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LEFT ATRIAL POSTERIOR WALL ISOLATION IN PERSISTENT ATRIAL FIBRILLATION DOES NOT INFLUENCE THE EFFICACY OF CATHETER ABLATION: A PILOT STUDY

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Aim. To study the role of left atrial posterior wall (LAPW) isolation in increasing the clinical efficacy of radiofrequency ablation (RFA) in patients with persistent atrial fibrillation (PeAF) during electrophysiological studies.

Methods. A single-center randomized prospective study. From February 2020 to February 2021, 35 procedures were performed on patients with PeAF. Patients were randomized into two groups - pulmonary vein isolation (PVI) plus LAPW isolation according to the "box lesion" scheme (the first group) and the PVI-only group (the second group). If it was impossible to achieve LAPW isolation, "debulking" was performed. After 3 months, regardless of the clinical status, EPS and RFA of the reconnection zones were performed.

Results. The full study protocol study was completed by 30 patients - 14 in the first group and 16 in the second group. The characteristics of the patients in the groups did not differ statistically. The duration of the primary and redo procedures, as well as the RFA time during the primary procedure in the first group is significantly longer than in the second group. Pulmonary veins were isolated in all patients participating in the study. In the first group, LAPW isolation was achieved only in 21.4% of cases (3 patients), in the remaining 78.6% of cases (11 patients) "debulking" was performed. PVI in the first group was maintained in 78.6% of cases (11 patients), and in the second group in 56.2% (9 patients), the difference was not statistically significant ($p=0.209$). In the first group, LAPW isolation was maintained in 28.6% of patients (4 patients). All patients with reconnection underwent RFA with the restoration of the conduction block. In the midterm (440 ± 82.1 days) of follow-up, the sinus rhythm was preserved in the first group in 11 patients (78.5%), and in the second group in 13 (81.2%) patients. There was no statistically significant difference between the groups (OR 0.846 95% CI 0.141-5.070, $p=0.641$).

Conclusions. In our study, LAPW isolation in addition to PVI in patients with PeAF did not improve the efficacy of treatment with a significantly longer duration of procedure and RFA time.

Keywords: persistent atrial fibrillation; radiofrequency ablation; left atrial posterior wall isolation; reconnection; electrophysiological study

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Interventional treatment of patients with persistent atrial fibrillation (AF) is currently an unresolved problem because, despite the development of catheter technologies, the efficacy of radiofrequency ablation (RFA) in this type of AF is about 50% [1]. Elimination of the triggering mechanisms by pulmonary vein (PV) isolation (PVI) is the «gold standard» in the treatment of AF [2]. The role of additional influences in the left atrium (LA) in the persistent form of AF remains unclear. The study STAR AF II showed no benefit of additional interventions in patients with persistent AF compared to patients who received PV RFA [3]. At the same time, a number of meta-analyses indicate improved efficacy of interventional treatment of AF when procedures are performed outside the pulmonary veins, including isolation of the pos-

terior wall of the left atrium (PWLA) [4, 5]. According to its electroanatomical properties, PWLA can be both a trigger and a substrate supporting AF [6, 7]. Thus, PWLA isolation, in addition to PVI, may improve the results of RFA in the persistent form of AF. It is quite difficult to achieve permanent isolation of PWLA; restoration of conduction is seen in more than 50% of patients [8]. A planned intracardiac electrophysiological examination (IC EPE) 3 months after RFA makes it possible to detect gaps in conduction, even if they are not accompanied by the clinical picture of arrhythmia recurrence, and to restore conduction block in a timely manner [9].

Purpose of the study: to investigate the role of left atrial posterior wall isolation in improving the clinical efficacy of radiofrequency ablation in patients with persistent

atrial fibrillation during routine intracardiac electrophysiological examinations.

MATERIAL AND METHODS

A single-center, randomised, prospective study. From February 2020 to February 2021, 506 RFAs were performed for atrial fibrillation. Of this number, 35 patients were selected. The characteristics of the patients are presented in Table 1. All patients signed voluntary informed consent. The study was approved by the institution's ethics committee and conducted in accordance with Good Clinical Practice.

Inclusion criteria: the patient has a persistent form of AF (definition of a persistent form from the expert agreement [10]). At the time of surgery, the patient may have sinus rhythm; AF is symptomatic, antiarrhythmic therapy is ineffective (at least one IC or class III drug) or there is intolerance to it; intake of warfarin with international normalised ratio targets (2.0-3.0) or direct oral anticoagulants; no pathology from the valve system of the heart; signed patient consent form; opportunity for dynamic follow-up; age 40 to 70 years.

Exclusion criteria: paroxysmal form of AF; typical or atypical atrial flutter; repeated RFA procedures; LA diameter > 55 mm according to echocardiography (EchoCG); left ventricular ejection fraction less than 45%; reversible causes of AF (electrolyte balance disorders, thyroid diseases, respiratory failure against chronic obstructive pulmonary disease); any open cardiac surgery within the last three months; left atrial auricular thrombosis confirmed by transesophageal EchoCG; myocardial infarction within the previous two months; contraindications to anticoagulant therapy.

All patients underwent the following examinations before surgery: general clinical tests, coagulogram, coronarography for men over 40 and women over 50 (which is the standard examination before PVI, accepted in our clinic), EchoCG to determine the volume of LA, transesophageal EchoCG to exclude thrombosis of LA auricle.

Patients were randomised into two groups in a 1:1 ratio using a random number generator. Randomisation was performed before the start of the procedure. In one group of patients, only PVI was performed. In the other group, PVI was supplemented with PWLA isolation according to the «box lesion» scheme - a line along the LA roof (roof line) and a line connecting the lower pole of the isolated pulmonary veins (floor line).

The surgeries were performed under intravenous sedation with dexmedetomidine and fentanyl. Transseptal puncture was performed under the control of fluoroscopy twice, and 2 unguided intraductal injectors were inserted into the LA cavity. The esophagus was then con-

trasted by swallowing 10 ml of Omnipack water-soluble contrast agent (GE HEALTHCARE IRELAND). Activated clotting time was maintained above 300 seconds by intravenous injection of heparin throughout the procedure. The anatomical map of LA was constructed using the CARTO 3 3D mapping system (Biosense Webster Johnson & Johnson, USA). The position of the esophagus was noted on PWLA, using a comparison of radiographic and anatomical mapping data. RFA was performed using EZ Steer Nav SmartTouch bi-directional irrigated electrodes (Biosense Webster Johnson & Johnson, USA). A Stockert RF energy generator (Biosense Webster Johnson & Johnson, USA) was used in power control mode, irrigation rate 30 ml/min, power 40 W, if the patient complained of chest pain the power was reduced to 30 W. When acting on the LA posterior wall in the projection of the esophagus, a power of 30 W was used, and the duration of irradiation at one point did not exceed 10 seconds. The Visitag module of the CARTO 3 system was used to visualise the points of RF energy application with the following parameters: catheter tip displacement level 2.5 mm, clamping force over 4 g at least 35% of the time, ablation index values of no more than 300 at the posterior wall and 450 at the LA anterior wall. The distance between the points was no more than 6 mm.

Input block was determined by the disappearance of PV adhesions. The output unit was verified for each pulmonary vein by stimulation with 10 mA current and 1 ms pulse duration from a LASSO catheter (10 or 20 pole) (Biosense Webster Johnson & Johnson, USA). Isolation of PWLA was considered to be achieved if ectopic activity of PWLA itself and/or the presence of «local seizures» without conduction to the atrial myocardium during PWLA stimulation were determined (Fig. 1). If it was not possible to isolate the posterior wall after performing a box lesion set, «debulking» (removal of PWLA potentials - massive RFA exposures to PWLA targeting any registered signal that deviated from the criteria for scar tissue (signal amplitude greater than 0.1 mV) was performed until electrical «silence» was achieved. External cardioversion was performed in case of persisting AF.

Table 1.

Characteristics of patients by group

	Total (n=35)	PVI+PW (n=14)	PVI (n=16)	P
Age, years	57.7±8.3	56.5±9.2	58.8±7.6	0.459
Male gender, n (%)	24 (80)	12 (85.7)	12 (75)	0.481
Body mass index, kg/m ²	29.4±3.5	30.2±3.3	28.7±3.7	0.250
LVEF, %	59.2±6.7	57.1±6.4	61.0±6.5	0.110
LA volume, ml	96.7±21.3	99.9±20.1	93.8±22.6	0.442
LA diameter, mm	42.0±3.8	42.1±3.2	41.9±4.46	0.887
Arrhythmic history, months	57.7±48.2	48.6±32.6	65.8±58.6	0.340
Diabetes mellitus, n (%)	2 (6.6)	2 (14.3)	0 (0)	0.126
Arterial hypertension, n (%)	26 (86.6)	13 (92.8)	13 (81.2)	0.146

Note: hereinafter PVI - isolation of pulmonary venous ostium, PW - posterior wall, P - significance of differences between PVI+PW and PVI groups, LVEF - left ventricular ejection fraction, LA - left atrium.

All patients were treated with antiarrhythmic drugs for 4 weeks after surgery, and anticoagulant therapy was continued in all patients. After 3 months, an IC EPE procedure (regardless of clinical status) was routinely performed to check the consistency of the inlet and outlet block in each pulmonary vein and the LA posterior wall, and repeated RFA at the reconnection sites if necessary.

Patients were monitored remotely due to the epidemiological situation. A telephone survey was conducted with the provision of ECG daily monitoring data 6 and 12 months after the first surgery. Medical record data were also provided, including any ECGs if the patient had been hospitalised or treated as an outpatient during the observation period. Recurrence of arrhythmia was considered as any recorded paroxysm of AF or atrial tachycardia lasting more than 30 seconds. The primary end point was no arrhythmia during the follow-up period. The secondary endpoint was the preservation of conduction block in the pulmonary veins and PWLA.

Statistical analysis of the results was performed using the system software package IBM® SPSS® Statistics (Version 20, 2011). For normal distribution, results were expressed as arithmetic mean $\pm$ standard deviation ($M \pm SD$) with 95% confidence interval (95% CI). For asymmetric distributions, results were expressed as median and interquartile range. Frequencies and fractions (in %) were used to describe qualitative data, with 95% CI calculated by the Wilson method. Pearson's χ^2 criterion was used for comparison. Performance was compared using a 2-sided log-rank test accompanied by Kaplan-Meier estimates. The critical level of statistical significance for testing statistical hypotheses was taken as 0.05.

RESULTS

A total of 35 patients were selected who underwent the primary procedure. The group of posterior wall isolation and PVI (group 1) included 18 patients; the group of only

PVI (group 2) included 17 patients. Four patients refused to undergo IC EPE due to the absence of arrhythmia episodes (three patients from the first group and one from the second group) and were excluded from the study. One patient from the posterior wall isolation group could not be contacted after repeated surgery and was also excluded from the study. Thus, the total number was 30 people (14 in the first group and 16 in the second group) (Fig. 2). The characteristics of the patients by group are shown in table 1 and did not differ statistically according to the main indices - weight, sex, age, duration of history, LA volume and ejection fraction, and the presence of concomitant pathology.

Procedure characteristics

The duration of the primary intervention and the time of RFA was significantly longer than that of the repeat intervention in the entire patient cohort. As the use of X-rays was only required in the interatrial septal puncture phase, the time of fluoroscopy was not statistically different between the primary and repeat procedures. The data are presented in Table 2. Comparison of the main indices of the procedures performed between the groups showed that the duration of primary and repeat surgeries and the time of RFA for the primary procedure were significantly longer in the first group than in the second.

In the PWLA isolation group, 85.7% (12 patients) had AF at the time of primary surgery, and 14.3% (2 patients) were operated on against sinus rhythm. In the second group, AF at the time of surgery was noted in 87.5% of cases (14 patients), sinus rhythm in 12.5% (2 patients). Spontaneous recovery of sinus rhythm during RFA was not observed in any case, all patients with AF underwent external electrical cardioversion.

PVs were isolated in all patients participating in the study. There were no anatomical features of pulmonary veins entering LA. In the first group, only in 21.4% of cases (3 patients) it was possible to achieve «true» isolation of PWLA, confirmed by the presence of local seizures during stimulation from the LASSO catheter. Spontaneous ectopic activity of the posterior wall was not observed. In the remaining 78.6% of cases (11 patients) «debulking» was performed before obtaining electrical silence of the posterior wall.

No life-threatening complications were recorded during the study. There were 2 complications related to vascular access during the primary procedure - false femoral artery aneurysm (PWLA isolation group) and arteriovenous junction (PVI group). Against a background of conservative treatment (compression), the complications receded without the need for surgical treatment. There were no complications during repeated interventions.

Echocardiographic data

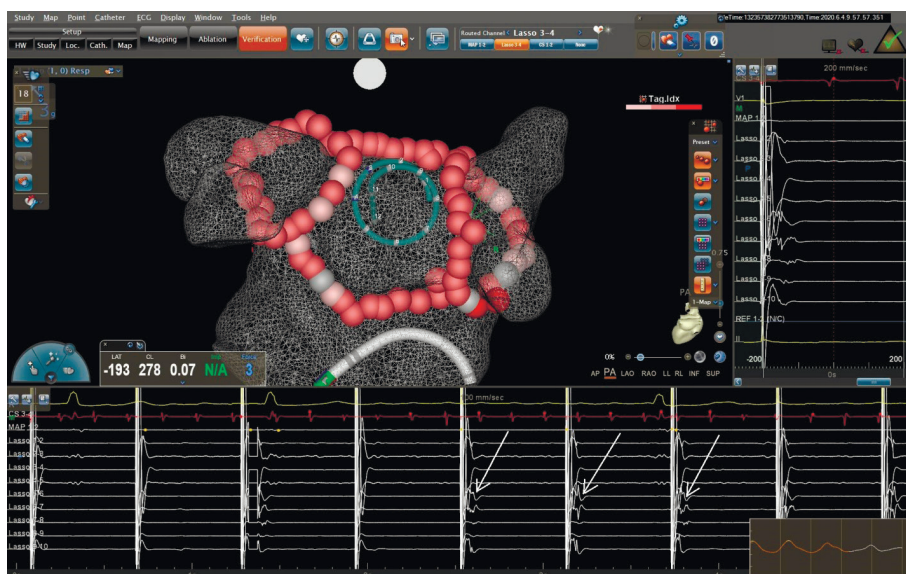


Fig. 1. Isolation of the posterior wall of the left atrium. Electrograms recorded during pacing with the Lasso catheter placed at the posterior wall of the left atrium show local captures indicated by white arrows, while atrial fibrillation persists on electrograms from the coronary sinus (red curve). This phenomenon indicates electrical isolation of the posterior wall of the left atrium.

Left ventricular ejection fraction and LA diameter did not change significantly 3 months after primary surgery in the two groups. LA volume in the PWLA isolation group tended to decrease, but the difference did not reach significance (Table 3).

Electrophysiological features

The average duration of IC EPE after the primary procedure was 93 [92;95.5] days. PVI in the first group was maintained in 78.6% of cases (11 patients), in the second group in 56.2% (9 patients), the difference being statistically insignificant ($p=0.209$). In the group of PWLA isolation, PVI and PWLA isolation was preserved in 3 patients, the remaining 11 patients required additional RFA treatment to eliminate excitation conduction gaps in the previously isolated areas. In the PVI group, RFA was required in 7 patients. The difference between the groups was not statistically significant ($p=0.113$). Restoration of excitation conduction in all PVs in the posterior LA wall isolation group was observed in one patient, in the left PV manifold in one patient, and in the left upper PV in one patient. In the second group, all pulmonary veins were reconnected in one patient, one case each in the left and right PV manifold, 3 cases in the right lower PV and one in the left lower PV.

The absence of posterior wall electrical activity in the course of repeated intervention was noted in 28.6% of patients (4 patients) - two after «debulking», two after «box lesion». All patients with restoration of excitation conduction in PV were subjected to additional RFA exposure with restoration of PVI. In all patients of the first group it was possible to achieve an isolation of the LA posterior wall without «debulking» during the repeated surgery.

Clinical efficacy

In the first group, sinus rhythm was observed in 11 (78.5%) patients 3 months after primary surgery, and in the second group also in 11 (68.7%) patients, although the difference was not statistically significant ($p=0.590$). Early recurrence of AF was seen in 8 patients (3 from the posterior wall isolation group and 5 from the PVI group), the persistent form of AF was seen in 2 patients from the first group, and in the remaining patients AF changed to the paroxysmal form. All patients with early recurrence of AF showed restoration of conduction in previously isolated areas. At the same time, 4 patients who participated in the study experienced restoration of conduction

of excitation without clinics for recurrent AF.

In the entire cohort of patients, sinus rhythm was preserved in 24 of 30 patients (80%) at mid-term follow-up (440±82.1 days after the initial procedure). In the first group, no arrhythmia was detected in 11 of 14 patients (78.5%), in the second group in 13 of 16 patients (81.2%).

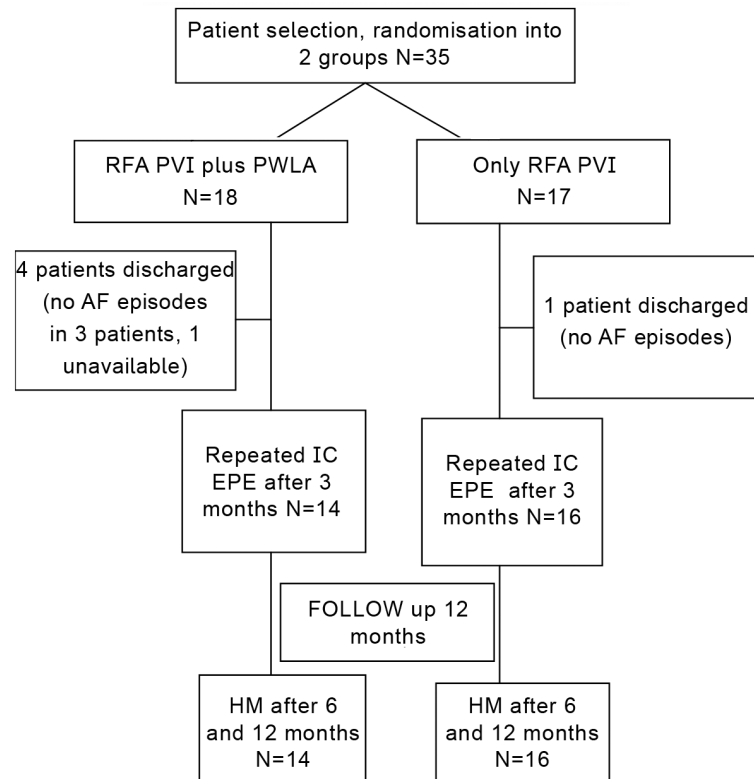


Figure 2. Scheme of the study.

Table 2.

Main characteristics of conducted surgeries by groups

Indicator	Total (n=30)	PVI+PW (n=14)	PVI (n=16)	P
First surgery				
Surgery time, min	107.6±22.9	122.1±20.5	95.0±16.7	0.000
Fluoroscopy time, s	187.6±101.8	176.4±87.9	197.4±114.5	0.580
RFA time, min	32.5±12.1	40.5±11.0	25.6±8.2	0.000
Repeat surgery				
Surgery time, min	59.5±29.4	73.9±32.1	46.9±20.3	0.009
Fluoroscopy time, s	217.6±122.4	251.1±148.9	188.3±88.2	0.165
RFA time, min	6.8±9.5	9.9±11.8	4.2±6.1	0.108

Note: RFA - radiofrequency ablation

Table 3.

LVEF, LA diameter and volume at baseline and 3 months after primary surgery by group

	PVI+PW (n=14)			PVI (n=16)		
	Originally	After 3 months	P	Originally	After 3 months	P
LVEF, %	57.1±6.5	58.1±7.7	0.467	61.0±6.5	62.2±5.6	0.382
LA diameter, mm	42.1±3.2	41.6±3.5	0.336	41.9±4.5	41.4±4.3	0.218
LA volume, cm ³	99.9±20.0	90.9±20.6	0.064	93.8±22.6	91.1±22.4	0.352

There was no statistically significant difference between the groups (odds ratio (OR) 0.846, 95% confidence interval (CI) 0.141-5.070, $p=0.641$) (Fig. 3).

DISCUSSION

The data on the clinical efficacy of PWLA isolation in patients with AF are inconsistent. Several studies were conducted with 30 to 250 patients, with different inclusion and exclusion criteria, different methods of isolating the posterior wall of LA and with different results.

D.Tamborero et al. conducted a study including 120 patients with paroxysmal, persistent and long-term persistent forms of AF. All patients underwent PVI and mitral isthmus ablation. After that, the patients were divided into 2 groups - the first group additionally underwent RFA of the LA roof, the second group underwent isolation of PWLA. It was possible to achieve conduction block in all created linear RFA lesions in 90% of cases in the first group and 92% in the second group. The follow-up period was 10 ± 4 months. In the first group, cardiac arrhythmias recurred in 27 patients (45%), and in the second group, AF recurred in 27 patients (45%). Twenty-five patients underwent repeated RFA and 84% had restoration of conduction in the previously isolated PV. LA roof conduction block persisted in 31% of cases in the first group, and LA posterior wall isolation in 33% in the second group [11].

J.M.Lee et al., cited data from a study that included 217 patients with a persistent form of AF (73.3% had a long-term persistent form of AF). Two groups were formed - in the first group only PVI was done and in the second group additional damage was done along the upper and lower junction lines between the right and left PV. If this was not sufficient to achieve PWLA isolation, additional RFA influences were performed, directed to the registered potentials along the posterior wall and exceeding the amplitude of 0.1 mV. The follow-up period was 16.2 ± 8.8 months. There was no statistically significant difference in the rate of arrhythmia return

between the groups. Sinus rhythm without antiarrhythmic therapy was present in 50.5% of patients in the first group and 55.9% in the second group ($p=0.522$). The RFA time in the second group was significantly longer than in the first group (5.365 ± 2.358 seconds versus 4.289 ± 1.837 seconds $p<0.001$) [12]. There was 1 case of atrioesophageal fistula in the PV isolation group 3 weeks after RFA with fatal outcome.

The meta-analysis by F. Lupercio et al. included data from 7 studies and 1152 patients. Patients who underwent posterior wall isolation in addition to PVI had a lower rate of recurrent AF (OR 0.55; 95% CI 0.39-0.77) as well as a lower rate of any atrial arrhythmias (OR 0.78; 95% CI 0.63-0.96) [4].

A meta-analysis by A.Thiyagarajah et al. evaluated the acute success of PWLA isolation and the number of complications associated with the procedure, as well as the long-term clinical effect, including the rate of recurrence of arrhythmias and restoration of conduction with PWLA. The final analysis included 17 studies (13 with box lesion posterior wall isolation, 3 with single ring isolation, 1 study with removal of LA posterior wall potentials) with 1643 patients. The incidence of acute success of PWLA isolation was 94.1% (95% CI, 87.2-99.3%). The 12-month freedom from any atrial arrhythmia after intervention was 65.3% overall (95% CI 57.7-73.9%) and 61.9% (54.2-70.8%) for persistent AF. Randomised controlled trials comparing PWLA isolation with PVI (3 trials, 444 patients) had inconsistent results and found no advantage for the PWLA isolation group. Repeat procedures were required in 161 patients, and the rate of restoration of conduction at the LA posterior wall was 63.1% (95% CI, 42.5-82.4%). Fifteen major complications (0.1%) have been reported - 10 cases of hemopericardium requiring drainage, 3 strokes, and 2 atrioesophageal fistulas [8].

As the role of PWLA isolation remains unclear, researchers around the world continue to address this question. There are several randomised multicenter studies investigating the effect of PWLA isolation on the efficacy of treatment of persistent AF. In total, about 1700 patients will participate in these five studies [14]. Perhaps the results can answer the question of who and when to isolate PWLA and in what way.

STAR AF II is a study that questioned the efficacy of extra PV lesions in LA in persistent AF. Patients who received only PVI had similar results in preserving sinus rhythm at follow-up as those who received additional interventions, with a significantly shorter surgery time and duration of RFA. However, the efficiency of the surgery did not exceed 50-55% [3]. In our study, sinus rhythm was preserved in 80% of patients with longer follow-up periods. There may be several explanations for this fact. First, the STAR AF II study did not use clamping force-controlled catheters, which could have affected the permanence of the lesion lines created in LA. Secondly, routine IC EPE allowed identifying patients with restoration of excitation conduction in previously isolated areas, who had no clinics of recurrent AF. Timely reinstatement of the blockade could improve the long-term results.

It should be noted that even with modern technol-

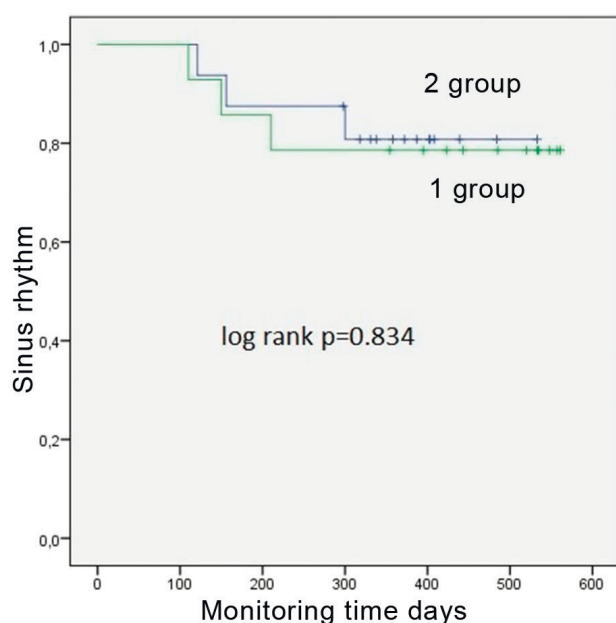


Figure 3. Frequency of sinus rhythm preservation in group 1 (IPVO+PW) and group 2 (IPVO).

ogies, it is quite difficult to achieve isolation of PWLA, which is related to the anatomical features of the LA structure and the risk of collateral damage when using RFA energy [12]. Only in 21.4% of the patients in our case, isolation of the PWLA could be achieved after performing a series of lesions according to the «box lesion» scheme, and the rest required additional RFA outside the roof and floor lines. This observation suggests the presence of epicardial fibers on PWLA, which must be effectively eliminated to obtain persistent PWLA isolation [15]. Sometimes, however, this may require extensive RFA to be applied to PWLA, potentially increasing the risk of complications, especially esophageal damage. The advent of alternative energy sources such as pulsed field ablation, which have a tropism for cardiomyocytes, reduces the risk of collateral damage and can potentially improve the long-term outcomes of interventional treatment of persistent AF [16]. Thus, in the PersAFOne study (25 patients), when pulsed field ablation technology was used, acute isolation of PVI and PWLA was achieved in all patients participating in the study. When repeated ICE was performed 3 months later, PVI was preserved in 96% of cases, and PWLA isolation was confirmed in

100% of patients. At the same time, no patient showed signs of esophageal damage or PV stenosis [17].

The lack of difference in the results of RFA in the isolation of PWLA may be due to the peculiarities of the currently used classification. At the moment, the definition of persistent AF has a rather broad scope. Patients in different clinical situations may have the same diagnosis and receive the same treatment. At the same time, some researchers distinguish an early (up to 3 months) and a late persistent form of AF [17]. It is likely that the distinction of different subtypes of persistent AF will allow a more differentiated approach to determining indications for additional influences outside the pulmonary veins.

CONCLUSION

In our study, isolation of the posterior wall of the left atrium in addition to isolation of the pulmonary vein in patients with persistent AF did not improve treatment efficacy with significantly longer procedure duration and radiofrequency ablation. Permanent isolation of the posterior wall of the left atrium is a difficult task even with modern technology.

REFERENCES

1. Tilz RR, Rillig A, Thum AM, et al. Catheter ablation of long-standing persistent atrial fibrillation: 5-year outcomes of the Hamburg Sequential Ablation Strategy. *J Am Coll Cardiol*. 2012;60: 1921-9. <https://doi.org/10.1016/j.jacc.2012.04.060>.
2. Hindricks G, Potpara T, Dagres N, et al. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC). *European Heart Journal*. 2021;42(5): 373-498. <https://doi.org/10.1093/eurheartj/ehaa612>.
3. Verma A, Jiang C, Betts TR, et al. Approaches to Catheter Ablation for Persistent Atrial Fibrillation. *N Engl J Med*. 2015;372: 1812-1822. <https://doi.org/10.1056/NEJMoa1408288>.
4. Lupercio F, Lin A, Aldaas O, et al. Posterior wall ablation as an adjunctive therapy to pulmonary vein isolation reduces recurrence of atrial fibrillation: a systematic review and meta-analysis. *Journal of the American College of Cardiology*. 2019;73(9): Supplement 1. [https://doi.org/10.1016/S0735-1097\(19\)31077-0](https://doi.org/10.1016/S0735-1097(19)31077-0).
5. Sau A, Al-Aidarous S, Howard J, et al. Optimum lesion set and predictors of outcome in persistent atrial fibrillation ablation: a meta-regression analysis. *Europace*. 2019;21(8): 1176-1184. <https://doi.org/10.1093/europace/euz108>.
6. Perez-Lugones A, McMahon JT, Ratliff NB, et al. Evidence of specialized conduction cells in human pulmonary veins of patients with atrial fibrillation. *J Cardiovasc Electrophysiol*. 2003;14(8): 803-809. <https://doi.org/10.1046/j.1540-8167.2003.03075.x>.
7. Ehrlich JR, Cha T, Zhang L, et al. Cellular electrophysiology of canine pulmonary vein cardiomyocytes: action potential and ionic current properties. *J Physiol*. 2003;551(Pt 3): 801-813. <https://doi.org/10.1113/jphysiol.2003.046417>.
8. Thiagarajah A, Kadhim K, Lau DH, et al. Feasibility, Safety, and Efficacy of Posterior Wall Isolation During Atrial Fibrillation Ablation A Systematic Review and Meta-Analysis. *Circ Arrhythm Electrophysiol*. 2019;12: e007005. <https://doi.org/10.1161/CIRCEP.118.007005>.
9. Kozlov AV, Durmanov SS, Bazylev VV. «Complete» and «incomplete» ablation lines for radiofrequency isolation of the pulmonary veins - is there a difference in reconnection and clinical efficacy? *Journal of Arrhythmology*. 2020;27(1): 55-62. (In Russ.). <https://doi.org/10.35336/VA-2020-1-55-62>.
10. Calkins H, Hindricks G, Cappato R, et al. 2017 HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. *Europace*. 2018;20(1): e1-e160. <https://doi.org/10.1093/europace/eux274>.
11. Tamborero D, Mont L, Berruezo A, et al. Left atrial posterior wall isolation does not improve the outcome of circumferential pulmonary vein ablation for atrial fibrillation: a prospective randomized study. *Circ Arrhythm Electrophysiol*. 2009;2(1): 35-40. <https://doi.org/10.1161/CIRCEP.108.797944>.
12. Lee JM, Shim J, Park J, et al. The Electrical Isolation of the Left Atrial Posterior Wall in Catheter Ablation of Persistent Atrial Fibrillation. *JACC: Clinical electrophysiology*. 2019;5(11): 2543-2552. <https://doi.org/10.1016/j.jacep.2019.08.021>.
13. Clarke JD, Piccini JP, Friedman DJ. The role of posterior wall isolation in catheter ablation of persistent atrial fibrillation. *J Cardiovasc Electrophysiol*. 2021; 1-10. <https://doi.org/10.1111/jce.15164>.
14. Pothineni NV, Lin A, Frankel DS, et al. Impact of left atrial posterior wall isolation on arrhythmia outcomes in patients with atrial fibrillation undergoing repeat ablation.

Clinical Atrial Fibrillation. 2021;2(5): 489-497. <https://doi.org/10.1016/j.hroo.2021.07.004>.

15. Di Biase L, Diaz JC, Zhang XD, et al. Pulsed field catheter ablation in atrial fibrillation. *Trends Cardiovasc Med*. 2021;28: S1050-1738(21)00083-9. <https://doi.org/10.1016/j.tcm.2021.07.006>.

16. Reddy VY, Anic A, Koruth J, et al. Pulsed Field Ablation in Patients With Persistent Atrial Fibrillation. *J Am Coll*

Cardiol. 2020;76(9): 1068-1080. <https://doi.org/10.1016/j.jacc.2020.07.007>.

17. Al-Jazairi M, Nguyen B, Ruben R et al. Antiarrhythmic drugs in patients with early persistent atrial fibrillation and heart failure: results of the RACE 3 study. *Europace*. 2021;9(21): 1359-1368. <https://doi.org/10.1093/europace/euab062>.

