Clinical and Electrophysiologic Outcomes of Patients Undergoing Percutaneous Endocardial Ablation of Scar-Related Ventricular Tachycardia: A Single-Center Experience

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ABSTRACT: **Background:** For patients with ventricular tachyarrhythmias, implantable cardioverter defibrillators are a mainstay of therapy to prevent sudden death. However, ICD shocks are painful, can result in clinical depression, and do not offer complete protection against death from arrhythmia. Radiofrequency catheter ablation of ventricular tachycardia in the setting of ischemic cardiomyopathy has emerged recently as a useful adjunctive therapy to ICD.

Objectives: To assess the feasibility, safety and efficacy of our initial experience in ablation of scar-related VT.

Methods: Eleven patients (all males, mean age 71 ± 8 years) with drug-refractory ischemic VT were referred to our center for scar mapping and ablation procedures using the CARTO navigation system.

Results: Eleven clinical VTs (mean cycle length 436 ± 93 ms) were induced in all patients. An endocardial circuit, identified by activation, entrainment and/or pace mapping, was found in eight patients with stable VT. These patients were mapped and ablated during VT. Three patients had predominantly unstable VT and linear ablation lesions were performed during sinus rhythm. Acute success, defined as termination of VT and/or non-inducibility during programmed electrical stimulation, was found in 9 patients (82%). During follow-up, a significant reduction in tachyarrhythmia burden was observed in all patients who had successful initial ablation, except for one who had recurrence of VT 2 days after the procedure and died 2 weeks later.

Conclusions: Ablation of ischemic VT using electroanatomic scar mapping is feasible, has an acceptable success rate and should be offered for ischemic patients with recurrent uncontrolled VT.

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KEY WORDS: ventricular tachycardia, scar, ablation, CARTO

Patients with severely reduced left ventricular function secondary to ischemic heart disease are at high risk for ventricular tachyarrhythmia and sudden cardiac death. Scar-related reentrant ventricular tachycardia is the most common underlying mechanism of sustained monomorphic VT in patients with ischemic heart disease. Intracardiac defibrillator is the mainstay for primary and secondary prevention of sudden cardiac death. However, recurrent ICD shocks have had physiological and psychological side effects. Antiarrhythmic drugs are used to reduce ICD therapy, but their role in reducing mortality is not proven. In addition, these drugs have important side effects including pro-arrythmic effect and worsening of heart failure status.

Radiofrequency ablation of VT in patients with ischemic cardiomyopathy was proposed to treat and control recurrent VT [1,2]. We present here our experience with VT ablation in patients with ischemic cardiomyopathy using the electro-anatomic mapping system (CARTO) [3].

PATIENTS AND METHODS

The study group comprised 11 patients with a history of myocardial infarction who were referred to our center for mapping and ablation because of recurrent episodes of ventricular arrhythmias and ICD treatments. Electroanatomic mapping was performed in all patients using the CARTO™ mapping and navigation system (Biosense-Webster, Johnson&Johnson, USA). This system uses a mapping catheter with a magnetic localization sensor at its tip to automatically and simultaneously record the three-dimensional coordinates of the location and orientation of tip as well as to acquire the local endocardial electrogram recorded from its tip electrode. By navigating the catheter and sampling its location and electric activity at a plurality of endocardial sites, the three-dimensional image of the chamber is reconstructed in real time with the electrophysiologic information color coded and superimposed on the chamber geometry. Clinical applications of the system include defining the mechanisms of

ICD = implantable cardioverter defibrillator
VT = ventricular tachycardia

arrhythmias and planning and guiding ablation therapy [4]. The CARTO system can generate the activation map (according to local activation times) and voltage map (according to voltage amplitudes of signals acquired from each point) that are superimposed in the anatomic map. Low voltage areas define scars and fibrosis (substrate mapping).

All patients underwent a regular electrophysiologic testing protocol prior to the mapping and ablation procedure with the CARTO mapping system. Intravenous heparin was administered for anticoagulation. In addition to the electroanatomic maps, detailed pace and entrainment mapping was conducted at several sites (the locations where such maneuvers were made were marked on the map) during sinus rhythm and during VT respectively. The presence of a scar in the maps was defined as a low voltage zone (< 0.2 mv) using voltage (substrate) mapping. Pace mapping along the scar border was done to locate the circuit exit, which is important for ablation of VT.

In patients with stable inducible or spontaneous VT, detailed endocardial electroanatomic mapping was performed during both sinus rhythm and during the tachycardia. Ablations during VT were performed at target sites according to the presence of mid-diastolic and presystolic potentials and based on the results of the activation and pace and entrainment mapping [5]. In contrast, in patients with unstable VTs, electroanatomic mapping and ablation were performed only during sinus rhythm. In these patients, linear ablation lesions were created along the scar border zone, from scar to scar, from scar to anatomic boundaries, and from the dense scar to the normal endocardium in areas with good pace mapping [6].

Following discharge the patients were followed at the arrhythmia clinic 4 weeks after the procedure and at 3 monthly intervals

RESULTS

Between May 2006 and November 2008, 11 patients (mean age 71 ± 8 years, all males) with ischemic heart diseases and reduced ejection fraction (23 ± 8%), recurrent unstable or incessant VT, and recurrent ICD therapy or external direct current shocks had undergone a detailed electrophysiologic study and VT ablation using the CARTO navigation system under local (seven patients) or general (four patients) anesthesia [Table 1]. All patients were treated with optimal medical therapy including beta-blockers, and at least two antiarrythmic drugs. Seven patients were referred from other centers, and two of them had already undergone a previous attempt of ablation. One patient had had a previous successful VT ablation procedure in our center, after which he was free of VT episodes for 5 years. He was referred for a repeated procedure due to recurrence of incessant VT of a different morphology.

Nine of the patients had ICDs before the electrophysiologic procedure and the remaining two patients had undergone ICD implantation several days after the procedure. A total of 11 clinical VTs (mean cycle length 436 ± 93 ms) were induced in all patients. Electroanatomic mapping was performed during sinus rythm and inducible stable VT in seven patients, during spontaneous incessant stable VT in one patient, and during sinus rhythm only in three patients with unstable VT. Radiofrequency ablation, using open-irrigated ablation catheter, was performed during VT in patients

Table 1. Patients' clinical characteristics

	1	2	3	4	5	6	7	8	9	10	11
Age (yrs)	60	75	75	75	72	73	73	76	80	54	70
Gender	M	M	M	M	M	M	M	M	M	M	M
EF (%)	35	15	20	20	15	20	20	35	20	20	35
No. of AADs	2	3	2	2	3	2	2	2	2	2	2
BBs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ACE-I	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
ICD	After ablation	2 yrs before	10 yrs before	5 yrs before	1.5 yrs before	7 yrs before	10 yrs before	0.5 yrs before	After ablation	7 yrs before	10 yrs before
Stable VT	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
VT-CL (ms)	350	400	540	520	510	430	260	350	540	500	400
Prior VT ablation	No	Yes, failed	No	No	No	5 yrs before, successful	Yes, failed	No	No	No	No
Acute success	Yes	Yes*	No	Yes	Yes	Yes	Yes, no attempt to induce VT	No	Yes	Yes	Yes

* This patient had recurrence of VT after 2 days, and died 2 weeks later

EF = ejection fraction, AADs = antiarrythmic drugs, BBs = beta blockers, ACE-I = angiotensin-converting enzyme inhibitors, CL = cycle length

Figure 1. Activation and voltage maps of a patient who was ablated during stable VT. The left panel displays the relevant bipolar voltage map showing the presence of a scar (red: bipolar amplitude ‹ 0.2 mV) in the inferior wall of the left ventricule. Blue and purple denotes healthy tissue (› 1.5 mV). The right panel shows the activation map during VT (with the activation wavefront propagating from red to purple). The exit site of the VT circuit was defined by the earliest local activation time (red area). The red "ball" icon identifies sites where radiofrequency ablation was performed.

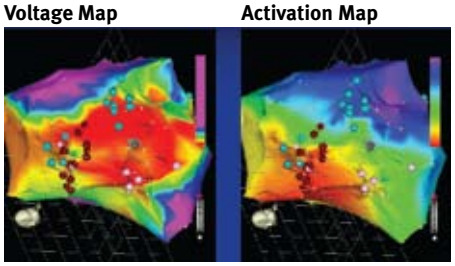
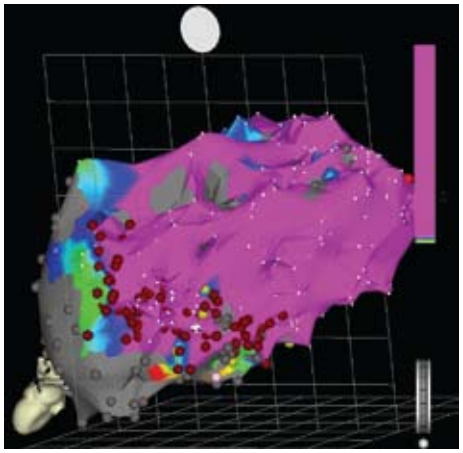


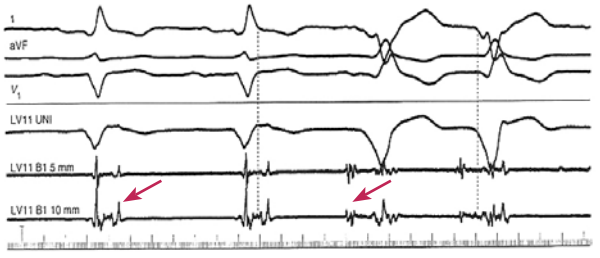
Figure 2. Voltage map of a patient who was ablated during sinus rythm. The gray area represents the dense scar (where no electrograms could be identified). The purple area represents viable tissue (› 0.5 mV). Note that linear ablation lesions (identified by the red symbols) were created along the border zone of the scar at the area where pace maps matching VT morphology (in all 12 leads) were identified



with stable VT (eight patients), and during sinus rhythm in patients with unstable VT (three patients) as described above [Figures 1-3].

Acute success, defined as termination of clinical VT and/or non-inducibility during programmed electric stimulation, was found in 9 patients (82%). In one of these patients programmed electric stimulation was not performed after ablation because of severe unstable VTs (which were judged to be not related to the clinical VT). Interestingly, VT was not observed after the ablation in this patient during clinical follow-up. The VT ablation procedure did not result in acute success in the remaining two patients.

Figure 3. Fractionated/late electrograms (arrow) constitute late activity during sinus rhythm and mid-diastolic activity during VT. The potentials indicate target site for ablation



FOLLOW-UP

During follow-up of at least 3 months, a significant reduction in the tachyarrythmia burden was observed in all patients who had successful initial ablation, except for one patient. This patient was ablated during sinus rhythm, which was considered a success (because of non-inducibility at the end of the procedure), had recurrence of VT 2 days after the ablation procedure and died 2 weeks later due to end-stage heart failure. Thus, long-term success occurred in 8 of the 11 patients (73%).

DISCUSSION

The treatment options for patients with recurrent VT associated with coronary artery disease are limited. The deleterious physiological and psychological effects of this life-threatening condition are significant, and there is an urgent need for another modality beside ICD and antiarrythmic drugs. In this report, we present our experience with ischemic VT ablation in a limited number of patients. The acute success is acceptable, but we could not calculate the exact success rate due to the small number of patients. Moreover, VT ablation is feasible and can be done during VT or sinus rhythm using electroanatomic scar mapping before or after ICD implantation. It was reported that multiple radiofrequency ablation lesions confined to infarct regions do not measurably affect left ventricular function [7].

Recently, Stevenson et al. [8] reported catheter ablation of monomorphic VT after myocardial infarction using electroanatomic mapping in 231 patients during sinus rhythm or VT. They found that catheter ablation is a reasonable option to reduce episodes of recurrent VTs in patients with prior myocardial infarction, even when multiple VTs (median, 3 per patient) and/or unmappable VTs (69% of patients) are present.

Marchlinski et al. [6] evaluated 16 ischemic and non-ischemic patients with drug refractory, unimorphic, unmappable VT with frequent ICD shocks by substrate/voltage mapping during sinus rhythm. Arrhythmia was controlled in 12 of 16 patients after radiofrequency point lesions extended linearly

from the dense scar, defined as voltage amplitude < 0.5 mV, to anatomic boundaries or normal endocardium under the guidance of electroanatomic and pace mapping. Prophylactic substrate-based catheter ablation, with the heart remaining predominantly in sinus rhythm, was reported to reduce the incidence of ICD therapy in patients with a history of myocardial infarction who received ICDs for the secondary prevention of sudden death compared to patients assigned to ICD alone [9]. Mapping and ablation of polymorphic ventricular tachycardia after myocardial infarction is also possible during sinus rhythm. In four of five patients with recurrent episodes of polymorphic VT after anterior myocardial infarction reported by Szumowski and co-authors [10], left ventricular electroanatomiic maps were created during sinus rhythm. The Purkinje arborization along the border zone of scar was found to have an important role in the mechanism of polymorphic VT in patients after myocardial infarction. Ablation of the local Purkinje network allowed suppression of polymorphic VT.

Despite the encouraging results, radiofrequency ablation of VT after myocardial infarction has had only moderate success and most patients will remain candidates for an implanted defibrillator, with ablation used for control of symptoms caused by frequent arrhythmia recurrences [11]. There are several reasons for the limited success of ischemic VT ablation. Ventricular scars are not electrically homogenous. They are composed of variable regions of dense fibrosis that create conduction block and surviving myocyte bundles with interstitial fibrosis and diminished coupling, which produce circuitous slow conduction paths that promote reentry [12]. Repeated programmed stimulation typically induces more than one monomorphic VT. Multiple VTs can be due to different circuits in widely disparate areas of scar, different axis from the same region of the scar, or changes in activation remote from the circuit due to functional regions of block [5]. In addition, catheter ablation using conventional techniques are suitable for stable VT. VT reentry circuit can be defined using electroanatomic mapping (CARTO) only during stable and tolerable tachycardia. However, many patients with reduced ejection fraction secondary to coronary heart disease have unstable VTs. These patients do not tolerate sustained VT or rapid pacing. Thus, electric or pace mapping is not available in most cases (unmappable VT with catheter technique). In these cases, scar mapping and ablation can be done only during sinus rhythm using the CARTO system [13]

CONCLUSIONS

Catheter ablation can control or prevent recurrent ischemic VT and reduce ICD therapy. The ablation can be done during VT in patients with stable VTs or during sinus rythm in patients with unstable unmappable VTs by targeting the scar border using electroanatomic substrate mapping. VT ablation should be offered to ischemic patients with recurrent uncontrolled VT.

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"After climbing a great hill, one only finds that there are many more hills to climb"

Nelson Mandela (b. 1918), first South African president to be elected in a fully representative democratic election. Before his presidency, Mandela was an anti-apartheid activist and leader of the African National Congress (ANC). Mandela served 27 years in prison, mostly on Robben Island. Following his release in 1990, he represented his party in the negotiations that led to multiracial democracy in 1994. As president from 1994 to 1999, he frequently gave priority to reconciliation. In South Africa, Mandela is known as *Madiba*, an honorary title adopted by elders of Mandela's clan. He has received more than 250 awards over four decades, including the 1993 Nobel Peace Prize.