# Successful ventricular tachycardia ablation in patients with electrical storm reduces recurrences and improves survival @



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**OBJECTIVE** The purpose of this study was to evaluate the characteristics and outcome of patients undergoing ablation after electrical storm (ES).

**METHODS** Clinical and procedural characteristics, ventricular tachycardia (VT) recurrence, and mortality rates from 1940 patients undergoing VT ablation were compared between patients with and without ES.

**RESULTS** The group of 677 patients with ES (34.9%) were older, were more frequently men, and had a lower ejection fraction, more advanced heart failure, and a higher prevalence of cardiovascular comorbidities as compared with those without ES (86.1% patients with ES had  $\geq$ 2 comorbidities vs 71.4%; P < .001). Patients with ES had more inducible VTs (2.5  $\pm$  1.8 vs 1.9  $\pm$  1.9; P < .001), required longer procedures (296.1  $\pm$  119.1 minutes vs 265.7

 $\pm$  110.3 minutes; P < .001), and had a higher in-hospital mortality (42 deaths [6.2%] vs 18 deaths [1.4%]; P < .001). At 1-year follow-up, patients with ES experienced a higher risk of VT recurrence and mortality (32.1% vs 22.6% and 20.1% vs 8.5%; longrank, P < .001 for both). Among patients with ES, those without any inducible VT after ablation had a higher survival rate (86.3%) than did those with nonclinical VTs only (72.9%), those with clinical VTs inducible at programmed electrical stimulation (51.2%), and not-tested patients (65.0%) (long-rank, P < .001 for all). In multivariate analysis, ES remained an independent predictor of in-hospital mortality, VT recurrence, and 1-year mortality (P< .001).

**CONCLUSION** Patients with ES have a high risk of VT recurrence and mortality. Patient and procedure characteristics are consistent

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with advanced cardiac disease and longer and more complex procedures. In patients with ES, acute procedural success is associated with a significant reduction in VT recurrence and improved 1-year survival.

#### Introduction

The use of implantable cardioverter-defibrillators (ICDs) and improvements in pharmacological therapies have improved survival in patients with impaired systolic function. ICD therapies can successfully terminate acute ventricular arrhythmias, but do not modify the arrhythmic substrate nor prevent subsequent ventricular tachycardia (VT) episodes. Electrical storm (ES) is a life-threatening arrhythmic emergency characterized by  $\geq 3$  VT or ventricular fibrillation (VF) episodes treated by the ICD within 24 hours.<sup>1–3</sup> Catheter ablation has been shown to reduce VT burden and appropriate ICD therapies in patients with structural heart disease.

The aims of this study were to characterize the population of patients who required catheter ablation for the treatment of ES and to evaluate the impact of acute procedural success on VT recurrence and survival of those patients from the largest available up-to-date multicenter database.

### Methods Study design

The International VT Ablation Center Collaborative Group (IVTCC) consists of 12 international sites that specialized in VT management with a developed protocol for data sharing.<sup>4</sup> For 1940 patients, physicians reported whether they had already experienced ES; those patients were included in the present analysis. *ES* was defined as  $\geq$ 3 VT/VF episodes within 24 hours. The study was approved by the institutional review boards of the respective participating centers.

#### Ablation procedure

Ablation procedure methodology of the IVTCC has already been described.<sup>4</sup> Ablation was performed targeting VTs induced by programmed electrical stimulation (PES) and modifying the electrical substrate.<sup>5,6</sup> After ablation, PES was repeated unless hemodynamic instability or prohibitive procedural duration.

#### **Clinical follow-up**

Patients were followed up by ICD interrogation at 3, 6, and 12 months. For patients not followed up at an IVTCC center, referring cardiologists were contacted and ICD interrogations reviewed. Remote control follow-ups were carefully checked for VT recurrence. Telephone interviews were also routinely performed with patients or family members. *Recurrent VT/VF* was defined as documented VT/VF lasting >30 seconds or any appropriate ICD therapy including antitachycardia pacing. Study end points were VT recurrence after the last ablation procedure, death, and heart transplant. Antiar-

**KEYWORDS** Ventricular tachycardia; Catheter ablation; Electrical storm; Ischemic cardiomyopathy; Nonischemic cardiomyopathy

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rhythmic therapy after ablation was at the discretion of the treating physician.

#### Statistical analysis

Continuous variables are expressed as mean  $\pm$  SD; the independent samples *t* test and Mann-Whitney *U* test was used to compare normally and nonnormally distributed continuous variables, respectively. Categorical variables are summarized as frequency and percentage and compared using the Pearson  $\chi^2$  exact test.

Univariate analysis was performed to evaluate the association of clinical and procedural variables in terms of VT recurrence and mortality. Kaplan-Meier survival curves were used to estimate freedom from recurrent VT, transplant, and death. The log-rank test was used to compare VT-free survival times of patients with and without ES, also stratified by the result of PES after ablation (no inducible VT [no-VT], only nonclinical VT [nc-VT], at least 1 VT inducible, clinical VT still inducible [c-VT], and PES not repeated [no-PES]); the same analysis was repeated within the group with ES.

Cox regression analysis was performed to identify risk/ protective factors for VT recurrence or death on the entire sample and also by considering patients with ES separately (see Supplemental Methods). Analyses were performed using R statistical software (R Development Core Team, 2016); the significance level was set at .05.

#### Results

A total of 1940 patients with structural heart disease who underwent VT ablation in 12 centers from the IVTCC were included in the present analysis; of those, 677 patients (34.9%) had an ES episode before the index ablation procedure. Patients with ES were older (64.4  $\pm$  12.5 years vs 61.3  $\pm$  13.6 years; P < .001), were more frequently men, and had a lower left ventricular ejection fraction (LVEF) and New York Heart Association (NYHA) class II or greater as compared with patients without ES. Patients with ES were also more frequently affected by cardiovascular comorbidities such as hypertension, hyperlipidemia, atrial fibrillation, diabetes, and chronic kidney disease and more frequently had an already implanted cardiac resynchronization therapy device; they more frequently had prior ablation, with a higher number of procedures than did patients with VT who presented without ES. The arrhythmia more frequently manifested with syncope in patients with ES. Patients undergoing VT ablation after ES were more likely to have been previously treated with antiarrhythmic drugs, in particular with class 1A and class 1B antiarrhythmic drugs,  $\beta$ -blockers, and amiodarone; they were also more frequently

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