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(Citation)
Journal of Arrhythmia,39(1):52-60

(Issue Date)
2023-02

(Resource Type)
journal article

(Version)
Version of Record

Received: 15 July 2022 | Revised: 26 October 2022 | Accepted: 3 November 2022

DOI: 10.1002/joa3.12796

Journal of Arrhythmia Open Access WILEY

ORIGINAL ARTICLE

Predictors of recurrence in patients without non-inducibility of ventricular tachycardia at the end of ablation

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Abstract

Background: Ventricular tachycardia (VT) non-inducibility at the end of ablation is associated with a less likely VT recurrence. However, it is not clear whether we should use VT non-inducibility as a routine end point of VT ablation. The aim of this study was to evaluate VT recurrence in patients in whom VT non-inducibility was not achieved at the end of the radiofrequency (RF) ablation and the factors attributing to the VT recurrence.

Methods: We analyzed that 62 patients in whom VT non-inducibility was not achieved at the end of the RF ablation were studied.

Results: Over 2 years, 22 (35%) of the cases had VT recurrences. A multivariate analysis showed that an LVEF ≥35% (HR: 0.19; 95% CI: 0.06–0.49; $p < .01$) and elimination of the clinical VT as an acute ablation efficacy (HR: 0.23; 95% CI: 0.04–0.81; $p = .02$) were independent predictors of fewer VT recurrences. RF ablation was associated with a 91.1% reduction in VT episodes.

Conclusion: Even if VT non-inducibility was not achieved, patients with an LVEF ≥35% or in whom the clinical VT could be eliminated might be prevented from having VT recurrences. The validity of the VT non-inducibility of any VT should be evaluated considering each patient's background and the results of the procedure.

KEYWORDS
catheter ablation, ventricular tachycardia, ventricular tachycardia non-inducibility

1 | INTRODUCTION

Radiofrequency (RF) ablation is a well-established treatment for recurrent ventricular tachycardia (VT), and many studies have shown that a successful RF ablation can prevent VT recurrence in patients with structural heart disease (SHD).[1–3]

In the early 1990s, the success of RF ablation was based on the confirmation of clinical VT non-inducibility.[4] After that, in the era of

the 3D mapping system, various indicators such as the disappearance of abnormal potentials was proposed,[5] and VT non-inducibility of any VT, not just the clinical VT, has also become one of the most important endpoints.[6–9] Previous studies have demonstrated that VT non-inducibility at the end of the RF ablation is less likely to be associated with a VT recurrence in patients with ischemic cardiomyopathy (ICM)[6] or non-ICM (NICM).[7] Although it would be desirable to achieve VT non-inducibility in all patients, it is not clear whether we should use VT non-inducibility as a routine endpoint of VT ablation, as in some patients it may not be realistic to achieve non-inducibility in clinical practice. In sicker patients, the risk of repeated induction tests, a prolonged operative time, and overtreatment should be considered.

The primary purpose of this study was to evaluate VT recurrence in patients in whom VT non-inducibility was not achieved at the end of the RF ablation and the factors that attributed to the VT recurrences in ICM and NICM patients. Furthermore, the impact of the clinical VT ablation on the outcomes was also assessed as a secondary purpose.

2 | METHODS

2.1 | Study population

From January 2009 to December 2019, 82 consecutive patients with SHD underwent RF ablation (114 procedures) for VT when the following were met: electrical storm, documented 12-lead electrocardiogram (ECG) of the clinical VT prior to an implantable cardioverter defibrillator (ICD) implantation,[10,11] multiple appropriate ICD therapies even on class 3 antiarrhythmic drugs, and antiarrhythmic drugs could not be used or continued due to side effects. Patients who underwent multiple procedures were evaluated during the last procedure.

VT non-inducibility was achieved in 20 patients, but it was not achieved in 62. To evaluate the validity of "VT non-inducibility" as an endpoint of the RF ablation, 62 patients in whom VT non-inducibility was not achieved were studied. This was a single-center retrospective study conducted at Kobe University Hospital. The study was approved by the ethics committee of Kobe University Medical Ethical Committee (No. B210142) on August 27, 2021, and all patients gave their written informed consent.

2.2 | Ablation procedure

The procedures were mostly performed under conscious sedation, but were under general anesthesia in 7 cases. Transvenous multipolar catheters were placed into the cardiac chambers appropriate for the arrhythmia being studied (right and/or left ventricular [RV and/or LV]). LV mapping was performed via the retrograde aortic or transseptal approach. When necessary, an epicardial approach using a percutaneous subxiphoid puncture was attempted at the beginning of the procedure as previously described.[12] Electroanatomic mapping systems such as CARTO3 (Biosense Webster) or Ensite (Abbott) were used. Intracardiac echocardiography assisted in defining the anatomical structures, monitoring for potential complications, and performing transseptal punctures. Systemic anticoagulation was achieved with intravenous heparin targeting a minimum activation clotting time of 350 s during LV and 250 s during RV mapping. The RF current was delivered with a 3.5-mm open irrigated tip catheter, with power settings of 30–50 W and temperature limit of 43°C. Contact force sensing catheters were used by the operators while aiming for a 5–30 g contact force.

2.3 | Mapping, ablation strategy, and induction protocol

Firstly, substrate mapping was performed during sinus rhythm (SR) or ventricular pacing. The areas of abnormal electrograms, such as fractionated or late potentials, were tagged to denote the type of electrogram, and pace mapping was performed in those areas. Pace mapping was also performed at the presumed isthmus and exit regions of the clinical VT. The QRS morphology and stimulus to QRS (St-QRS) interval were evaluated. At the area of interest, a pace map was performed at maximum output (1.0 ms, 20 V), and the output was decreased until pacing could no longer capture the myocardium to evaluate the functional pace map response.

Secondly, programmed ventricular stimulation was delivered with up to double extra-stimuli at two different basic cycle lengths (CLs) (600 and 400 ms) from at least two sites (the right ventricular apex, outflow tract, or left ventricle). If the induced VT was hemodynamically tolerated, activation mapping was acquired, and entrainment pacing was delivered if possible. In cases of hemodynamically unstable VT, the tachycardias were interrupted by overdrive pacing or direct current (DC) defibrillation. When VT was not induced, the induced VT was hemodynamically unstable, or the VT was not sustained, pace mapping was performed and compared to the clinical VT morphology to confirm the VT exit.

The VT isthmus was defined as sites where mid-diastolic potentials (MDPs) during the VT were present, and the RF ablation terminating the VT or pace mapping exhibited multiple exit sites (MESs).[13] RF ablation was applied at the target VT isthmus during VT, based on the findings from the activation, entrainment, and pace mapping. For hemodynamically unstable VTs, RF ablation was applied at sites with abnormal electrograms, a longer St-QRS, and the presence of a functional pace map response. Fundamentally, all the clinical VTs were targeted in all cases. The non-clinical VTs were also targeted in cases that appeared repeatedly during the procedure.

Finally, programmed ventricular stimulation was delivered with up to double extra-stimuli at two different basic CLs from at least two sites, down to 200 ms or until the refractory period.

2.4 | The definition of non-inducibility and the evaluation of the acute ablation efficacy

At the end of the RF ablation, those in which no sustained VT could be induced, were designated to have VT non-inducibility and were defined as a "complete success" for the acute ablation efficacy. The patients in whom only non-sustained VT (termination within 30 s) or ventricular fibrillation (VF) was induced, were also classified as having VT non-inducibility. In contrast, if sustained VT was induced, regardless of whether it was clinical or non-clinical, the patient was judged to have residual VT inducibility, those with only non-clinical VT were defined as having a "partial success" and those with the clinical VT as a "failure". Among the patients in whom VTs were sustained or induced at baseline, the patients that did not undergo a VT induction test or only received an inadequate VT induction test at the end of the procedure due to the patient's condition, were also classified as a "failure". The induced VTs were defined as being clinical if they matched the arrhythmia captured clinically on the 12-lead ECG or, in cases where no ECG was available, they matched the tachycardia CL of the ICD log (difference < 30 ms).

2.5 | Follow-up

Clinical follow-up visits and ICD interrogations were scheduled at 1, 3, 6, and 12 months after the procedure, with remote device monitoring when possible. Patients who refused an ICD implantation were followed every 3 months and asked to visit the hospital immediately if symptoms appeared. Patients with heart failure, beta blockers and other drugs recommended at the time of treatment were introduced as much as possible. Considering that long-term amiodarone administration would have the risk of interstitial pneumonia, sotalol was mainly used in the ICD recipients. However, amiodarone was used in patients whose VT was refractory to the sotalol.

2.6 | VT burden

The pre-procedure VT burden was defined as the number of VT episodes and shock therapies for up to 2 years from the time of the ablation procedure. The post-procedure VT burden was determined after 2 years from the day of the ablation procedure. In the redo procedures, the pre-procedure VT burden was defined as the number of VT episodes occurring between the previous ablation procedure and when the redo ablation procedure was performed. VT episodes were defined as continuous VT for 30 s and/or a syncopal event, or as VT that required an appropriate intervention for termination. We also defined incessant VT as that which persisted or immediately reoccurred despite appropriate intervention to terminate the VT.

2.7 | Statistical analysis

Continuous variables are presented as either means (±SD) or medians (with interquartile ranges [IQR]) and categorical variables as numbers and percentages (%). The differences in the continuous variables between the two groups were assessed by an unpaired t test or Mann–Whitney test. Categorical variables were compared through a Fisher exact test. The estimated event free survival probabilities were calculated using a Kaplan–Meier analysis; log-rank statistics were used for group comparisons. The follow-up period from the last procedure was calculated with the median value and IQR. At first, to assess the clinical predictors of VT-free survival and survival from cardiac death, a univariable Cox proportional analysis was performed. Sequentially, variables with a $p < .10$ in the univariable analysis were included in the multivariable analysis, and the hazard ratios (HR) and 95% CI were calculated. A $p < .05$ was considered statistically significant. All statistical analyses were performed using JMP (versionPro13; SAS Institute) and GraphPad Prism 9 (GraphPad Software, Inc.) software.

3 | RESULTS

3.1 | Patient characteristics

During the study period, 82 patients underwent VT ablation, and 62 in whom VT non-inducibility was not achieved at the end of the procedure were studied (Figure 1). The baseline patient characteristics are summarized in Table 1. The mean age was 66 ± 14 years, and 54 patients (87%) were male. The average LV ejection fraction (LVEF) was 37 ± 13%.

The most frequent underling heart disease of the VT was ICM (39%); sarcoidosis (24%) and dilated cardiomyopathy (18%) were also common. Thirty patients (48%) had electrical storms before the RF ablation, and 19 (31%) had persistent incessant VT at the beginning of the RF procedure.

3.2 | Procedural details

The procedural data of the VT ablation performed in this study were shown in Table S1. An epicardial access was required in 13 (21%) patients. Thirty-nine patients (63%) underwent a first procedure, 18 (29%) a second, and 2 (3%) a third. The mean procedural time was 247 ± 67 min, and total number of RF points was 30 ± 19 points. The electroanatomical maps were created with CARTO in 85% of the cases and Ensite in 13%. The 3D mapping system was not used in 1 case (2%) because of the influence from a ventricular assist device.

3.3 | Procedural outcomes

The number of VT morphologies documented prior to the ablation, that were considered clinical VTs, was 1 (IQR, 1–1; range, 1–5; total 81), and the number of VT morphologies documented during the procedure was 2 (IQR, 1–2; range, 0–10; total 123) (clinical VT was 1 [IQR, 1–1; range, 0–5; total 64], and non-clinical VT was 1 [IQR, 0–1; range, 0–9; total 59]) (Tables 2 and 3).

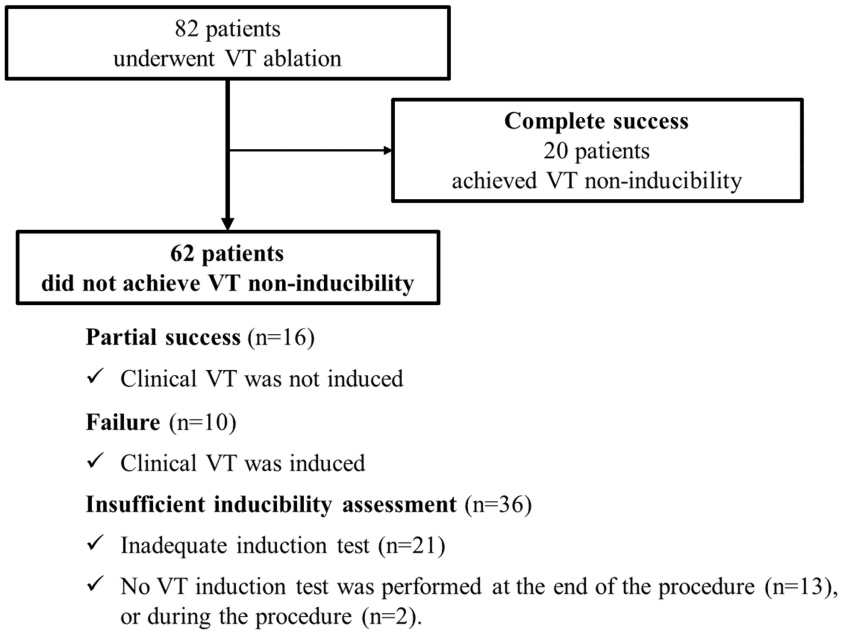

FIGURE 1 Flow chart of the protocol for the patient enrollment. During the study period, 82 patients underwent VT ablation, and 62 in whom VT non-inducibility was not achieved at the end of the procedure were studied. VT, ventricular tachycardia.

Among the 81 clinical VTs, 18 (22%) persisted incessantly at the beginning of the ablation, 46 (57%) were induced during the procedure, and 17 (21%) were not induced during the procedure (Table 2). Among the 64 clinical VTs, which were documented during the procedure, an adequate activation map could be acquired in 22 VTs (34%). The VT isthmus could be identified in 33 clinical VTs (52%); 24 VTs were eliminated after the RF ablation, and 9 VTs could not be eliminated because the isthmus was transmural (7 VTs) or was proximate to a major coronary artery (2 VTs).

3.4 | Procedural complications

Cardiac tamponade occurred in 1 case (2%) and required drainage. One groin hematoma (2%) was conservatively managed (Table S1).

3.5 | Clinical outcome

3.5.1 | VT recurrence

During the follow-up period of 2 years, 22 (35%) of the cases experienced VT recurrences (Table 4; Figure 2).

3.5.2 | Predictive factors of VT recurrence

Table 5 shows the univariable and multivariable Cox regression analyses of the VT recurrence. In the univariable analysis, an LVEF ≥35% (HR 0.20; 95% CI 0.06–0.50; $p < .01$) and partial success as an acute ablation efficacy (HR 0.24; 95% CI 0.04–0.83; $p = .02$) were associated with fewer VT recurrences (Figure 2). A Cox proportional model was used for the multivariate analysis, and variables with a $p < .10$ in the univariable analysis were included in the model. An LVEF ≥35% (HR 0.19; 95% CI 0.06–0.49; $p < .01$) and partial success (HR 0.23;

TABLE 1 Baseline patient characteristics

Patients, $n = 62$	
Age (years)	66 ± 14
Male/female	54/8
NYHA class (I/II/III/IV)	20/31/9/2
Underlying heart disease	
ICM, *n* (%)	24 (39%)
Sarcoidosis, *n* (%)	15 (24%)
DCM, *n* (%)	11 (18%)
ARVC, *n* (%)	4 (6%)
HCM, *n* (%)	2 (3%)
Post myocarditis, *n* (%)	2 (3%)
Congenital, *n* (%)	1 (2%)
Valvular heart disease, *n* (%)	1 (2%)
Unknown, *n* (%)	2 (3%)
HT, *n* (%)	25 (40%)
DM, *n* (%)	16 (26%)
AF, *n* (%)	26 (42%)
Previous ICD or CRTD, *n* (%)	37 (60%)
LVEF (%)	37 ± 13
LVEF ≥35%	31 (50%)
LVDd (mm)	59 ± 10
Prior amiodarone, *n* (%)	22 (35%)
Sotalol, *n* (%)	10 (16%)
Beta blocker, *n* (%)	55 (89%)

Note: Data are presented as the mean ± SD, medians (with interquartile ranges) or *n* (%).

Abbreviations: AF, atrial fibrillation; ARVD, arrhythmogenic right ventricular cardiomyopathy; CRTD, implantable cardiac resynchronization therapy defibrillator; DCM, dilated cardiomyopathy; DM, diabetes mellitus; HCM, hypertrophic cardiomyopathy; HT, hypertension; ICD, implantable cardioverter defibrillators; ICM, ischemic cardiomyopathy; LVDd, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; VT, ventricular tachycardia.

TABLE 2 VT episodes per patients

Patients, $n = 62$	
VT episodes before RF ablation	
Number of VT episodes, *n*	3 [2, 9]
Number of VT morphologies, *n*	1 [1,1]
1/2/3/4≦	50/9/1/2
Number of shock therapies, *n*	2 [1, 5]
Electrical storm, *n* (%)	30 (48%)
Incessant VT, *n* (%)	18 (29%)
VT episodes during RF ablation	
Number of all VT morphologies, *n*	2 [1–2]
0/1/2/3/4≦	10/16/21/9/6
Number of clinical VT morphologies, *n*	1 [1–1]
0/1/2/3/4≦	12/40/8/1/1
Number of non-clinical VT morphologies, *n*	1 [0–1]
0/1/2/3/4≦	31/19/5/3/4

Note: Data are presented as the *n* (%).
Abbreviations: MDP, mid diastolic potential; VT, ventricular tachycardia.

TABLE 3 Details of the VT episodes

VT episodes before RF ablation	
Clinical VT, *n*	81
VT episodes during RF ablation	
Clinical VT that was documented during the procedure, *n*	64
Persistence incessantly at the beginning of the procedure, *n*	18
Induced during the procedure, *n*	46
Non-clinical VT (Not documented prior to the procedure), *n*	59
Acquired adequate activation map	
Clinical VT, *n* (%)	22/64 (34%)
Non-clinical VT, *n* (%)	5/59 (8%)
Eliminated VT after RF ablation	
Clinical VT, *n* (%)	24/64 (38%)
Non-clinical VT, *n* (%)	3/59 (5%)

Note: Data are presented as the *n* (%).
Abbreviations: RF, radiofrequency; VT, ventricular tachycardia.

95% CI 0.04–0.81; $p = .02$) were independent predictors of fewer VT recurrences in the multivariate analysis.

3.5.3 | VT burden reduction

Figure 3 shows the VT episodes before and after the RF ablation. A significant VT burden reduction after the VT ablation was observed in the entire population. RF ablation was associated with a 91.1% reduction in VT episodes. Before and after the RF ablation, the median number of VT episodes was 3 (IQR, 2–9) and 0 (IQR, 0–1) ($p < .01$), and the number of shock therapies was 2 (IQR, 1–5) and 0 (IQR, 0–0), respectively ($p < .01$). The number of VT episodes and shock therapies were significantly reduced post-VT ablation, even in patients with an LVEF ≥35% and LVEF <35% (Figure S1).

TABLE 4 Clinical outcome data

Patients, $n = 62$	
VT episodes	
VT recurrences, *n* (%)	22 (35%)
Number of VT episodes, *n*	0 [0, 1]
Number of shock therapies, *n*	0 [0, 0]
Incessant VT, *n* (%)	7 (11%)
All-cause mortality	14 (22%)
Arrhythmogenic cardiac death, *n* (%)	4
Terminal heart failure, *n* (%)	5
Unknown, *n* (%)	5
Post-ablation medication use	
Amiodarone, *n* (%)	27 (44%)
Sotalol, *n* (%)	15 (24%)
Beta blocker, *n* (%)	55 (89%)

Note: Data are presented as the median (with interquartile ranges) or *n* (%).
Abbreviation: VT, ventricular tachycardia.

3.5.4 | Mortality

Fourteen patients died during the follow-up. The cause of death was arrhythmogenic cardiac death (4 patients), terminal heart failure (5 patients), and unknown (5 patients) (Table 4).

3.5.5 | ICD implantation after ablation

Implantable cardioverter defibrillators had been implanted in 37 patients (60%) before ablation and in 20 (32%) after ablation. So totally, ICDs were implanted in 57 patients, 92% of the study population. Five patients did not undergo an ICD implantation. Of them, one patient died during hospitalization due to heart failure, and the remaining four patients refused ICD implantation.

4 | DISCUSSION

4.1 | Main findings

We evaluated the VT recurrence in patients in whom VT non-inducibility could not be achieved at the end of the RF ablation and the factors attributing to the VT recurrence in ICM and NICM patients.

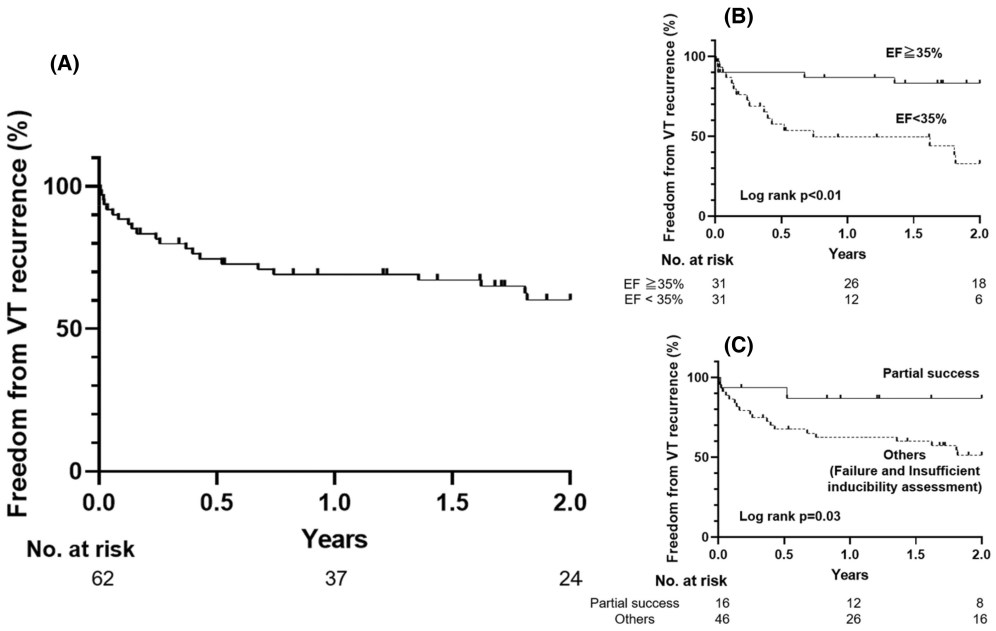

FIGURE 2 Kaplan–Meier curves demonstrating the freedom from VT recurrence. (A) During the follow-up period of 2 years, 22 (35%) of the cases experienced VT recurrences. (B) An LVEF ≥35% and (C) partial success as an acute ablation efficacy were associated with fewer VT recurrences. LVEF, left ventricular ejection fraction; VT, ventricular tachycardia.

TABLE 5 Univariable and multivariable regression models for VT recurrences

	Univariable analysis		Multivariable analysis	
	HR (95% CI)	*p* value	HR (95% CI)	*p* value
Age	1.01 (0.98–1.05)	.53		
Male sex	0.55 (0.20–1.91)	.28		
ICM	1.80 (0.77–4.23)	.17		
AF	1.86 (0.79–4.36)	.15		
LVEF ≥35%	0.20 (0.06–0.50)	<.01	0.19 (0.06–0.49)	<.01
Epicardial ablation	1.02 (0.33–2.58)	.97		
Electrical storm	1.81 (0.78–4.40)	.16		
Partial success	0.24 (0.04–0.83)	.02	0.23 (0.04–0.81)	.02
Failure	1.28 (0.37–3.46)	.66		
Insufficient inducibility assessment	2.10 (0.86–5.87)	.12		

Abbreviations: AF, atrial fibrillation; CI, confidence interval; HR, hazard ratio; ICM, ischemic cardiomyopathy; LVEF, left ventricular ejection fraction; VT, ventricular tachycardia.

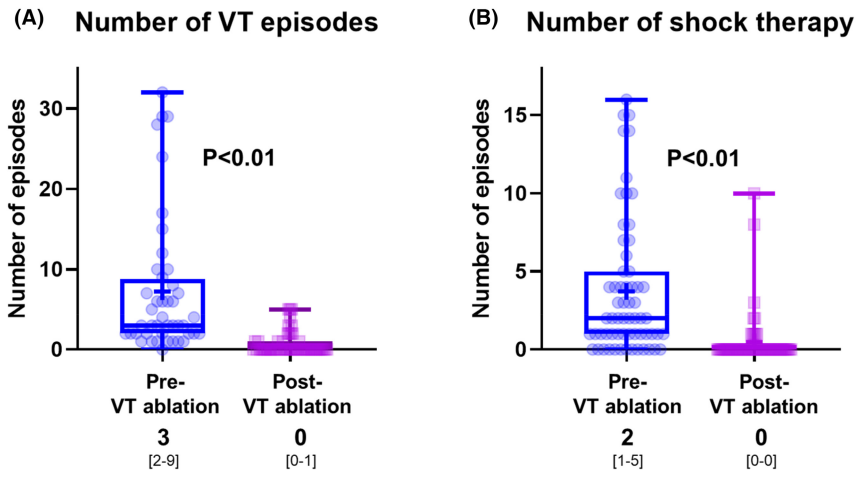

FIGURE 3 Boxplot graph comparing the number of pre- and post-VT ablation (A) VT episodes and (B) shock therapies. VT, ventricular tachycardia.

The main findings of our study were:

1. During the follow-up period of 2 years, 65% of the patients in whom VT non-inducibility was not achieved at the end of RF ablation had no recurrence.
2. Patients whose LVEF was more than or equal to 35%, and those in whom partial success was achieved as an acute ablation efficacy were independent predictors of fewer VT recurrences in the multivariate analysis.
3. Even in patients with VT recurrences, VT ablation could significantly reduce the VT burden.

4.2 | Endpoint of the VT ablation

Double extra-stimuli are a major induction protocol and we used the, however, there have been some reports that 3 or 4 extra-stimuli can render a better predictability of future VT recurrences,[6,7] and achieving the combined endpoint of the abolition of the abnormal electrograms and VT non-inducibility further reduces VT recurrence.[8,9] In the present study, 20 patients in whom VT non-inducibility was achieved had a small VT recurrence rate of 15%. However, we need to consider the risk of overtreatment at the same time; the enlargement of a scar area by RF ablation may lead to a more depressed cardiac function. There is not enough detailed reporting on the subsequent events in patients with residual VT inducibility at the end of the procedure. In our study, patients having an LVEF ≥35% or partial success were independent predictors of VT non-recurrence in patients in whom VT non-inducibility was not achieved. This may indicate that we should try to eliminate the clinical VT as much as possible, and that in this group of patients, inducible residual non-clinical VT is acceptable. Based on our findings, we might consider that the patients whose VT is inducible with 3 or 4 extra-stimuli will have VT recurrence, but will have a better clinical outcome such as a reduction in the VT burden.

4.3 | LV dysfunction and VT recurrence

In this study, the recurrence rate was lower in the patients with an LVEF ≥35%, even with residual VT inducibility. In a sub-analysis of the AVID (Antiarrhythmics vs. Implantable Defibrillator) trial, the efficacy of ICD therapy was reported to depend on the degree of LV dysfunction in patients with secondary prevention of sudden cardiac death, and in patients with an LVEF <35%, ICD therapy had an advantage. On the other hand, in patients with an LVEF ≥35%, the efficacy of the ICD therapy was equivalent to that of antiarrhythmic drugs.[14] Also in a recent trial, Groeneveld et al. reported that in 42 patients with an LVEF >35% and a hemodynamically non tolerated VT, only 6 patients (14.3%) had VT recurrences, and all were hemodynamically tolerated.[15] That suggests that the classification by the degree of LV dysfunction may make sense, and may help determine how aggressively induced VT should be treated.

Patients with an EF < 35% are considered to have more myocardial dysfunction and are more likely to have multiple arrhythmia substrates. Although a more aggressive induction and ablation may be necessary to reduce the VT recurrence rate in them, the dilemma is that patients with such a reduced cardiac function may be more susceptible to hemodynamic compromise and invasive procedures with a prolonged operative time. In the present study, the VT burden was significantly reduced even in the group with an EF < 35%, suggesting that a balanced protocol that ensures safety is desirable.

4.4 | Importance of a successful ablation of all clinical VT isthmuses

Previous randomized multicenter trials have shown that substate ablation reduces any VT recurrences during the follow-up as compared to targeting only a clinical and stable VT, making substate ablation a basic strategy for VT ablation.[16–18] In the present study, the elimination of the clinical VT in addition to a substate ablation was shown to be associated with fewer VT recurrences. Hadjis et al. reported that the identification of the VT isthmus in addition to a substate ablation significantly reduced the recurrence rate (HR 0.21, 95% CI: 0.07–0.63, $p < .01$).[19] Cano et al. also reported that a baseline inducibility of greater than 1 VT morphology was an independent predictor of VT recurrence (HR 12.05, 95% CI: 1.60–90.79, $p = .02$) and complete activation mapping was associated with a reduction in the VT recurrence.[20]

In this study, patients in whom VT non-inducibility could not be achieved at the end of the RF ablation were included, so in many cases, VT was induced with or without hemodynamic stability at the end of the RF ablation. Nevertheless, a successful ablation of all clinical VTs was correlated with non-recurrence, suggesting that the identification of the VT isthmus is important in addition to the basic strategy for a substate ablation.

4.5 | VT burden reduction

The term "recurrence" has been used to evaluate the outcome of the ablation therapy, however, recently the concept of a VT burden reduction has been proposed.[21,22] The VT burden can be more valuable in terms of the clinical benefit than recurrence as a dichotomous event. In the present study, the VT burden was reduced by 91.1% even in patients in whom VT non-inducibility could not be achieved at the end of RF ablation, and VT ablation significantly reduced the number of VT episodes and shock therapies. In addition, a reduction in the VT burden also could be achieved in patients with an LVEF <35% in our study, however VT recurrence was relatively common as compared to that in patients with an LVEF ≥35%. We should carefully consider the balance of an aggressive ablation strategy and the risk involved in performing it, especially in the sicker patients. The decision of the endpoint of the VT ablation was considered in an individual manner. Although

the design of the current study did not allow us to examine the prevention of mortality, a reduction in the ICD shock therapies may improve the patient survival.[23]

5 | CLINICAL IMPLICATIONS

It is known that the achievement of VT non-inducibility at the end of the VT ablation in patients with SHD leads to a lower recurrence. Therefore, VT non-inducibility has been used as an endpoint in many cases. However, in some cases, the ablation may be excessive, or the risk of an induction test may be high. In this study, we included patients in whom VT non-inducibility was not achieved at the end of the VT ablation. We found that the recurrence rate was lower in patients with an EF ≥35% or in patients who achieved partial success as an acute ablation efficacy. In these patients, even if non-clinical VT inducibility remains, it may not affect the subsequent prognosis. In addition, the VT burden was reduced after the VT ablation, and the shock therapy was also significantly reduced before and after the ablation. That suggested that it may be necessary to examine the validity of the VT non-inducibility in each patient.

6 | STUDY LIMITATIONS

This study was a single-center retrospective observational analysis. Therefore, the number of study patients was relatively small. According to the intraoperative findings, e.g., that multiple VT morphologies were documented, the VT did not terminate during the ablation, etc., the physicians decided not to perform an induction test. Therefore, those patients were considered as patients in whom VT would probably have been induced if an induction test had been performed. Furthermore, this study included patients with ICM and NICM, and NICM consisted of a non-uniform etiology. The response to the RF ablation and clinical course may differ for each cardiomyopathy. Further, the methods used for antiarrhythmic drugs were dependent on each physician. However, because of the limited number of operators, our strategy to treat patients with VTs was consistent and our results can be applied to clinical practice.

7 | CONCLUSION

Even if VT non-inducibility was not achieved at the end of the RF ablation, 65% of the patients had no VT recurrences. Among them, patients whose LVEF was more than or equal to 35% or who could achieve partial success as an acute ablation efficacy, might prevent VT recurrences. In addition, even if the VT recurred, the VT burden decreased after the VT ablation. The validity of VT non-inducibility for any VT should be evaluated with consideration of each patient's background and the results of the procedure.

AUTHOR CONTRIBUTIONS

Kazutaka Nakasone: clinical practice/data sampling/drafting article. Koji Fukuzawa: concept/design/data analysis/interpretation/drafting article. Kunihiko Kiuchi: data collection/statics. Mitsuru Takami: data collection/statics. Jun Sakai: data collection/statics. Toshihiro Nakamura: data collection/statics. Atsusuke Yatomi: data collection/statics. Yusuke Sonoda: data collection/statics. Hiroyuki Takahara: data collection/statics. Kyoko Yamamoto: data collection/statics. Yuya Suzuki: data collection/statics. Kenichi Tani: data collection/statics. Hidehiro Iwai: data collection/statics. Yusuke Nakanishi: data collection/statics. Ken-ichi Hirata: approval of article.

ACKNOWLEDGMENTS

The authors would like to thank Mr. John Martin for his linguistic assistance.

CONFLICT OF INTEREST

The Section of Arrhythmia is supported by an endowment from Abbott JAPAN and Medtronic JAPAN and has received a scholarship fund from Biotronik JAPAN. Ken-ichi Hirata chairs the Section, and Koji Fukuzawa and Kunihiko Kiuchi belong to the Section. However, all authors report no conflict of interest for this manuscript's contents.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Name of the ethics committee: Kobe University Medical Ethical Committee (reference number: B210142).

PATIENT CONSENT STATEMENT

Written informed consent was obtained from the patients.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Nakasone K, Fukuzawa K, Kiuchi K, Takami M, Sakai J, Nakamura T, et al. Predictors of recurrence in patients without non-inducibility of ventricular tachycardia at the end of ablation. J Arrhythmia. 2023;39:52–60. https://doi.org/10.1002/joa3.12796