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Long-Term Outcome of Catheter Ablation of Electrical Storm due to Recurrent Ventricular Tachycardia in a Large Cohort of Patients with Idiopathic Dilated Cardiomyopathy

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Abstract: Background: Recurrent therapies due to monomorphic ventricular tachycardia (VT) in patients with implantable cardioverter-defibrillator (ICD) can adversely affect their long-term survival. We intended to evaluate the long-term effect of the catheter ablation of electrical storm due to monomorphic VT in patients with idiopathic dilated cardiomyopathy (DCM).

Methods and Results: Between December 2006 and 2011, 40 consecutive patients (24 men, mean age $57.9 \pm 13.6$ years) with DCM and repeatable monomorphic VT who had ICD underwent 70 radiofrequency catheter ablation procedures, including 23 epicardial (33%), at our center. After a median of 1.5 ablations, acute complete success was achieved in 22 patients (65%). During a mean follow-up of 820 days (range 238–2120 days) 29 patients (72.5%) were free from VT recurrence. Compared to those without acute complete success ($n = 18$), in those with acute complete success ($n = 22$), 20 (90.9%) and 9 (50%) were free from any VT recurrence and ICD therapy, respectively (Fisher’s $p = 0.005$). During follow-up 2 (9.1%) and 4 (22.2%) patients died in the above mentioned groups, respectively. More aggressive ablation strategies to ablate all inducible VTs improves long-term freedom from VT and probably survival in these patients.

Key words: ventricular tachycardia, electrical storm, idiopathic dilated cardiomyopathy, catheter ablation, epicardial, survival

Introduction

Ventricular tachycardia (VT) most commonly develops in patients with structural heart disease. Myocardial fibrosis in these patients facilitates re-entry [1]. There is limited data available on catheter ablation of ventricular arrhythmias in patients with dilated cardiomyopathy [2–6]. Although implantable cardioverter-defibrillators (ICD) can provide rescue therapy by terminating ventricular arrhythmias they cannot prevent the recurrence and electrical storm which can adversely affect long-term survival [5, 7].

This single-centre study assesses the effect of catheter ablation of electrical storm due to monomorphic VT in patients with idiopathic non-ischemic cardiomyopathy (DCM) and its effect on their long term survival.

Methods

Study Population

Between December 2006 and December 2011, 40 consecutive patients with DCM and electrical storm due to monomorphic VT underwent catheter ablation procedures at our centre. All patients had an ICD implanted and electrical storm was defined as ≥ 3 episodes of monomorphic VT triggering appropriate ICD therapy (anti-tachycardia pacing and/or shock) within 24 hours despite optimal medical management of the VT including antiarrhythmic medications.

Mapping and Catheter Ablation

The detailed ablation protocol has been described in detail elsewhere [8, 9]. All patients gave written informed consent for the procedure of electrophysiology study and radiofrequency catheter ablation. Prior to the ablation procedure baseline pacing thresholds, sensed amplitudes, pacing, and shock impedances as well as battery status were measured. In fasting state and under deep sedation (in all but 2 patients)
with midazolam, fentanyl, and propofol, left ventricle (LV) mapping studies were performed. After femoral vascular access, a quadripolar (Inquiry, Irvine Biomedical Inc., St. Jude Medical Inc., Irvine, CA, USA) catheter was placed in the right ventricular apex and was used for the programmed stimulation and as the reference for activation mapping in Carto (XP and 3) electroanatomical mapping system (Biosense Webster Inc., Diamond Bar, CA, USA). The transseptal puncture was performed under fluoroscopic guidance and a large curl 8.5 Fr Agilis steerable sheath (St. Jude Medical Inc.) was placed into the left atrium. Intravenous heparin (100 U/kg initial bolus, followed by subsequent bolus doses to achieve an activated clotting time of 200–250 seconds) was administered. Left ventricular mapping was performed using an irrigated tip catheter (Navistar Thermocool, Biosense Webster Inc.).

Programmed right ventricular apical stimulation (S1: 500, 430, 370, and 330 ms, with up to 3 premature extra stimuli with a minimum interval of 180 ms) was initiated to induce the clinical VT. The procedure of VT ablation was done during VT if it was hemodynamically stable. During substrate mapping, our goal was to define the scar area and the areas in which diastolic, and fractionated electrograms were recorded (Fig. 1, 2). The scar region was defined as areas with bipolar local electrograms ≤ 0.5 mV and the normal myocardium was defined as areas with a bipolar local electrogram ≥ 1.5 mV. Pace mapping was performed to delineate the various components of re-entry circuit, especially the protected isthmus. Catheter ablation was guided by activation, substrate, and pace mapping. The standard ablation setting consisted of a pre-selected catheter tip temperature of 48 °C, a power of 50 W and a flow rate of 30–40 ml/min. Right ventricular stimulation at the end of the procedure was done to assess the effect of catheter ablation. The procedure’s end point was defined as non-inducibility of any monomorphic VT. In 7 patients (30.7%) epicardial mapping and ablation via subxyphoidal access was done to ablate the clinical VT (Fig. 2).
Radiofrequency Catheter Ablation

Seventy ablation procedures, including 23 (33%) cases of epicardial access and ablation, were performed during the study period (median 1.5/patient). All clinical and inducible non-clinical VTs were targeted for ablation. Left ventricular endocardial mapping was performed via transseptal approach in all patients. During electrophysiology study and catheter ablation procedure, 1–5 VTs were inducible in all but one patient (mean 2.0 ± 1.1 VT/patient, clinical VT cycle length 360 ± 82 ms; range 220–600 ms). Ablation of clinical VT was successfully done after a median ablation number of 1.5/patient in all but 5 patients (86%), however additional ablation of all non-clinical VTs was successful in 22 patients (63%). In 13 patients (37%) at least one non-clinical VT remained inducible. The total procedure and fluoroscopy times amounted to 165 ± 58 minutes and 32.8 ± 21 minutes for the first ablation procedures and 192 ± 45 minutes and 51.5 ± 28 minutes, respectively, for repeated ablation procedures.

Follow-up

During mean follow-up of 820 ± 491 days (range 238–2120 days), and after a median of 1.5 ablation procedures per patient 29 patients (72.5%) had no recurrence of VT based on regular ICD interrogations and clinical visits, and received no ICD therapy (Fig. 2a–d). Six patients (15%) died during the follow-up period. Among the patients with no recurrence of VT (n = 29) 2 (6.9%) died during the follow-up period. Among patients with VT recurrence after the last catheter ablation procedure (n = 11) 4 (36.4%) died during the follow-up period (p = 0.039).

Discussion

Our data showed that radiofrequency catheter ablation of monomorphic VT effectively controls long-term recurrence of VT during a mean follow-up of 820 ± 491 days in ICD patients with DCM as underlying heart disease, although many patients required more than one catheter ablation procedure to prevent recurrence of VT during follow-up (Fig. 2a, b). Complete success in catheter ablation was associated with improved survival (Fig. 2d) even though the sample size prevented conclusions regarding statistical significance. There was no statistically significant difference between the patients with and without acute complete success with respect to age (p = 0.78), ejection fraction (p = 0.64), and gender (p = 0.79).

Carbucchio and colleagues studied 95 consecutive patients with ICD (including 10 with DCM) who experienced electrical storm due to monomorphic VT [3]. Among the patients with all clinical VTs abolished during ablation no recurrence of electrical storm occurred during the follow-up period and mortality was significantly lower compared to those who showed persistent inducibility of ≥ 1 VT at the end of the procedure [3].

In our cohort, ablation off all inducible VTs (clinical and non-clinical) was associated with better long-term freedom from VT (Fig. 2c). Our data suggest that successful catheter ablation of all clinical and inducible (non-clinical) monomorphic VTs not only prevents further VT recurrences and ICD therapies but might also improve long-term survival of such patients. Therefore, more aggressive ablation strategies, including epicardial mapping and ablation of all inducible VTs, improve ablation outcome and probably survival among those who had an initially failed ablation procedure (Fig. 2d).

Soejima and colleagues studied 28 patients with dilated cardiomyopathy and recurrent VT [6]. Endocardial and epicard-
dial mappings were performed in 26 (93%) and 8 (29%) patients, respectively. The majority of the endocardial scar areas (63%) were adjacent to mitral valve annulus. Of the 19 identified VT circuit isthmuses, 12 (63%) were associated with an endocardial scar and 7 (37%) with an epicardial scar. During the follow-up period of 334 ± 280 days, 54% of patients with myocardial re-entry were free from VT recurrence [6].

To delineate the arrhythmia substrate in patients with non-ischemic cardiomyopathy, Cano and colleagues performed endocardial and epicardial bipolar voltage mapping in 22 patients (19 male, EF = 30% ± 13%, mean prior ablation = 1.8± patient) with DCM [10]. A total of 73 VTs was induced in these 22 patients with a mean cycle length of 392 ± 109 ms. Epicardial VT circuits could be identified in 18 (82%) patients. Low-voltage areas were present in 18 epicardial (82%) and 12 endocardial (54%) maps and were typically located in the basal posterior left ventricle (Fig. 1). In all patients with epicardial VT, the mean epicardial low-voltage area was greater than the endocardial area. During follow-up of 18 ± 7 months, ablation resulted in VT elimination in 15 of 21 patients (71%) including 14 of 18 patients (78%) with epicardial VT [10]. Nakahara and colleagues studied 33 (including 16 with DCM) patients referred for catheter ablation of VT [11]. Electroanatomic mapping was performed endocardially (n = 33) and epicardially (n = 19; 58%). The late potentials were defined as low-voltage electrograms (< 1.5 mV) with onset after the QRS interval. Very late potentials were defined as signals with onset > 100 ms after the QRS complex [11]. Mean total low-voltage areas in patients with ischemic heart disease were 101 ± 55 cm² (endocardial) and 56 ± 33 cm² (epicardial), compared with DCM of 55 ± 41 cm² and 53 ± 28 cm², respectively. Within the total low-voltage area, very late potentials were observed more frequently in ischemic than in DCM patients in the endocardium (4.1% vs 1.3%; p = 0.0003) and epicardium (4.3% vs 2.1%, p = 0.035). A late potential-targeted ablation strategy was effective in patients with ischemic cardiomyopathy (82% nonrecurrence at 12 ± 10 months of follow-up), whereas DCM patients had less favorable outcomes (50% at 15 ± 13 months of follow-up) [11].

Tokuda and colleagues studied 226 patients (age 52 ± 14 years; 79% men, 53% DCM) with sustained monomorphic VT due to non-ischemic cardiomyopathy. Among these patients acute complete success was achieved in 55% and freedom from death, heart transplantation, and readmission for VT recurrence were achieved in 173 (77%) patients and is comparable to our patient samples [12].

### Conclusion

Catheter ablation of electrical storm due to monomorphic VT in patients with DCM effectively controls long-term recurrence of VT during a mean follow-up period of 820 days (range, 238–2120 days). Although the majority of patients required more than one catheter ablation procedure, successful catheter ablation of all inducible clinical and non-clinical VTs was associated with higher freedom from VT during follow-up and improved long-term survival and this suggests that more aggressive ablation strategies targeting all inducible VTs may improve the long-term freedom from VT and probably survival. Further multicenter studies are needed to clarify these issues.

### Conflict of Interest

None.

### References

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