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Original Research Article

Arrhythmic Storm as a Cause of Sudden Cardiac Death: Effectiveness of Catheter Ablation

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Abstract: ***The Aim*:** To make the analyses the clinical characteristics of patients with arrhythmic storm and possibility of radiofrequency ablation for prevention arrhythmogenic form of sudden cardiac death. ***Material and Methods*:** In the observation were included 40 patients (90.0% male, average age - 62.2±10.3 years) with implantable cardioverter-defibrillators, in which the episodes of arrhythmic storm (AS) were registered. All patients underwent "enhanced" antiarrhythmic therapy, and in some cases, inotropic drug support. In patients with hemodynamically tolerated VT, electroanatomic mapping was performed. Mapping and ablation of tachyarrhythmias were performed using the navigation system Carto XP (Biosense Webster, USA). Catheter ablation was performed against the background of tachycardia with subsequent destruction of all potential reentry circles, fragmented and late potentials. ***Results*:** The arrhythmic storm was recorded at different stages after implantation; the median time of occurrence of AS episodes from the moment of implantation was 5.2 months. The number of adequate electrical stimulations during AS was 8.2±4.1 per day. In 17 (42,5%) patients was registered monomorphic ventricular extrasystoles, in 12 (30,0%) - pleomorphic tachycardias, in 23 (57,5%) –ventricular tachycardias (VT). In primary catheter ablation, the acute efficiency of catheter destruction of the substrate of clinically significant VT was 60.0% (24 patients). VT after RFA was observed in 20 patients (50%). In 15 patients (37.5%), there was no induction of any VT. In the postoperative period in a hospital setting, ventricular tachyarrhythmias did not recur in any of the patients, and no deaths episodes were recorded. Ablation of trigger mechanisms of the Purkinje potential caused a distinct positive effect: ventricular tachyarrhythmias were not induced, including during aggressive ventricular pacing. No new episodes of ventricular tachyarrhythmia and ICD triggering were recorded during the two years of observation. ***Conclusions*:** 40% of patients with arrhythmic storm require emergency catheter ablation. In 90% of cases of arrhythmic storm occurs implantable cardioverter-defibrillators. Catheter ablation in all cases made it possible to control the arrhythmic storm, including over a long period of observation.

Keywords: Sudden Cardiac Death, Arrhythmic Storm, Catheter Ablation, Clinical Case.

INTRODUCTION

Sudden cardiac death (SCD) accounts for more than a third of all cardio-vascular deaths. In the USA, 300,000 to 350,000 people die of SCD each year, accounting for 15% of all deaths.

For primary and secondary prevention and treatment of SCD according to the arrhythmic variant, the only possible and effective method is used to manage implantable cardioverter-defibrillators (ICD) [15]. Arrhythmic storm (AS) is defined as three or more episodes of ventricular tachycardia/ventricular fibrillation (VT/VF) in patients with ICD occurring within 24 hours, with effective rhythm recovery after cardioversion/defibrillation. ES occurs in the population with a frequency of up to 28% in secondary prevention and in 4% in primary prevention of SCD [11].

In Ukraine, the 2015 Recommendations of the European Society of Cardiology are used as a working document for the management of this clinical condition.

In our country, in the structure of cardiac diseases, the mortality rate for SCD is 117 (89.79%) cases [15].

Antiarrhythmic drugs are used to stabilize the patient in the acute phase. Short-term prognosis improves with beta-blockers usage. Beta-blockers should be combined with amiodarone to improve rhythm control [12].

The incidence of arrhythmic storm varies from 10 to 28% with a follow-up period of one to three years in studies in which ICD implantation was performed for the secondary prevention of sudden cardiac death (SCD). In the MADIT II trail, which studied the primary prevention of SCD, the level was significantly lower - 4% [14]. The time from ICD installation to the onset of an electrical storm also varied between studies. Thus, in the earliest clinical trials, the average time to the onset of an arrhythmic storm was determined in 4-5 months after implantation of the device [2], and in newer studies – in 2–3 years [3]. At the same time, the number of ventricular tachyarrhythmias occurring during an arrhythmic storm varies significantly: from 5 to 55 [5]. Most arrhythmic episodes were monomorphic ventricular tachycardias (VT), while polymorphic VT and ventricular fibrillation (VF) were less common [2].

According to the previous researches, the effectiveness of endocardial catheter ablation of the VT substrate varies in patients with different nosology of structural myocardial damage, which, in some cases, is due to the deep (subepicardial) location of the critical zone of tachycardia and limited depth of penetration of radiofrequency (RF) exposure during endocardial applications. Thus, the depth of RF damage reaches 6-8 mm according to various authors [2, 3, 6].

The actual problem of arrhythmology is the identification of risk factors for arrhythmic storm. It cannot be ruled out that the development of an arrhythmic storm significantly depends on left ventricular dysfunction (LVD), the presence of chronic kidney disease and VT [6].

In the AMIOVIRT study, patients with arrhythmic storm storms had a two-fold increase in the risk of death from any cause, especially in the first three months after AS. The observed increase in mortality due to progression of cardiac dysfunction suggests that arrhythmic storm either is a critical point in the development of irreversible heart failure (HF) or is the initial manifestation of HF [8].

If the manifestation of the arrhythmic storm cannot be suppressed by medical therapy, catheter ablation is the treatment of choice. Thus, Zeppenfeld K. et al. were the first ones to use catheter ablation in 6 patients with arrhythmic storm, which gave a significant positive effect, but the frequency of recurrence of single episodes of ventricular tachyarrhythmias was stayed at 80% [15]. Other authors reported a significant reduction in the number of ICD-shocks in 21 patients after radiofrequency ablation (RFA) of drug-resistant VT. Chang WI. *et al.,* [3] were the first to describe the benefits of electroanatomic mapping of AS in 19 patients. The efficiency of the operation was 66% during 26 weeks of follow-up.

Similar results were described by Benali K. *et al.,* in 5 patients with coronary artery disease who underwent RFA: during the follow-up period of 12-30 months, 3 patients had no recurrence of arrhythmias, 2 patients had single episodes of VT in the postoperative period [1].

The aim of this study was to evaluate the early and long-term effectiveness of urgent catheter ablation in a group of patients with postinfarction ventricular tachyarrhythmias and arrhythmic storm.

The Aim

To make the analyses the clinical characteristics of patients with arrhythmic storm and possibility of radiofrequency ablation for prevention arrhythmogenic form of sudden cardiac death.

MATERIAL AND METHODS

During the observation of patients with ICD, the occurrence of an arrhythmic storm was noted in 40 patients. At the same time, the total number of recorded episodes of AS - 51. The majority of patients — 36 (90.0%) were male. The average age at the time of the AS - 62.2±10.3 years.

The arrhythmic storm was recorded at different stages after implantation; the median time of occurrence of AS episodes from the moment of implantation was 5.2 months.

After emergency hospitalization, examination was carried out to rule out acute coronary syndrome and reversible causes of arrhythmic storm; in 10 cases, coronary angiography was performed. For the purpose of medical relief of AS was used amiodarone, without complete suppression of the arrhythmia.

From the debut of AS to the emergency RFA, one to three days elapsed. Seven patients had a history of adequate and successful episodes of VT relief with ICD.

All patients underwent "enhanced" antiarrhythmic therapy, and in some cases, inotropic drug support. In three cases, in patients with ICD, hemodynamically unstable episodes of VT were recorded, occurring at an extremely high frequency, including those switching into VF.

In patients with hemodynamically tolerated VT, electroanatomic mapping was performed. Mapping and

ablation of tachyarrhythmias were performed using the navigation system Carto XP (Biosense Webster, USA).

Catheter ablation was performed against the background of tachycardia with subsequent destruction of all potential reentry circles, fragmented and late potentials. In case of VT occurring with acute hemodynamic disturbances against the background of a high heart rate, the so-called "fast" VT, pacing induction was not used.

RESEARCH RESULTS

Prior to the arrhythmic storm, all patients had ICDs installed. According to ICD telemetry information, the number of adequate electrical stimulations during AS was 8.2±4.1 per day.

Clinical characteristics of patients with arrhythmic storm are given in table 1. In 17 patients, monomorphic VT was recorded, in 12 hemodynamically stable pleomorphic tachycardias from two to three morphologies. In 23 cases, electrical mapping was performed against the background of hemodynamically tolerated VT. The cycles of documented VT during the session of catheter ablation were significantly longer compared to the values at admission (477±27 and 357±22 ms, respectively, $p<0.05$), which is due to the use of active antiarrhythmic therapy in the hospital.

Table 1: Clinical characteristics of patients with arrhythmic storm

Indexes	Abs.	%
Men	36	90,0
Women	4	10,0
Atrial Fibrillation in Anamnesis	10	25,0
ISD, primary prevention	10	25,0
ISD, secondary prevention	30	75,0

After performing of the full catheter ablation, the final stage of the intervention consisted of a pacing protocol to induce tachyarrhythmias. The absence of induction of any VT was regarded as an acute effect of ablation. In case of provocation of any type of VT, repeated catheter destruction was performed. In all cases of hemodynamically tolerated mapped VT, the reentry mechanism was determined.

Electrophysiological characteristics of mapping and radiofrequency ablation are presented in Table 2.

Table 2: Electrophysiological characteristics of ventricular arrhythmias

Indexes	Abs.	%
Pacing-induced mapped VT	16	40,0
Spontaneous mapped VT	18	45,0
Average number of VT morphologies per patient	13	32,5
Hemodynamically intolerable VT	12	30,0
Induced or spontaneous VF	12	30,0
Anterior or anterior- septal wall of the left ventricle	25	62,5
Posterior LV wall, including with involvement of Purkinje fibers	15	37,5
Average VT cycle length, ms	477±27	

In all patients, interventions were completed without acute heart failure, respiratory failure, or other complications. After the intervention, all patients underwent ECG and hemodynamic parameters monitoring in the conditions of the department of anesthesiology and resuscitation.

Two patients underwent replacement of the implanted device due to the depletion of the ICD discharge due to the development of the arrhythmic storm.

In primary catheter ablation, the acute efficiency of catheter destruction of the substrate of clinically significant VT was 60.0% (24 patients). A partial effect of the operation (VT induction, but with a more aggressive pacing protocol) was observed in five patients.

Induction of previously unreported VT morphologies after RFA was observed in 20 patients (50%). In 15 patients (37.5%), there was no induction of any VT. Catheter elimination of not only ventricular tachyarrhythmias, but also triggers that cause VT/VF, also contributes to the effective suppression of the arrhythmic storm.

An interesting clinical case is the successful catheter ablation of ventricular tachyarrhythmia from the parts of Purkinje fibers, which were the trigger for the development of VT/VF.

Male M., 55 years old, was hospitalized in the intensive care unit because of arrhythmic storm episode. History of myocardial infarction of the posterior wall of the left ventricle, stenting of the coronary arteries (2018 year). An ICD was installed for secondary prevention of

SCD. Registration of a standard ECG revealed frequent ventricular extrasystole (VE) with episodes of accelerated idioventricular rhythm, as well as transformation into VT and VF, Fig 1.

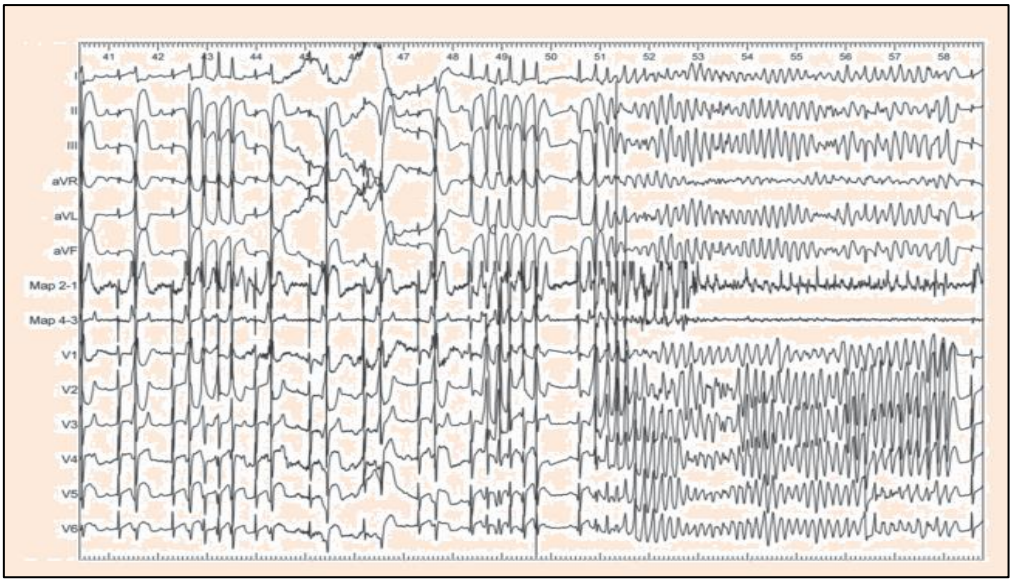

Fig. 1: Electrocardiogram of a patient with the signs of the arrhythmic storm (early PVCs, VT runs, VF)

The development of an arrhythmic storm occurred 5 years after stenting. According to ICD telemetric information, 13 device interventions were registered during an electrical storm for 12 hours: 6 episodes of antitachycardia pacing and 7 defibrillations.

An emergency catheter ablation was performed using a guided mapping system. The trigger zone was identified using bipolar mapping. Conduction channels were identified in the scar region of the left ventricle. The second stage consisted of performing an activation search against the background of frequent PVCs, idioventricular rhythm and VT. LV mapping showed a discrete Purkinje potential from the scar related zone, preceding the PVC and idioventricular rhythm by 48 ms.

In this clinical case, the distal branches of the Purkinje fibers from the scar related area play an active role as a pathological pacemaker and provoke the development of VF. Catheter destruction of this zone completely eliminated ventricular tachyarrhythmias with the restoration of stable sinus rhythm, Fig 2.

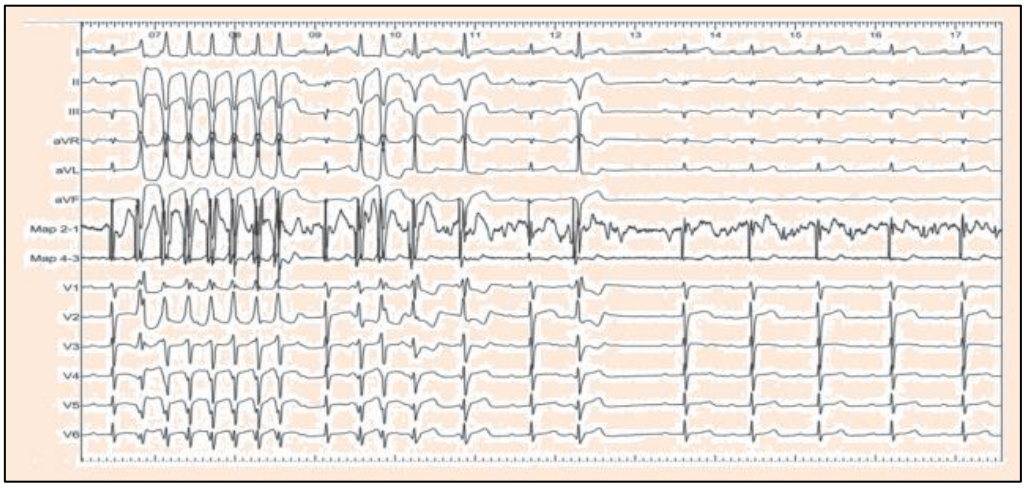

Fig. 2: Restoration of sinus rhythm as a result of catheter ablation

Ablation of trigger mechanisms of the Purkinje potential caused a distinct positive effect: ventricular tachyarrhythmias were not induced, including during aggressive ventricular pacing. In addition to the significant positive effect of catheter elimination of ventricular tachyarrhythmia, the infarcted scar in the posterior septal wall underwent extended catheter ablation aimed at conduction channels, fractionated potentials, late potentials within the scar and along its perimeter.

No new episodes of ventricular tachyarrhythmia and ICD triggering were recorded during the two years of observation of the patient.

Thus, the "surviving" Purkinje fibers show trigger activity, enhanced automatism, and supernormal excitability. Such phenomena, combined with the prolongation of the action potential of the ventricles, due to increased dispersion of refractoriness, may serve as a decisive factor in the occurrence of VT and VF. The presence of various triggers leading to the development of an electrical storm during intracardiac EPS should be carefully mapped to increase the success of catheter ablation of ventricular tachyarrhythmias in such patients.

In the postoperative period in a hospital setting, ventricular tachyarrhythmias did not recur in any of the patients, and no deaths episodes were recorded.

During the first year of follow-up, 12 patients (30.0%) experienced recurrent VT, in one case, rare paroxysms were successfully stopped by antitachycardia stimulation of the ICD without the development of an electrical storm.

Besides in three patients, repeated catheter destructions were performed, while rare VT paroxysms with initially assumed epicardial localization continued to persist in two, and in another case, ventricular tachyarrhythmias were not recorded after catheter treatment.

The average interval after discharge to the recurrence of arrhythmia was 4.7±1.64 months. The emergency and long-term efficiency of eliminating the arrhythmic storm was 100%, and the effectiveness of suppressing arrhythmic events in the long term was 75%, taking into account repeated RFA sessions.

DISCUSSION

The arrhythmic storm is a complex clinical event in which arrhythmic events, on the one hand, can be a clinical manifestation of sudden cardiac death, worsening the severity of the prognosis. It is not clear to what extent the arrhythmic storm is a factor in the formation of an unfavorable prognosis, and to what extent it is an indicator of this process.

The main studies on the effectiveness of ICDs in the secondary prevention of SCD were VANISH, AMIOVIRT and CIDS.

The prospective randomized study VANISH included 346 patients after registered episodes of SCD. At the initial stage, after 11 months, there were too large differences in the incidence of sudden death between patients with CDI (0%) and those receiving propafenone (17%, p = 0.0009), after which the use of the latter was discontinued. Subsequently, groups of patients treated with amiodarone and metoprolol were studied, in which the two-year total mortality was 19.6%, versus 12.1% in patients with ICD, with a SCD rate of 11 and 2%, respectively (p = 0.001) [8].

Almost twice as many patients (659 people) joined the CIDS (Canadian Implantable Defibrillator Stady) study. Among them, sudden death was recorded in 314 people, ventricular tachycardia (VT) accompanied by syncope - in 87 patients, and LV EF less than 35% - in 167 patients. All of them were randomized into two equal groups: 1) receiving amiodarone - 331 patients; 2) ICD implanted – 328 patients. When observed for 3 years, mortality rates in the groups were 30 and 25%, respectively, while the differences were close to statistically significant (p = 0.07) [4]. The AMIOVIRT study (Amiodarone versus implantable cardioverter-defibrillator) included 1016 people with a history of sudden death associated with VT/VF and symptomatic VT with an LV EF of less than 40%. In the control group, in addition to amiodarone, sotalol was used in 10% of patients. The observation period was 3 years. When evaluating the results, mortality in the drug therapy group was 35.9%, while in patients with ICD - 24.6% (p<0.001), with an advantage in reducing mortality in the latter by 31% [8].

The effectiveness of ICD in the primary prevention of SCD has been studied in many studies, the main ones being: MADIT, MADIT II [16], MUSTT, SCD-HeFT [7].

Treatment in the acute phase of the arrhythmic storm often requires simultaneous intravenous administration of several antiarrhythmic drugs, which are often ineffective.

Randomized multicenter trial MADIT (Multicenter Automatic Defibrillator Implantation Trial) [14] included 196 patients after MI with LVEF less than 35%, with spontaneous non-sustained VT paroxysms and inducible sustained VT that could not be controlled by procainamide. In the drug therapy group, 74% of patients received amiodarone. Mortality among these patients, recorded during two years of follow-up, was 38.6% in the drug therapy group and 15.8% in patients with CDI, and by the fourth year, these rates were 49 and 29%, respectively. Mortality in the ICD group decreased by 54%. In addition to showing the benefit of ICDs as a primary prevention of SCD, the study's main finding was that amiodarone was inappropriate in procainamide-resistant patients in the acute VT test.

In some patients, the choice should be made in favor of catheter ablation, since only the modification of electrophysiological parameters can radically eliminate ventricular tachyarrhythmias.

Catheter ablation should be performed as early as possible to avoid progressive hemodynamic deterioration and worsening of acute heart failure.

Suppression of potentially lethal arrhythmias at an early phase (from one to three days), according to our

data, helps to prevent the deterioration of hemodynamic parameters and improves survival rate.

In our study, catheter ablation demonstrates high efficiency in the treatment of arrhythmological variant of acute cardiac death accompanied by arrhythmic storm.

Patients with monomorphic, hemodynamically stable tachycardias are the most favorable group of patients for intervention. In 30.0% of cases during electrophysiological investigation (EPI), mapping was performed against the background of hemodynamically tolerated VT, either spontaneous or induced by stimulation. In our study, the successful mapping of sustained episodes of VT was facilitated by an increase in the length of the tachycardia cycle, which was ensured by the use of active antiarrhythmic therapy.

Monomorphic tachyarrhythmias, including those originating from the Purkinje system, may be triggers for the occurrence of VF. Elimination of such triggers by catheter ablation avoids the recurrence of VF.

According to Frankel *et al*., in patients with structural heart disease and electrical storm episodes, procedures were successful in 89% of cases [8].

In our study, in 25.0% of cases (10 people), arrhythmogenic Purkinje fibers served as a source of PVC, VT, including those transforming into VF. Mapping of potentially arrhythmogenic zones followed by successful catheter ablation effectively suppresses the activity of Purkinje fibers.

The use of an extended approach of catheter ablation in the elimination of ventricular tachyarrhythmias made it possible to include in this work not only patients with monomorphic VT, but also pleomorphic, polymorphic VT/VF.

CONCLUSIONS

According to the study, 40% of patients with arrhythmic storm require emergency catheter ablation. In 90% of cases of arrhythmic storm occurs in patients with an ICD installed for secondary prevention of SCD. The use of catheter ablation in all cases made it possible to control the arrhythmic storm, including over a long period of observation. Thus, ablation is a life-saving operation and can be recommended as a systematic approach to the elimination of life-threatening arrhythmias in the early stages in the absence of reversible causes. Catheter destruction may be the only method of dealing with ventricular tachyarrhythmias that are resistant to medical therapy.

Conflicts of Interests: No

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