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NONFLUOROSCOPIC CATHETER ABLATION OF TACHYARRHYTHMIAS IN PATIENTS WITH ANTIARRHYTHMIC DEVICES

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Aim. To assess safety and effectiveness of zero fluoro catheter ablation (CA) of tachyarrhythmias in patients with antiarrhythmic device.

Methods. One hundred ninety-seven patients with implanted antiarrhythmic device and indication for catheter ablation of tachyarrhythmias were included in retrospective study. In control group of patients n=63 (mean age 65.5±11.9 years) all procedures were performed under fluoroscopic guidance. In a study group, n=134 (mean age 66.1±15.6 years) all procedures were performed without the use of fluoroscopy. To reconstruct 3D anatomy we used navigation systems: magnet and impedance. In some cases we used intracardiac ultrasound. In the first group there were 65% of patients with pacemakers, 4.8% patients with implantable cardioverters-defibrillators and 30.2% of patients had cardiac resynchronization systems. In second 70.1%, 12.7% and 17.2% respectively. In control group CA was performed within 24 hours after device implantation in 13 patients (20.6%), in study group - 23 (17.2%). In the rest cohort of patients mean period between device implantation and CA was 29.26±28 months - in control group, 38.8±39 months. Antiarrhythmic device programming was performed before and right after CA.

Results. Interventional catheter procedure was performed in 98.4% of patients in control group and in 98.5% of patients in study group. Radiation exposure in control group was 0.24 mZv, in study group 0 mZv. There were no conversions from zero fluoroscopy procedure to X -ray controlled due to different reasons. In control (fluoroscopy controlled) group 8 hours after CA ventricle lead dislodgement was diagnosed. Antiarrhythmic device in this patient was implanted 6 days before CA. There were no lead dislodgements or cardiac pacing disorders in study group.

Conclusion. Zero fluoroscopy CA of tachyarrhythmias in patients with antiarrhythmc device is as safe and effective as standard fluoroscopy controlled procedure.

Key words: fluoroscopy; zero fluoroscopy; catheter ablation; implantable antiarrhythmic device; atrial fibrillation; atrial flutter; ventricular arrhythmias

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Currently, radiofrequency catheter ablation (RFA) is the treatment of choice for various types of tachyarrhythmias [1–3]. However, performing such procedures typically requires the use of fluoroscopy to visually guide manipulations within the heart and major vessels [4]. Fluoroscopy, in turn, is a source of ionizing radiation, which negatively affects both the patient and the medical staff"[5, 6]. The active use of 3D navigation systems for such procedures reduces the need for fluoroscopy[7]. In some cases, interventions can be performed with minimal radiation exposure[8, 9] or even without its use at all [10, 11].

The use of 3D navigation systems allows for the reconstruction of the heart chambers on one hand, and visualization of electrophysiological catheters used for RFA on the other. However, these systems cannot visualize endocardial leads (ELs) of cardiac implanted electronic devices (CIED) or heart valves. As a result, performing RFA in patients with implanted CIED carries certain risks to the ELs, such as damage, lead dislodgement, increased pacing thresholds, and more. According to our knowledge, performing RFA without any fluoroscopy in patients with CIED has not been described in the global literature to date.

In this study, we retrospectively analyzed the experience of performing non-fluoroscopic RFA in patients with implanted CIED.

METHODS

From January 1, 2016, to January 30, 2021, 197 patients with CIED underwent RFA for tachyarrhythmias. Standard procedures using fluoroscopy (control group) were performed on 63 patients, while alternative non-fluoroscopic procedures (study group) were performed on 134 patients. The clinical characteristics of patients in both groups are presented in Table 1.

Indications for surgery were determined based on the recommendations of the Russian Society of

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Arrhythmologists (RSO) and following mandatory CIED programming. Procedures in both groups were performed in a fluoroscopy-equipped operating room. In the control group, fluoroscopy was routinely used for catheter visualization, while in the study group, magnetic and impedance-based navigation systems were utilized. Surface ECG registration and endocardial electrophysiological studies, including endogram recordings, were performed uniformly in both groups. Intracardiac ultrasound was used for transseptal punctures.

In cases of atrioventricular nodal reentrant tachycardia (AVNRT), which occurred only in the study group, non-irrigated ablation catheters were used in 7 patients (5.2%), while irrigated catheters were used in all other cases. For patients with implanted cardioverter-defibrillators (ICDs), the high-energy shock function was disabled in the operating room prior to the procedure. Immediately after the procedure, pacing parameters for each lead were checked, and the shock function was reactivated.

During atrioventricular node ablation (AVNA), dual- or triple-chamber CIED were programmed to the VVI mode with a basal heart rate (HR) of 30 beats per minute. For single-chamber CIED (implanted only in patients with permanent atrial fibrillation (AF)), the basal HR was programmed to 30 bpm. Following the creation of a third-degree atrioventricular block, dual- and triple-chamber CIED were returned to atrioventricular pacing mode with physiological basal HR values programmed. In single-chamber CIED, the previous basal HR settings were restored.

In the control group, RFA was performed simultaneously with CIED implantation or within the first 24 hours after implantation in 13 patients (20.6%), and in the study group, in 23 patients (17.2%). In other cases, the period between CIED implantation and RFA for tachyarrhythmias was 29.26 ± 28 months (range 1–111 months) in the control group and 38.8 ± 39 months (range 1–201 months) in the study group. The types and scope of procedures in both groups are presented in Table 2.

On the day following the procedure, all patients underwent device reprogramming by the operating surgeon or attending cardiologist. For patients with chronically implanted pacemakers (>1 year), follow-ups occurred once every 12 months, and for those with ICDs, every 6 months. If CIED implantation and RFA were performed during the same hospitalization, device reprogramming was scheduled 6 months after discharge, regardless of the device type.

Mandatory tests on the day following RFA included echocardiography and ultrasound examination of femoral puncture sites in the major vessels. Chest X-rays were included in the postoperative examination protocol for patients who had undergone RFA via subclavian access or in cases of changes in stimulation parameters of endocardial CIED leads during programming.

RESULTS

Interventional catheter procedures were performed in 98.4% of patients in the control group and 98.5% of patients in the study group. In one case in the control group, RFA of a ventricular ectopic focus in the right ventricular outflow tract (RVOT) was unsuccessful due to its proximity to the site of the endocardial ventricular lead implantation. In all other cases, RFA was successfully performed.

In the study group, RFA was unsuccessful in two patients with ventricular ectopic foci. In the first case, the ectopic focus in the left ventricular outflow tract could not be accessed due to the presence of an aortic valve prosthesis, and transseptal access was not considered by the operating surgeon. In the second case, attempts at RFA were not made due to the ectopic activity's proximity to the cardiac conduction system and the high risk of developing atrioventricular block in a patient with a single-chamber ICD. Both patients were prescribed antiarrhythmic drug therapy with positive results. In all other cases, RFA was successfully performed.

Radiation exposure during RFA was 0 mSv in the study group and 0.24 ± 0.5 mSv in the control group (range 0.001–2.625 mSv). The radiation dose reflects the RFA procedure only, excluding preoperative or postoperative imaging. The study aimed to assess the feasibility of fully

Table 1.

Clinical characteristics of patients included in the study

Indicator	Study group	Control group
Gender (male/female)	55/79	31/32
Age, years	66.1±15.6	65.5±11.9
Height, cm	165.2±9.8	165.7±9.33
Weight, kg	79.2± 17.6	87.4±16.6
Impaired glucose tolerance, n (%)	29 (21.6)	15 (23.8)
Hypertension, n (%)	106 (79.1)	55 (87.3)
Chronic kidney disease, n (%)	32 (23.9)	4 (6.3)
Obesity, n (%)	35 (26.1)	20 (31.7)
Thyroid dysfunction, n (%)	34 (25.4)	12 (19)
Cerebrovascular accident, n (%)	10 (7.5)	11 (17.5)
Oncological history, n (%)	16 (11.9)	7 (11.1)
Stenting*, n (%)	19 (14.2)	16 (25.4)
Open-heart surgery, n (%)	18 (13.4)	3 (4.8)
Implanted PM, n (%)	94 (70.1)	41 (65)
Implanted ICD, n (%)	17 (12.7)	3 (4.8)
Implanted CRT-P / CRT-D, n (%)	23 (17.2)	19 (30.2)

Note: Hereinafter, * - Coronary and major arteries; P - Pacemaker; ICD - Implantable cardioverter-defibrillator; CRT - Cardiac resynchronization therapy.

non-fluoroscopic RFA. The preoperative preparation and postoperative protocols were identical in both groups, but the total radiation dose for hospitalization was documented in the discharge summary.

In this study, no conversions from non-fluoroscopic to fluoroscopy-controlled procedures were required. Intracardiac ultrasound was additionally used in one patient with an ICD and recurrent ventricular tachycardia originating from the left ventricle after unsuccessful retrograde transaortic catheter ablation attempts. Using transseptal access, the ablation catheter was guided into the left ventricle through the mitral valve with a steerable introducer. The operative times for each condition are shown in Table 3.

In the control group, a patient underwent RFA of the AVN for drug-resistant AF/flutter six days after pacemaker implantation. The patient had a history of RFA for AF/flutter five years prior. Eight hours post-RFA, the patient's condition deteriorated due to ventricular lead dislodgement and third-degree AV block, with a heart rate of 36 bpm. Following ventricular lead reimplantation, the patient's condition stabilized. In all other cases, no dysfunction of the CIED was detected during early postoperative programming in either group.

In the control group, one case of restored AV node conduction after RFA required repeat ablation during the same hospitalization. In the study group, a patient with atypical left atrial flutter (AFL) after mitral valve replacement experienced flutter recurrence during pacemaker programming the next day. Repeat intervention was not performed during the same hospitalization. The pacemaker was set to DDIR mode with a basal HR of 70 bpm, and antiarrhythmic therapy was prescribed.

External cardioversion to restore sinus rhythm was performed in two patients (3.2%) in the control group after RFA for AF and nine patients (6.7%) in the study group. Three cases followed ablation for AF, and three followed ablation for typical atrial flutter, where two patients presented with AF at the procedure's start, and one developed AF during ablation. Two cases occurred after ablation for atypical flutter. One patient had undergone mitral valve replacement and tricuspid repair and presented with AF before surgery. Sinus rhythm was restored but later transitioned to right atrial incisional tachycardia. Another developed a prolonged tachycardia cycle with subsequent AF during ablation.

In the study group, a patient undergoing programmed ventricular stimulation with three extrastimuli developed ventricular fibrillation, which was successfully reverted to sinus rhythm with a single external defibrillation attempt. All complications during the early postoperative period are shown in Table 4.

In both groups, pulsating hematomas in the upper third of the right thigh were identified the day after RFA: one in the control group after AV node ab-

Table 2.

Types of Surgical Interventions in Patients with CIED

Type of surgical intervention	Study group	Control group
AV node ablation, n (%)	69 (51.5)	45 (71.4)
RFA of atrial fibrillation, n (%)	21 (15.7)	5 (7.9)
RFA of ventricular tachycardia, n (%)	5 (3.7)	2 (3.2)
RFA of RVOT tachycardia, n (%)	7 (5.2)	-
RFA of typical atrial flutter, n (%)	13 (9.7)	7 (11.1)
RFA of atypical atrial flutter, n (%)	7 (5.2)	1 (1.6)
RFA of ventricular ectopy, n (%)	6 (4.5)	2 (3.2)
RFA of ventricular fibrillation, n (%)	1 (0.7)	-
RFA of accessory pathways in WPW syndrome, n (%)	2 (1.5)	-
RFA of supraventricular ectopy, n (%)	2 (1.5)	-
RFA of inappropriate sinus tachycardia, n (%)	1 (0.7)	1 (1.6)
Catheters in a chamber with an implanted EL, n (%)	94 (70.1)	53 (84.1)
Total number, n	134	63

Note: Hereinafter, AV – Atrioventricular; RFA -Radiofrequency ablation; RVOT - Paroxysmal reciprocating AV nodal tachycardia; AP - Accessory pathways; EL - Endocardial lead.

Figure 1. Non-fluoroscopic catheter ablation of left ventricular tachycardia in a patient with an implanted cardioverter-defibrillator using transseptal access and a steerable introducer: a - Intracardiac ultrasound visualization; b - Surface ECG and endograms; c - Electroanatomical 3D map of the left ventricle.

lation and one in the study group after RFA for AF. Both cases were successfully treated conservatively with manual compression under ultrasound guidance within the first four hours of diagnosis.

A pericardial effusion (0.4 cm) was detected the day after AV node ablation in one study group patient and treated conservatively. Non-RFA-related complications included hematomas in the CIED pocket in three study group patients who underwent simultaneous pacemaker implantation and AV node ablation. All were on anticoagulant therapy and successfully managed conservatively. A left-sided pneumothorax was diagnosed in a study group patient who also underwent simultaneous pacemaker implantation and AV node ablation. The pneumothorax was resolved by draining the left pleural cavity.

DISCUSSION

Non-fluoroscopic RFA is the standard (routine) approach for interventional treatment of arrhythmias at the Federal Center of Cardiovascular Surgery in Krasnoyarsk. At the time of preparing this study, the center had performed over 5,000 non-fluoroscopic interventions. Considering the growing population of patients with CIED and the expanding indications for RFA, it was not surprising that patients with CIED requiring RFA began to emerge. Interventions for these patients were performed as experience in non-fluoroscopic procedures increased in the general population.

The main concerns were related to the risk of damage or dislodgement of ELs, especially in patients dependent on cardiac pacing. Cases of pacing disruption during RFA and external cardioversion have been described in the literature[12]. However, in all reported cases, the external defibrillator electrodes were placed over the CIED.

In our experience, no CIED malfunctions were identified in any of the 11 patients who underwent external cardioversion or the one patient who underwent defibrillation. In one case, ventricular lead dislodgement occurred six days after pacemaker implantation and eight hours after RFA of the AVN. After the RFA, the pacemaker was immediately reprogrammed to DDDR mode in the operating room, and no pacing dysfunction was detected. Pacing parameters remained unchanged after the RFA. Moreover, a mandatory examination one hour post-procedure (a standard practice in our center) also found no issues with pacemaker function, and the patient's heart rate at the time of examination was 65 bpm. Thus, the association between ventricular lead dislodgement and the performed RFA remains debatable.

When performing electroanatomical 3D reconstruction using navigation systems without intracardiac ultrasound visualization, it is not possible to precisely determine the position of ELs and their proximity to the ablation catheter. In this study, no difficulties were encountered with catheter manipulation within the heart chambers, entanglement with ELs, or fixation in subvalvular structures or trabeculae. This may be attributed to the algorithm developed and implemented at our center for performing RFA in patients with CIED.

Preoperative preparation for RFA in patients with CIED must include reviewing chest X-rays to identify the EL placement (a standard for patients scheduled for interventional electrophysiology procedures). It is advisable to separate the timing of CIED implantation and subsequent RFA by at least three months to reduce the risk of EL dislodgement during RFA or in the early postoperative period.

To enhance safety, the use of ablation catheters equipped with force-sensing technology to monitor tissue contact pressure is recommended. Such devices have recently become more commonly adopted in clinical practice. EL extraction or catheter withdrawal should always be performed in a straightened configuration to avoid accidental entanglement with the ELs, which could lead to dislodgement. During intracardiac manipulations, excessive rotational movements (over 1800° in one direction) should be avoided to prevent catheter entanglement with the ELs. A practical approach may involve removing the catheter and reinserting it in a neutral position.

In cases where catheter extraction from heart chambers proves difficult due to entanglement, ultrasound or fluoroscopic visualization is recommended. When planning RFA in heart chambers with implanted ELs near the implantation site, fluoroscopy (switching to a fluoroscopy-controlled procedure) may be necessary to assess the distance between the ablation catheter and the EL. This is particularly important for patients entirely dependent on cardiac pacing.

For recently implanted CIED requiring RFA with a high risk of ventricular EL dislodgement, it may be prudent to consider placing a "backup" diagnostic lead in the right ventricular cavity. Most patients in the study group underwent procedures without direct vi-

Table 3.

Duration of surgical interventions in patients with CIED

AV node ablation, min	Study group	Control group
RFA of atrial fibrillation, min	58,4±37,3	60,3±28,2
RFA of ventricular tachycardia, min	93,3±39,2	146±23,3
RFA of RVOT tachycardia, min	108±20,4	82,5±2,5
RFA of typical atrial flutter, min	98±29,9	-
RFA of atypical atrial flutter, min	84,8±28	115,7±34,6
RFA of ventricular ectopy, min	165±59,9	90
RFA of ventricular fibrillation, min	87,5±24,7	82,5±12,5
RFA of accessory pathways in WPW syndrome, min	230	-
RFA of supraventricular ectopy, min	80±20	-
RFA of unusual sinus tachycardia, min	150±30	-
RFA of atypical sinus tachycardia, min.	70	40

sualization of ELs, raising particular concerns for patients with cardiac resynchronization devices (CRTs), where the left ventricular lead is implanted in the coronary sinus system. No advantages of non-fluoroscopic RFA would outweigh the risk of left ventricular lead dislodgement, which would necessitate reimplantation and its associated risks. However, no issues with left ventricular leads were observed in either group.

Procedure duration was comparable between the groups for RFA of AF, typical AFL, and AVNA. In the study group, procedure times for AF and typical AFL were shorter than in the control group. This was primarily due to the use of a recently implemented high-power (50W), short-duration (9–14 seconds) RFA technique and ablation indices for linear lesions, which significantly reduced ablation times. These methods were applied to a larger proportion of patients in the study group compared to the control group. Other stages of RFA for AF and AFL were similar in duration between the groups.

In other cases, comparisons were not possible due to the small number of patients for each condition. Further prospective, randomized controlled studies are required to better understand the issue and establish unified guidelines for performing RFA in patients with CIED.

Table 4.

Complications in the early postoperative period after RFA of tachyarrhythmias in patients with CIED

Type of complication	Study group	Control group
Lead dislodgement		1
Pericardial effusion	1	
CIED pocket hematoma	3	
Pulsating thigh hematoma	1	1
Pneumothorax	1	

CONCLUSION

Non-fluoroscopic RFA of tachyarrhythmias in patients with CIED is both effective and safe. Special caution should be exercised when performing RFA in patients with implanted cardiac resynchronization devices, where the left ventricular lead is placed in the coronary sinus system, as well as in patients with CIED implanted less than six months prior. In such cases, the risk of lead dislodgement may outweigh the benefits of the non-fluoroscopic approach. Using intracardiac ultrasound visualization for the manipulation of ablation and diagnostic catheters in heart chambers with implanted ELs can significantly reduce the risk of adverse events. However, this requires additional venous access and increases the cost of the non-fluoroscopic RFA procedure. Prior to performing RFA for tachyarrhythmias, it is essential for the operator to have precise knowledge of the position of the endocardial leads and the patient's dependence on the pacemaker.

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