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Efficacy and Safety of Nonfluoroscopic Approach During Catheter Ablation of Ventricular Tachycardias

Aim To evaluate a possibility of using radiofrequency catheter ablation guided by intracardiac echocardiography (ICE), its efficacy and safety for treatment of ventricular tachycardia (VT) of various etiology.

Material and Methods Catheter intervention was performed for 20 enrolled patients with symptomatic VT. Ablation procedures were guided by a 3D electroanatomical mapping system and ICE.

Results Mean duration of the procedure was 201.2±62.5 min. The procedure was successful (non-inducibility of VT) in 100% of cases. None of the patients had postoperative complications.

Conclusion Ablation of VT arrhythmogenic substrate guided by 3D electroanatomical navigational mapping and ICE without X-ray is feasible and safe.

Keywords Ventricular tachycardia; radiofrequency catheter ablation; nonfluoroscopic approach; intracardiac echocardiography

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Introduction

Catheter ablation (CA) is a key method of treating patients with persistent ventricular arrhythmias in cases when antiarrhythmic therapy (AAT) is ineffective or intolerable and when patient is unwilling to take drugs for a long time [1]. These long-lasting and complex interventions are typically conducted under fluoroscopic control that is patients and health professionals are exposed to a large amount of radiation [2, 3].

The long-term cumulative effect of fluoroscopy is a significant concern. Patients currently often have to go through an increasing number of ionizing radiation-related examinations and procedures throughout their lives [4, 5]. It has been estimated that a patient's lifetime risk of acquiring cancer increases by 0.1% with every hour of radiation exposure [3–9]. A higher risk of tumors in health professionals is also noted in the studies [10, 11].

Therefore, it is necessary and crucial to take measures to decrease radiation exposure in medical facilities. Since there is no level of radiation exposure that is considered safe, it is crucial to follow the ALARA (as low as reasonably achievable) rule when performing medical procedures [12].

The widespread use of 3D navigation mapping of the heart and intracardiac echocardiography (ICE) has made it possible to reduce or completely abandon the use of fluoroscopy throughout the entire procedure.

Using ICE, a substrate associated with structural heart lesions can be visualized intraoperatively in real time, sheaths and catheters can be positioned in the heart chambers, the contact of an electrode with the heart tissue can be evaluated, and potential consequences can be seen [13].

Non-fluoroscopic methods of arrhythmic substrate ablation are still in the early stages of development, which is why there are only few relevant studies including by the Russian researchers [14–17]. It should be emphasized that CA of ventricular tachycardias (VT) is a challenging surgical technique due to the fact that the arrhythmic substrate is frequently difficult to reach. Complications are more common in this type of interventions than in catheter procedures in supraventricular arrhythmias, which is why an operator have to have greater skills. The use of a 3D navigation system in conjunction with ICE gives the operator direct control over all actions, which reduces the risk of complications. There are, however, very few studies on CA of the VT substrate without

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fluoroscopy, despite the considerable practical value. There are no papers on catheter treatment in VT without fluoroscopy in the Russian literature.

Objective

Evaluate the feasibility, efficacy, and safety of radiofrequency CA in conjunction with ICE for the treatment of patients with VT of various origin.

Material and methods

The study included 20 (18 male and 2 female) patients with VT at the age of 20 to 75 years.

Inclusion criteria: persistent VT and indications for surgery; signed voluntary informed consent.

Exclusion criteria: hemodynamically significant coronary artery stenosis requiring endovascular treatment, epicardial VT focus; substrate located in coronary sinuses, catecholaminergic VT, long QT syndrome.

Characteristics of the included patients are detailed in Table 1.

For preoperative preparation, all patients underwent ECG, Holter monitoring, transthoracic echocardiography, contrast-enhanced magnetic resonance imaging (MRI) to visualize the structural myocardial lesion, coronary angiography (CAG) to exclude hemodynamically significant coronary artery stenosis requiring surgery.

All patients took AAT of three main classes, as monotherapy and as drug combinations (Table 2). Antiarrhythmic drugs were gradually discontinued before CA depending on their half-lives.

From the very beginning of the surgery, the fluoroscope was turned off, and all medical and nursing personnel did not use radiation shielding.

Surgery technique

The interventions were performed using the CARTO-3 navigation system and the ACUSON x300 ultrasound scanner. Computerized 3D heart models were constructed and targeted using AcuNav ICE and PentaRay Advanced High-Density Mapping and Thermocool SmartTouch Ablation catheters.

The data obtained were analyzed using the Statistica 10.0 suite. Qualitative values are expressed as the absolute values and percentages. A two-tailed Fisher F-test and a Mann–Whitney U-test were used for statistical analysis. The results are presented as the means and standard deviations (M ± SD) or the medians and interquartile ranges (Me [Q1; Q3]) depending on a type of distribution of variables. Differences were statistically significant when p was less than 0.05.

Table 1. Clinical and demographic characteristics of patients (n = 20)

Parameter	Value
Age, years	61 [46; 67]
Male/female, n (%)	18 (90)/2 (10)
Arrhythmia substrate: LV/RVOT, n (%)	17 (85)/3 (15)
Duration of VT history, months	21.25±20.4
Idiopathic rhythm disorder, n (%)	8 (40)
ICD, n (%)	5 (25)
ICD therapy:	
• Pacing, n (%)	6 (30)
• Antitachycardia pacing, n (%)	2 (10)
BMI, kg/m2	27 [25; 29.25]
Smoking, n (%)	10 (50)
Hypertensive heart disease, n (%)	12 (60)
CAD, n (%)	12 (60)
CHF, n (%)	13 (65)
LVEF, %	51 [38.75; 57]
Type 2 DM, n (%)	3 (15)
CKD, n (%)	5 (25)

The data are presented as the medians and interquartile ranges between the 1st and 3rd percentiles (Me [Q1; Q3]. RVOT, right ventricular outflow tract; VT, ventricular tachycardia; ICD, implantable cardioverter defibrillator; BMI, body mass index; CKD, chronic kidney disease.

Results

All patients underwent transthoracic echocardiography and a 12 lead ECG at admission. The data obtained are provided in Table 3.

Table 2. Antiarrhythmic therapy before catheter ablation

Classes, drugs	Rate of administration, n (%)	Mean daily doses, mg
Class I		
Anaprilin	3 (15)	75±25
Propafenone	3 (15)	450±150
Class II		
Bisoprolol	11 (55)	3.5±2.3
Metoprolol	2 (10)	75±35
Class III		
Amiodarone	5 (25)	200±100
Sotalol	3 (15)	160±120

The data are expressed as the means and standard deviations (M ± SD).

Table 3. Main parameters of transthoracic echocardiography and 12 lead ECG Holter monitoring

Parameter	Value
Echocardiogram	
LVEF, %	50.00 [42.25; 56.50]
LVEDD, mm	61 [56.00; 68.25]
LVESD, mm	43 [22; 63]
LVEDV, mL	170 [126; 220]
LVESV, mL	96 [61.75; 124.50]
PASP, mm Hg	31.5 [27.5; 35.5]
LA, mm	43.5 [41.5; 46.0]
LA volume, mL	75 [66.5; 82.5]
12 lead ECG Holter monitoring	
Leading rhythm, n (%):	
• Sinus	18 (90)
• Atrial fibrillation	2 (10)
HR, bpm	
• Moderate	64.50 [53.75; 74.00]
• Minimum	45.00 [39.75; 53.25]
• Maximum	103.50 [79.75; 112.25]
VES/24 hours	1095.0 [215.5; 2303.5]
VES/h	42.0 [11.5; 333.5]
% of total number of QRS complexes	1.29 [0.36; 10.00]
Number of VT runs	15.0 [7.5; 86.5]
Maximum number of VT complexes	5.0 [5.0; 8.5]
VCR in VT, bpm	111. 0 [102.0; 152.5]

The data are presented as the medians and interquartile ranges (Me [Q1; Q3]. ECG, electrocardiography; LVEDD, left ventricular end-diastolic dimension; LVESD, left ventricular end-systolic dimension; LVEDV, left ventricular end-diastolic volume; LVESV, left ventricular end-systolic volume; PASP, pulmonary artery systolic pressure; LA, left atrium; VES, ventricular extrasystole; VT, ventricular tachycardia; VCR, ventricular contraction rate.

Gadolinium-enhanced MRI was performed for patients without contraindications before CA. The key results are presented in Table. 4.

Preoperative MRI showed fibrotic changes in the myocardium, mainly of ischemic origin, in most patients. The geometry of the scar and the area of the lesion were determined, and whether it was transmural, which gave a more complete look at the possible localization of the VT focus. The MRI findings also help define the intervention strategy more precisely and make it easier to decide between endo- and epicardial ablation.

Surgery procedure

After performing standard access to the central veins, an 8Fr ICE catheter is inserted through the introducers and connected to the ultrasound system. Under the ICE control, two diagnostic catheters are inserted into the heart cavity, positioned in the coronary sinus and the right ventricle. Thereafter, a J-shaped long sheath is inserted through the right femoral vein to the superior vena cava and an unguided 8.5 Fr intracardiac sheath is inserted through the sheath.

When the VT substrate is localized in the left ventricle (LV), access to the left heart is carried out, depending on the location of the focus, through the interatrial septum under the ICE control using an uncontrolled intracardiac sheath and a BRK-1 transseptal puncture needle, or a retrograde access is performed through the femoral artery.

The CARTO-3 navigation system and a PentaRay Advanced high-density electroanatomical mapping multipolar catheter and a Thermocool SmartTouch ablation catheter are used for the mapping, and ablation was performed with the same ablation catheter.

The anatomy and function of the ventricles and cardiac chambers were examined by ICE for blood clots at the beginning of the procedures. Mapping in structural lesions of the heart was initiated in the akinetic/dyskinetic areas or aneurysmal dilatation area as seen in ICE. Arrhythmia was induced by programmed ventricular stimulation. The ablation target sites were selected in VT based on the localization of early fragmented signals and the registered mesodiastolic potentials. In hemodynamically unstable VT, target ablation zones were determined at sinus rhythm by

Table 4. Main findings of gadolinium-enhanced MRI of the heart conducted before catheter ablation

Parameter	Value
Patients, n	15
LVEF, %	43 [27; 48]
LVEDD, mm	65.0 [58.0; 70.5]
IVS thickening, mm	
• Basal segment	14.50 [13.75; 15.25]
• Middle segment	13.00 [12.50; 13.75]
• Apical segment	13.00 [12.75; 13.25]
No structural damages, n (%)	3 (20)
Non-ischemic fibrosis, n (%)	2 (13.3)
Ischemic fibrosis, n (%):	10 (66.6)
Region, n	
• Basal	1
• Lateral	1
• Inferior	7
• Anteroseptal	2
LV aneurysm, n (%)	4 (26.6)
Posterior papillary muscle, n (%)	4 (26.6)

The data are presented as the medians and interquartile ranges (Me [Q1; Q3]. MRI, magnetic resonance imaging; LVEDD, left ventricular end-diastolic dimension; IVS, interventricular septum.

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identifying sites with late potentials (low-amplitude signals of delayed electrical impulses in the myocardium).

Activation mapping was performed during VT in patients without structural lesions of the heart, the ablation targeted the zones of the earliest ventricular activation. In VT instability, stimulation mapping was conducted, and radiofrequency CA was performed in the areas where stimulated QRS complexes coincided QRS complexes of VT by 95-100% in 12-leads of surface ECG.

Radiofrequency CA was successful in all 20 patients. Adequate catheter tip-to-tissue contact during the procedure was confirmed by ICE in all patients. The procedure was successful, i.e., VT was not induced after ablation, in all patients. Pericardial effusion was excluded after the intervention in all patients. There were no procedure-related complications.

The mean duration of procedures was 201.2 ± 62.5 minutes. VT as absent in the postoperative period during hospital stay in 100% of cases.

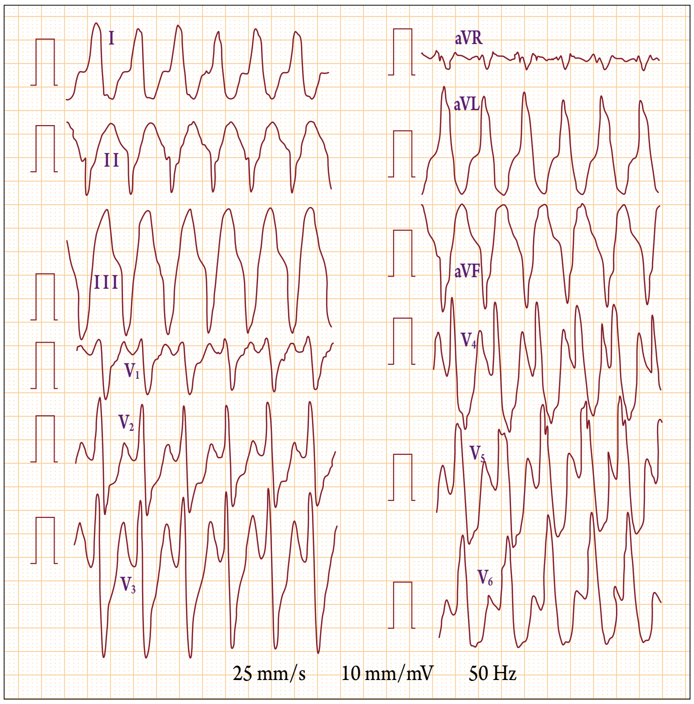
After the interventions, 20 patients were followed-up for 30 days, and no VT recurrence was detected. Repeated outpatient Holter monitoring did not detect any clinically significant ventricular arrhythmias. There were no deaths or repeated hospitalizations.

Below are the most representative case studies of CA of VT of various origin performed without fluoroscopy.

Case study #1

Patient V., 62 years old, was hospitalized with the diagnosis of paroxysmal ventricular tachycardia. Complaints of heart palpitations accompanied by pressing retrosternal pain not associated with exercises and occurring mainly at night. The medical history includes inferior myocardial infarction in November 2019. The patient took various antiarrhythmic drugs (including sotalol, amiodarone), but recurrent ventricular arrhythmias still occurred during AAT. At admission, the patient used metoprolol 50 mg/day. Recurrent VT repeated several times during the hospital stay (Figure 1). Holter monitoring registered frequent ventricular ectopic activity in the form of 10,403 ventricular extrasystoles (VES), which was 13 % of the total number (594 VES/h). VT runs were also recorded. A moderate decrease in systolic function (LV ejection fraction 35 %) was detected by echocardiography. The akinetic zone with a pronounced aneurysmal deformity was determined along the inferior wall of the LV. MRI of the heart (Figure 2) showed a dilation of LV (LV end-diastolic dimension was 75 mm) in the basal and middle segments, where a saccular aneurysm of the inferior LV

Figure 1. ECG of Patient B: ventricular tachycardia paroxysm



wall (basal and middle segments; about 6×4.5 cm, wall thickness 3 mm) was detected.

After contrast-enhancement, delayed transmural (100% of the myocardial thickness) accumulation of the drug in the inferior myocardial wall, in the basal and middle segments of the LV, was noted, which spilled into the lower parts of the myocardium of the interventricular septum (IVS) and the lateral wall of the basal segment.

CAG revealed uneven contours of the coronary arteries and no hemodynamically significant stenosis.

Thus, a radiofrequency intervention for the treatment of VT was indicated to the patient. Metoprolol was discontinued before the procedure.

Procedure

When vascular access was achieved, diagnostic and mapping catheters were positioned in the heart cavities under the ICE control (Figure 3).

Electrophysiologic testing was conducted. VT was induced via program stimulation, which was morphologically identical to VT registered earlier. Due to the unstable hemodynamics during VT paroxysm, electroanatomical voltage mapping of the LV was performed when the sinus rhythm was restored by overdrive stimulation. The electrical activity of tissues is shown from red to purple on the voltage map. The navigation system marked scarred areas with red. Signals of the electrical pathways are marked by yellow dots to prevent possible complications accompanied by damage to these

Figure 2. Delayed gadolinium-enhanced magnetic resonance imaging of the heart – Patient B.

The arrow points to a saccular aneurysm of the left ventricle.

areas (Figure 4, A). The late potentials are highlighted in the overall picture by black dots.

Radiofrequency lesions were performed in areas with late potentials, around the LV aneurysmal deformation (Figure 4, B). VT was not induced after the ablation. The total time of the procedure was 280 minutes.

Holter monitoring showed in the postoperative period that the number of ventricular rhythm disturbances decreased significantly to 6,203 VES (9% of the total amount, 296 VES/h), VT runs were not recorded. Bisoprolol 2.5 mg/day was prescribed to the patient at discharge.

Case study #2

Patient K., 61 years old, was hospitalized with the diagnosis of heart rhythm disorder, persistent paroxysms of monomorphic VT, ventricular extrasystoles. Since 2019, frequent persistent paroxysms of VT accompanied by hypotension, asthenia, and palpitations. Multiple ambulance calls were made in this regard. Sinus rhythm was restored by amiodarone infusion and cardioversion. Amiodarone was administered for the purpose of prevention, but the drug treatment was accompanied with QT elongation of more than 550 ms, elevated levels of thyroid-stimulating hormone, and VT paroxysms, thus this therapy was considered ineffective. Class II antiarrhythmic drugs and sotalol were administered without effect. At admission, the patient took allapinin 75 mg/day, but rhythm disorders still remained during the described therapy. Holter monitoring registered severe ectopic activity: 17,339 VES, which was 24% of the total number of QRS complexes, 1,309 VES/h; ventricular tachycardia runs 15 complexes with ventricular contractions rate (VCR) of 147 per minute. Echocardiography revealed limited motion of the basal segment of the LV posterior septal region.

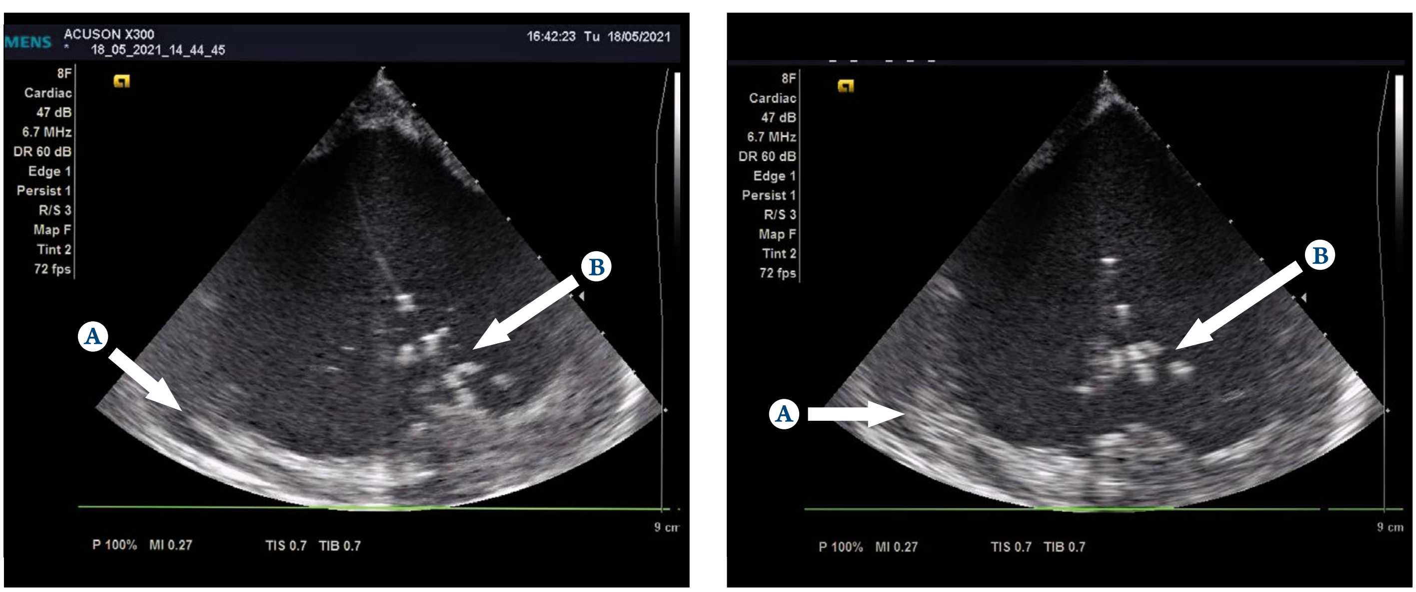
Contrast-enhanced MRI detected a scarred area of IVS with transmural and intramiocardial involvement, which is atypical for ischemic lesion, fibrosis, presumably of inflammatory origin, is more likely (Figure 5).

Arteries are intact according to CAG. Ablation of arrhythmogenic substrate was indicated due to frequent hemodynamically significant paroxysms of non-ischemic monomorphic VT and AAT failure.

Procedure

Internal jugular and right femoral veins and femoral artery were puncture, hemostatic sheaths were installed. ICE transducer was inserted into the heart cavity via the introducer sheath installed in the

Figure 3. PentaRay Advanced mapping catheter in the left ventricular cavity – Patient B.



A – LV aneurysm; B – multipolar catheter.

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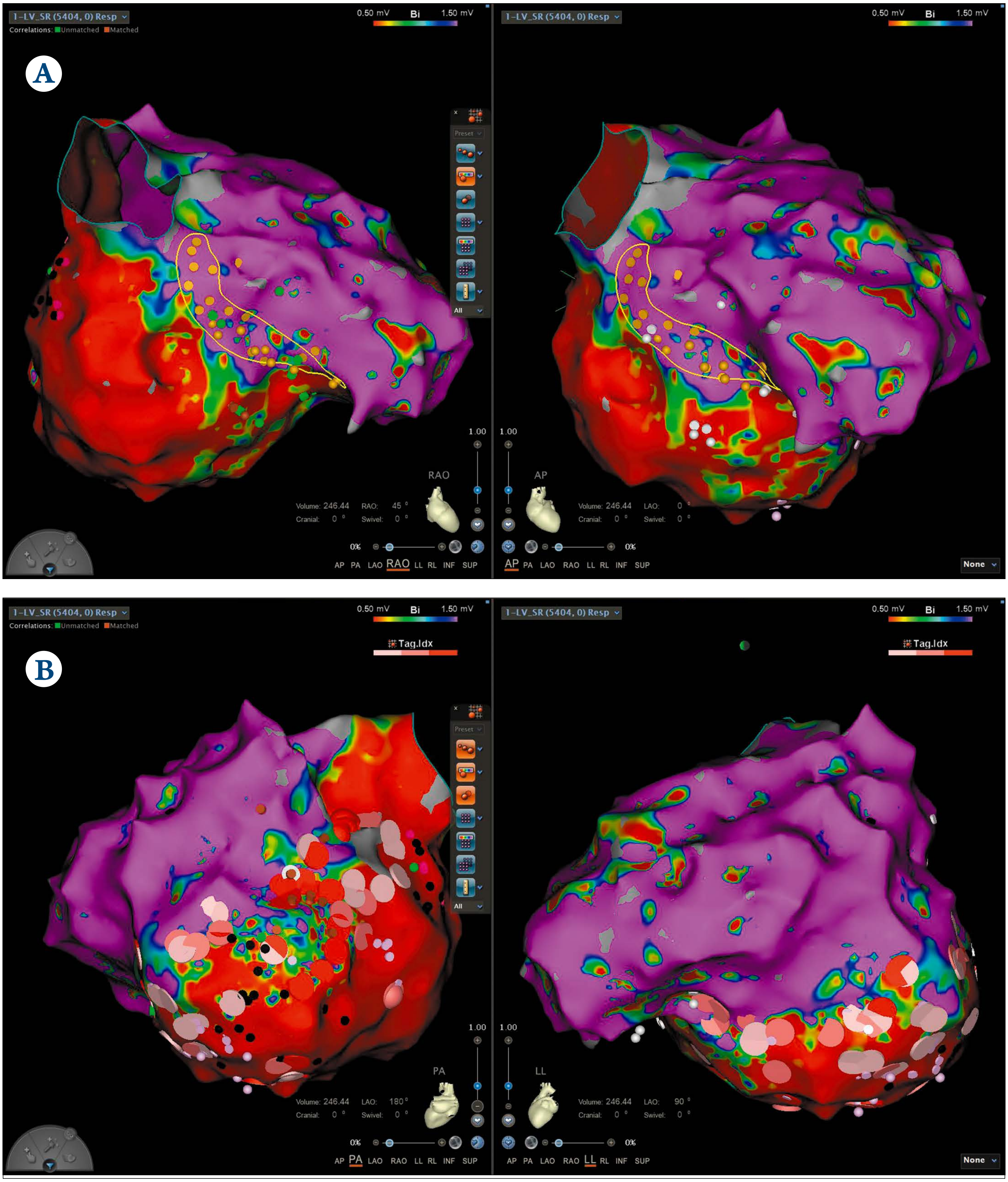
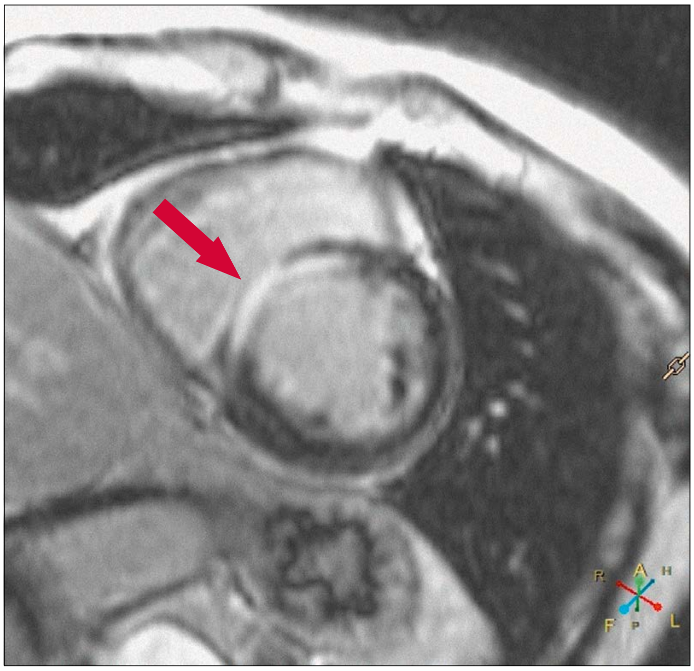
Figure 4. Voltage map of the Patient B's left ventricle



A – before radiofrequency exposure (the electrical pathways of the heart are marked by yellow dots);
B – after ablation (areas of exposure are shown by red and pink dots).

femoral vein. Diagnostic catheters were positioned. Electrophysiologic testing was conducted, VT paroxysm was induced with VCR198–200 per minute and unstable hemodynamics. A spontaneous conversion to sinus rhythm was observed. A PentaRay multipolar catheter was introduced into the LV via retrograde (transaortic)

Figure 5. Delayed gadolinium-enhanced magnetic resonance imaging of the heart – Patient K. Interventricular septum fibrosis



The arrow points to the fibrosis site.

access. Mapping was conducted throughout the aorta when the catheter was inserted in the heart (Figure 6). The hypokinetic zone the basal sections of the IVS to the LV apex was detected by ICE.

Black dots mark on the map the late potential zones in the basal IVS and the apex. These areas were ablated using the Thermocool SmartTouch catheter (Figure 7). ICE clearly showed the contact of the ablation catheter with the heart tissue, which is a criterion of the effective exposure (Figure 8). Tachycardia was not induced in the repeated electrophysiologic testing.

The control Holter monitoring registered that the number of VES decreased to 6,133 per day, which was 8% (888 VES/h) of the total number of QRS complexes; there were no VT paroxysms. Bisoprolol 5 mg/day was prescribed to the patient at discharge as supporting therapy.

The post-operative period was uneventful.

Discussion

There are few studies on conducting CA without fluoroscopy at the moment. The literature data on the application of this technique is mainly devoted to patients with supraventricular arrhythmias, while practically none are available for patients with ventricular arrhythmias. In 2021, meta-analysis data were published on the efficacy of non-fluoroscopic CA, the rate of recurrences and complications, and the duration of the procedure. Sixteen studies were reviewed and a total of 6,052 patients were included, of whom 2,219 patients were subjected non-fluoroscopic CA, and 3,833

Figure 6. Electroanatomical voltage map of the left ventricle and the aorta of Patient K.

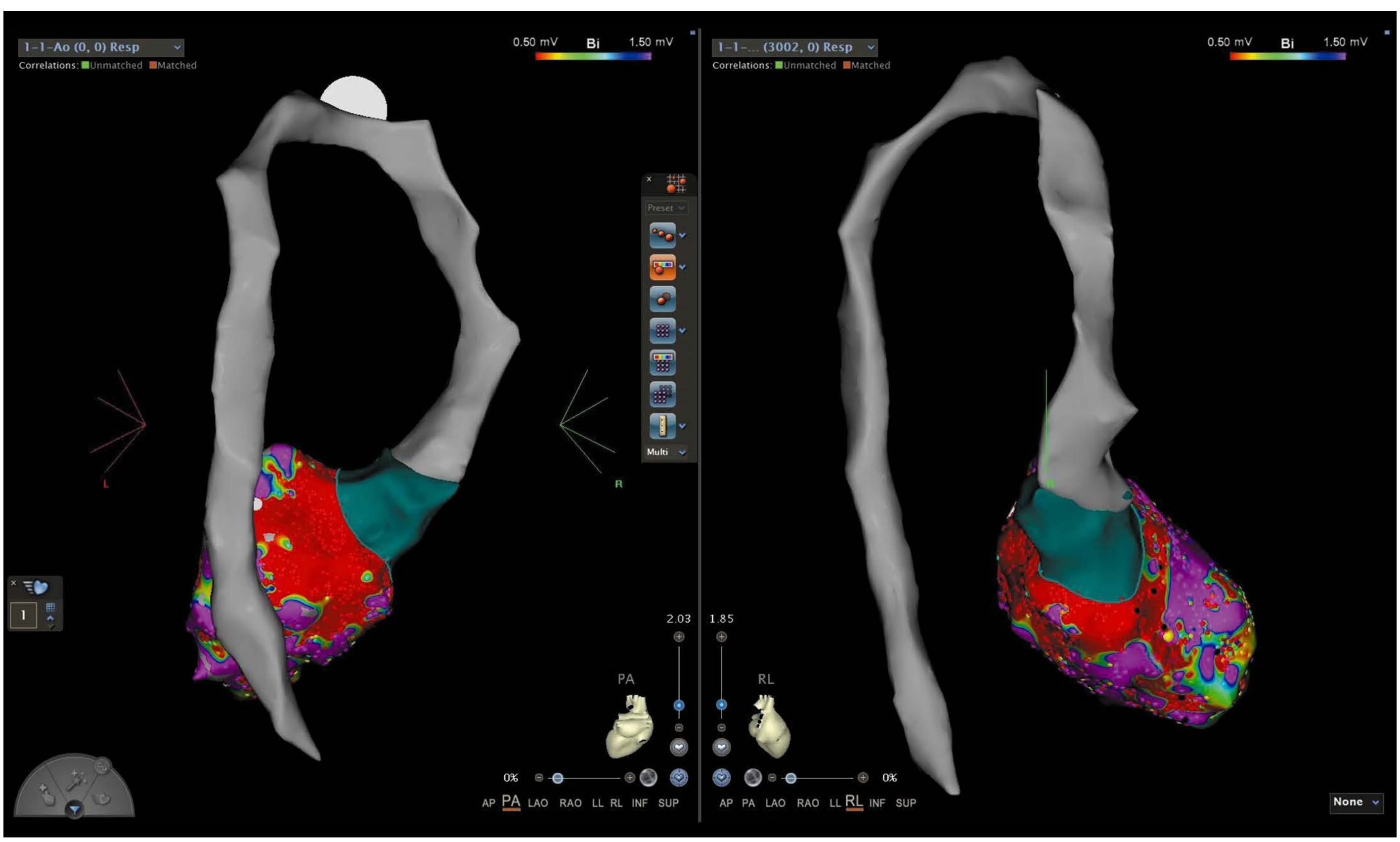


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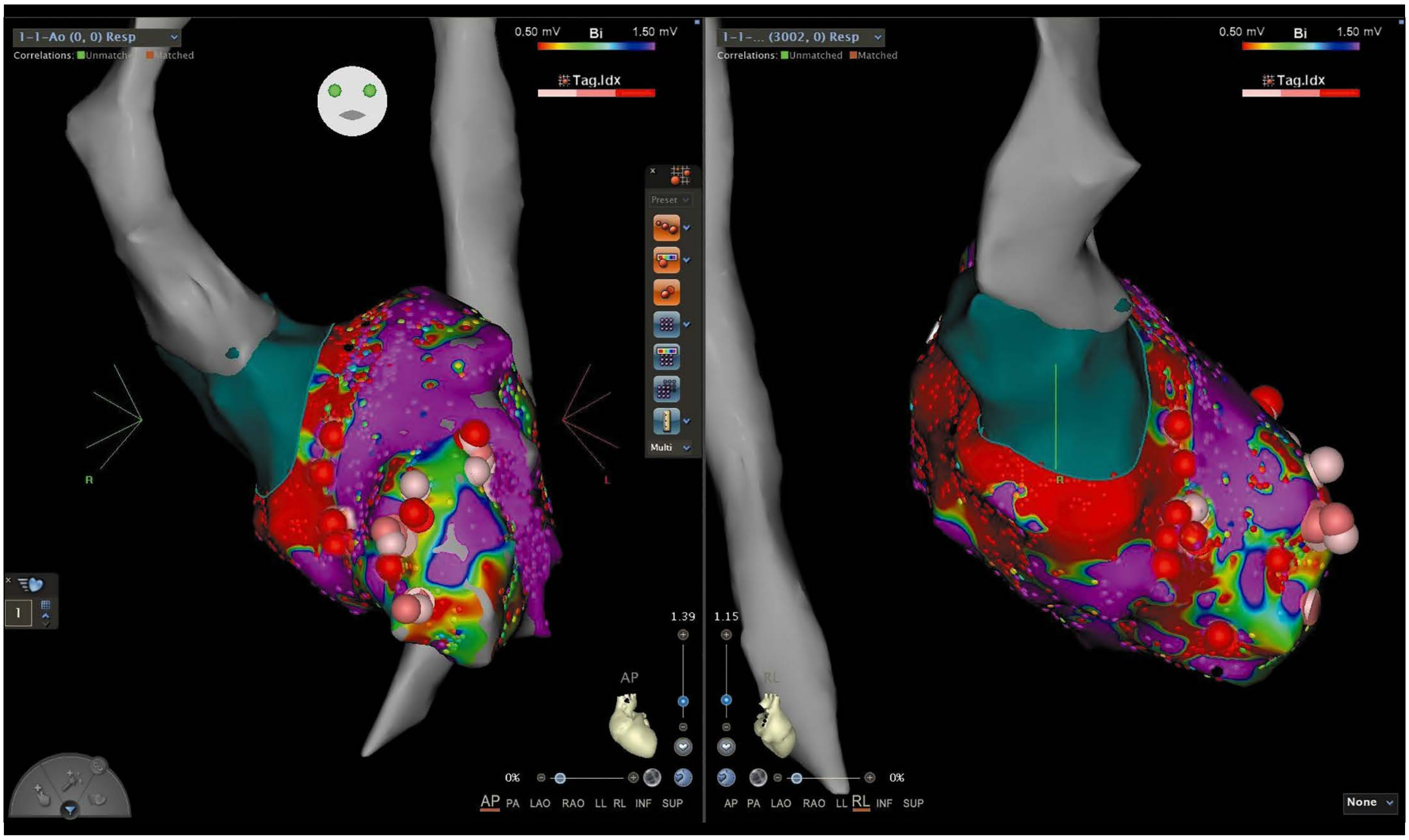
Figure 7. Left ventricular map of patient K. after ablation

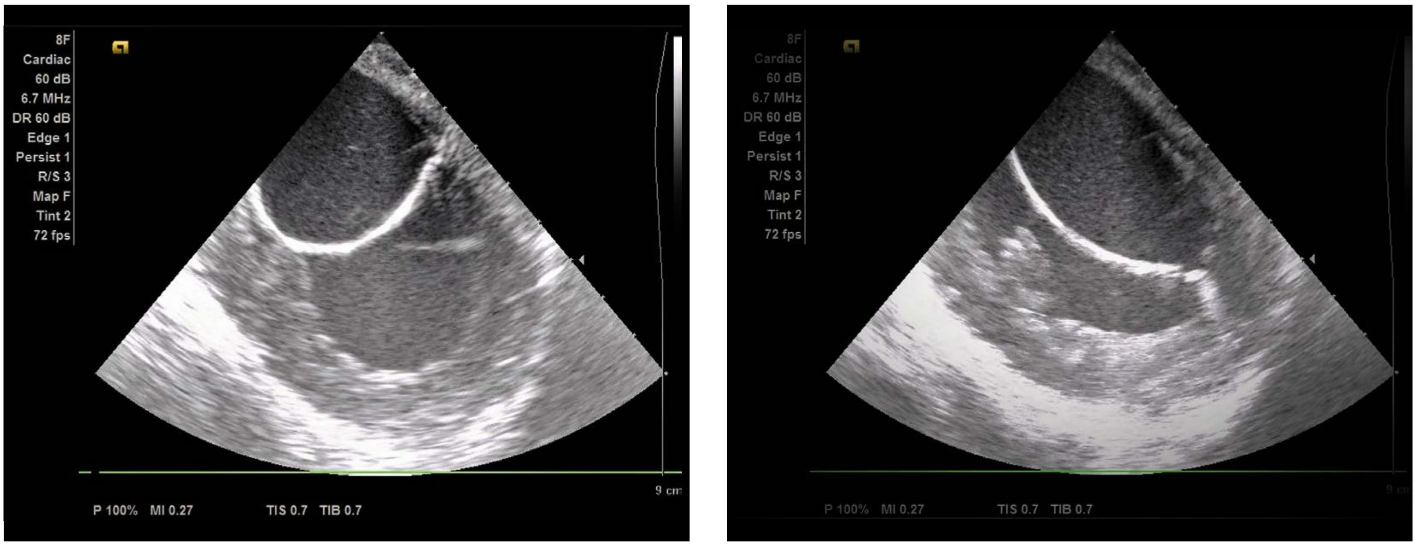


Red and pink volumetric points mark ablation zones.

procedures were performed using standard ablation techniques. Only 1.26 % of patients were transferred from the non-fluoroscopic ablation group to the fluoroscopic group. According to the data obtained, time the procedure did not increase significantly without the use of fluoroscopy compared to the standard technique (weighted average difference 2.32 min; 95 % confidence interval (CI) 2.85–7.50), and no statistically significant differences were registered in the incidence of complications (odds ratio (OR) 0.72; 95 % CI 0.45–1.16), procedure failure (OR 1.10; 95 % CI 0.75–1.59), or recurrent rhythm disorders [18].

Our non-fluoroscopic procedures performed for 20 patients with VT had no clinically significant complications, and fluoroscopy was not required in any case. ICE made it possible to conduct high-quality mapping, and time of the procedure did not differ significantly from similar interventions [18, 19].

Figure 8. Ablation catheter in the left ventricular cavity of Patient K.



The above meta-analysis included only 2 studies on VT CA with 254 patients who were not subjected to fluoroscopy and 369 patients with fluoroscopy. There was no statistically significant difference in time of the procedure between the two groups (weighted average difference of 9.54 min; 95 % CI –23.89–4.82; p = 0.193). There were no clinically significant complications of the non-fluoroscopic interventions for the treatment of VT in those studies. These data are consistent with our findings.

All diagnostic and ablation catheters in our and other studies were operated under the ICE control without fluoroscopy. Retrograde transaortic access was also performed without ionizing radiation. Multipolar mapping and ICE were used in several foreign studies on CA without fluoroscopy. These methods can reduce the duration or completely abandon fluoroscopy.

It should also be noted that patients with ischemic and non-ischemic origin of VT were included in our study. CA in conjunction with ICE and without fluoroscopy was safe and effective in both situations. There are no publications on the origin of rhythm disorders and performing CA without fluoroscopy.

Conclusion

State-of-the-art capabilities of cardiac mapping and intracardiac echocardiography allows catheter interventions without the use of fluoroscopy even in such complex procedures as catheter ablation of the ventricular tachycardia substrate. Non-fluoroscopic technique for the ventricular tachycardia substrate ablation is effective and possible under the control of intracardiac echocardiography and three-dimensional navigation mapping. Nevertheless, electrophysiologists should have sufficient experience in using fluoroscopy to switch to non-fluoroscopic techniques and appropriate capabilities to ensure patient safety.

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