



Ventricular tachycardia ablation and substrate modification in ICD patients with electrical storm

Minglong Chen 

Section of Electrophysiology, Division of Cardiology, the First Affiliated Hospital of Nanjing Medical University, Nanjing, Jiangsu 210029, China.

Abstract

The electrical storm (ES) is defined as a state of electrical instability with three or more sustained ventricular arrhythmias (VAs) occurring within twenty-four hours, which needs intravenous antiarrhythmic medications and frequent defibrillation. Recently, radiofrequency catheter ablation evolved as a sole therapy to terminate ES in patients with ICD, and the survival has been reported to be improved with successful ablation during follow-up. In this review, we briefly summarize substrate mapping and substrate ablation strategy in patients with ES, and discuss the reason of recurrence after ablation.

Keywords: electrical storm, ventricular tachycardia, substrate, ablation

Implantable cardioverter defibrillator (ICD) has been recommended for primary or secondary prevention of sudden cardiac death in patients with ischemic or non-ischemic cardiomyopathy and life-threatening cardiac rhythm disorders^[1-3]. Electrical storm (ES) is defined as a state of electrical instability, with three or more sustained ventricular arrhythmias (VAs) occurring within twenty-four hours, which needs intravenous antiarrhythmic medications and frequent defibrillation therapies (≥ 3 episodes and separated by 5 minutes in 24 hours). The estimated incidence of ES is approximately 4% or 20% in primary or secondary prophylactic ICDs^[4,5], respectively. Recently, more studies demonstrated the significant association between ES events and death⁵⁻⁷. Patients with ES are estimated from case series to survive 1-year, varying from 5% to 35%^[1,2]. The most common cause of death in patients with ICD-ES is related to heart failure because of frequent storms. Recurrent shocks also can reduce quality of life^[8].

Radiofrequency catheter ablation may be a sole therapy to terminate ES in patients with ICD and survival has been reported to be improved with successful ablation during follow-up^[7,9]. The individualized patient profile can yield a different mapping strategy and the corresponding ablation strategy. Recently, a systematic review elucidated that the most common mechanism of ES seen in 83% patients was scar-related reentry in a total of 471 ES patients from thirty-nine publications^[10]. According to this meta-analysis, substrate guided mapping and ablation is a reasonable strategy in ES patients with unstable hemodynamic VT or non-inducible VT during the procedure^[11-14]. Substrate mapping can identify, by three dimensional mapping (NavX or CARTO system), the possible reentry circuit. This is based on low-voltage and fragmental potential which can be analyzed during stable sinus or paced rhythm. However, this strategy is less precise for localization of the reentry circuit and needs more extensive ablation over a relatively

[✉] Corresponding author: Minglong Chen, M.D., Section of Electrophysiology, Division of Cardiology, the First Affiliated Hospital of Nanjing Medical University, 300 Guangzhou Road, Nanjing 210029, China. Tel/Fax: +0086-25-8371-7168/+0086-25-

8371-7168, E-mail: chenminglong@njmu.edu.cn.

Received 19 December 2014, Accepted 28 December 2014, Epub 15 January 2015

The author reported no conflict of interests.

large area within the scar. Based on the substrate geometry, radiofrequency lesions can then be placed roughly parallel to the low-voltage region border; linear perpendicular to the border, extending through the exit region into the dense scar region^[12]. Areas of late and fragment low-voltage potentials observed during sinus or paced rhythm would also be targeted for ablation^[13]. The goal and ideal procedural endpoint was complete elimination of local abnormal ventricular activities, including fractionated, double or late potentials and no capture of ablation area with maximal output (amplitude = 20 mA and pulse width = 10 ms)^[15,16]. The most common mapping and radiofrequency ablation region was left or right endocardium. A combination of endocardial and epicardial mapping was applied in patients with recurrence after the first procedure or initially failed endocardially^[17,18].

A prospective evaluation of radiofrequency catheter ablation in 95 patients with medication-refractory ES showed that ES was acutely suppressed in all patients; 92% of the patients were free of ES and 66% were free of VT after a median follow-up of 22 months. Epicardial mapping and ablation was performed in ten patients; 19% of the patients required repeat catheter ablation. Eight percent of the patients had ES recurrence at 5 ± 7 months, four of whom died. In total, 12% of the patients died of cardiac causes, the remaining seven deaths originating from refractory heart failure^[7]. In a retrospective study of 52 patients experiencing their first ES, the patients were divided the catheter ablation group ($n = 23$) and drug therapy group ($n = 29$) according to the operator's preference and the time of occurrence. There was no statistically significant mortality difference between the two groups. The recurrence of ES was also similar (38% in ablation vs. 57% in medication, $P = 0.29$), and the 38% recurrent patients in the ablation group were proved to have lower LVEF ($< 25\%$). Patients with a higher LVEF ($> 25\%$) in the ablation group had a lower ES recurrence compared to the medical group (21% vs. 62%, $P = 0.002$). However, 82.6% of the ablated patients were on antiarrhythmic medications. Another interesting finding was that no difference was noticed in the estimated mortality in ablated and non-ablated patients (47% vs. 32%, $P = 0.039$)^[19]. In an observational study of a multihospital network to facilitate VT ablation for 37 ES patients, five patients with ES died prior to ablation, 29 patients had monomorphic VT and there were 3 patients with ventricular fibrillation. Among the 32 patients, 27 underwent ablation within 24 hours after transfer and five underwent emergent ablation within 8 hours. Acute success was achieved in 11 of the 17 patients with ischemic cardiomyopathy and 8 of the 14 patients with nonischemic

cardiomyopathy during the ablation procedure; one patient died during the procedure. After a mean follow-up of 15 months, 3 patients died, 10 had recurrent VA and 2 had recurrent ES. Although the result of catheter ablation to suppress ES is encouraging, the effect of this multihospital network on procedural success rates and mortality cannot be determined without a control group^[18]. A meta-analysis evaluating 471 patients presenting with ES demonstrated 68% with ischemic cardiomyopathy, 17% with idiopathic-dilated cardiomyopathy, 5% with ARVD/C, and 6% without structural heart disease. ES was from monomorphic VT in 77%, polymorphic VT in 7% and VF in 11% (45% of patients with VF had no structural heart disease). The cumulative data demonstrated an acute ablation success rate for ES, with 91% patients having elimination of clinical ventricular arrhythmia and 72% with all inducible VT with a 0.6% procedure-related mortality rate. During follow-up, only 6% of the patients had recurrence of ES and 17% mortality over 61 ± 37 weeks of follow-up, with 10% of the deaths owing to progressive heart failure and 4% of the deaths due to recurrent VA. Patients with nonischemic cardiomyopathy or incessant VA tended to have a worse outcome^[10]. However, this meta-analysis excludes large trials of catheter ablation, such as the Multi-Center ThermoCool trial^[20], the Euro-VT trial^[21] and a study of epicardial ablation^[22], because these studies did not report the effect of ventricular substrate map and ablation on survival for ES patients. Another meta-analysis study of catheter ablation as an adjunct to medical therapy for VT in patients with structural heart disease^[23] found that VT recurrence had a significant reduction (35%) in the ablation group compared to the medical group ($P < 0.001$), although there was no statistically significant difference in mortality between the two groups. However, in this meta-analysis^[23], the author combined two studies to analyze the different strategies to treat ES. In 116 patients with ICD, ES occurred in 40% of the patients^[24,25]; 17 of the patients were assigned to adjunctive ablation and 29 patients were assigned to medical therapy. The results implied that the ablation group showed a trend toward reduction of ES compared to medical therapy (Mantel-Haenszel pooled relative risk 0.61, $P = 0.066$).

Recently, a novel substrate ablation strategy for unmappable VT with ES was reported^[16]. The study found that electrical isolation of the entire substrate was feasible and appeared to be an effective treatment in patients with ES. Isolation was defined as the presence of both an entrance and exit block within the entire low-voltage area border-zone. In this study, twelve patients (54 ± 8 years, LVEF $32 \pm 13\%$)

underwent catheter ablation for sustained VT. Seven patients had ES and recurrent defibrillator shocks. Substrate isolation was achieved in seven patients through endocardial mapping and ablation (including one transient isolation patient), three of which had a focal discharge within the isolated area. During a mean follow-up of 479 days, eight patients remained free of VT recurrence after the first procedure; five patients in the entire isolation group had no recurrence of VT.

There might be many factors in baseline characteristics and the ablation procedure that can predict a higher risk of death or ES recurrence. However, no single factor in the baseline can significantly predict this poor result. Even the LVEF appeared to have a small association with mortality. Some studies supported this^[7,26]; but other studies argued the opposite relationship^[27]. The published systematic meta-analysis^[10] demonstrated that storm in patients with incessant VA predicted poor outcomes compared with frequent VA; patients with VF and polymorphic VT also had significantly lower recurrence compared with monomorphic VT. The successful ablation procedure suggests a favorable long-term result; however, ES patients with failed ablation procedure might have moderate increase in mortality.

In conclusion, catheter ablation is a suitable and useful strategy for treating recurrent VT with ES. However, a successful procedure does not mean an improved survival rate because many of these patients still die of progressive heart failure.

References

- [1] Moss AJ, Zareba W, Hall WJ, et al. Prophylactic implantation of a defibrillator in patients with myocardial infarction and reduced ejection fraction. *N Engl J Med* 2002; 346(12):877–883.
- [2] Bardy GH, Lee KL, Mark DB, et al. Amiodarone or an implantable cardioverter-defibrillator for congestive heart failure. *N Engl J Med* 2005;352(3):225–237.
- [3] Myerburg RJ, Castellanos A. Clinical trials of implantable defibrillators. *N Engl J Med* 1997;337:1621–1623.
- [4] Sesselberg HW, Moss AJ, McNitt S, et al. Ventricular arrhythmia storms in postinfarction patients with implantable defibrillators for primary prevention indications: a MADIT-II substudy. *Heart Rhythm* 2007;4(11):1395–1402.
- [5] Exner DV, Pinski SL, Wyse DG, et al. Electrical storm presages nonsudden death: the antiarrhythmics versus implantable defibrillators (AVID) trial. *Circulation* 2001; 103(16):2066–2071.
- [6] Hohnloser SH, Al-Khalidi HR, Pratt CM, et al. Electrical storm in patients with an implantable defibrillator: incidence, features, and preventive therapy: insights from a randomized trial. *Eur Heart J* 2006;27(24):3027–3032.
- [7] Carbucicchio C, Santamaria M, Trevisi N, et al. Catheter ablation for the treatment of electrical storm in patients with implantable cardioverter-defibrillators: short- and long-term outcomes in a prospective single-center study. *Circulation* 2008;117(4):462–469.
- [8] Sears SE, Jr., Conti JB. Understanding implantable cardioverter defibrillator shocks and storms: medical and psychosocial considerations for research and clinical care. *Clin Cardiol* 2003;26(3):107–111.
- [9] Frankel DS, Mountantonakis SE, Robinson MR, et al. Ventricular tachycardia ablation remains treatment of last resort in structural heart disease: argument for earlier intervention. *J Cardiovasc Electrophysiol* 2011;22(10): 1123–1128.
- [10] Nayyar S, Ganesan AN, Brooks AG, et al. Venturing into ventricular arrhythmia storm: a systematic review and meta-analysis. *Eur Heart J* 2013;34(8):560–571.
- [11] Soejima K, Suzuki M, Maisel WH, et al. Catheter ablation in patients with multiple and unstable ventricular tachycardias after myocardial infarction: short ablation lines guided by reentry circuit isthmuses and sinus rhythm mapping. *Circulation* 2001;104(6):664–669.
- [12] Marchlinski FE, Callans DJ, Gottlieb CD, et al. Linear ablation lesions for control of unmappable ventricular tachycardia in patients with ischemic and nonischemic cardiomyopathy. *Circulation* 2000; 101(11):1288–1296.
- [13] Arenal A, Glez-Torrecilla E, Ortiz M, et al. Ablation of electrograms with an isolated, delayed component as treatment of unmappable monomorphic ventricular tachycardias in patients with structural heart disease. *J Am Coll Cardiol* 2003;41(1):81–92.
- [14] Cesario DA, Vaseghi M, Boyle NG, et al. Value of high-density endocardial and epicardial mapping for catheter ablation of hemodynamically unstable ventricular tachycardia. *Heart Rhythm* 2006;3(1):1–10.
- [15] Komatsu Y, Daly M, Sacher F, et al. Endocardial ablation to eliminate epicardial arrhythmia substrate in scar-related ventricular tachycardia. *J Am Coll Cardiol* 2014;63(14):1416–1426.
- [16] Tilz RR, Makimoto H, Lin T, et al. Electrical isolation of a substrate after myocardial infarction: a novel ablation strategy for unmappable ventricular tachycardias—feasibility and clinical outcome. *Europace* 2014;16(7):1040–1052.
- [17] Kozluk E, Gaj S, Kiliszek M, et al. Efficacy of catheter ablation in patients with an electrical storm. *Kardiol Pol* 2011;69(7):665–670.
- [18] Deneke T, Shin DI, Lawo T, et al. Catheter ablation of electrical storm in a collaborative hospital network. *Am J Cardiol* 2011;108(2):233–239.
- [19] Izquierdo M, Ruiz-Granell R, Ferrero A, et al. Ablation or conservative management of electrical storm due to monomorphic ventricular tachycardia: differences in outcome. *Europace* 2012;14(12):1734–1739.
- [20] Stevenson WG, Wilber DJ, Natale A, et al. Irrigated radiofrequency catheter ablation guided by electroanatomic mapping for recurrent ventricular tachycardia after myocardial infarction: the multicenter thermocool ventricular tachycardia ablation trial. *Circulation* 2008;118(25):2773–2782.
- [21] Tanner H, Hindricks G, Volkmer M, et al. Catheter ablation of recurrent scar-related ventricular tachycardia using electroanatomical mapping and irrigated ablation technology: results of the prospective multicenter Euro-VT-study. *J Cardiovasc Electrophysiol* 2010;21(1):47–53.
- [22] Della Bella P, Brugada J, Zeppenfeld K, et al. Epicardial ablation for ventricular tachycardia: a European multicenter study. *Circ Arrhythm Electrophysiol* 2011;4(5):653–659.

- [23] Mallidi J, Nadkarni GN, Berger RD, et al. Meta-analysis of catheter ablation as an adjunct to medical therapy for treatment of ventricular tachycardia in patients with structural heart disease. *Heart Rhythm* 2011;8(4):503–510.
- [24] Reddy VY, Reynolds MR, Neuzil P, et al. Prophylactic catheter ablation for the prevention of defibrillator therapy. *N Engl J Med* 2007;357(26):2657–2665.
- [25] Kuck KH, Schaumann A, Eckardt L, et al. Catheter ablation of stable ventricular tachycardia before defibrillator implantation in patients with coronary heart disease (VTACH): a multicentre randomised controlled trial. *Lancet* 2010;375(9708):31–40.
- [26] Kozeluhova M, Peichl P, Cihak R, et al. Catheter ablation of electrical storm in patients with structural heart disease. *Europace* 2011;13(1):109–113.
- [27] Arya A, Eitel C, Bollmann A, et al. Catheter ablation of scar-related ventricular tachycardia in patients with electrical storm using remote magnetic catheter navigation. *Pacing Clin Electrophysiol* 2010;33(11):1312–1318.

CLINICAL TRIAL REGISTRATION

The *Journal* requires investigators to register their clinical trials in a public trials registry for publication of reports of clinical trials in the *Journal*. Information on requirements and acceptable registries is available at www.icmje.org/faq_clinical.html.