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Efficacy of catheter ablation in patients with an electrical storm

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Abstract

Background: Electrical storm (ES) is a life-threating condition requiring prompt and effective therapy. This may be achieved by the use of catheter ablation.

Aim: To assess safety and efficacy of catheter ablation in patients with ES.

Methods: We performed 28 ablation procedures from February 2006 to May 2010 due to ES in 24 patients (21 men, 3 women, aged 62.5 ± 7.8 years). Eighteen patients had a history of myocardial infarction, 2 — dilated cardiomyopathy, 2 — hypertrophic cardiomyopathy (one also had myocardial infarction), 1 — spongiform cardiomyopathy, 1 — heart failure after aortic valve replacement and 1 — myocarditis. The mean value of ejection fraction was 27.3 ± 6.5% (15–40%). Procedures were performed using the CARTO system. Two patients after an endocardial map had also epicardial mapping performed and one of these patients underwent epicardial cryoablation. The other one underwent a radiofrequency catheter ablation.

Results: During the follow-up period of 27.8 ± 15.9 months 16 (66%) patients had no ventricular tachycardia (VT)/ventricular fibrillation (VF) episodes. Sporadic VT episodes were observed in 3 patients. Recurrence of ES occurred in 3 (12%) patients and 3 (12%) patients died during the follow-up due to the progresion of heart failure.

Conclusions: 1. Ablation of ventricular arrhythmias in the course of ES in patients with organic heart disease is safe and effective, and probably improves their prognosis. 2. After ablation, some patients have adequate interventions of implantable cardioverter-defibrillator due to progression of the disease. 3. The method does not prevent haemodynamic mortality.

Key words: electrical storm, radiofrequency catheter ablation, cryoablation, epicardial ablation, ventricular tachycardia, ventricular fibrillation

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INTRODUCTION

Electrical storm (ES) in post-myocardial infarction (MI) patients or in patients with another structural heart disease represents a major clinical issue. The definition of ES includes 3 or more episodes of ventricular tachyarrhythmias requiring electrotherapy over 24-hour period [1, 2]. Currently, 3 or more appropriate discharges (pacing or defibrillation) of the implanted cardioverter-defibrillator (ICD) over 24 hours have been also included in the definition [2]. The problem concerns ca 10–30% (up to 40%) of ICD patients. The extremal form of ES is malignant ES, in which 10 or more adequate ICD interventions take place within 1 hour [2]. Recurrent ventricular tachycardia (VT) refractory to medical treatment and ventricular fibrillation (VF) are related to adverse prognosis. In a study by Nademanee et al. [4], in which catheter ablation was not performed, intensive ES treatment was related to two-week mortality rate of 30%. Introduction of the catheter ablation of arrhythmia substrate or trigger improved the prognosis in this patient group.

Pharmacological treatment of ES includes beta-adrenolytics [5–9], amiodarone [5–9] (class III) and lidocaine (class IB) [6–8, 10]. Also, less documented nifekalant has been used [2]. In patients with Brugada syndrome, quinidine and isoproterenol have been proposed as effective ES suppressants [9, 11]. The latest guidelines include also procainamide and ajmaline [9]. For ventricular arrhythmia suppression temporary overdrive pacing of 110–120/min can also be used, opti-

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mally in AAI mode or as cardiac resynchronisation therapy. In the acute phase, deep sedation is recommended with fentanyl and midazolam. When these methods fail, ablation is an option for the patient.

The aim of the study was to assess safety and effectiveness of the interventional treatment with ablation in patients with ES.

Study group

Between February 2006 and May 2010, 28 ablations for ES were performed in our centre in 24 patients: 21 men and 3 women aged 62.5 ± 7.8 years. Eighteen patients had a history of MI, 2 had dilated cardiomyopathy, 2 — hyperthrophic cardiomyopathy (including one with history of MI), 1 — non-compaction cardiomyopathy, 1 — heart failure (HF) and a history of aortic valve replacement and 1 — a history of myocarditis. Mean left ventricular ejection fraction was 27.3 ± 6.5% (15––40%). In 23 patients, an ICD was implanted prior to the procedure, and in 1 patient — after the procedure. Detailed characteristics of the study group are presented in Table 1. All the patients gave their written informed consent to the ablation of the arrhythmia substrate.

Table 1. Detailed characteristics of patients included in the study

Patient no.	Age [years]	Sex	Type of arrhythmia	Aetiology	EF [%]	FU [months]	Events during FU	Other comments
1	56	M	VT, 3 morphologies	MI (CABG)	25	62		CRT-D
2	74	M	VT, VF	MI	18	15	Death	
3	72	M	VT, VF	MI	30	54		
4	57	M	VT various	MI	30	51	Redo after 1 month	
5	61	M	VT, VF	DCM	17	17	Death	CRT-D
6	69	M	VT various	MI, HCM	31	46	Redo after 1 and 15 months	
7	52	M	VT monomorphic	HCM	40	8	Death	
8	63	M	VT, VF	MI	25	41		
9	63	M	VT various	MI	25	40		
10	71	M	VT (on IEGM)	MI	25	36		Axillo-femoral and femoro-popliteal bypass
11	53	M	VT various	MI	20	30	No ES recurrence; ablation of VT after 1 year	
12	63	M	VT up to 260/min	MI	25	29		Abdominal Ao aneurysm
13	51	F	VT polymorphic	Myocarditis	20	25		
14	73	M	VT (on IEGM)	MI	26	23		
15	65	M	VT various, persistent AF	MI, CABG	28	22	Sporadic recurrences	
16	59	M	VT (on IEGM)	MI	28	21		Thrombocytopenia
17	54	M	VT (on IEGM)	MI	35	20		
18	60	F	VF focal	Non-compaction cardiomyopathy	35	20		LBBB
19	42	M	Polymorphic VT up to 300 bpm	DCM	40	17	After 1 month ES supressed pharmacologically	
20	66	M	VT various	AVR	35	14		
21	65	M	VT/VF	MI	15	13		
22	60	M	Polymorphic VT	MI	28	8		
23	67	M	VT various	MI	28 > 17	8	Redo after 4 months	Stent in right iliac artery, endarterectomy + PTA of the carotids
24	70	F	VT various	MI	28	7		CRT-D

EF — ejection fraction; FU — follow-up; M — male; VT — ventricular tachycardia; VT various — ventricular tachycardia with various electrophysiological characteristics; MI — myocardial infarction; CABG — coronary artery bypass grafting; CRT-D — cardioverter-defibrillator with the function of resynchronisation; VF — ventricular fibrillation; DCM — dilated cardiomyopathy; HCM — hypertrophic cardiomyopathy; ES — electrical storm; Ao — aorta; F — female; IEGM — intracardic electrocardiogram; AF — atrial fibrillation; LBBB — left bundle branch block; AVR — aortic valve replacement; PTA — percutaneous transluminal angioplasty

METHODS

The ablation procedures were performed with electro-anatomical CARTO system (Biosense, Johnson & Johnson) with use of an open-loop irrigated catheter. Nominal parameters of the ablation equipment were as follows: maximum temperature 48°C, maximum output power 35–45 W (depending on muscle thickness and local potential reduction on the ablation electrode) with flow velocity at the electrode tip of 20 mL/min.

In one patient, VT loop mapping and critical isthmus ablation were performed. In the remaining patients, due to haemodynamic instability caused by the arrhythmia and/or multiple type or polymorphic VT, the mapping was performed while in sinus rhythm. In post-MI patients, the scar region and injury zone were identified (area of less than 1 mV, sensitive to 20 mA pacing). Application lines were performed within the injury zone, between the scars or between the scar and an anatomical barrier (commonly the mitral valve). In patients with non-ischaemic cardiomyopathy, injury zones and pathological signals of Purkinje fibers (which were also the additional targets in post-MI patients) were searched for.

One procedure was performed with trans-septal approach, 3 with trans-septal and trans-aortic approach, the remaining with trans-aortic approach only. In 2 patients intra-cardiac echocardiography was used during the procedure. In 2 patients, after the endocardial mapping was performed, a minimally invasive surgical approach was used to acquire an epicardial map. In one of these patients epicardial cryoablation was performed due to close proximity of the left anterior descending coronary artery. In the remaining patients radiofrequency (RF) ablation was carried out by endocardial approach.

In 3 patients, the procedure was performed under general anaesthesia (in 1 patient due to haemodynamic and electrical instability and in 2 other patients due to epicardial approach). The remaining procedures were performed under local anaesthesia with fentanyl and midazolam administered for sedation.

Follow-up duration was 27.8 ± 15.9 months. The success of the ablation procedures was assessed by history taking, hospital discharge reports and ICD control visit records. In several cases we contacted the doctors taking care of the patients in outpatient facilities. We talked to families of the deceased patients. Detailed data regarding the procedures are presented in Table 2.

RESULTS

In our study group peri-procedural deaths were not recorded. In one patient, who initially presented with the left bundle branch block, complete heart block occurred following the procedure, as the VF trigger was in close proximity to the right bundle branch. The risk of the block was accepted by the patient and by the doctors prior to the procedure, because the patient was already protected with an ICD and the ablation of the trigger responsible for ES was deemed more important for this patient than the potential pacemaker dependency. No significant peri-procedural complications were observed.

During follow-up, 16 (66%) patients were free of arrhythmia. Sporadic VT bouts, terminated by the ICD with anti-tachycardia pacing, without discharge, were observed in 2 (8%) patients. The ES recurrence was noted in 3 patients, after 4 (14%) procedures; in 2 cases after 1 month, in one case after 4 months and in one case after 17 months. Three (12%) patients died, the deaths occurred after 8.5, 15 and 16.5 months from ablation. One patient died from cardiovascular causes that could not be identified in more detail. Two patients died due to decompensated HF and electro-mechanical dissociation (both were hospitalised in our intensive cardiac care unit at the time).

DISCUSSION

Our study shows that RF ablation or cryoablation of the arrhythmia substrate is an effective method of treatment of ventricular arrhythmias, refractory to pharmacological treatment in patients with ES. The method allowed for long-lasting freedom from arrhythmia not only in post-MI patients, but also in patients with other cardiomyopathies. Early recurrences of arrhythmia (about 1 month after the procedure, 2 patients) point to the failure of the procedure. It could have been related to the lack of unambiguous end-point of ablation in these patients. The ES recurrence after 4 months in one patient was secondary to significant progression of HF. The progression of HF was probably also the cause of late (over 1 year after the procedure) ES episodes and deaths.

The summary of studies related to ES treatment is presented in Table 3. In post-MI patients, the effectiveness of RF ablation in the treatment of ES was reported by Bansch et al. [10]. The triggers of polymorphic VT in 4 patients were monomorphic premature ventricular contractions (PVCs). In a similar group described by Peichl et al. [5], 2 out of 9 patients treated with ablation died due to HF progression over 13 ± 7 months of follow-up. In one patient ES recurred, but the PVCs were of different morphology. Despite the potential to eliminate arrhythmias that are directly life-threatening, the ablation procedure can not inhibit HF progression in the long-term and prevent its consequences. Two (or possibly three) of our patients died due to decompensated HF.

Premature ventricular contractions originating from Purkinje fibres play an important role in the development of recurrent VT and VF in patients with structural heart disease [5, 6, 10–12]. The Malcochov group performed two successful ablations in patients with amyloidosis in whom PVCs originating from Purkinje fibres were responsible for the initiation of recurrent VF [13]. In a patient with severe aortic regurgitation described by Li et al. [14], the elimination of PVCs from Purkinje fibres prevented the recurrences of VF in 2-month follow-up. There is also a case report of a patient with Brugada syndrome [11]. In our group, pathological potential elimination was carried out in 9 patients.

In patients with ischaemic cardiomyopathy and ICD in whom pharmacotherapy, deep sedation, overdrive pacing and cardioversion of VT were unsuccessful, arrhythmia substrate

Table 2. Characteristics of the ablation procedures

Patient no.	Type of procedure	Arrhythmia substrate treated	Time of procedure	X-ray scopy	Remarks
1	Endocardial, RF	LV inferior wall	240	12.4	
2	General anaesthesia, endocardial, RF	LV inferior wall	360	18.52	
3	Endocardial, RF	Base of PPM	200	9.98	
4	Endocardial, RF	LV inferior wall	220	30.93	t-s + tAo
4	Endocardial, RF	LV inferior wall	260	21.02	
5	Endocardial, RF	LV anterior wall	130	5.41	
6	Endocardial, RF	MV-Ao intervalvular fibrosa	170	7.78	During VT
6	Endocardial, RF	LV anterior wall	265	10.47	
	Epicardial map				
6	Endocardial, RF	Anterior wall injury zone and HPP	265	6.93	
7	Epicardial krio	Anterior wall along LAD	290	9.78	
	Endokardial map				
8	Endocardial, RF	LV anterior wall	275	0.83	
9	Endocardial, RF	Apical aneurysm margins	125	8.03	
10	Endocardial, RF	Lateral wall, injury zone, HPP	265	32.57	ICE t-s
11	Endocardial, RF	Antero-septal	115	0.57	
12	Endocardial, RF	Lateral wall HPP	155	13.22	t-s + tAo
13	Endocardial, RF	Antero-septal, HPP	170	8.58	
14	Endocardial, RF	LV inferior wall, injury zone, HPP	185	12.98	ICE, t-s + tAo
15	Endocardial, RF	Infero-lateral wall, MV region, HPP	175	3.13	
16	Endocardial, RF	Apex > inferior wall > MV	150	0	VT cessation
17	Endocardial and epicardial (via Cs), RF	LV inferior wall, posterior wall by the Cs	150	0.6	
18	Endocardial, RF	Focal, by the RBB	115	0	AVB III
19	Endocardial, RF	Lateral wall LV	130	0.08	
20	Endocardial, RF	Antero-septal part of RVOT/LVOT by the RBB	130	3.67	
21	Endocardial, RF	Periapical	200	3.13	
22	Endocardial, RF	Infero-lateral LV, HPP	115	0	
23	Endocardial, RF	Infero-lateral LV	205	2.2	
23	Endocardial, RF	Inferior and lateral wall LV up to the MV, HPP with LPB	210	9.9	t-s + tAo with stabilising sheath
24	Endocardial, RF	Inferior and posterior wall, HPP	235	14.42	

RF — radiofrequency current; LV — left ventricle; PPM — posterior papillary muscle; t-s — transseptal approach; tAo — transaortic approach; MV — mitral valve; Ao — aorta; VT — ventricular tachycardia; HPP — His-Purkinje potentials; LAD — left anterior descending coronary artery; ICE — intracardiac echocardiography; Cs — coronary sinus; RBB —right bundle branch; AVB — atrio-ventricular block; RVOT — right ventricular outflow tract; LVOT — left ventricular outflow tract; LPB — left posterior branch of the His bundle

ablation in the scar area caused full recovery in 3 patients and only sporadic ICD discharges in another two subjects [8]. The potential impact of ablation procedure on survival of patients with ICD in whom ES developed was emphasised by Carbucicchio et al. [3]. In their study, 95 the patients with coronary artery disease, dilated cardiomyopathy and arrhythmogenic right ventricular cardiomyopathy were included. They noted that the procedure prevented ES recurrences in the long-term, what can have a positive impact on cardiovascular mortality.

Reddy et al. [15] went even further in terms of improvement of prognosis in this patient group. In a prospective randomised study of 128 patients they demonstrated that performing prophylactic ablation of arrhythmia substrate in patients qualified for secondary prevention ICD implantation, significantly reduces the number of ES and ICD interventions. In terms of mortality reduction, only a trend was noted during the follow-up period of 22.5 ± 5.5 months (9% in the ablation group *vs* 17% in the control group), what is chiefly related to the fact that haemodynamic deaths were predominant in these patients.

Limitations of the study

As the procedures we describe were life-saving and were performed in patients referred from many centres from all over

Table 3. Summary of the literature data on ablation for electrical storm

	Patient no.	Aetiology	FU [months]	Effectiveness	Additional remarks
Bansch et al. [10]	4	1–7 days after revascularisation post MI (EF 25–37)	5.5, 14, 33	100%	
Kolettis et al. [7]	1	DCM	12	100%	
Schreieck et al. [8]	5	Post MI, beta-blockers + + amiodarone + IB unsuccesful; sedation, faster pacing	12–30	Full 60% Sporadic ICD intervention 40%	Anatomic ablation
Li et al. [14]	1	AVR	2	100%	
Peichl et al. [5]	9	Post MI	13 ± 7	8 patients without ES; 1 patient died — HF progression; 1 patient had recurrence	
Thoppil et al. [6]	1	Post MI	3	No arrhythmia	
Carbucicchio et al. [3]	95	CAD 72, DCM 10, ARVD 13	1–43	No VT 66%, no ES 92%, death 12%	Epicardial ablations 10
Nakagawa et al. [11]	1	Brugada syndrome	29	100%	RVOT

FU — follow-up; MI — myocardial infarction; EF — ejection fraction; DCM — dilated cardiomyopathy; ICD — implantable cardioverter-defibrillator; AVR — aortic valve replacement; ES — electrical storm; HF — heart failure; CAD — coronary artery disease; ARVD — arrhythmogenic right ventricular cardiomyopathy; RVOT — right ventricular outflow tract

the country, our work is a non-randomised retrospective analysis without the control group. Thus, it can not demonstrate the superiority of interventional management with ablation over other methods of treatment in ES patients. However, the treatment results are similar to results reported by other ablation centres and distinctly better than in the studies reporting on medical management.

CONCLUSIONS

1. The ablation of the ventricular arrhythmia substrate in the course of ES in patients with structural heart disease is a safe and effective method of treatment and probably improves the prognosis.
2. A proportion of these patients require ICD interventions as a result of disease progression.
3. The method does not prevent haemodynamic deaths.

Conflict of interest: *none declared*

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Ocena skuteczności ablacji podłoża arytmii u pacjentów z burzą elektryczną

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Streszczenie

Wstęp: Nawracające częstoskurcze komorowe oraz epizody migotania komór u pacjentów po przebytym zawale serca lub z inną chorobą organiczną serca wiążą się ze złym rokowaniem. Burzą elektryczną nazywa się wystąpienie u pacjenta 3 lub więcej wymagających elektroterapii tachyarytmii komorowych w ciągu 24 godzin. Obecnie definicja obejmuje najczęściej 3 adekwatne interwencje kardiowertera-defibrylatora (ICD) w ciągu 24 godzin. Problem dotyczy ok. 10–30% (do 40%) pacjentów z ICD. Skrajną postacią choroby jest złośliwa burza elektryczna, czyli 10 adekwatnych interwencji ICD w czasie godziny. W przypadku nieskuteczności leczenia przyczynowego i farmakoterapii antyarytmicznej szansą dla pacjenta jest ablacja.

Cel: Celem pracy była ocena bezpieczeństwa i skuteczności leczenia pacjentów z burzą elektryczną za pomocą ablacji.

Metody: Od lutego 2006 do maja 2010 r. w ośrodku autorów z powodu burzy elektrycznej wykonano 28 zabiegów ablacji u 24 pacjentów (21 mężczyzn, 3 kobiety w wieku 62,5 ± 7,8 roku). Zawał serca przebyło 18 osób, 2 z kardiomiopatią rozstrzeniową, 2 z kardiomiopatią przerostową (w tym 1 po zawale serca), 1 z kardiomiopatią gąbczastą, 1 z niewydolnością serca po wymianie zastawki aortalnej i 1 po zapaleniu mięśnia sercowego. Frakcja wyrzutowa wynosiła średnio 27,3 ± 6,5% (15–40%). Wszyscy pacjenci wyrazili pisemną, świadomą zgodę na zabiegi, które wykonano z użyciem systemu elektroanatomicznego CARTO z zastosowaniem elektrody przepływowej. Ze względu na niestabilność hemodynamiczną stwierdzanych zaburzeń rytmu i/lub mnogie lub wielokształtne formy częstoskurczu komorowego mapowanie przeprowadzono podczas rytmu zatokowego. Jeden zabieg wykonano z dostępu trasseptalnego, 3 z dostępu transseptalnego i transaortalnego, pozostałe tylko z dostępu przezaortalnego. U 2 pacjentów po utworzeniu mapy endokardialnej zdecydowano się na sporządzenie mapy epikardialnej z małego dostępu chirurgicznego. U 1 z tych chorych zastosowano krioablację epikardialną. U pozostałych wykonano ablację prądem o wysokiej częstotliwości (RF). U 3 osób zabieg przeprowadzono w znieczuleniu ogólnym (u 1 pacjenta ze względu na niestabilność hemodynamiczną i elektryczną, u 2 w związku z zabiegiem epikardialnym). Pozostałe zabiegi wykonano w znieczuleniu miejscowym z sedacją fentanylem i midazolamem.

Wyniki: W prezentowanej grupie nie występowały zgony okołozabiegowe. U 1 pacjentki, która wyjściowo miała blok lewej odnogi pęczka Hisa, po zabiegu wystąpił blok całkowity, ponieważ trigger wywołujący migotanie komór wywodził się z miejsca znajdującego się bezpośrednio przy prawej odnodze pęczka Hisa. W średnim czasie obserwacji wynoszącym 27,8 ± 15,9 miesięcy bez napadów arytmii pozostaje 16 (66%) osób. Sporadyczne napady częstoskurczów komorowych, przerywane stymulacją antytachyarytmiczną z ICD, bez wyładowań, miewa 2 (8%) pacjentów. Nawrót burzy elektrycznej wystąpił u 3 chorych, po 4 (14%) zabiegach, 2 razy po miesiącu, jeden po 4 miesiącach i jeden po 17 miesiącach. Zmarło 3 (12%) pacjentów — 1 z bliżej nieznanych przyczyn kardiologicznych, 2 w wyniku dekompensacji niewydolności serca w mechanizmie rozkojarzenia elektromechanicznego.

Wnioski: 1. Ablacja podłoża komorowych zaburzeń rytmu serca w przebiegu burzy elektrycznej u pacjentów z chorobą organiczną serca jest bezpieczną i skuteczną metodą leczenia, prawdopodobnie poprawia ich rokowanie. 2. Część osób z powodu postępu choroby wymaga interwencji ICD. 3. Metoda nie zapobiega zgonom hemodynamicznym.

Słowa kluczowe: burza elektryczna, ablacja RF, krioablacja, ablacja epikardialna, częstoskurcz komorowy, migotanie komór

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