ORIGINAL ARTICLE

Ventricular fibrillation induced by radiofrequency energy delivery for premature ventricular contractions arising from the right ventricular outflow tract: is implantable cardioverter-defibrillator indicated?

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KEY WORDS

catheter ablation, premature ventricular contractions, radiofrequency catheter ablation, right ventricular outflow tract, ventricular fibrillation

ABSTRACT

INTRODUCTION Inadvertently induced ventricular fibrillation (VF) by radiofrequency (RF) energy delivery for premature ventricular complexes (PVCs) is a rare phenomenon; nevertheless, it is crucial to assess long-term risk of sudden cardiac death in these patients.

OBJECTIVES The aim of our study was to define the long-term prognosis in patients with normal ejection fraction (EF), in whom VF was inadvertently induced by RF energy application during ablation of symptomatic idiopathic PVCs originating from the right ventricular outflow tract (RVOT).

PATIENTS AND METHODS Among over 20 000 RF catheter ablations performed at 5 tertiary centers (2008–2016), 6 patients (5 men) had VF induced by RF application to the RVOT. The mean (SD) age of patients was 35.2 (16.8) years. All patients had normal EF (≥60%). We analyzed the risk of malignant ventricular arrhythmias and assessed heart function during follow-up.

RESULTS After ablation, baseline contrast-enhanced magnetic resonance imaging was performed in 4 of the 6 patients; no area of late gadolinium enhancement was observed. One patient received an implantable cardioverter-defibrillator (ICD). Exercise tests revealed only rare PVCs. All patients completed the follow-up (mean [SD] duration of follow-up, 64.0 [34.9] months). All patients were alive, with no cases of syncope, documented ventricular tachycardia, or VF. The patient with an ICD received 2 inappropriate high-voltage therapies.

CONCLUSIONS Patients with inadvertently induced VF via RF energy application during ablation of PVCs from the RVOT, who have normal left ventricular function and no electrocardiography abnormalities have good prognosis and low VF risk during long-term follow-up. Therefore, ICD placement seems to be not indicated for these patients.

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INTRODUCTION Idiopathic premature ventricular complexes (PVCs) originating from the right ventricular outflow tract (RVOT) in adult patients without structural heart disease are considered benign and with good prognosis. According to current guidelines, ablation is indicated for this

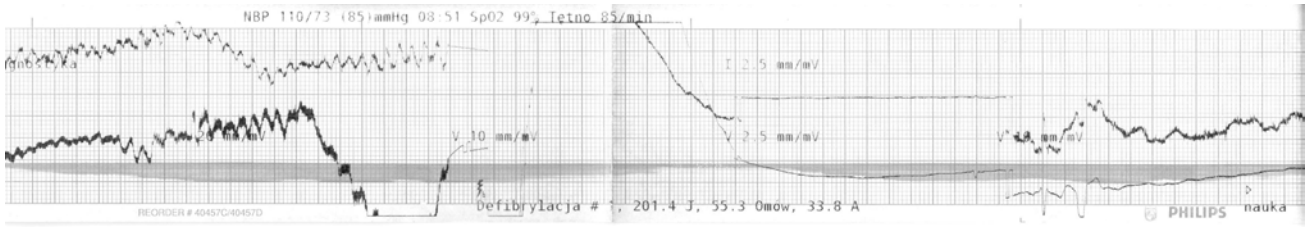

FIGURE 1 Electrocardiogram recording from external defibrillator. Transthoracic, external cardioversion delivery for inadvertently induced ventricular fibrillation by radiofrequency energy application (patient no. 3, **TABLE 1**)

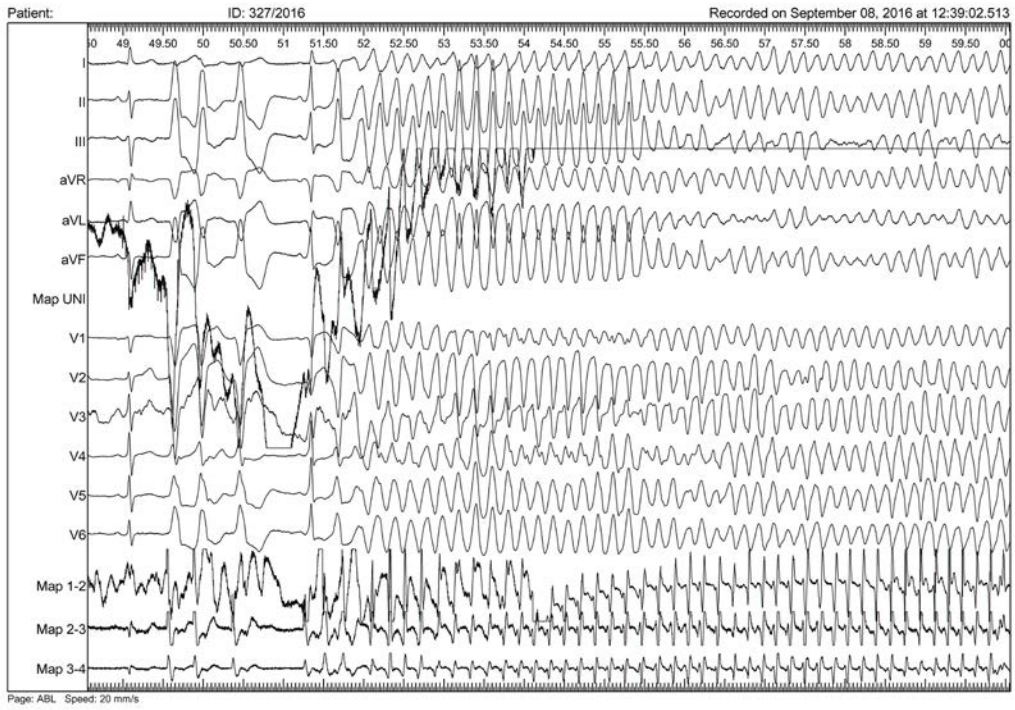

FIGURE 2 Ventricular fibrillation triggered during radiofrequency energy delivery (patient no. 6, **TABLE 1**)

group of patients (class I recommendation).[1,2] Application of radiofrequency (RF) energy in sinus rhythm at the earliest activation of the PVC site induces repetitive PVCs or tachycardia with QRS morphology similar to the PVCs as a result of an increase in the temperature of calcium-overloaded cells and the development of afterdepolarization, and subsequent triggered activity.[3] In some patients, the rapid acceleration of ventricular arrhythmia induced by RF application may lead to ventricular fibrillation (VF).[4]

Implantation of implantable cardioverter-defibrillator (ICD) and frequent discharges can lead to posttraumatic stress disorder.[5]

The aim of the study was to define long-term risk of sudden cardiac death in patients with inadvertenly induced VF by RF application during ablation of PVCs originating from the RVOT.

PATIENTS AND METHODS

Study population

We retrospectively analyzed the data of over 20 000 patients (2008–2016) who had been referred to 5 tertiary centers specialized in RF catheter ablation for all types of arrhythmias. We included patients based on the following criteria: 1) VF inadvertently induced by RF application during ablation of symptomatic monomorphic PVCs originating from the RVOT; 2) normal ejection fraction (EF) ≥60%; 3) no history of sustained ventricular tachycardia (VT) or VF; 4) no history of myocardial infarction, diagnosed cardiomyopathy, or any abnormalities on electrocardiography (ECG) suggesting additional electrical disease.

Six patients (5 men) fulfilled the above criteria. The mean (SD) age of patients was 35.2 (16.8) years. In all patients, ventricular arrhythmia required cessation of the RF delivery, and in 5 patients, a transthoracic external cardioversion delivery was required (**FIGURE 1**). One patient had nonsustained self-terminating VF (**FIGURE 2**). VF episodes occurred during normal state and were not connected with isoproterenol infusion.

The study was conducted according to the principles of the Declaration of Helsinki. All patients provided written informed consent for the ablation procedure and for the scientific data analysis. The consent for the procedure was approved by the institutional ethics committee.

Electrophysiological study and catheter ablation

An electrophysiological study was performed in the fasting and sedated state. All patients signed

TABLE 1 Baseline characteristics of the patients

Parameter	Patient					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Age, y	19	23	29	36	38	66
Sex	M	M	F	M	M	M
EF, %	69	60	60	70	70	64
CAD	No	No	No	No	No	Yes
Arterial hypertension	Yes	No	No	No	No	Yes
3-dimensional system	EnSite	CARTO	CARTO	CARTO	CARTO	CARTO
No. of RF ablations	1	1	1	1	3	1
Follow-up	71	106	57	88	58	3
ICD implanted	No	Yes	No	No	No	No

Abbreviations: CAD, coronary artery disease; EF, ejection fraction; ICD, implantable cardioverter–defibrillator; RF, radiofrequency

an informed consent prior to the ablation procedure. Antiarrhythmic drugs were discontinued at least 5 half-lives before the procedure. A heparin bolus of 50 to 100 IU/kg was administered, and after each hour, another bolus of 1000 IU was administered. Intracardiac bipolar electrograms, as well as 12-lead ECG, were recorded digitally. All measurements were performed using on-screen electronic calipers at a sweep speed of 100 to 200 mm/s and gain setting of 0.1 to 0.2 mV/cm. The following catheters, in accordance with the study protocol, were used: 1) a 7 F steerable, diagnostic quadripolar catheter with 2–5–2 mm interelectrode spacing (Marinr MCXL, Medtronic, Inc., Minneapolis, Minnesota, United States) placed in the coronary sinus; and 2) ablation catheters: an 8 F irrigated-tip catheter or DS ablation catheter (Biosense Webster, Inc., Diamond Bar, California, United States).

The origin of PVCs was determined based on detailed activation and pace mapping. In particular, during activation mapping, the local activation time was consistently measured from the onset of the electrogram (earliest positive or negative deflection) of the mapping catheter's distal bipole to the earliest onset of the QRS complex in any of the 12 ECG leads and to the steepest negative deflection in the unipolar signal displayed in the mapping system. Activation times were measured by 2 independent observers and displayed on a 3-dimensional electroanatomic map. We used a 3-dimensional system CARTO XP or CARTO 3 system (Biosense Webster, Inc.) or EnSite™ NavX (St. Jude Medical, St. Paul, Minnesota, United States). Stimulator pins were not connected to the direct ports on the Carto 3 system.

RF energy was delivered with a power of 35 W and a maximum temperature of 45°C. Acute success was defined as elimination of clinical arrhythmia during RF and the inability to induce clinical PVCs at the end of the procedure, with no recurrence during 24 hours of postprocedural hospital ECG monitoring. In all patients, antiarrhythmic drugs were not reinitiated if ablation was acutely successful.

Follow-up The follow-up data were obtained from hospital and outpatient clinic records. The evaluation of the patients comprised clinical history, physical examination, a 12-lead ECG, echocardiography, 24-hour Holter monitoring, exercise test, magnetic resonance imaging (MRI), electrophysiological study, and coronary angiography in patients with risk factors for ischemic heart disease. All patients were evaluated at least 3 times. Holter monitoring was performed at an interval of 6 months in the first year after the last successful RF ablation procedure and at an interval of 12 months thereafter. Patients were asked systematically about symptoms of recurrent arrhythmias and encouraged to notify the clinic in the case of recurrence at any time during the follow-up. Patients with recurrent arrhythmia were offered a repeat ablation. In 4 of 6 patients, MRI was performed. One patient received an ICD and we checked the device regularly.

Statistical analysis Categorical variables were expressed as numbers and percentages, and continuous variables—as median and range or mean with 1 standard deviation. Categorical variables were compared using the χ^2 test. A P value of less than 0.05 was considered significant. Analyses were performed using SPSS software (IBM, Armonk, New York, United States).

RESULTS

The baseline characteristics of the patients are presented in TABLE 1. Six patients had 8 RF ablations (mean [SD], 1.33 [0.5]). Five patients underwent ablation with the CARTO XP or CARTO 3 system and one patient—with EnSite™ NavX.

We used ThermoCool catheter in 4 patients, Smart Touch catheter in 1 patient, and Celsius DS ablation catheter in 1 patient (all catheters, Biosense Webster).

VFs occurred during normal state and were not associated with infusion of isoproterenol or other β-mimetics.

All patients had frequent PVCs with a preablation burden of 23% to 42% and with no evidence of decreased left ventricular function. The mean (SD) left ventricular EF was 65.5% (4.8%). One patient had stable coronary artery disease (coronary angioplasty and stent implantation in the right coronary artery 3 years prior to RF ablation, without any complaints and normal exercise test results). After VF episodes, contrast-enhanced MRI was performed in 4 patients but did not show any area of late gadolinium enhancement. An electrophysiological study and ventricular stimulation performed in 1 patient 6 months after the VF episode did not show ventricular arrhythmia. An exercise test performed in all patients after ablation did not reveal any

significant arrhythmia besides infrequent single PVCs. One patient (no. 2, TABLE 1) had an ICD implanted. The mean (SD) procedure time was 70 (19.7) minutes (range, 60–110 minutes) and the mean (SD) fluoroscopy time was 2.5 (2.3) minutes (range, 0.9–4.17 minutes).

Long-term outcomes During the mean (SD) follow-up duration of 64.0 (34.9) months, all patients were alive and none experienced syncope episodes or documented VT or VF. All patients had normal heart function with a normal EF. The patient with the ICD, during the 106 months of follow-up, had 2 inappropriate ICD discharges: the first due to supraventricular tachycardia and the second due to T-wave oversensing. He did not experience VT or VF episodes.

DISCUSSION

To our knowledge, this study is the first to report on a group of patients with VF inadvertently induced by RF application, with a long-term follow-up. Sustained polymorphic VT or VF during RF ablation of PVCs arising from the RVOT has rarely been described and only as case reports.[6,7]

The mechanism underlying these events is still unknown. Previous case reports have suggested that hyperthermia causes membrane depolarization, reversible and irreversible loss of excitability, and abnormal automaticity.[8,9] Other authors suggested that PVCs or tachycardia initiated during RF ablation might be due to thermal facilitation of triggered activity. Less possible underlying mechanisms include ischemia and mechanical stimulation induced by the ablation catheter. Stimulation from temperature elevation or mechanical stress during RF energy deliveries may cause VF in patients with idiopathic ventricular arrhythmias arising from the RVOT. However, malignant forms of VT, VF, and polymorphic VT are occasionally initiated by PVCs arising from the RVOT.[8,9] Functional block and delayed conduction by rapid firing due to triggered activity or micro-reentry arising from a single focus may lead to chaotic ventricular conduction causing VF or polymorphic VT (or both).[10] The R-on-T phenomenon is also possible. Noda et al[11] reported a malignant entity of VF or polymorphic VT initiated by PVCs originating from the RVOT in patients without structural heart disease.

Park et al[12] reported a spontaneous VF occurrence in patients with PVCs, during infusion of isoproterenol. In our patients, VF was not connected with infusion of any β-mimetic.

The decision to implant the ICD in a single patient was made by the team in 2008, but we have no knowledge of the future risk of arrhythmia in our study group.

The most important finding of this study is that patients with VF induced during RF delivery have a good prognosis and the risk of malignant arrhythmia seems to be low. Nevertheless, a careful evaluation of these patients in the outpatient clinic is recommended.

Study limitations This was a retrospective analysis; therefore, several limitations must be considered. The main limitation was the small number of enrolled patients. Moreover, not all data concerning the ablation procedures were available.

VF during RF ablation could result from current leak in the ablation system. This may be caused by shortening and inadequate grounding of the current leak. Nevertheless, in our study, VF occurred independently in 5 electrophysiological labs, and the above mechanism seems to be extremely rare.

Conclusions Patients with VF inadvertently induced by RF energy application during the ablation of monomorphic PVCs originating from the RVOT, who have normal left ventricular function on echocardiography and no ECG abnormalities suggesting additional electrical disease, have a good prognosis and a low risk of VF during long-term follow-up. Therefore, ICD placement seems not to be indicated in these patients.

CONTRIBUTION STATEMENT MO and PD are the main coauthors of the study; they contributed to data collection, study concept, data analysis and interpretation, and critical revision and final approval of the manuscript. PU, RB, and RL contributed to data analysis, interpretation, and final approval of the manuscript. DK, EK, DŁ, MS, ZK, and MB contributed to data collection and final approval of the manuscript. ŁS contributed to final approval of the manuscript.

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REFERENCES

1 Priori SG, Blomström-Lundqvist C, Mazzanti A, et al. 2015 ESC Guidelines for the management of patients with ventricular arrhythmias and the prevention of sudden cardiac death: The Task Force for the Management of Patients with Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death of the European Society of Cardiology (ESC) Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC). Europace. 2015; 11: 1601-1687.

2 Wojdyła-Hordyńska A, Kowalski O, Hordyński GJ, et al. The effect of radiofrequency catheter ablation of frequent premature ventricular complexes and arrhythmia burden on left ventricular function. Kardiol Pol. 2017; 75: 698-704.

3 Mugelli A, Cerbai E, Amerini S, et al. The role of temperature on the development of oscillatory afterpotentials and triggered activity. J Mol Cell Cardiol. 1986; 18: 1313-1316.

4 Yamada T, McElderry HT, Allred JD, et al. Ventricular fibrillation induced by a radiofrequency energy delivery for idiopathic premature ventricular contractions arising from the left ventricular anterior papillary muscle. Europace. 2009; 11: 1115.

5 Maryniak A, Szumowski L, Orczykowski M, et al. Anxiety and depression among the patients with frequent implantable cardioverter-defibrillator discharges. Int J Cardiol. 2009; 20; 132: e80-e801.

6 Ito S, Tada H, Lee JD, et al. Ventricular fibrillation induced by a radiofrequency energy delivery for idiopathic right ventricular outflow tachycardia. Int J Cardiol. 2008; 128: e65-e67.

7 Iijima K, Chinushi M, Furushima H, et al. Ventricular fibrillation triggered during and after radiofrequency energy delivery to the site of origin of idiopathic right ventricular outflow tract arrhythmia. Pacing Clin Electrophysiol. 2009; 32: 406-409.

8 Nath S, Lynch C, Whayne JG, et al. Cellular electrophysiological effects of hyperthermia on isolated guinea pig papillary muscle. Circulation. 1993; 88: 1826-1831.

9 Letsas KP, Efremidis M, Bramos D, et al. Sustained polymorphic ventricular tachycardia induced during radiofrequency catheter ablation of idiopathic right ventricular outflow tract extrasystoles. Indian Pacing Electrophysiol J. 2011; 11: 56-58.

10 Shimizu W. Arrhythmias originating from the right ventricular outflow tract: how to distinguish "malignant" from "benign"? Heart Rhythm. 2009; 6: 1507-1511.

11 Noda T, Shimizu W, Taguchi A, et al. Malignant entity of idiopathic ventricular fibrillation and polymorphic ventricular tachycardia initiated by premature extrasystoles originating from the right ventricular outflow tract. J Am Coll Cardiol. 2005; 46: 1288-1294.

12 Park YM, Lee HS, Lim RS, et al. Inadvertently developed ventricular fibrillation during electrophysiologic study and catheter ablation: incidence, cause and prognosis. Korean Circ J. 2013; 43: 474-480.