Acute and long-term results of bipolar radiofrequency catheter ablation of refractory ventricular arrhythmias of deep intramural origin

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BACKGROUND Successful bipolar radiofrequency catheter ablation (RFCA) of refractory ventricular arrhythmias (VAs) has been reported. However, the efficacy, safety, and long-term outcomes of bipolar RFCA of VAs are not fully determined.

OBJECTIVE The purpose of this study was to evaluate the effectiveness and safety of bipolar RFCA in treating refractory VAs during long-term follow-up.

METHODS Eighteen patients who underwent bipolar RFCA for ventricular tachycardia (VT) at 7 institutions were retrospectively investigated. Underlying heart diseases included remote myocardial infarction (n = 3 [17%]) and nonischemic cardiomyopathy (n = 15 [83%]). Although unipolar RFCA was performed in all patients, either it failed to suppress VT or VT recurred. The interventricular septum, left ventricular free wall, and left ventricular summit were targeted for bipolar RFCA.

RESULTS Acute success (VT termination and/or noninducibility) was achieved with bipolar RFCA in 16 patients (89%). Complications during the procedure included complete atrioventricular block (n = 2) and coronary artery stenosis (n = 1). One patient underwent chemical ablation after bipolar RFCA failure. At 12-month follow-up, VT reoccurred in 8 patients (44%). However, in patients with recurrence, VT burden had decreased: only 4 patients underwent re-RFCA, and only 1 of the 4 required chemical ablation. In the remaining 4 patients, re-RFCA was not required, as VT was controlled by medication or an implantable cardioverter–defibrillator.

CONCLUSION Bipolar RFCA is useful for acute suppression of refractory VT. Although VT recurrence rates during long-term follow-up were relatively high, we observed a significant reduction in VT burden.

KEYWORDS Bipolar ablation; Complication; Outcome; Radiofrequency catheter ablation; Ventricular arrhythmias

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Introduction

Radiofrequency catheter ablation (RFCA) is the mainstay of therapy for ventricular arrhythmias (VAs). However, if the arrhythmia origin or circuit is located at deep intramural sites, RFCA might be difficult and fail. If endocardial or epicardial approaches do not suppress VAs, some patients may require intramural or transmural ablation. Furthermore, lesions created during bipolar ablation have been reported to be larger than those created during sequential unipolar ablation.[1] Creating transmural lesions may be effective in suppressing

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VAs of deep intramural origin. This study aimed to evaluate the effectiveness and safety of bipolar ablation in treating refractory VAs during long-term follow-up.

Methods

Study population

Eighteen patients with structural heart disease who underwent their first bipolar RFCA for ventricular tachycardia (VT) at 7 institutions from 2012 to 2017 were retrospectively investigated. Unipolar RFCA was performed in all patients, but either it failed to suppress VT or VT recurred. Clinical data collection was approved by our institutional review boards. Of the 18 patients, 3 had a history of remote myocardial infarction and 15 had a history of nonischemic cardiomyopathy (NICM). This study was approved by the local research ethics committees of the participating institutes, and all patients provided written informed consent for bipolar RFCA.

Electrophysiological study and mapping

Details on electrophysiological study and mapping are given in the Supplemental Methods.

Ablation strategy

We first attempted to terminate VT or make VT noninducible by performing unipolar RFCA from multiple sites (sequential unipolar RFCA). When VT was not terminated or still was inducible after sequential unipolar RFCA, we performed bipolar RFCA. If VT remained inducible after bipolar RFCA, we considered performing chemical ablation (ie, transcoronary ethanol infusion). After coronary angiography, a guidewire was inserted into the target branch of the coronary artery. An over-the-wire balloon was deployed into the target branch vessel, and ethanol was infused into the target vessel.[2]

Bipolar RFCA setup

Details on the bipolar RFCA setup are given in the Supplemental Methods.

Measuring outcomes

All patients were observed using a bedside or telemetry electrocardiographic monitor device until discharge and subsequently followed in the outpatient clinic. The primary endpoint was VT recurrence in the setting of appropriate implantable cardioverter–defibrillator (ICD) or cardiac resynchronization therapy–defibrillator (CRT-D) therapy. The secondary endpoint was all-cause mortality.

Statistical analysis

Continuous variables are expressed as mean ± SD. Categorical variables are expressed as number (percentage). Kaplan–Meier survival analysis was used to estimate the endpoint survival function. All statistical analyses were performed using SPSS for Windows Version 23 (IBM Corp., Armonk, NY).

Results

Baseline characteristics

Baseline characteristics are given in Table 1. Three patients (17%) had remote myocardial infarction as an underlying heart disease. All other patients had NICM. Although unipolar RFCA was performed before bipolar RFCA in 17 patients (94%), either ablation failed or VT recurred. Median interval between the last unipolar RFCA session and the first bipolar RFCA session was 73 days (range 6–1278 days). In the remaining 1 patient (no. 7), bipolar RFCA was performed after failed unipolar RFCA in the initial session.

Ablation results

RFCA results are listed in Table 2. Bipolar radiofrequency (RF) was started at 30 W and then increased up to 45 W when impedance did not sufficiently decrease in all cases except one. Bipolar RF was started at 20 W in the remaining 1 patient (no. 14) with summit VT because 1 ablation catheter was in the anterior interventricular vein and then RF was increased up to 40 W. Unipolar RFCA was first performed before bipolar RFCA in the same session (number of RF applications: 2–43; 156–7496 seconds). After unipolar RFCA failure, bipolar RFCA was performed (number of RF applications: 1–27; 30–1451 seconds).

The ventricular septum was targeted during bipolar RFCA in 9 patients (50%), and bipolar RFCA of the left ventricular (LV) free wall was performed in 3 patients (16%). In 1 patient (no. 17) with cardiac sarcoidosis, VT originated from the anterior junction of the LV and right ventricle (RV). Although unipolar RFCA at the anterior junction of the LV and RV septa terminated VT, VT remained inducible. Bipolar RFCA between the LV and RV septa subsequently was performed and resulted in temporary suppression of arrhythmia; however, VT still was inducible. Therefore, the ablation catheter at the RV septum was moved to an epicardial site opposite to the anterior junction of the LV septum. VT was terminated and became noninducible after bipolar RFCA of the free wall.

In 5 patients (28%), VT was thought to originate from the LV summit. After failure of unipolar RFCA at the RV outflow tract, aortic sinus cusp, LV outflow tract, and distal to the coronary sinus, bipolar RFCA was performed. In 4 of these patients, 1 catheter was placed at an LV outflow tract endocardial site and another catheter was placed at either an LV epicardial site in 2 patients, an anterior interventricular vein in 1 patient, or the left atrial appendage in 1 patient. In the remaining patient, 1 catheter was placed at the left coronary cusp and another catheter was placed at the RV outflow tract septum.

In a patient (no. 18) with LV summit VT who received bipolar RFCA between an LV endocardial site and epicardial site, VT originating from a different site—the ventricular septum—became inducible. Therefore, bipolar RFCA at the ventricular septum also was performed. Pacing from the RV septum during VT exhibited concealed entrainment, and the postpacing interval was similar to the VT cycle

Table 1 Baseline characteristics

						Previous medication			Echocardiography		Previous sessions
Case	Age (y)	Sex	Underlying heart disease	SMVT or NSVT	ICD implantation	Amiodarone	β-Blocker	Other	LVDD (mm)	LVEF (%)	(unipolar RFCA)
1	74	M	Cardiac sarcoidosis	SMVT	CRT-D	+	+	Mexiletine	53	43	2
2	56	M	Remote MI	SMVT	None	–	+	Bepridil	55	47	2
3	73	M	NICM	NSVT	None	–	+	Sotalol	50	44	1
4	63	M	Cardiac sarcoidosis	SMVT	ICD	–	+	Sotalol	60	55	5
5	61	M	NICM	SMVT	None	–	+	—	57	51	1
6	65	M	Cardiac sarcoidosis	SMVT	ICD	+	+	—	53	51	2
7	73	M	Left ventricular aneurysm	SMVT	ICD	+	+	—	64	44	0
8	70	M	Cardiac sarcoidosis, post-AVR	SMVT	ICD	+	+	Sotalol	73	12	2
9	63	M	HCM	SMVT	ICD	+	+	—	52	40	1
10	71	M	HCM	SMVT	None	–	–	—	54	40	2
11	67	M	Remote MI	SMVT	ICD	+	–	—	75	21	2
12	71	M	Dilated cardiomyopathy	NSVT	None	–	+	Propafenone	60	29	2
13	70	M	Remote MI	SMVT	ICD	+	+	—	59	42	1
14	60	M	Dilated cardiomyopathy	NSVT	None	–	+	Mexiletine	74	21	2
15	52	M	Cardiac sarcoidosis	SMVT	ICD	–	–	Sotalol	59	40	1
16	64	F	Dilated cardiomyopathy	SMVT	ICD	+	+	—	57	40	2
17	68	F	Cardiac sarcoidosis	SMVT	CRT-D	–	+	Bepridil	43	51	3
18	45	M	HCM	SMVT	ICD	+	–	—	54	61	1
Mean ± SD	65 ± 8	16 M							58 ± 9	41 ± 13	1.7 ± 1.1

AVR = aortic valve replacement; CRT-D = cardiac resynchronization therapy–defibrillator; HCM = hypertrophic cardiomyopathy; ICD = implantable cardioverter–defibrillator; LVDD = left ventricular end-diastolic dimension; LVEF = left ventricular ejection fraction; MI = myocardial infarction; NICM = nonischemic cardiomyopathy; NSVT = nonsustained ventricular tachycardia; RFCA = radiofrequency catheter ablation; SMVT = sustained monomorphic ventricular tachycardia.

Table 2 Bipolar ablation results

No.	VT morphology	CARTOSOUND	Ablation target site	Ablation catheter (no. 1)		Ablation catheter (no. 2)		Acute success	Acute result	Complication
1	3	–	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	Termination and nonsustainable	Steam pop
2	2	–	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	Noninducible	
3	1	–	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	NSVT elimination	
4	5	+	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	Noninducible	Complete AVB*
5	3	+	LV summit	Irrigated	LCC	Irrigated	RVOT	Yes	NSVT elimination	
6	5	+	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	Noninducible	
7	3	+	Septum	Irrigated	LV septum	Irrigated	RV septum	No	2 VTs became noninducible, 1 VT inducible	
8	7	+	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	Noninducible	Complete AVB
9	4	–	LVFW	Irrigated	LV endo	Irrigated	Epi	Yes	VT termination and noninducible	
10	1	–	LVFW	Irrigated	LV endo	8-mm NI	Epi	Yes	NSVT elimination	
11	4	+	LVFW	Irrigated	LV endo	4-mm NI	Epi	Yes	VT termination and noninducible	
12	1	+	LV summit	Irrigated	LV endo	8-mm NI	Epi	Yes	NSVT/VPC elimination	
13	2	+	Septum	Irrigated	RV septum	4-mm NI	LV septum	Yes	VT termination and noninducible	
14	1	+	LV summit	Irrigated	LV endo	8-mm NI	AIVV	Yes	NSVT/VPC elimination	
15	5	+	Septum	Irrigated	LV septum	Irrigated	RV septum	Yes	VT termination and noninducible	
16	3	+	LV summit	Irrigated	LV endo	Irrigated	LAA	Yes	VT termination and noninducible	
17	2	+	Anterior junction	Irrigated	LV septum	Irrigated	RV septum	Yes	VT termination and noninducible	
				Irrigated	LV endo	Irrigated	Epi			
18	2	+	LV summit	Irrigated	LV endo	Irrigated	Epi	Yes	Noninducible	
			Septum	Irrigated	LV endo	Irrigated	RV endo	No	Inducible, chemical ablation was needed	Coronary artery occlusion

AIVV = anterior interventricular vein; AVB = atrioventricular block; endo = endocardium; epi = epicardium; LAA = left atrial appendage; LCC = left coronary cusp; LV = left ventricle; LVFW = left ventricular free wall; NI = nonirrigated; NSVT = nonsustained ventricular tachycardia; RV = right ventricle; RVOT = right ventricular outflow tract; VPC = ventricular premature complex; VT = ventricular tachycardia.

*Complete AVB occurred during unipolar ablation at the LV septum.

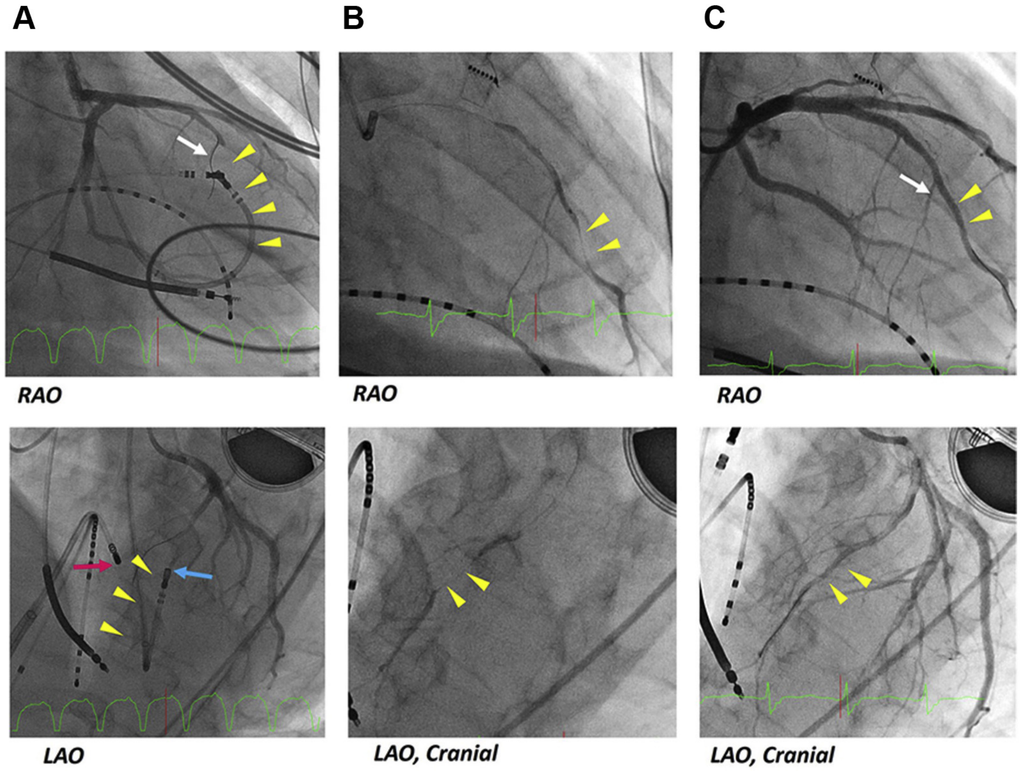

Figure 1 Coronary angiography after bipolar radiofrequency catheter ablation (RFCA). In patient no. 18, ventricular tachycardia still was inducible after bipolar RFCA between the left ventricular (LV) and right ventricular (RV) septa. **A, B:** Ethanol infusion into the septal artery *(white arrow)* was planned. Coronary angiography revealed total occlusion of the left anterior descending artery (LAD) (segment no. 8, *yellow arrowheads*), which had not been observed before bipolar RFCA. The LAD was located between 2 catheters placed at the LV septum (*blue arrow*) and RV septum (*red arrow*). **C:** Percutaneous coronary intervention was performed, and a drug-eluting stent was implanted. LAO = left anterior oblique; RAO = right anterior oblique.

length. Pacing from the LV septum also exhibited concealed entrainment with prolonged stimulus–QRS duration, and the postpacing interval also was similar to the VT cycle length. Therefore, bipolar RFCA between the RV and LV septa was performed (Supplemental Figure S1). In addition to this case, most patients in this study had multiple VT morphologies.

In 16 patients (89%), termination and/or noninducibility of all VTs was achieved by bipolar RFCA. In 1 patient (no. 7) with an LV posterior septum aneurysm, VT still was inducible after sequential unipolar RFCA and bipolar RFCA at the inferior septum.

In the remaining case of a patient (no. 18) with hypertrophic cardiomyopathy (HCM), VT originating from the apical septum remained inducible after sequential unipolar and bipolar RFCA between the LV and RV apical septa.

Complications

For all ablation procedures, complications occurred in 4 patients. Steam pop occurred during bipolar RFCA with >45-W output at the ventricular septum in 1 patient (no. 1). However, neither cardiac tamponade nor septal perforation occurred in any case. In 2 patients, complete atrioventricular block (AVB) occurred; nevertheless, it occurred during unipolar RFCA at the LV septum in 1 patient (no. 4) with cardiac sarcoidosis. Although he had undergone ICD implantation before this RFCA session, it was upgraded to CRT-D to avoid full RV pacing with reduced cardiac systolic function at a later date. In another patient (no. 8) who had already received CRT-D and full biventricular pacing, complete AVB was revealed after bipolar RFCA, because VT ablation was performed during biventricular pacing. In 1 patient (no. 18) with HCM, coronary angiography revealed occlusion of the left anterior descending artery (LAD; segment 8) after bipolar RFCA (Figure 1). Intravascular ultrasound showed no thrombus or atherosclerosis, and we assumed intimal edema. An intravenous vasodilator was not effective, and a drug-eluting stent was immediately implanted. In this case, multidetector computed tomography recorded before RFCA revealed a myocardial bridge at this site (Supplemental Figure S2). Hence, the proximity of the LAD to the myocardial bridge and anterior septum might be a cause of LAD occlusion during septal bipolar RFCA.

Follow-up data

Figure 2 and Supplemental Table S1 give the clinical outcomes after bipolar RFCA. Eight of 18 patients (44%) had VT recurrence by 12 months (Figure 2A). Another 2 patients had VT recurrence during longer follow-up of 3–70 months. Therefore, 10 of 18 patients (56%) experienced VT recurrence (Figure 2B).

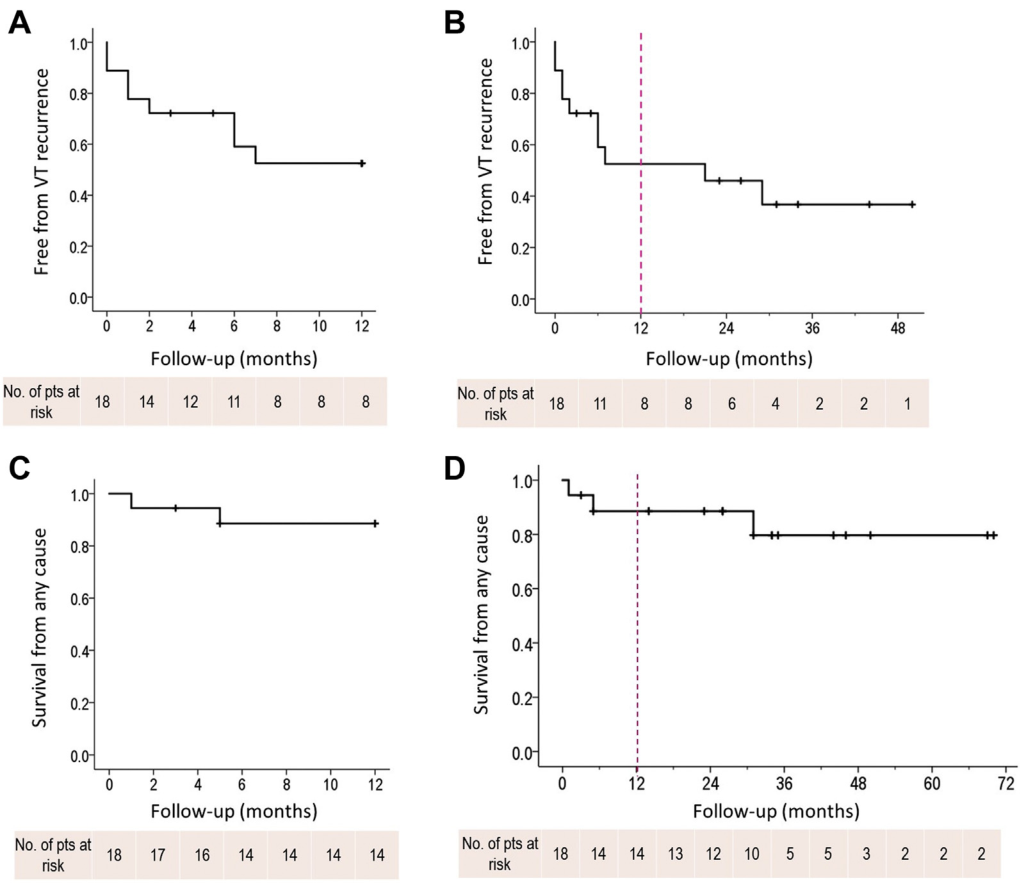

Figure 2 Ventricular tachycardia (VT) recurrence and patient survival. Kaplan–Meier curves showing VT recurrence at 12-month follow-up (**A**) and maximum 50-month follow-up (**B**); and survival from any cause of death at 12-month follow-up (**C**) and maximum 70-month follow-up (**D**). Although the VT recurrence rate was high, the mortality rate was relatively low during long-term follow-up.

Although the VT recurrence rate was high, the mortality rate during follow-up was relatively low (Figures 2C and 2D). Three patients died during follow-up. One patient (no. 14) with dilated cardiomyopathy did not have VT recurrence but died of heart failure 5 months after bipolar RFCA. One patient (no. 11) with remote myocardial infarction who had undergone bipolar RFCA because of VT storm died 1 month after RFCA due to malignant lymphoma. Another patient (no. 1) with cardiac sarcoidosis died of sudden death of unknown cause 31 months after bipolar RFCA.

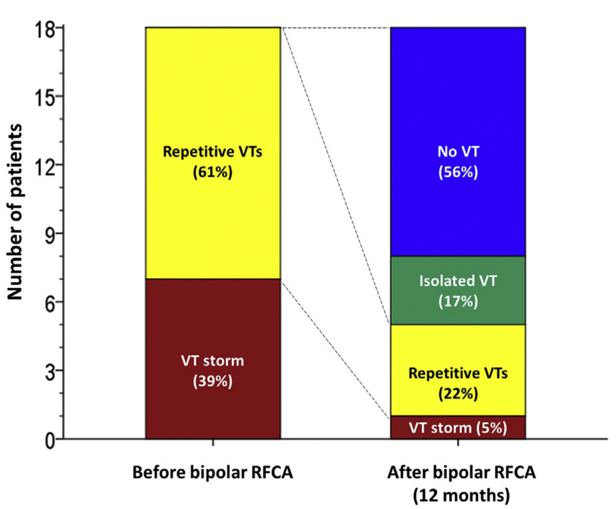

Figure 3 Change in ventricular tachycardia (VT) burden after bipolar radiofrequency catheter ablation (RFCA). VT burden decreased after bipolar RFCA, even in patients with VT recurrence (n = 8). Whereas 7 patients suffered from VT storm before bipolar RFCA, only 1 patient had VT storm after bipolar RFCA. Only 4 of 8 patients with VT recurrence required re-RFCA.

VT burden was decreased after bipolar RFCA even in patients with VT recurrence (Figure 3). Although VT storm was recorded in 7 patients before bipolar RFCA, it was observed in only 1 patient after bipolar RFCA. Only 4 patients required another round of RFCA (re-RFCA) because of ongoing ICD shocks for repetitive VT (n = 3) or VT storm (n = 1). VT storm recurred in 1 patient (no. 9) with HCM, and re-RFCA was performed 1 month after bipolar RFCA. The morphology of the patient's recurrent VT was different from the previously targeted VT. Because VT still was inducible after re-RFCA, chemical ablation was performed and VT became noninducible. Among other cases of VT recurrence, re-RFCA was performed in 3 patients (no. 4, 6, and 8) with cardiac sarcoidosis due to the frequency of events and delivery of ICD shocks. In these 3 patients, recurrent VT also differed from any VT that had been recorded and targeted during the previous ablation procedure.

Discussion

This study had several findings. First, acute success was achieved with bipolar RFCA in most patients with refractory VAs (89%). Second, complications (eg, steam pop, complete AVB, coronary artery occlusion) during the ablation procedure occurred in 4 patients (22%). Third, VA recurrence rate was relatively high (44%) at 12-month follow-up after acute success with bipolar RFCA. Nevertheless, VT burden was decreased even in patients with VT recurrence. Re-RFCA for sustained VT was necessary in only 4 patients, and recurrent VT was morphologically distinct from VT that had been targeted in the previous procedure.

RFCA is the mainstay of therapy for VAs. However, if the arrhythmia originates from a deep intramural site, RFCA may be difficult and fail.[1,3,4] Sequential unipolar RFCA from multiple sites for summit VT has been reported to be effective.[5] Although we also performed sequential unipolar RFCA from multiple sites for patients with summit VT (no. 5, 12, 14, 16, and 18), the effectiveness was transient. The differences in results of unipolar RFCA from multiple sites between our present study and the previous report have several probable causes. First, in the present study, a contact force sensing catheter was not used in 2 of 5 cases because of its unavailability in Japan at that time. Second, we did not attempt unipolar RFCA with half-normal saline as the cooling irrigant, which was reported only recently.[6] Third, the epicardial approach was not used in 3 of 5 cases in the present study.

Previous studies reported that bipolar RFCA using 2 ablation catheters could create larger lesions than unipolar RFCA.[1,4,7] Therefore, bipolar RFCA could create a transmural lesion that was effective in treating refractory VA, which had not responded to treatment during previous unipolar RFCA.[8,9]

Although clinical use of bipolar RFCA has been reported, most of the studies were small case series[1,9] or case reports.[8,10–12] According to those reports, the acute success rate of bipolar RFCA was high. However, the long-term outcomes after bipolar RFCA remained underexplored.

In the present study, as with previous reports, bipolar RFCA was effective in achieving acute success, which was defined as VT termination and VT noninducibility in most patients (89%). However, 8 of 18 patients (44%) who underwent successful bipolar RFCA had VT recurrence at 12-month follow-up. One possible reason is incomplete ablation. In a previous study that evaluated the mechanisms of VT recurrence after unipolar RFCA in patients with arrhythmogenic RV cardiomyopathy and NICM, incomplete ablation was the most common reason for VT recurrence, which was defined as index VT recurrence or ablation in a previously unablated region inside an index scar.[13] Because of several disadvantages with bipolar RFCA, incomplete ablation or other irreversible effects may occur more readily. First, local endocardial electrogram and pace mapping are not reliable because of the deep intramural origin of arrhythmia. A previous study concluded that septal coronary venous mapping using an electrode wire is helpful in characterizing the arrhythmia substrate and identifying the RFCA target in greater detail.[14] We did not use this technique in our cases; however, in order to obtain detailed information, inserting the wire or narrow electrode catheter into the septal coronary veins may solve this problem. Second, temperature and impedance measurements were available for only 1 catheter, which was connected to the standard location on the generator.

Visualizing the catheter connected to the cutaneous patch cable in the 3-dimensional mapping system was difficult. Therefore, we did not obtain information on the vector or contact force of the catheter tip.[15] For these reasons, the transmural lesion may not have been created, resulting in VT recurrence in some cases. Furthermore, in the previous reports, recurrent VT tended to originate from the vicinity of previous ablation lesions in patients with large scars, so it is possible that a previous ablation procedure formed new VT borders or resulted in scar progression.[16] In 1 patient in our study (no. 4), recurrent VT was different from any VT that had been targeted in the previous procedure, and its origin was slightly above the previous ablation site. Therefore, more extensive ablation is crucial for modifying as much of the arrhythmogenic substrate as possible.[13] However, an endocardial low-voltage area was not observed in most cases of deep intramural foci.[17] Therefore, it was difficult to effectively modify the substrate with bipolar RFCA. Preprocedural cardiac magnetic resonance imaging or cardiac computed tomography may be useful in detecting scars in such patients.[18,19]

Another possible cause of VT recurrence is progression of the patient's underlying heart disease. In a previous study that included patients with arrhythmogenic RV cardiomyopathy and NICM, disease progression, such as ventricular remodeling, ventricular dilation, and decreased ejection fraction, was observed in 75% of patients when ablation was repeated.[13] Other studies aiming to evaluate the long-term rate and mode of recurrence after ablation demonstrated that VT recurrence was commonly due to new VT that had not been targeted during the initial ablation.[16] In the present study, at least 4 of 8 patients with recurrent VT demonstrated a distinct VT from that had been previously targeted. Most of these patients (3/4) were diagnosed with cardiac sarcoidosis, so multiple VT origins and cardiac disease progression may have been factors. Thus, a full-medication regimen including antiarrhythmic drugs and other pharmacologic therapies is important in preventing the progression of arrhythmias even after acute success with bipolar RFCA.

Various ablation techniques for intraseptal or intramural scarring have been reported, including bipolar RFCA, retrograde or anterograde coronary ethanol injection,[2,20,21] and irrigated needle ablation.[22,23] The optimal technique for treatment of refractory VT originating from intramural regions remains controversial. Chemical ablation by ethanol injection has some advantages compared to bipolar RFCA. For example, by first injecting cold saline, we can perform a reversible evaluation of conduction system damage and VT termination before injecting ethanol.[15] Moreover, ethanol ablation can create transmural and intramural lesions with greater certainty. Many clinical reports about the effectiveness of ethanol ablation for refractory VT after failed RFCA have been published.[2,20,21] In the present study, ethanol infusion into the septal artery was successful in terminating VT after failed septal bipolar RFCA in a patient with HCM. This patient (no. 18) remained free of VT 12 months after ablation. In another HCM case, chemical ablation also was effective for recurrent VT originating from the LV free wall after successful bipolar RFCA. In this case, VT has not recurred for 33 months. However, the target patients are limited by coronary artery anatomy, and infarct size is difficult to predict.[2,15] Further studies are required to understand the risks and benefits of these different strategies.

Simultaneous unipolar RFCA has been reported.[24] Although the better strategy between bipolar RFCA and simultaneous unipolar RFCA remains unknown, information on the temperature and impedance is available for each catheter during simultaneous unipolar RFCA. In this respect, simultaneous unipolar RFCA is safer and may be more reliable for creating lesions. However, an experimental study reported that bipolar RFCA has higher core lesion temperatures, corresponding to a denser and larger necrotic core, than simultaneous unipolar RFCA.[25]

Study limitations

First, this study was retrospective in design and had a small sample size. Second, the follow-up period was relatively short. Nonetheless, to our knowledge, this is the largest series of patients who have undergone bipolar RFCA for treatment of refractory VT with long-term follow-up. Third, because this was a multicenter retrospective study, inadvertent selection bias could have affected the generalizability of observed outcomes. This study included all patients from our 7 centers who had undergone bipolar RFCA for refractory VT from 2012 to 2017. However, it is possible that these patients do not represent a true cross-section of patients with refractory VT.

Conclusion

Bipolar RFCA is useful for acute suppression of refractory VT. Although VT recurrence rates during long-term follow-up were relatively high, we observed a significant reduction in VT burden and a favorable effect on cardiac mortality. Thus, it is worthwhile to attempt bipolar RFCA after failed unipolar RFCA for refractory VT.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrthm.2020.04.028.

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