and high risk of related complications, the improvement of AF treatment techniques is an urgent problem [1]. Catheter ablation is the treatment of choice for medication-resistant AF. In paroxysmal AF, the efficiency of catheter ablation reaches 70-80%, while in persistent AF, patients require repeat procedures for long-term maintenance of sinus rhythm [2, 3]. As a result, in recent years, alternative surgical minimal invasive and thoracoscopic approaches have been widely used [4, 5]. Despite the higher efficiency of these methods in comparison with the catheter ablation, in some patients with persistent AF, it is necessary due to postoperative atrial tachycardia [2, 6].

The aim was to determine the mechanisms of development and approaches to interventional treatment of postoperative atrial tachycardia in patients after thoracoscopic ablation (TA) of AF.

Material and methods

Thoracoscopic AF ablation was performed in 46 patients (38 men, 8 women) with mean age of 56,5±9,4 years, performing the box-lesion procedure, which included bilateral pulmonary vein (PV) and left atrial (LA) posterior wall ablation (Figure 1A). In 78,2% (n=36) of patients, the LA appendage was amputated. In 4,3% (n=2) of patients, the linear right atrial (RA) ablation was performed: the line between the vena cava ("cava-caval") and the line to the RA appendage (Table 1).

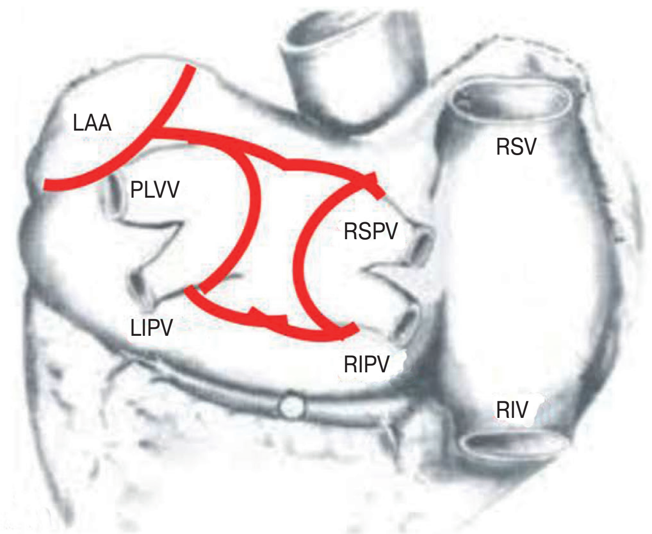
A total of 19,5% (n=9) of patients had postoperative atrial tachycardia (after 16,2±14,5 days), which required additional intervention after a three-month blind period. The characteristics of patients with atrial tachycardia are presented in Table 2.

Before thoracoscopic and catheter ablation, all patients underwent multislice computed tomography of LA and PV, 24-hour Holter monitoring, transthoracic and transesophageal echocardiography. During the perioperative period, all patients receive antiarrhythmic and anticoagulant therapy

The Seldinger technique was used for gaining central venous access. Regardless of the arrhythmia type, transseptal puncture was performed under fluoroscopic guidance to access the LA. Heparin was injected according to the generally accepted approach at a dose of 100 U/kg, followed by re-administration under the control of aspartate aminotransferase.

An ablation lead and multipolar diagnostic leads for high-density mapping with PentaRay (Biosense Webster) or Orion (Boston Scientific) were inserted into the LA. Anatomical reconstruction of LA and RA was performed with voltage mapping to visualize lesions and to assess adequateness of PV and LA posterior wall isolation. Analysis of high-density voltage maps and propagation maps of tachycardia made it possible to visualize the areas of delayed conduction, local block, and to verify the tachycardia circle.

After radiofrequency ablation (RFA) and restoration of sinus rhythm, high-density mapping from the coronary sinus were repeated to verify the



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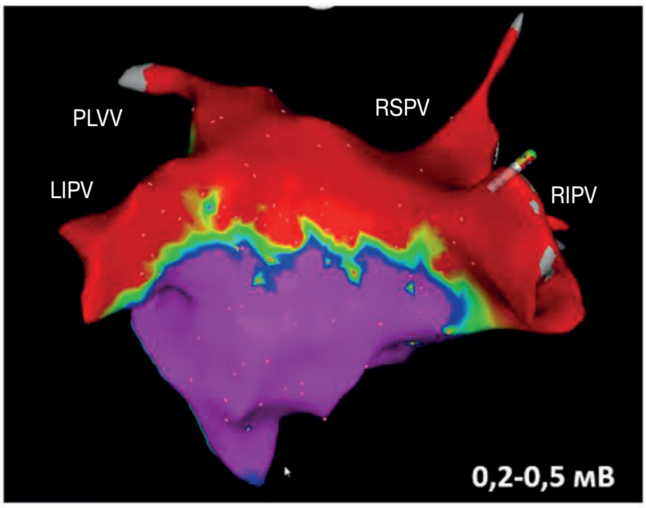

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Figure 1. LA after thoracoscopic AF ablation. **A.** Scheme of thoracoscopic ablation. **B.** Voltage map after three-dimensional reconstruction of LA in a patient after thoracoscopic ablation. Isolation of PV and LA posterior wall. LA voltage map (signal amplitude 0,2 mV-0,5 mV).
Abbreviations: RSPV — right superior pulmonary vein, PLVV, LSPV — left superior pulmonary vein, RIPV — right inferior pulmonary vein, LIPV — left inferior pulmonary vein, LAA — left atrial appendage.

Table 1

Interventions within thoracoscopic ablation

Intervention	Number of patients
LA ablation (“Box-Lesion”)	15,2% (7)
LA ablation (“Box-Lesion”), LAA amputation	78,2% (36)
LA ablation (“Box-Lesion”), LA appendage amputation and RA ablation (“cava-caval” line and the line to RAA)	4,3% (2)
LA ablation (“Box-Lesion”), anterior line to mitral valve, LAA amputation	2,17% (1)

Abbreviations: LA — left atrium, RA — right atrium, LAA — left atrial appendage, RAA — right atrial appendage.

Table 2

Characteristics of patients after thoracoscopic ablation

	Patients after thoracoscopic ablation	Patients with sinus rhythm	Patients with atrial tachycardia
Number	46	37	9
Age (years)	56,5±9,4	56,1±9,5	54,2±9,2
Sex (men/women)	38/8	31/6	7/2
BMI (kg/m^2)	29,5±3,76	28,9±3,9	30,8±3,1 (p>0,05)
AF type			
paroxysmal	21,7% (10)	24,3% (9)	11,1% (1)
persistent	15,2% (7)	8,1% (3)	44,4% (4)
long-standing persistent	63,04% (29)	67,5% (25)	44,4% (4)
Patients with a history of RFA	30,4% (14)	27,1% (10)	44,4% (4)
LA volume (ml)	162,6±38,6	158,34±38,5	180,2±35,6 (p>0,05)

Abbreviations: BMI — body mass index, LA — left atrium, RFA — radiofrequency ablation, AF — atrial fibrillation, p — level of statistical significance.

conduction block and the absence of electrical activity.

This study was performed in accordance with the Helsinki declaration and Good Clinical Practice standards. The local medical ethics committee approved this study. All patients signed informed consent.

Statistical processing included descriptive statistics methods with calculating mean values, standard deviations. The statistical significance of the differences between groups was assessed using the Student’s t-test.

Results

Complete isolation of the PV was established in 55,5% (n=5), residual fragmented spike activity without conduction in the LA during PV stimulation — in 44,4% (n=4): 3 — right superior PV, 2 — left superior PV. In all cases, additional antral PV isolation was performed until the potentials disappeared (Figure 1B).

In 22,2% (n=2) of patients, we revealed typical isthmus-dependent atrial flutter, which was eliminated by RFA of the cavo-tricuspid isthmus (CTI). In the majority of patients with tachyarrhythmias (77,7%; n=7), atypical left atrial flutter was revealed.

In 66,6% (n=6) of patients, a zone of inadequate thoracoscopic ablation in LA roof was established. In these cases, additional linear ablation was performed, closing the upper line between the superior PVs. There was a restoration of sinus rhythm or an activation front change from left atrial to right atrial (Figure 2).

Perimitral atrial flutter with zone of delayed conduction along the LA anterior wall was detected in 11,1% (n=1) of patients. Linear RFA was performed from the LA roof to the mitral valve with restoration of sinus rhythm (Figure 3).

Analysis of the clinical data of patients after thoracoscopic ablation with atrial arrhythmias and sinus rhythm, two main factors affecting the occurrence of arrhythmias were identified. In the group with arrhythmias, the LA volume and body mass

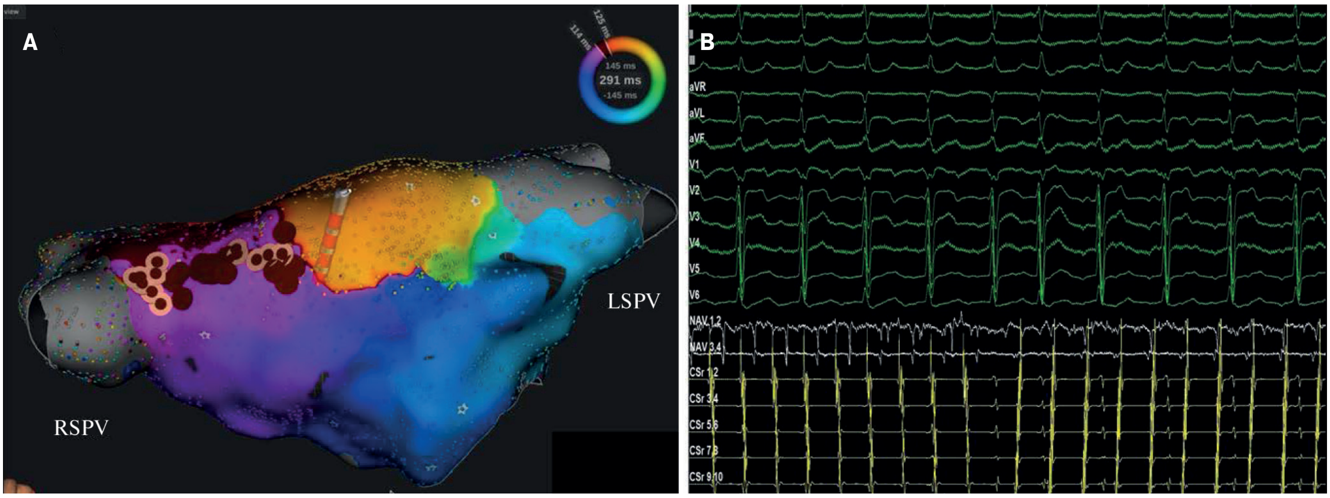

Figure 2. Elimination of left atrial flutter with a cycle length of 299 ms in a patient after thoracoscopic ablation. **A**. High-density map of LA activation, created using the Orion lead. Gaps within LA roof line, where RF exposure was performed. **B.** Transition of left atrial flutter into right atrial flutter under LA roof ablation. I-III, aVL, aVR, aVF, V1-V6 — ECG leads, CS 1-10 — recording from a 10-pole diagnostic lead in the coronary sinus, NAV 1-4 — electrogram from the ablation lead.
Abbreviations: RSPV — right superior pulmonary vein, LSPV — left superior pulmonary vein, LA — left atrium, ECG — electrocardiogram.

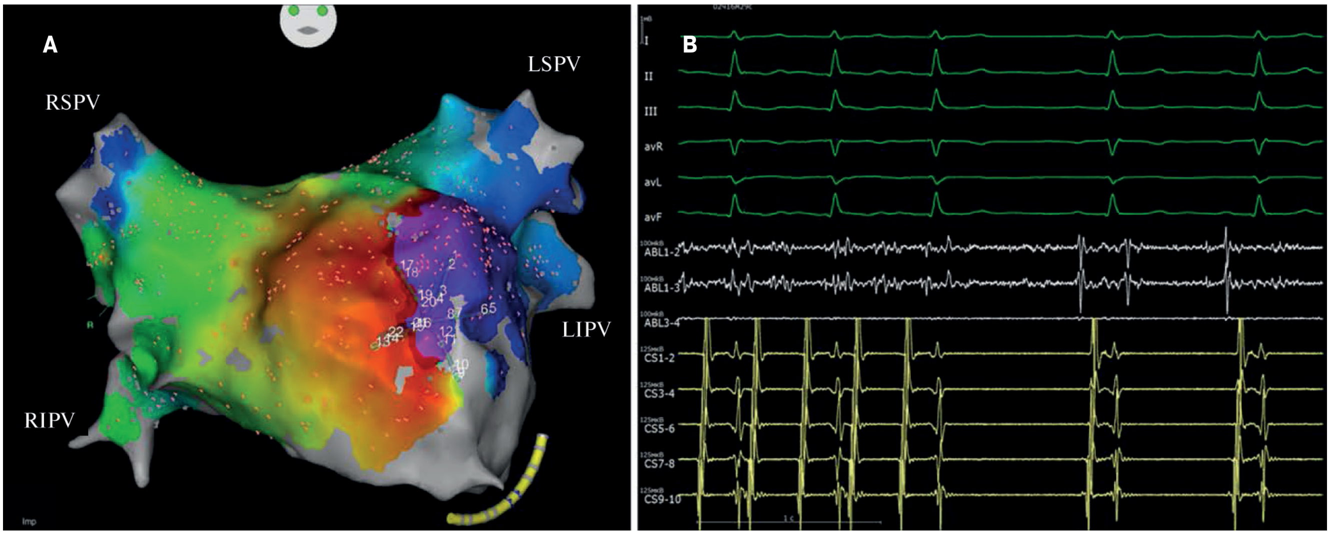

Figure 3. Elimination of left atrial perimitral atrial flutter in a patient after thoracoscopic ablation. **A.** High-density map of LA activation, created using the PentaRay lead. Gap along the LA anterior wall. **B.** Restoration of sinus rhythm with LA anterior wall ablation. I-III, aVL, aVR, aVF, V1-V6 — ECG leads, CS 1-10 — recording from a 10-pole diagnostic lead in the coronary sinus. ABL 1-4 — recording from the ablation lead.
Abbreviations: RSPV — right superior pulmonary vein, LSPV — left superior pulmonary vein, LA — left atrium, RIPV — right inferior pulmonary vein, LIPV — left inferior pulmonary vein, ECG — electrocardiogram.

index (BMI) were 180,2±35,6 ml vs 158,34±38,5 ml (p>0,05) and 30,8±3,1 kg/m^2 vs 28,9±3,9 kg/m^2 (p>0,05), respectively (Table 2).

The average follow-up period was 9,8±2,7 months. All patients after catheter ablation maintained a stable sinus rhythm.

Discussion

The first radical surgery of AF was performed by J. Cox in the 80s of the last century [7]. The cut-and-sew technique provided good effect and long-term freedom from AF, but the surgical injury limited its use. Subsequently, the technique was significantly modified, mainly due to the use of alternative energy sources [8]. However, in some cases, despite the method's effectiveness, atrial tachycardia may occur in the postoperative period, requiring detailed atrial high-density mapping [9-12].

Cases of tachycardia after thoracoscopic ablation (n=8) are described in the study by Liu X and Dong

J (2009) [13]. A recurrence of AF was registered in 3 patients, and typical atrial flutter was observed in the rest. Activation and voltage mapping revealed pulmonary vein gaps and inadequacy of the LA roofline. Gaps were localized in the upper and lower PV segments. With catheter ablation, electrical activity in these areas disappeared quite quickly. The authors associate the inadequacy of ablation with the lack of radio frequency energy at the ends and at the junction of leads. The study by Hye Bin Gwag, et al. (2019) [14] included 154 patients after thoracoscopic ablation. In the postoperative period, AF recurrence was registered in 11 patients, and atypical atrial flutter in 11 patients. In 13 patients, PV gap zones were identified, most of which were in the posterior PV segments. During the follow-up period (9,1±1,4 months), 76,7% of patients maintained a stable sinus rhythm after the catheter procedure.

Study by Beukema RJ, et al. (2016) described catheter ablation of atrial tachycardia, which occurred in 23 of 41 patients after thoracoscopic ablation [15]. Recurrence of paroxysmal AF was diagnosed in 20 patients. Recurrence of AF in combination with atrial tachycardia was noted in 2 patients, and an AF in combination with type 1 atrial flutter was diagnosed in 1 patient. Electrophysiological testing revealed PV gaps in all 23 patients. Most often, electrical activity was recorded in the ridge area, as well as in the lower segment of the right inferior PV. RFA were performed in these areas. The patient with typical atrial flutter underwent additional ablation at the CTI. The authors conclude that in this category of patients, the effects were not initially transmural. The reasons may be tactical and technical issues such as insufficient RF applications or uneven energy distribution. The authors also suggest that transmurality during thoracoscopic ablation was not achieved due to overweight (83% of patients had a BMI >25 kg/m^2). Therefore, a significant part of the RF energy may be consumed by the epicardial adipose tissue, which leads to the RFA failure.

Conclusion

Patients after thoracoscopic ablation may have atrial tachyarrhythmias despite effective PV isolation. The major causes of arrhythmias are inadequate ablation lines in areas of increased epicardial fat. This creates zones of myocardial heterogeneity, and, as a consequence, areas of delayed conduction and prerequisites for the re-entry.

According to our data, the main predictors of ablation failure and arrhythmia recurrence are large LA volume and high BMI of patients. The use of high-density mapping allows to accurately verify the zones of delayed conduction and block and increase the efficiency of tachycardia elimination.

CTI plays a role in the development of typical atrial flutter, since this area is inaccessible for thoracoscopic ablation, and endocardial treatment makes it possible to radically cure these patients.

In this study, all 9 patients maintained a stable sinus rhythm. The effectiveness of the procedure was 100% with a follow-up period of 9,8±2,7 months.

Thus, a combination of epi- and endocardial techniques is the most effective approach to the surgical treatment of persistent AF.

Relationships and Activities: none.

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