Journal für Kardiologie
Austrian Journal of Cardiology
Österreichische Zeitschrift für Herz-Kreislauferkrankungen

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Journal für Kardiologie - Austrian Journal of Cardiology 2013; 20 (7-8), 212-215

Krause & Pachernegg GmbH • Verlag für Medizin und Wirtschaft • A-3003 Gablitz

P.b.b. 02Z031105M, Verlagsort: 3003 Gablitz, Linzerstraße 177A/21 Preis: EUR 10,–

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 ± 13.6 years) with DCM and repeated 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 (63%). 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 (p = 0.267).

Conclusion: Catheter ablation in DCM patients with electrical storm due to monomorphic VT prevents VT recurrence in 72.5% of the patients; however, many patients need more than one ablation procedure. Successful catheter ablation may play a protective role and was associated with a trend toward reduced mortality during the follow up period. 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

Kurzfassung: Langfristige Wirkung der Katheterablation bei elektrischem Sturm bei Patienten mit idiopathischer dilatativer Kardiomyopathie. *Hintergrund:* Rezidivierende Therapien aufgrund monomorpher ventrikulärer Tachykardien (VT) bei Patienten mit implantierbaren Defibrillatoren (ICD) können negative Auswirkungen auf ihr langfristiges Überleben haben. Wir haben die langfristige Wirkung der Katheterablation von monomorphen VTs bei Patienten mit idiopathischer dilatativer Kardiomyopathie (DCM) untersucht.

Methoden und Ergebnisse: Zwischen Dezember 2006 und 2011 wurden bei 40 Patienten mit DCM und rezidivierenden monomorphen VTs (24 Männer, mittleres Alter 57,9 ± 13,6 Jahre) in unserem Zentrum 70 Katheterablationen (darunter 23 [33 %] epikardial) durchgeführt. Alle induzierbaren VTs wurden in 22 Patienten (63 %) abladiert. Während einer mittleren Nachbeobachtungszeit von 820 Tagen (238–2120 Tage) waren 29 Patienten (72,5 %) frei von VT-Rezidiv. Bei Patienten mit (n = 22) und ohne (n = 18) akutem Erfolg waren 20 (90,9 %) bzw. 9 (50 %) frei von VT-Rezidiv und ICD-Therapie (p = 0,005). Während des Follow-up verstarben 2 (9,1 %) bzw. 4 (22,2 %) Patienten der oben genannten Gruppen (p = 0,267).

Fazit: Katheterablation in DCM-Patienten mit monomorphen VTs könnte VT-Rezidive bei 72,5 % der Patienten verhindern, doch benötigen viele Patienten mehr als eine Ablation. Erfolgreiche Katheterablation wurde mit einem Trend zu einer verminderten Mortalität während des Follow-up assoziiert. Ablationstrategien zur Ablation alle induzierbaren VTs kann zur Verbesserung der langfristigen Freiheit von VT und wahrscheinlich Mortalität bei diesen Patienten führen. **J Kardiol 2013; 20 (7–8): 212–5.**

Schlüsselwörter: ventrikuläre Tachykardie, elektrischer Sturm, idiopathische dilatative Kardiomyopathie, Katheterablation, Mortalität, epikardial

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 can not 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.

Received: December 4, 2012; accepted: December 8, 2012; Pre-Publishing Online: February 18, 2013

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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 (antitachycardia 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)

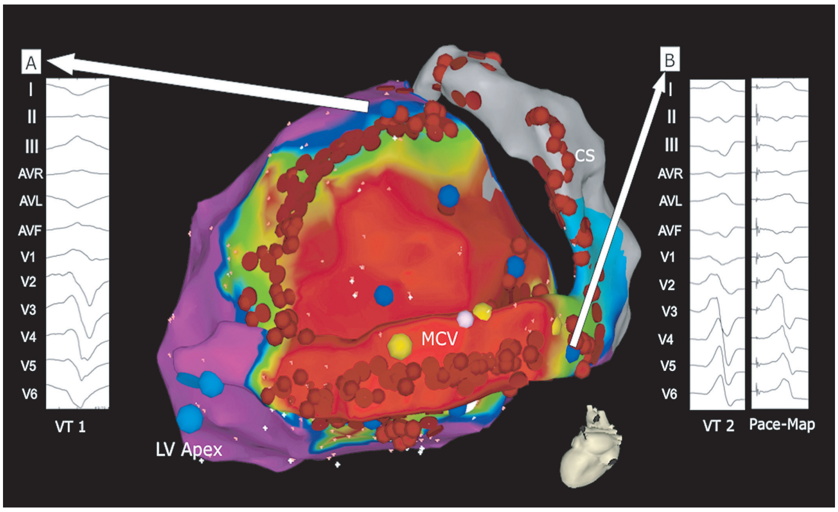

Figure 1. Electroanatomical bipolar voltage map of a left ventricle, the coronary sinus (CS) and the middle cardiac vein (MCV) of a patient with nonischemic dilated cardiomyopathy and ventricular tachycardia (VT) is shown in a caudal left posterior oblique projection. Bipolar voltage of < 0.5 mV (suggestive of a dense scar) is depicted in red and the normal myocardium (with bipolar voltage > 1.5 mV) is represented in purple, with other colors corresponding to the intermediate signal amplitude seen in the scar's border zone. **(A)** shows a 12-lead of VT 1 and **(B)** shows a 12-lead ECG of an VT 2 and corresponding pace map, pointed out from origin with white arrows. Dark blue dots indicate phrenicus capture, light blue dots indicate termination of VT during ablation. Red dots indicate ablation points.

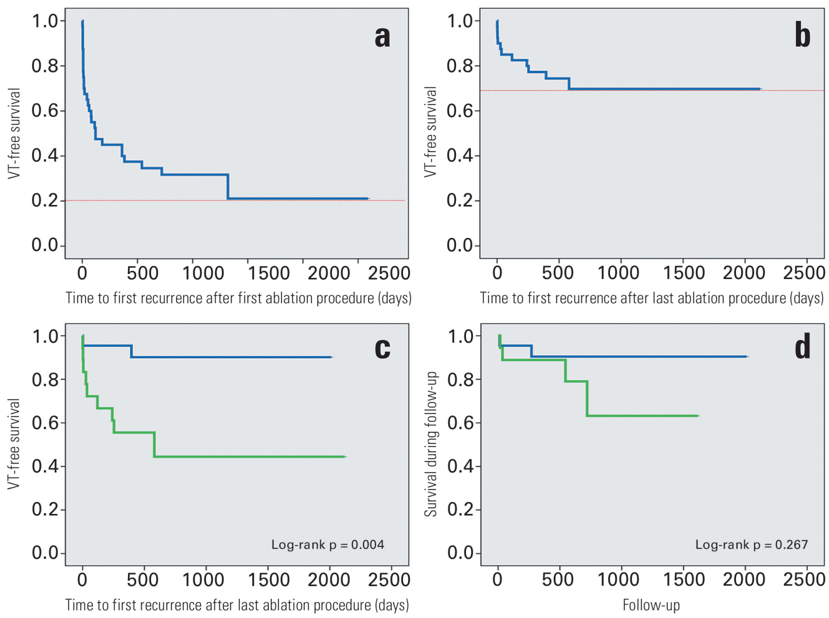

Figure 2. Kaplan-Meier plot of the time to first VT recurrence after first **(a)** and last catheter ablation procedures **(b)**; VT free survival **(c)** and all-cause mortality **(d)** according to acute results of the catheter ablation procedure; the blue line represents acute complete success of ablation defined as ablation of clinical and all non-clinical inducible ventricular tachycardias. The green line represents the group in which the clinical VT (n = 5) or another non-clinical ventricular tachycardia remained inducible at the end of the ablation procedure. The Log-Rank (Mantel-Cox) test is used to generate p-values.

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).

Table 1: Patient characteristics at baseline

Variables	Group 1*	Group 2**	Total	p
Number	22	18	40	–
Age (years)	58.5 ± 13.6	57.2 ± 13.9	57.9 ± 13.6	0.78
Gender (♂; n/%)	19 (86%)	15 (83%)	34 (85%)	0.79
LVEF	33.9 ± 14.0	32.0 ± 10.6	33.0 ± 12.5	0.64
LVEDd (mm)	61.9 ± 13	61.4 ± 8.3	61.6 ± 10.9	0.89
BBRVT (n; %)	1 (4.5%)	3 (16.7%)	4 (10%)	0.31
Follow-up	818 ± 482	821 ± 515	820 ± 491	0.98

*Acute complete success of ablation defined as ablation of clinical and all non clinical inducible ventricular tachycardias.
**In this group clinical VT (n = 5) or another non-clinical ventricular tachycardia remained inducible at the end of the ablation procedure.
BBRVT: bundle branch reentrant ventricular tachycardia; LVEF: left ventricular ejection fraction; LVEDd: left ventricular end diastolic dimension.

Definitions

Unsuccessful catheter ablation was defined as inducibility of clinical VT at the end of the ablation procedure. Acute complete success was defined as the lack of inducibility of any VT at the end of procedure and partial success was defined as inducibility of ≥ 1 non-clinical VT despite non-inducibility of clinical VT at the end of the catheter ablation procedure.

Statistical Analysis

Variables are expressed as mean ± SD (or median, range), and percentage. Differences in frequency of characteristics were assessed by independent sample t-test for continuous variables. For discrete variables chi-square statistics (or Fisher's exact test if applicable) were used. Probability of VT recurrence based on the time to first arrhythmia recurrence between the 2 groups (successful and unsuccessful catheter ablation) was determined by Kaplan-Meier analysis with Log-Rank test. Time to first VT recurrence was plotted according to the Kaplan-Meier method. A 2-tailed p-value < 0.05 was considered statistically significant. We used SPSS® 13.0 (SPSS Inc. Chicago, IL, USA) for data storage and analysis.

Results

Baseline Clinical and Demographic Characteristics

Forty consecutive patients (24 men, mean age 57.9 ± 13.6 years) with DCM and electrical storm due to monomorphic VT were studied. Mean left ventricular ejection fraction was 33 ± 12.5%. Antiarrhythmic medication (Class Ic and/or III) and betablockers were tried in all patients with no success. All patients had evidence of a monomorphic VT morphology on stored ICD electrograms or 12-lead ECG. Table 1 shows the patients' baseline characteristics.

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).

Carbucicchio 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 epicardial 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 cm^2 (endocardial) and 56 ± 33 cm^2 (epicardial), compared with DCM of 55 ± 41 cm^2 and 53 ± 28 cm^2, 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.

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