Original Article

Catheter ablation of scar based ventricular tachycardia — Procedural characteristics and outcomes

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ABSTRACT

Background: Ventricular tachycardia (VT) is a major cause of morbidity in patients with cardiomyopathy. Radiofrequency ablation has emerged as the mainstay of the management of recurrent sustained VT in these patients. We describe the clinical characteristics, procedural and medium term outcomes of patients undergoing ablation of scar VT in a tertiary care center in India.
Methods: This was a single-center descriptive cohort study. All patients who underwent ablation for scar related VT were included. Endpoints were immediate procedural success, procedural complications and recurrence during follow up.
Results: A total of 72 patients with scar VT underwent ablation with electroanatomic mapping. Previous myocardial infarction (MI) was the commonest etiology (69.4%) with arrhythmogenic right ventricular cardiomyopathy (ARVC) being the next common (19.4%). Acute procedural success was achieved in 69.4% patients, partial success in 9.7% and failure in 1 patient (1.4%). Outcome was labeled indeterminate in 19.4% who did not undergo post ablation VT induction. Procedural complications were seen in 4%. Follow up data was available in 95% of the patients with a mean follow up of 28.9 ± 22.8 months. At one year, freedom from VT was 83.8% and mortality was 13.2%. Overall mortality during follow up was 22.1% while VT recurrence was seen in 35.3%. Recurrence rate was higher in ARVC as compared to previous MI.
Conclusions: Ablation of scar VT has high acute success rates. Ablation is safe with low risk of major complications. Rates of recurrence are higher in patients with ARVC as compared to post MI VT.

1. Introduction

Myocardial scarring, the replacement of myocytes by areas of dense fibrous tissue with collagen is a sequel of many different conditions, most commonly coronary artery disease. Bundles of surviving myocytes within this scar usually exhibit slow and non-uniform conduction due to poor intercellular coupling. These form the substrate for reentry resulting in ventricular tachycardia (VT).[1] Patients with scar VT usually receive implantable cardioverter defibrillators (ICD), which are principally useful for the termination of ventricular fibrillation and sustained VT. Antiarrhythmic drugs are often used as adjunctive therapy to prevent recurrent arrhythmias and patients with recurrence on drugs usually require radiofrequency ablation.

The advent of electroanatomic mapping has resulted in a significant improvement in understanding of the substrate of scar VT and the results of ablation as it provides precise identification of the location of abnormal substrate, reentrant circuits and the sequence of activation during ventricular tachycardia. Ablation has showed significant reduction in ICD therapies and the dosage of antiarrhythmic therapies. However, ablation continues to be underutilised in developing nations because of a combination of lack of awareness among treating physicians, costs associated with the procedure and the lower success rates compared to ablation of simple arrhythmias.

We here sought to present the outcomes and follow up data of a single center experience in the ablation of scar VT in a developing country.

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2. Methods

2.1. Patients

This was an ambidirectional cohort study of patients with scar VT who underwent catheter ablation at our center between January 2011 and June 2018. Scar VT was defined as ventricular tachycardia that was demonstrated or presumed to be related to scar, identified by the presence of low voltage bipolar electrograms. The patients were followed up at six monthly intervals for a minimum of 1 year after ablation. The study was conducted after approval of the Institute ethics committee and informed written consent was obtained from all the patients.

2.2. Pre-procedure evaluation

All patients underwent detailed echocardiography for evaluation of ejection fraction (EF), regional wall motion abnormalities, ventricular dilatation, aneurysms and clot. Previous MI was diagnosed from the history and clinical records and characteristic regional wall motion abnormalities on echocardiography. Coronary angiography was done when deemed necessary. ARVC was diagnosed based on ECG, echocardiography, cardiac MRI and intracardiac mapping following the task force criteria. All patients were on guideline directed medical therapy. Most of the patients were on antiarrhythmics, most commonly amiodarone and had VT recurrence on drugs. Reversible causes of VT including electrolyte imbalances, acute ischemia, heart failure and drug related proarrhythmia were ruled out before the procedure.

Incessant VT was defined as continuous sustained VT lasting several hours, which recurred promptly despite repeated intervention for termination. VT storm was considered as 3 or more separate episodes of sustained VT within 24 h, each requiring termination by an intervention.

Patients were categorized as those with ICD and those without ICD. Patients with ICD were defined as those in whom an ICD was present at the time of ablation or was implanted within a month after the procedure.

2.3. Procedure

Procedure was done with local anesthesia and sedation in most patients. General anesthesia was used when required, usually in patients with hemodynamic instability. Mapping was done with the use of an electroanatomic mapping system with either magnet-based navigation (CARTO 3, Biosense Webster) or with impedance-based navigation (NavX, Abbott). Using a quadripolar catheter placed in the right ventricular apex, VT induction was performed at baseline with up to two or three ventricular extrastimuli at drive cycle lengths of 600 and 400 ms. Clinical VT was defined as VT that had been documented on 12-lead electrocardiogram (ECG) during clinical episodes or VT that was consistently inducible with cycle length matching episodes recorded in the implanted defibrillator when available.

Left ventricle (LV) was accessed for mapping usually by a retrograde approach. Transseptal access was used when retrograde approach was difficult because of peripheral vascular disease or aortic valve disease or when the substrate was difficult to reach from a retrograde approach. Right ventricle was accessed by transvenous approach with use of a long, deflectable sheath when required. Epicardial mapping was only considered when endocardial mapping showed no significant substrate or endocardial ablation failed to eliminate VT. Anticoagulation was achieved with unfractionated heparin. If LV was accessed endocardially, ACT was maintained between 250 and 300 s during the procedure. In all cases, point by point mapping was done using an irrigated ablation catheter. Substrate mapping was done in the left ventricle usually during RV pacing and in the right ventricle during sinus rhythm. Endocardial bipolar voltage less than 1.5 mV was considered as low voltage and the cutoff for scar was voltage <0.5 mV.[2] Local abnormal ventricular activity (LAVA) was identified by the presence of low voltage, high frequency electrograms distinct from the far field ventricular electrogram.[3] Local activation time during substrate mapping was marked on the latest activation to allow easy identification of these areas in an activation map. When ECG of clinical VT or induced VT was available, pace mapping was performed from these sites to identify the potential exit.

When hemodynamically stable VT was induced, activation mapping of the VT was performed. Usually a window of interest of 95–100% of the cycle length was used. When diastolic activation was found, entrainment was performed with high output pacing to identify regions in the critical isthmus based on short post pacing interval and concealed fusion.

Ablation was done with the irrigated catheter at settings of 30–40 W and 17–30 ml/min of normal saline. Generally, power was delivered for 1 min at each location. When LAVA were not eliminated with 30 W, ablation was done at 40 W.

Post ablation testing was done in patients who were hemodynamically stable. Acute success was defined as no VT induction after at least 2 ventricular extrastimuli. Partial success was defined as the induction of VT with a different morphology from the clinical VT. Failed ablation was defined as the induction of clinical VT after ablation. In patients in whom post ablation VT induction was not done, the outcome was labeled as indeterminate.

2.4. Predischarge evaluation

All patients were observed in hospital for 24 h after the procedure. Post interventional patients were kept on guideline directed medical therapy. Antiarrhythmics were usually continued at discharge. Patients with significant LV dysfunction who underwent extensive endocardial ablation within the left ventricle were started on oral anticoagulation with heparin bridging.

2.5. Follow-up

All patients were followed up at one month after the ablation and then every six months. During follow up patients were asked about the recurrence of tachycardia. Patients with implanted defibrillators underwent device interrogation. Antiarrhythmics were usually tapered after 6 months if there was no recurrence of VT and gradually stopped over the next 3–6 months. If patients died during follow up, the close relatives were interviewed in person or over telephone. Cause of death was categorized as cardiac or non-cardiac and cardiac deaths were further categorized as sudden or non-sudden, based on the time from symptom onset to death, sequence of events and any available medical records.

2.6. Statistical analysis

Continuous variables are reported as mean ± SD and categorical variables as percentages or frequencies. The Student's t test and chi-square test were used for comparison between groups. Mann–Whitney U test was used for comparison of independent groups on a continuous variable. The Kaplan–Meier method was used to plot freedom from sustained VT. $p < 0.05$ was defined as significant for all analyses.
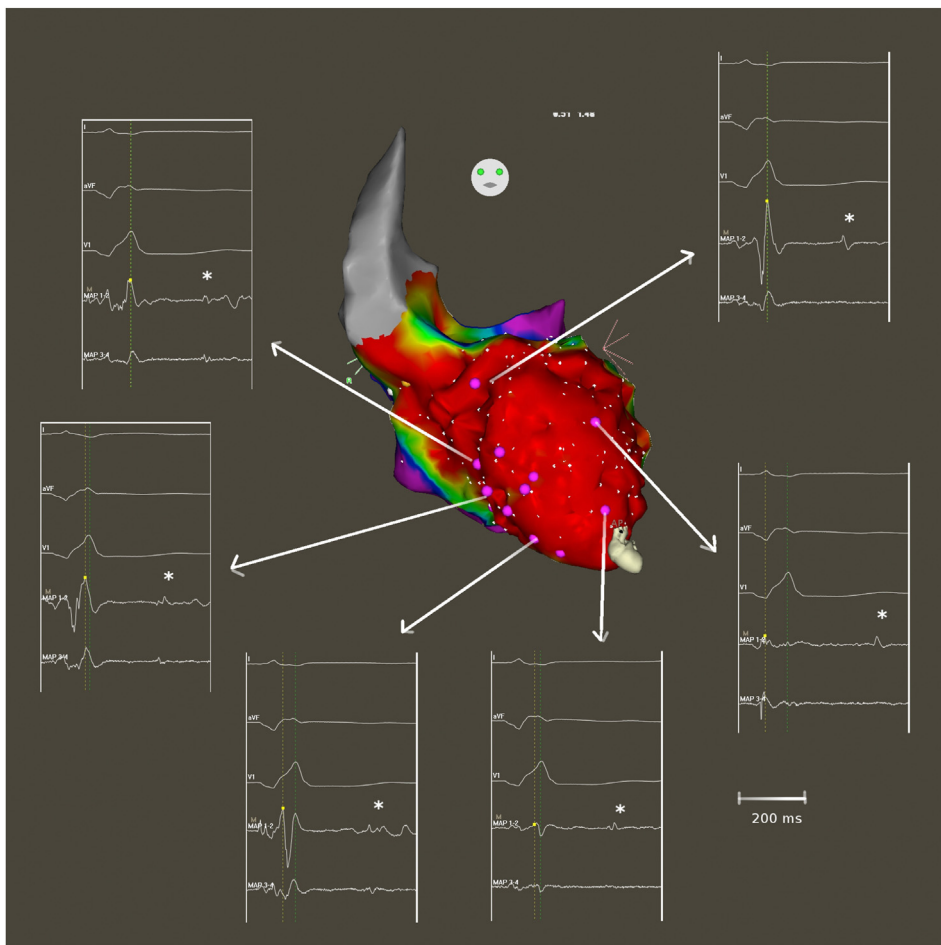
Fig. 1. Substrate mapping. Figure shows an illustrative substrate map acquired during sinus rhythm in a patient with previous anterior wall MI, severe LV dysfunction and presenting with drug refractory VT storm. Voltage map in an anteroposterior view is shown in the center showing a large area of low voltage. Electrograms from 6 locations around the low voltage zone are shown. Local abnormal ventricular activity (LAVA) can be noted in the bipolar electrograms recorded from the mapping catheter and are marked with asterisks.

3. Results

3.1. Study population

The study population consisted of 72 patients with scar VT who underwent ablation. Previous MI was the diagnosis in 50 (69.4%) patients, while arrhythmogenic right ventricular cardiomyopathy (ARVC) was the diagnosis in 14 (19.4%). In the other 8 (11.1%) patients, the diagnosis was valvular heart disease in 3, congenital heart disease in 2 and idiopathic dilated cardiomyopathy (DCMP) in 3. The characteristics of the patients are summarized in Table 1.

Table 1
Baseline characteristics of patients.

	Total (n = 72)	ICMP(n = 50)	ARVC (n = 14)
Age (years)	51.8 ± 11.1	52.7 ± 10.6	50.4 ± 13.7
Male Sex	64 (88.9%)	48 (96%)	9 (64.3%)
LVEF (%)	40.5 ± 11.3	36.7 ± 8.2	50.1 ± 12.9
Clinical VT			
1 morphology	68 (94.4%)	46 (92%)	14 (100%)
≥1 morphology	4 (5%)	4 (8%)	0
ICD implant			
Present	33 (45.8%)	25 (50%)	7 (50%)
Absent	39 (54.2%)	25 (50%)	7 (50%)

Table 2
Procedural characteristics of patients.

|	Total (N = 72)	ICMP (N = 50)	ARVC (N = 14)
Pre-ablation VT induction			
No VT induced	14 (19.5%)	11 (22%)	3 (21.4%)
Single morphology	40 (55.5%)	36 (72%)	9 (64.3%)
2 or more morphologies	18 (25%)	13 (26%)	2 (14.3%)
Mapping strategy			
Substrate only	52 (72%)	41 (82%)	6 (42.9%)
Substrate with Activation	20 (28%)	9 (18%)	8 (57.1%)
RF ablation number	39.4 ± 36.3	41.6 ± 24.4	30.6 ± 30.3
RF time (in seconds)	1923 ± 1072	1969 ± 1030	1509 ± 1366
Fluoro time (in minutes)	14.1 ± 13.8	12.3 ± 14.1	16.8 ± 12.9
Procedure time (in minutes)	206.1 ± 66.9	200.2 ± 64.0	195.9 ± 59.8
Post ablation VT induction			
Attempted	57 (79%)	39 (78%)	10 (71.4%)
Acute procedural outcomes			
Successful	50 (69.4%)	36 (72%)	9 (64.3%)
Partial success	7 (9.7%)	3 (6%)	1 (7.1%)
Indeterminate	14 (19.4%)	10 (20%)	4 (28.6%)
Unsuccessful	1 (1.4%)	1 (2%)	0
Complications			
Total	3 (4%)	2 (4%)	1 (7%)
AV block	1 (1.3%)	1 (2%)	0
Perforation with tamponade	1 (1.3%)	0	1 (7%)
Acute pulmonary edema	1 (1.3%)	1 (2%)	0
Stroke	0		
Death	0		
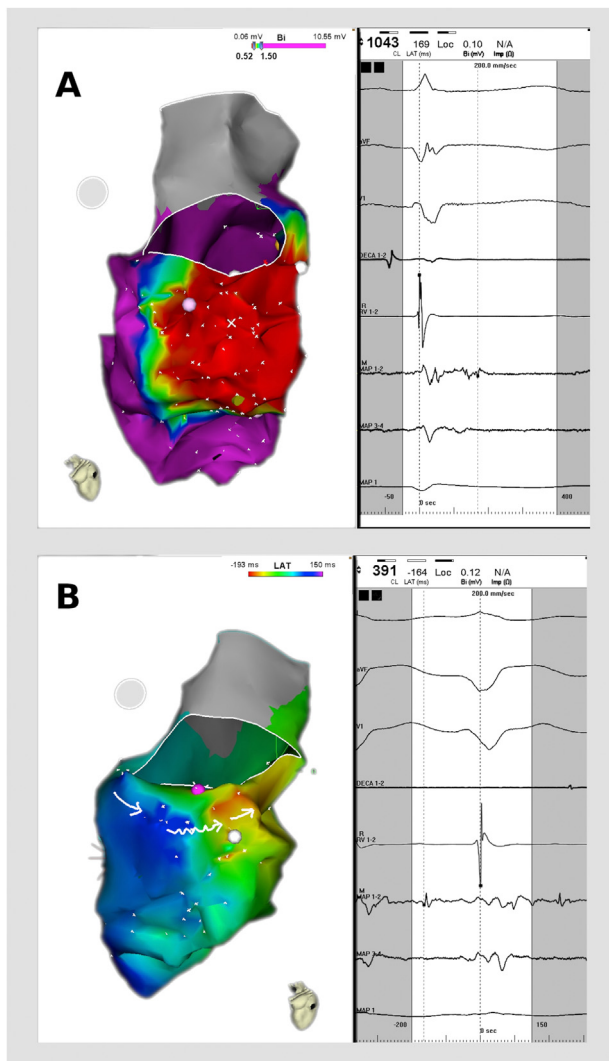
Fig. 2. Activation mapping. Example of an activation map acquired during sustained VT in a patient with old inferior wall MI is shown. Panel A shows a voltage map on the left in an inferior view of the left ventricle. On the right, electrograms are shown from the middle of the scar showing late potentials. In panel B, same view is shown for an activation map acquired during sustained ventricular tachycardia. Activation map shows macroreentry around the mitral annulus while electrograms on the right show a mid-diastolic electrogram within the scar.

3.2. VT characteristics and ablation strategy

VT induction was attempted in all patient who were undergoing ablation. Monomorphic VT was the presentation in 64 (89%) patients, VT storm in 3 (4%) patients and incessant VT in 5 (6.9%) patients.

Substrate mapping was the most common strategy and was adopted in all patients. Fig. 1 is an illustrative substrate map acquired during sinus rhythm in a patient with previous anterior wall MI, severe LV dysfunction and presenting with drug refractory VT storm. In addition to substrate mapping, activation mapping along with entrainment to identify the tachycardia circuit was done in 20 (28%) patients in whom VT was sustained and hemodynamically stable. Fig. 2 shows an example of an activation map acquired during sustained VT in a patient with old inferior wall MI. Fig. 3 shows an example of entrainment at the isthmus in a patient with sustained VT.

CARTO (Biosense) system was used for mapping in 71 patients and NavX (Abbott) was used for mapping in one patient.

Acute procedural success was achieved in 50 (69.4%) patients and partial success in 7 (9.7%) patients. Ablation was unsuccessful in 1 (1.3%) patient. The remaining 14 (19.4%) patients did not undergo postablation testing due to hemodynamic instability. Procedural characteristics are summarized in Table 2.

3.3. Post ablation follow up

Four patients (5.5%) with follow up period less than one year were deemed as lost to follow up and excluded from the analysis. Mean follow up was 28.9 ± 22.8 months. At 1 year, 11 patients (16%) had a recurrence of ventricular tachycardia. Recurrence at the end of follow up was seen in 24 patients (35.3%). Recurrence was higher in ARVC patients (30% at 1 year) compared to post MI patients (10.4% at 1 year) (Fig. 4).

There were 9 deaths (13.2%) at 1 year and 15 deaths (22%) at the end of follow up. Nine post MI patients (18.7%) and three ARVC patients (23.1%) died at the end of follow-up (Fig. 4). Majority of deaths among the patients were cardiac, with almost equal distribution of sudden and non-sudden deaths in post MI and ARVC patients (Table 3).

Only 33 of the 72 patients had ICD implants, mainly due to financial constraints. Sudden cardiac death was seen in 2 patients with ICD implant (6%) during follow up, whereas it was seen in 5 patients (12%) who had no ICD implant. The patients with ICD who died suddenly were not brought to the hospital nor was the device interrogated elsewhere, so rhythm recorded in the device was not available.

The number of ablations was higher in patients without recurrence. Acute procedural success was not different in those with and without recurrence (Table 4). When separately analysed in patients with ARVC and ICMP, no relation was still seen between acute success and long term recurrence. However, the number of ablations was higher in those without recurrence in the ICMP subgroup. Recurrence at 2 years was higher (52% vs 22%, $p = 0.02$) for procedures done in the first half of the study period (2011—2014) compared to that in the second half (2015—2018). Fig. 5 is a flowchart showing a summary of the outcomes.

Table 3
Follow-up analysis.

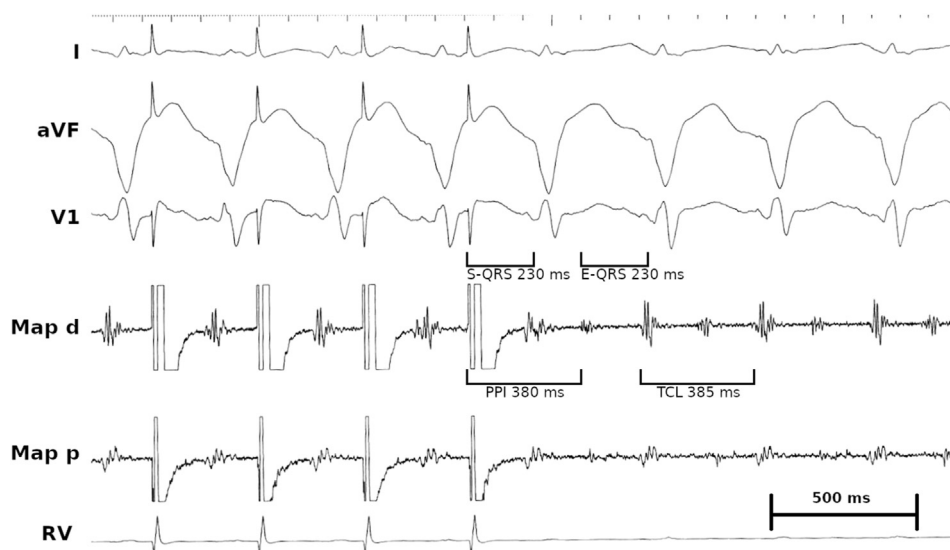|	Total (n = 68)	ICMP (n = 48)	ARVC (n = 13)
Loss to follow up (<1 year FU)	4/72 (5.5%)	2/50 (4%)	1/14 (7.1%)
Mean follow up (in months)	28.9 ± 22.8	27.8 ± 22.1	39.2 ± 23.6
Recurrence at 1 year − n (%)	11 (16.1%)	5 (10.4%)	4 (30.8%)
Recurrence long term	24 (35.3%)	14 (29.2%)	7 (53.8%)
Total deaths	15 (22.0%)	9 (18.7%)	3 (23.1%)
Non cardiac	2 (2.9%)	1 (2%)	1 (7.6%)
Cardiac			
Sudden	7 (10.2%)	4 (8.3%)	1 (7.6%)
Non sudden	6 (8.8%)	4 (8.3%)	1 (7.6%)

Fig. 3. Entrainment mapping. Entrainment is being performed at a location with mid diastolic potentials during ventricular tachycardia. Identical morphology in the three ECG leads and the measurements suggest that this location lies in the critical isthmus. E-QRS = Electrogram to QRS interval, S-QRS = Stimulus to QRS interval, PPI = Post pacing interval and TCL = tachycardia cycle length.

Among 25 patients who had a recurrence, 9 (36%) underwent repeat ablation. One of these patients had subsequent recurrence during the follow up. The other 8 patients remained free of VT during follow-up.

4. Discussion

In a series of patients undergoing ablation for scar VT, we found that ablation using electroanatomic mapping is efficacious with acute success in 69.4% and safe with major complications in 4%. At
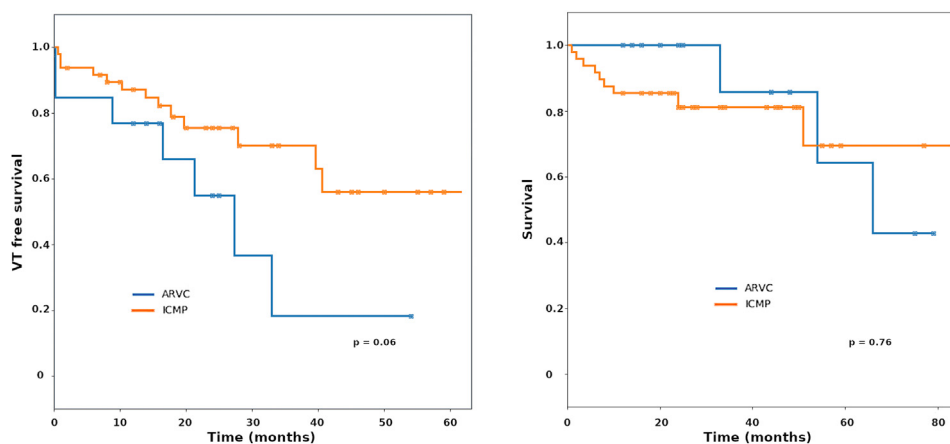

Fig. 4. Freedom from VT and survival after ablation. Kaplan—Meier curves for freedom from VT recurrence (left panel) and death (right panel) in post MI and ARVC patients on follow-up.

Table 4
Difference in baseline and procedural characteristics and outcomes in patients with and without recurrence.

	Recurrence (n = 24)	No recurrence (n = 44)	
RF number	30.8 ± 23.3	44.6 ± 27.3	0.009
RF Time (seconds)	1418 ± 937	2091 ± 1087	−0.034
Acute Procedural outcomes			0.277
Success	14 (29.2%)	34 (70.8%)	
Partial Success	3 (50%)	3 (50%)	
Indeterminate	7 (54%)	6 (46%)	
Unsuccessful	0	1 (100%)	
Ablation strategy			0.42
Substrate + Activation	9 (47.3%)	10 (52.7%)	
Only substrate	15 (30.6%)	34 (69.4%)	

Note: Percentages are shown for proportion in each cell within the row. For example, 29.2% of those with acute success had recurrence during follow up.
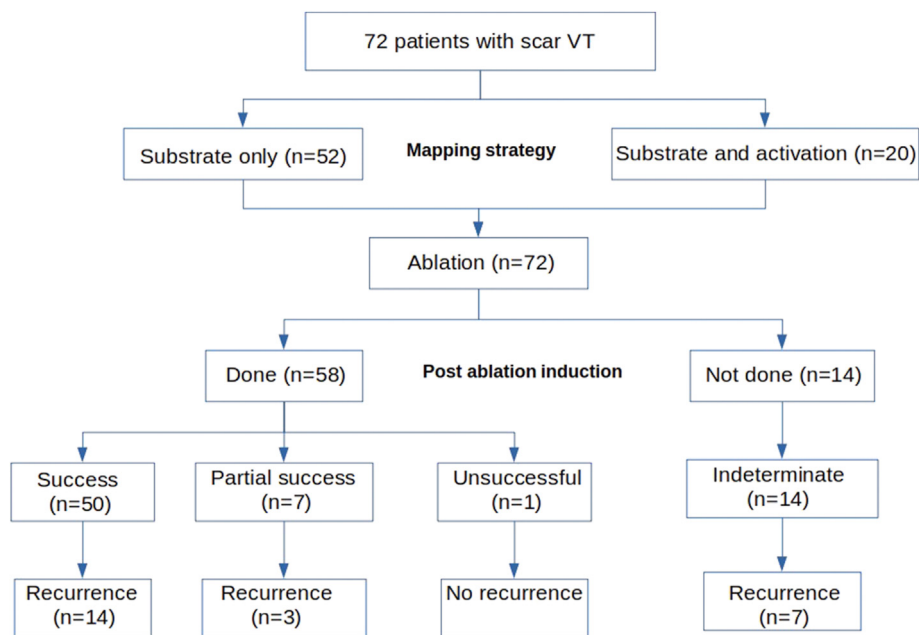
Fig. 5. Ablation procedure and outcomes. Flow chart showing the procedural outcomes and VT recurrences in our study.

one year follow up, recurrence of VT was seen in 16.1% and there were 9 deaths (13.2%). This study provides some of the first prospective data on outcomes after scar VT ablation in India and gives a realistic appreciation of the long-term ablation outcome.

Complete elimination of any VT was achieved in 69.4% of the patients. In 9.7% of patients, clinical VT was no longer inducible, but other inducible VT was still present. In post–MI scar VT, acute complete success was seen in 72% of patients and in ARVC, it was 64.3%. These results are in line with the previously published studies from other regions and attests to fairly good immediate success rates in both post MI VT[4,5,6,7] and ARVC.[8,9]

Substrate based ablation strategy targeting all abnormal electrograms within the scar was the dominant strategy in our practice. Activation mapping was possible in only 28% of our patients. Role of activation mapping is limited because of hemodynamically unstable VT which can occur in up to 69% in the lab.[5,10] The high success rate and acceptable recurrence rates in our study provide further support to this approach of substrate mapping as the primary strategy. Previous studies have also found a strategy of substrate ablation during sinus rhythm or pacing similar or superior to activation mapping guided approach.[10,11]

We performed epicardial mapping only in the absence of an endocardial substrate or strong suspicion of critical epicardial substrate. One patient with idiopathic dilated cardiomyopathy with recurrent VT and ICD therapies underwent epicardial mapping and ablation after no substrate was found on endocardial mapping. No other patient underwent epicardial mapping. Combined endo-epicardial mapping is advocated now in more patients, especially in the setting of ARVC and may offer better outcomes than endocardial mapping alone.[9,12]

Survival free of any VT recurrence was observed in 84.9% of our patients by the end of 1 year and in 65.7% by the end of follow-up extended up to 5 years. The outcome in ICMP patients appears better than the published data in previous multicenter trials.[4,5] In the Multicenter Thermocool Ventricular Tachycardia Ablation trial, the reported VT recurrence was 47% at 6 months and in Ventricular Tachycardia Ablation in Coronary Heart Disease (VTACH) study, it was 47% in the ablation arm. One reason for lower recurrence rate

at 1 year maybe that we routinely continue Amiodarone after ablation, tapering it after 6 months if there was no recurrence, whereas in some studies antiarrhythmics were stopped after ablation. Almost 50% of our patients do not have ICDs and it is also possible that this can lead to less recurrence being documented as some device detected episodes may be asymptomatic.

Compared with post–MI VT the long term success rates in ARVC were significantly worse with regard to VT free survival. There are two possible explanations for the higher recurrence rate in ARVC. One is the fact that this is a progressive disease with ongoing development of scar and resultant new substrate. This is expected to result in late recurrences. Even though survival curves show comparable rates of VT recurrence in post MI and ARVC patients in early follow up period, the occurrence of higher late recurrences as seen in Fig. 4 suggests that this may be an important reason. The other is that the substrate is likely to involve a significant epicardial component unlike in patients with previous MI. This is likely to result in higher recurrence earlier after ablation and this could potentially be reduced with more liberal use of epicardial approach in these patients.[9] Disease progression, the rule in ARVC, is seen in up to 71% of patients and scar progression in 57% in a study can explain the high rate of VT recurrences discordant with the procedural outcomes.[13]

The importance of post procedure induction remains contentious.[5] While the complete elimination of all VTs is an obviously desirable endpoint, patients who continue to have non-clinical VT induced present a dilemma. In our study, there was a 50% recurrence in patients with partial success as compared to 29% recurrence in those with a successful ablation. Although this difference was not statistically significant, this suggests that such patients may have a higher recurrence rate compared to those with elimination of all VT. The study design does not answer the question of whether further ablation may be beneficial in such patients. Similarly, the recurrence rate in patients with an indeterminate result was also 50%. It is likely that patients with residual non-clinical VT and those in whom post ablation testing was not done represent those with a different substrate with a higher recurrence risk.

Recurrence rate was lower for patients treated in the second half of the study period compared to those in the first half. This could reflect learning curve of the operator. However, evolution of ablation strategies, especially the growing understanding of the effectiveness of substrate based approach and improvements in the mapping systems could also have contributed to this improvement in outcomes.

In our study, major procedure related complications were noted in 4% of our patients and periprocedural death in none, similar to what is reported as 7% and 1.5% respectively in other studies.[13,14] Permanent AV block occurred after ablation at the basal LV septum in one patient with prior MI, significant basal septal scarring and recurrent VT with ICD shocks. One elderly female patient developed cardiac tamponade due to perforation during mapping and ablation in the right ventricle. She was managed with immediate pericardiocentesis. The third complication was a patient who developed acute pulmonary edema during the procedure necessitating abandoning the procedure and managing the heart failure.

There were a total of 13 cardiac deaths (19%) during the entire follow up. It is comparable to the trend reported in other studies.[5,14] Sudden cardiac death, presumably arrhythmic, was seen in 7 of these patients. Kaplan meier curves show higher number of deaths in post MI patients in early (<3 years) follow-up period but no mortality noted in ARVC patients in the same time period. It could be possibly due to the fact that post MI patients with underlying cardiomyopathy at the time of VT are sicker and tend to die because of advanced disease, whereas ARVC patients presenting with VT are generally in a better stage of disease with less early mortality.

About half the study population did not get an ICD implant, which is a reflection of the costs associated with ICD implant making it unaffordable to many patients even when required for secondary prevention. More sudden deaths were seen during follow up in the patients without ICDs and it is likely that long term outcomes may be better if all the patients had received an ICD implant.

4.1. Limitations

This study is a single center study representing the experience of a single operator. The study represents outcomes after a dominant strategy of endocardial mapping only and epicardial mapping was used sparsely. Given the higher complication risk associated with epicardial access and the low likelihood of substantial epicardial substrate in post—MI VT unlike in other non-ischemic cardiomyopathy, our strategy of pursuing epicardial ablation, only if endocardial approach fails, appears reasonable, especially in post—MI patients. However, based on current understanding, an endocardial only approach may be suboptimal in most patients with ARVC. Point by point mapping technique was used in all patients. Newer high density mapping systems, by their ability to collect a large number of points in a short period of time and by the better definition of signals due to the smaller inter-electrode spacing provide a more precise assessment of substrate and may improve outcomes. However, traditional point by point mapping still continues to be used to a significant extent, especially in settings with cost constraints. Anti-arrhythmics were continued in every patients after ablation in our study which would have reduced the VT recurrence rate. VT induction was not done in all patient post ablation making the definition of immediate procedural outcomes uncertain. Not all patients underwent ICD implantation as per guidelines due to the cost of the device. This could have resulted in an increased mortality during follow up. This could also have resulted in a lower recurrence rate due to arrhythmias which were asymptomatic or mildly symptomatic.

5. Conclusions

Radiofrequency ablation with electroanatomic mapping is a treatment modality with high acute success rate in patients with scar related ventricular tachycardia. Complications are uncommon and recurrence rate is acceptable during follow up. Patients with ARVC have a higher recurrence rate compared to those with prior MI.

Disclosures

None for any of the authors.

Conflicts of interest

All authors have none to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ihj.2020.09.009.

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