

# Ventricular tachycardia burden reduction after substrate ablation: Predictors of recurrence



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**BACKGROUND** Substrate-based ventricular tachycardia (VT) ablation is a first-line treatment in patients with structural cardiac disease and sustained VT refractory to medical therapy. Despite technological improvements and increased knowledge of VT substrate, recurrence still is frequent. Published data are lacking on the possible reduction in VT burden after ablation despite recurrence.

**OBJECTIVE** The purpose of this study was to assess VT burden reduction during long-term follow-up after substrate ablation and identify predictors of VT recurrence.

**METHODS** We analyzed 234 consecutive VT ablation procedures in 207 patients (age  $63 \pm 14.9$  years; 92% male; ischemic heart disease in 65%) who underwent substrate ablation in a single center from 2013 to 2018.

**RESULTS** After follow-up of  $3.14 \pm 1.8$  years, the VT recurrence rate was 41.4%. Overall, a 99.6% reduction in VT burden (median VT episodes per year: preprocedural 3.546 [1.347–13.951] vs postprocedural 0.001 [0–0.689];  $P = .001$ ) and a 96.3% decrease in implantable cardioverter-defibrillator (ICD) shocks (preprocedural

1.145 [0.118–4.467] vs postprocedural 0.042 [0–0.111] per year;  $P = .017$ ) were observed. In the subgroup of patients who experienced VT recurrences, VT burden decreased by 69.2% (median VT episodes per year: preprocedural 2.876 [1.105–8.801] vs postprocedural 0.882 [0.505–2.283];  $P < .001$ ). Multivariable analysis showed persistence of late potentials (67% vs 19%; hazard ratio 3.18 [2.18–6.65];  $P < .001$ ) and lower left ventricular ejection fraction (EF) (30 [25–40] vs 39 [30–50];  $P = .022$ ) as predictors of VT recurrence.

**CONCLUSION** Despite a high recurrence rate during long-term follow-up, substrate-based VT ablation is related to a large reduction in VT burden and a decrease in ICD therapies. Lower EF and persistence of late potentials are predictors of recurrence.

**KEYWORDS** Arrhythmic burden reduction; Implantable cardioverter-defibrillator shock prevention; Ventricular tachycardia ablation; Ventricular tachycardia recurrence predictors; Ventricular tachycardia storm; Ventricular tachycardia substrate ablation

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## Introduction

Ventricular tachycardia (VT) is a significant cause of morbidity and mortality in patients with structural heart disease. Implantable cardioverter-defibrillators (ICDs) have

been shown to be effective in preventing sudden death due to ventricular arrhythmias, but they are not able to prevent recurrent VT episodes. In addition, although ICDs improve survival, quality of life can be negatively affected by recurrent VT episodes and ICD therapies. Moreover, there is evidence that ICD shocks, both appropriate and inappropriate, have adverse effects on survival.<sup>1</sup> Medical treatment with antiarrhythmic drugs does not show efficacy in preventing recurrent episodes of VT. In addition, the safety of drugs (especially amiodarone, which is the most effective antiarrhythmic drug) is not superior to VT ablation.<sup>2</sup> In this situation, VT ablation in patients with recurrent VT episodes has risen as an alternative and assumed a primary role over time.<sup>3</sup>

In most high-volume ablation centers, VT recurrence occurs in 25%–50% of patients during long-term follow-up after

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ablation.<sup>4,5</sup> However, evaluation of ablation treatment in terms of recurrence as a dichotomous variable, as has been demonstrated for atrial fibrillation ablation, omits a potential clinical benefit in terms of reduction in arrhythmia burden.<sup>6</sup>

VT ablation after an initial VT episode has resulted in a significant reduction in ICD shocks and hospitalizations, and one study demonstrated a trend toward improved survival and reduced likelihood of VT storms.<sup>7,8</sup>

Initial experience has reported significant VT burden reduction after ablation in patients with nonischemic cardiomyopathy (NICM).<sup>9</sup> In addition, studies have described patient clinical profile risks of VT recurrence.<sup>10</sup> However, extensive data regarding decreases in VT burden after substrate-based ablation are lacking. The aim of the present study was to evaluate VT burden reduction and to assess the presence of possible recurrence predictors in patients who had undergone substrate VT ablation in long-term follow-up.

## Methods

### Study population

Two hundred seven consecutive patients (234 total procedures) who had undergone scar-related VT ablation at a single center from 2013 to 2018 were prospectively included in the study and underwent follow-up. Inclusion criteria were the presence of a ventricular scar on late gadolinium enhanced cardiac magnetic resonance (LGE-CMR) or electroanatomic mapping (EAM) and sustained monomorphic VT documented by 12-lead electrocardiogram or ICD electrogram. During data revision, 16 VT ablation procedures (8%) were excluded for different therapeutic strategies, 14 (7%) for incomplete data on the procedure, and 12 (6%) for incomplete data at follow-up. The final sample included 169 patients and 192 procedures, of which 150 were a first procedure and 42 were redo procedures (23 after an initial VT ablation during the study period, 15 after an initial VT ablation before the study period, and 4 after an initial VT ablation performed at another institution).

Patients were prospectively followed-up with a complete clinical evaluation before the ablation, including cardiac ultrasound and LGE-CMR. Visits were scheduled in the outpatient clinic at 3, 6, and 12 months, and then yearly after the first year of ablation. Patients' ICDs were interrogated for episodes of VT and administration of electrical therapies. Antiarrhythmic therapy was also analyzed and reported. The study was approved by the local ethics committee and adhered to the Helsinki Declaration revised in 2013.

### Procedural data

Procedures were performed with patients under conscious sedation or general anesthesia. Invasive arterial pressure was obtained by radial (or femoral if radial puncture failed) artery cannulation. After femoral venous access was obtained, a multipolar diagnostic catheter was positioned at the right ventricular (RV) apex. EAM of the left ventricle (LV) (and RV if a substrate was detected by LGE-CMR) was obtained during stable sinus rhythm or RV paced rhythm using the CARTO 3

(Biosense Webster, Diamond Bar, CA) in 181 cases (94%), Rhythmia (Boston Scientific, United States) in 4 (2%), and En-Site (St. Jude Medical, United States) in 7 (4%).

Whenever possible, LGE-CMR was acquired to identify the presence of scar. All LGE-CMR images were processed with ADAS-3D software (Galgo Medical SL, Barcelona, Spain) following a previously described protocol.<sup>11</sup> In brief, LV endocardial and epicardial borders were semi-automatically delineated, and 9 concentric surface layers were created automatically along the LV wall, from endocardium to epicardium. Pixel signal intensity maps were obtained from the LGE-CMR images, projected over each LV layer using a trilinear interpolation, and color-coded in order to visualize the distribution of signal intensity. To differentiate scar core from border zone (BZ) and BZ from healthy tissue, thresholds were calculated between core and BZ as 60% of maximum signal intensity and between BZ and healthy tissue as 40% of maximum signal intensity, using a maximum variation of  $\pm 5\%$ , as previously described by our group.<sup>12</sup>

The scar dechanneling ablation technique has been previously described.<sup>11</sup> The workflow involved the identification of conductive channels (CCs) by EAM (and/or by LGE-CMR postprocessing model reconstruction). Isolated late potentials (ILPs) were manually tagged during mapping to define CCs inside the scar. Radiofrequency energy was delivered using an externally irrigated 3.5-mm-tip ablation catheter with 45°C temperature control, power limit 40–50 W, and irrigation rate 26–30 mL/min (40 W and 17 mL/min at epicardium) at the CC entrances during sinus rhythm. Remapping was used to confirm the elimination of all CCs and to check for residual ILPs. Residual ILPs identified by remapping were targeted with the same ablative approach and completely eliminated when possible. The procedural endpoint comprised abolition of CC entrances, late potential (LP) abolition, and no VT inducibility at the end of the procedure. The same approach was used in all procedures.

In 21% of cases, a multipolar mapping catheter was used. In most cases, point-by-point mapping with an ablation bipolar catheter was performed. A sensor force tip catheter was used in 39% (75/192) of VT ablation procedures.

Epicardial mapping and ablation were performed when preprocedural LGE-CMR showed an epicardial scar, when endocardial mapping did not identify subendocardial scars, when electrocardiography of clinical or induced VT suggested an epicardial origin, or when endocardial ablation was unsuccessful.

### Burden of VT

The preprocedural burden of VT was defined as the number of VT episodes and ICD therapies between the first episode of VT experienced until the day of the ablation procedure. The postprocedural burden of VT was established between the ablation day and the last day of follow-up.

In redo procedures, preprocedural burden of VT was defined as the number of VT episodes between the first ablation procedure until the day of the redo ablation procedure. A

VT episode was defined as continuous VT for 30 seconds and/or a syncopal event, or as VT that required an appropriate intervention for termination (cardioversion or ICD therapy). ICD therapies were qualified and quantified by evaluating the remote monitoring and outpatient clinic monitoring.

### Statistical analysis

Continuous variables are given as mean  $\pm$  SD or median with interquartile range (confidence interval [CI]) as appropriate. The Student *t* test was used to compare the means of 2 variables. Categorical variables are given as the total number or percentage and were compared between groups using the  $\chi^2$  or Fisher test. To compare the pre- and post-burden of VT, the nonparametric Wilcoxon test for paired data was used. Redo procedures were only analyzed for VT burden and separately from the other analysis.

Recurrence-free survival over time was calculated from the ablation date to the recurrence date or last day of follow-up in case of absence of recurrences. In cases with repeat ablation during the study period (23 patients), this time was calculated only for the first procedure. Any patient was counted double in the survival analysis. Recurrence-free survival was calculated by the Kaplan-Meier method, and comparisons between groups were performed with the log-rank test. Univariable recurrence predictors were identified with Cox regression models. The relationship between clinical characteristics, procedural data, and time to recurrence during follow-up was evaluated using survival analysis methodology (Cox regression models). Those significant predictors in univariable analyses were included in multivariable analyses carried out with a backward approach. The hazard ratio (HR) and 95% CI of VT recurrence are reported for each predictor (CI and HR were indicated in squared brackets). All analyses were performed using SPSS Version 18.0 (SPSS, Chicago, IL) and R software for Windows Version 3.6.1 (R Project for Statistical Computing, Vienna, Austria). All statistical tests were 2-sided, and  $P < .05$  was considered significant.

## Results

### Study population

Median age of the population was 67 [CI 54–75] years; 16 of 169 subjects (9.5%) were female; and ischemic cardiomyopathy (ICM) was the most frequent substrate (104/169 [62%]). Etiologies other than ICM (65 [38%]) were mainly 38 cases (22%) of arrhythmogenic cardiomyopathy and 17 cases (10%) of dilated cardiomyopathy. Baseline patient characteristics are listed in Table 1.

Preprocedural antiarrhythmic therapy consisted of beta-blockers in 69% of subjects, amiodarone in 49%, sotalolol in 15%, and class I antiarrhythmic drugs in 6%.

In 46% of cases, the indication for VT ablation was the occurrence of appropriate ICD shocks. Median number of VT episodes per year was 3.546 [1.347–13.951], and VT storms were an indication for VT ablation in 30.2% of cases.

**Table 1** Demographics and clinical baseline characteristics of the study population (n = 169)

Age (yr)	63 $\pm$ 14.9
Male/female	153/16
Hypertension	98 (58)
Diabetes mellitus	45 (26)
Dyslipidemia	83 (49)
Smokers	71 (42)
COPD	37 (22)
CKD	41 (24)
Ischemic cardiomyopathy	104 (62)
NYHA functional class	
I	63 (37)
II	79 (47)
III	27 (16)
LVEF (%)	37.5 $\pm$ 13.5
Previous ICD	130 (77)
Complete coronary revascularization	67/104 (64)

Values are given as mean  $\pm$  SD, n/n, or n (%).

CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; ICD = implantable cardioverter-defibrillator; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association.

Patients with NICM had more preprocedural VT episodes (11.6  $\pm$  17 vs 4.35  $\pm$  7.75;  $P = .06$ ); ICD shocks (4.2  $\pm$  10 vs 1.03  $\pm$  1.7;  $P = .02$ ); and VT storms (27 [41%] vs 24 [23%];  $P = .007$ ).

### Procedural data

In 72 patients (66%), preprocedural LGE-CMR was performed and analyzed using dedicated software (see Methods). The pixel signal intensity mapping model with conducting channels was then integrated into the EAM navigator system during the VT ablation procedure.

Epicardial access (in addition to endocardial access) was the first-line strategy in 55 procedures (30%) and the second-line strategy after failed endocardial ablation in 6 cases (3.6%). In 6 of 61 cases (9.8%), epicardial access failed due to pericardial adhesions or complications.

No intraprocedural deaths occurred. Major complications occurred in 4.8% of VT ablations. Complications are listed in Table 2. Total radiofrequency time was 948 (589–1466) seconds.

Noninducibility of VT was achieved in 70.8% (136/192) of cases, and no detection of LPs at the last remap was achieved in 65.6% (126/192) of cases.

**Table 2** Procedural complications

Minor complications (5.8%)	
Vascular access complications	9
Postprocedural pericarditis	2
Phrenic paralysis	1
Major complications (4.8%)	
Pericardial effusion	2
Complete atrioventricular block	2
Embolic myocardial infarction	2
Embolic cerebral ischemic events	2
Hemorrhagic events	2

Values are given as n.

**Table 3** VT burden reduction

Variables	First VT ablation			Redo ablation			VT recurrence subgroup		
	Before ablation	After ablation	P value	Before ablation	After ablation	P value	Before ablation	After ablation	P value
VT episode incidence	3.546 (1.347–13.951)	0.001 (0.001–0.689)	<.001	2.916 (0.986–9.492)	0.001 (0.001–0.721)	<0.001	2.876 (1.105–8.801)	0.882 (0.505–2.283)	<.001
Shock therapy incidence	1.145 (0.118–4.467)	0.001 (0.001–0.138)	<.001	0.739 (0.001–3.555)	0.001 (0.001–0.444)	0.001	1.122 (0.325–4.252)	0.506 (0.001–1.327)	.017
ATP therapy incidence	0.293 (0.001–2.129)	0.001 (0.001–0.695)	.003	2.184 (0.109–8.005)	0.001 (0.001–1.184)	0.003	1.184 (0.001–4.633)	1.180 (0.001–3.598)	.958

Values are given as median number of events per year (confidence interval) unless otherwise indicated.  
ATP = antitachycardia pacing; VT = ventricular tachycardia.

### Follow-up data

Mean follow-up time was  $3.14 \pm 1.8$  years (preprocedural mean follow-up time: 33.27 vs postprocedural 33.45 months). Overall recurrence was 41.4% (recurrence at 1-year follow-up: 24.3%). There were 6 early recurrences of VT (intra-hospital recurrence while the patient was still admitted). Regarding overall VT recurrence, 36.3% of patients experienced administration of ICD therapies, 64.2% in the form of ICD shock (mean number of ICD shocks:  $2.7 \pm 4.0$ ). No differences were found in the recurrence rate between different types of cardiomyopathy. Overall mortality during the follow-up period was 18.2%.

### VT burden analysis

Significant VT burden reduction after the VT ablation procedure was observed in the whole population. Catheter ablation was associated with a 99.6% reduction in VT episode incidence in patients who first underwent an ablation procedure. Before and after ablation, median and mean episodes per year were 3.546 [1.347–13.951] and 0.001 [0–0.689] and  $21.8 \pm 71.3$  vs  $1.8 \pm 8.3$ , respectively ( $P < .001$ ). In addition, in the redo VT ablation group, a significant reduction in VT episodes was observed (99.5%) (2.916 [0.986–9.492] vs 0.001 [0–0.444] VT episodes per year;  $P = .001$ ). Reduction in ICD therapy incidence and antitachycardia pacing (ATP) therapy was also found to be significant for both groups (Table 3, and Figures 1 and 2).

Importantly, in the subgroup of patients who experienced VT recurrence, significant reductions in VT burden reduction (69.2%) (2.876 [1.105–8.801] vs 0.882 [0.505–2.283] VT episodes per year during follow-up;  $P < .001$ ), ICD shock therapy (1.122 [0.325–4.252] vs 0.506 [0–1.327] ICD therapies per year;  $P = .017$ ), and VT storm (preablation 30.2% vs postablation 11.2%;  $P < .001$ ) were observed.

### VT recurrence predictors

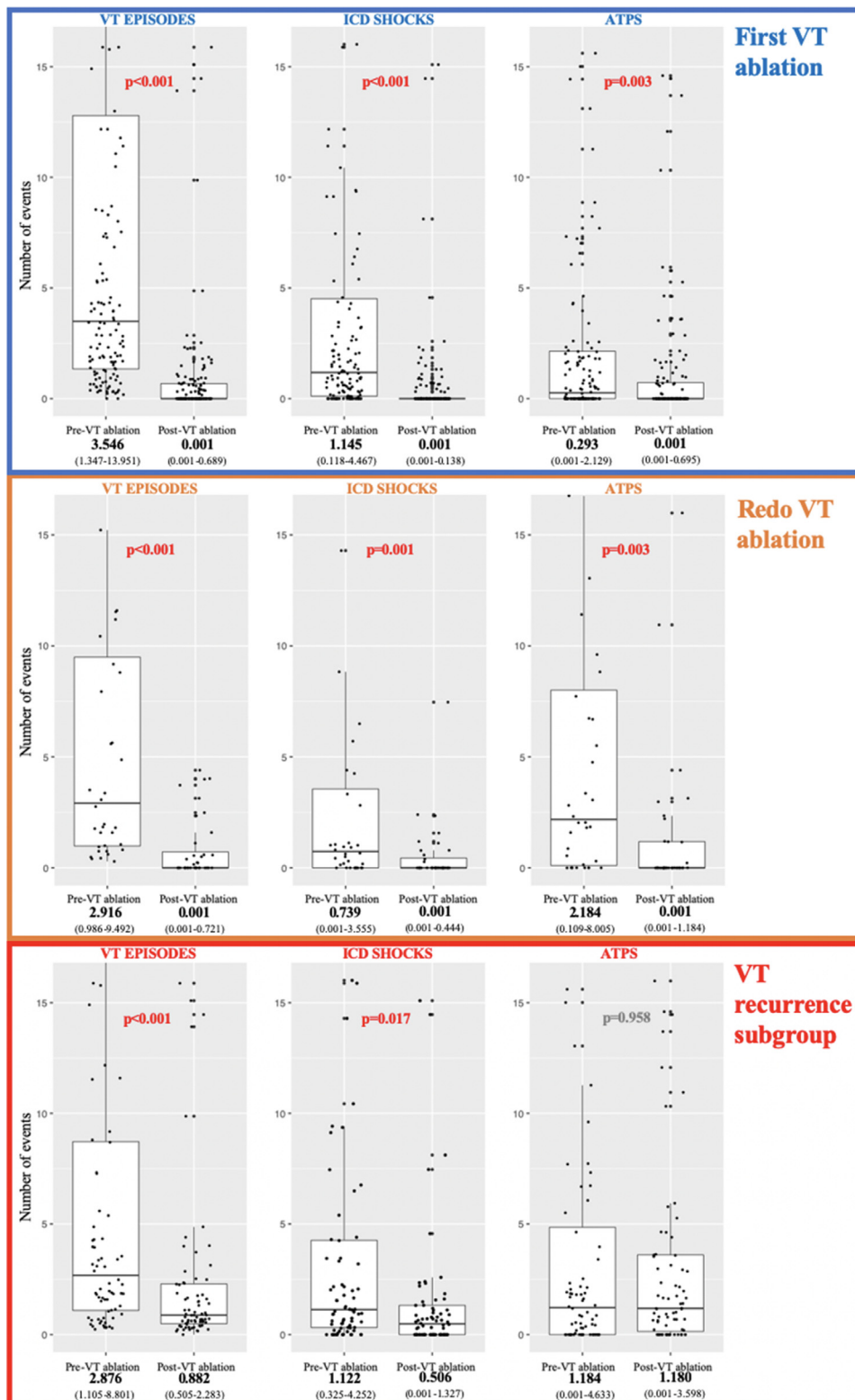
New York Heart Association functional class III–IV (HR 2.08 [1.2–3.7];  $P = .011$ ) and chronic kidney disease (HR 1.74 [1.02–2.97];  $P = .031$ ) significantly predicted VT recurrence only in univariable analysis. Low left ventricular ejection fraction (LVEF) (30% [25%–40%] vs 39% [30%–50%];  $P = .002$ ) and increased LV end-diastolic volume (61 [55–68] mL vs 58 [51–64] mL;  $P = .04$ ) were related to VT recurrence.

Procedural factors demonstrated to be predictive factors for VT recurrence were noncomplete abolition of LPs (67% vs 19%;  $P < .001$ ; HR 4.25 [2.57–7.00]); postprocedural inducibility of sustained monomorphic VT (45% vs 13%;  $P < .001$ ; HR 2.39 [1.49–3.83]); and intraprocedural requirement for external cardioversion ( $P < .001$ ; HR 2.36 [1.42–3.94]).

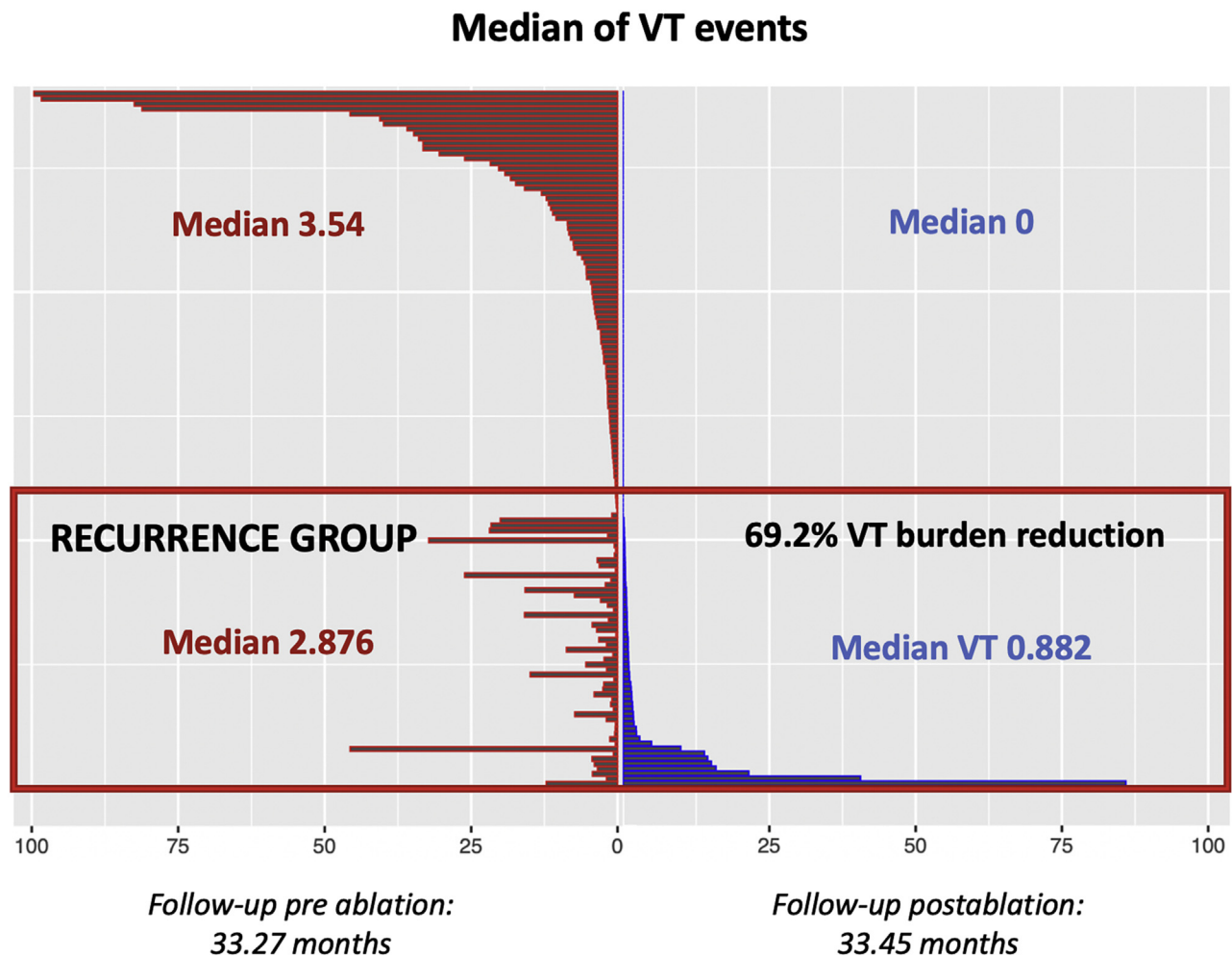
No differences in recurrence were found among the types of approaches to the substrate (endocardial, epicardial, transeptal, or retro-aortic).

In multivariable analysis, incomplete elimination of ILP (HR 3.8 [2.18–6.65];  $P < .001$ ) and LVEF (HR per %: 0.97 [0.95–0.99];  $P = .022$ ) were independent predictors of VT





**Figure 1** Boxplot graph comparing pre- and postablation VT episodes (left), ICD shocks (center), and ATPs (right). **Top:** VT burden reduction after the first VT ablation procedure. **Middle:** VT burden reduction after a redo VT ablation procedure. **Bottom:** VT burden reduction in a patient who experienced VT recurrence at follow-up. Values are given as median number of events per year (confidence interval). ATP = antitachycardia treatment pacing; ICD = implantable cardioverter-defibrillator; VT = ventricular tachycardia.



**Figure 2** Waterfall plot of ventricular tachycardia (VT) burden before (left) and after (right) ablation. **Top:** Patients without any recurrence. Sequence is from high to low pre-ablation VT burden. **Bottom:** Patients with VT recurrence. Sequence is from low to high post-ablation VT burden. VT burden decreases significantly in patients with recurrences.

recurrence (Table 4). Kaplan-Meier survival estimates for freedom from VT recurrence between patients depending on ILPs are shown in Figure 3.

In addition, when redo procedures were excluded (both redo procedures during the study period and in those patients with ablation before inclusion in the study), the same predictors of recurrence were found, that is, incomplete elimination of ILP (HR 3.49 [1.89–6.43];  $P < .001$ ) and LVEF (HR per %: 0.98 [0.96–0.99];  $P = .022$ ).

#### Amiodarone and antiarrhythmic drug de-escalation

After ablation, amiodarone use was reduced in a significant percentage of patients (preprocedural amiodarone intake 87/169 [51.5%] vs postprocedural 68/169 [37.8%];  $P = .024$ ). Secondary effects of amiodarone were reported in 24 patients, more frequently hypothyroidism in 19 patients. Class I antiarrhythmic (mexiletine) long-term treatment was reported in 10 patients (5.9%) in the preablation period and in 7 (4.1%) during follow-up. Sotalol was the treatment of choice in 26 patients (15.4%) in the preablation period and in 29 (17.2%) during follow-up.

#### Discussion

##### VT recurrence as a dichotomous variable vs VT burden reduction

This study is the first to systematically report VT burden reduction in patients undergoing substrate-based VT ablation (endocardial and/or epicardial substrate). We demonstrated that the VT ablation procedure is an effective therapy for reducing the number of VT episodes and ICD shocks, not only in the overall cohort (99% reduction) but also in the subgroup of patients with VT recurrence (69% reduction), regardless of the type of structural heart disease and ablation repetition. We consider VT burden to be more valuable in terms of clinical benefit than recurrence as a dichotomous event.

Substrate-based VT ablation has emerged over the past several decades as first-line treatment in patients with VT refractory to medical therapy. Most studies that analyzed the feasibility and clinical impact of VT ablation have reached up to 1 year of follow-up and/or have analyzed the recurrence rate as a dichotomous variable. The rate of VT recurrence as a dichotomous variable, despite all technical improvements

**Table 4** VT recurrence predictors

	Overall (n = 169)	Recurrence (n = 70)	No recurrence (n = 99)	Univariable analysis			Multivariable analysis		
				HR	95% CI	P value	HR	95% CI	P value
Age (years)	67 (54–75)	69 (49–76)	65 (55–74)	1.00	0.98–1.02	.653			
NYHA functional class III–IV	27 (16)	16 (23)	11 (11)	2.08	1.18–3.67	<b>.011</b>			
Hypertension	98 (58)	39 (56)	59 (60)	1.138	0.71–1.83	.592			
Diabetes	45 (27)	18 (26)	27 (27)	1.10	0.65–1.89	.720			
CKD	41 (23)	23 (33)	18 (18)	1.74	1.02–2.97	<b>.031</b>			
COPD	37 (22)	14 (20)	23 (23)	1.26	0.70–2.28	0.430			
AF	22 (13)	12 (17)	10 (10)	1.68	0.90–3.16	.103			
ICM	104 (62)	42 (63)	62 (63)	1.13	0.69–1.86	.619			
VT storm	51 (30)	21 (30)	30 (30)	1.31	0.79–2.19	.300			
preprocedural									
Incessant VT	20 (12)	10 (14)	10 (10)	1.46	0.75–2.87	.268			
LVEF (%)	35 (25–46)	30 (25–40)	39 (30–50)	0.97	0.95–0.99	<b>.002</b>	<b>0.97</b>	<b>0.95–0.99</b>	<b>.022</b>
LVEDV (mL)	60 (54–65)	61 (55–68)	58 (51–64)	1.03	1.00–1.06	<b>.040</b>			
LVESV (mL)	41 (34–50)	45 (40–53)	38 (32–46)	1.02	0.99–1.05	.123			
HD mapping catheter	35 (21)	13 (19)	22 (22)	1.03	0.56–1.90	.910			
Sensor force catheter ablation	63 (37)	20 (29)	43 (43)	0.85	0.50–1.44	.547			
Epicardial access	61 (36)	26 (37)	35 (35)	0.51	0.16–1.69	.277			
Procedural time (min)	200 (160–256)	206 (172–275)	195 (155–255)	1.00	0.99–1.01	.308			
RF time (s)	948 (589–1466)	1099 (674–1638)	930 (560–1365)	1.00	1.00–1.01	.347			
RF total points	27 (17–47)	28 (15–43)	27 (17–37)	1.00	0.99–1.01	.637			
Incomplete ILP elimination	66 (39)	47 (67)	19 (19)	4.25	2.57–7.00	<b>&lt;.001</b>	<b>3.8</b>	<b>2.18–6.65</b>	<b>&lt;.001</b>
Residual VT	44 (26)	31 (45)	13 (13)	2.39	1.49–3.83	<b>&lt;.001</b>			
Intraprocedural external cardioversion	68 (40)	40 (57)	28 (28)	2.36	1.42–3.94	<b>&lt;.001</b>			

Values are given as median (CI) or n (%) unless otherwise indicated. Bold values are those with statistical significance.

AF = atrial fibrillation; CI = confidence interval; HD = high-density; HR = hazard ratio; ICM = ischemic cardiomyopathy; ILP = isolated late potential; LVEDV = left ventricular end-diastolic volume; LVESV = left ventricular end-systolic volume; RF = radiofrequency; other abbreviations as in Tables 1 and 3.

and extensive ablations, is still high (25%–45%).<sup>2,13</sup> However, few studies have analyzed VT burden in addition to the presence of recurrence.<sup>14</sup> In our study, although the overall recurrence rate (again as a dichotomous variable) was high, as reported in the literature, we focused on VT burden reduction. In our study, the 99.6% reduction in VT episodes, from 3.546 to 0.001 events per year after ablation, in our view is much more illustrative of the clinical benefit of VT ablation than the dichotomous recurrence rate. In the same sense, even in patients with recurrence after ablation (which clinically would be considered a failure in terms of recurrence as a dichotomous variable), VT burden after ablation decreased significantly (>69%). Moreover, a reduction in VT burden translates to a reduction in ICD shocks and VT storms. Although this was not the aim of the present study and its design did not allow for considerations regarding prevention of mortality, ICD shocks are related to mortality.<sup>15</sup> ICD shocks and VT storm avoidance potentially can improve patient survival, although some patients have recurrences in the form of isolated VT episodes.

As widely reported,<sup>6</sup> this treatment can have an impact on the psychological burden of patients and improve their rehospitalization rates. Porta-Sánchez et al<sup>16</sup> reported on health

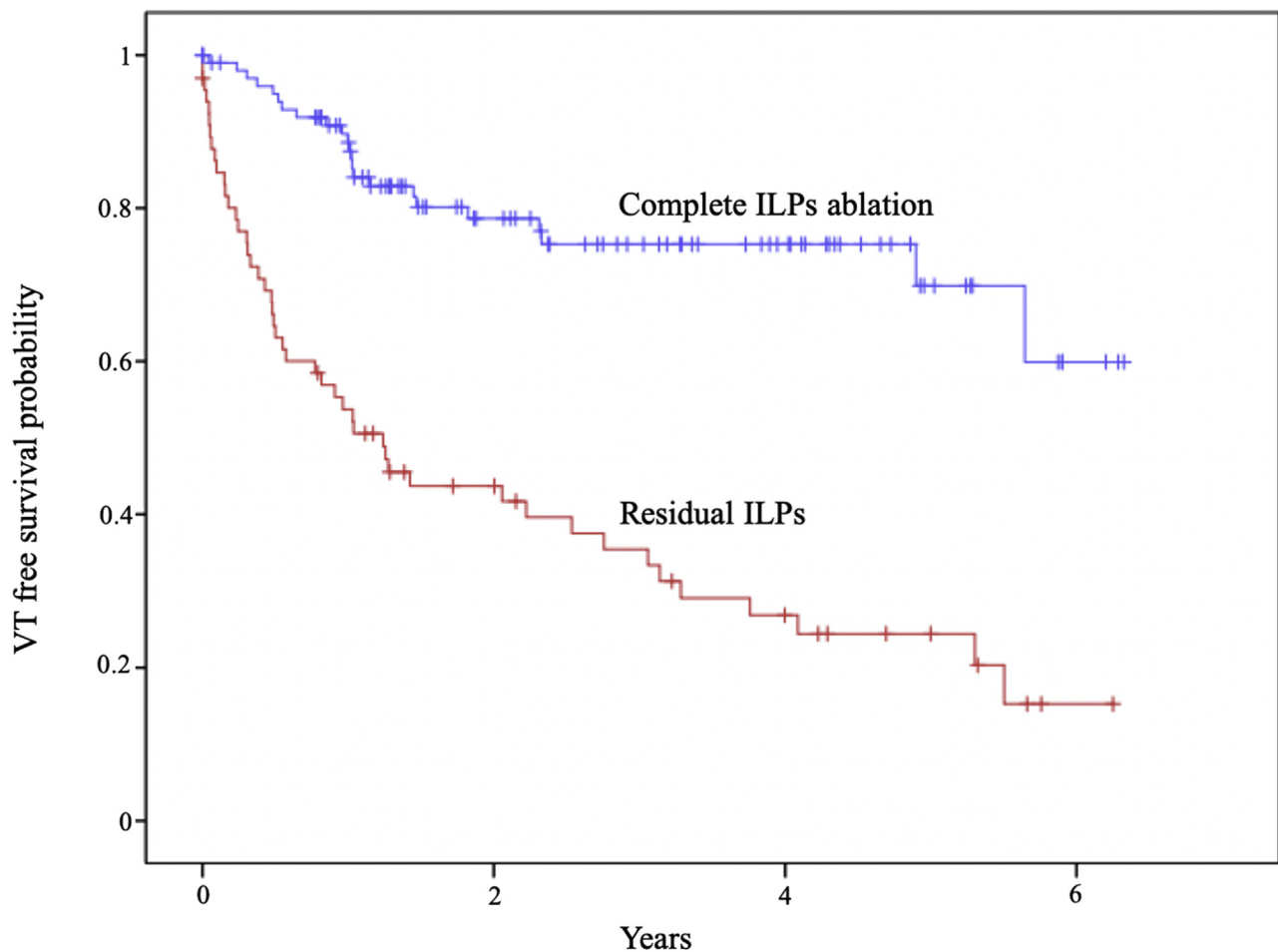
care-related cost reductions associated with VT ablation compared to medical therapy.

Regarding VT burden reduction, a few studies have analyzed the decrease in ICD therapy incidence and frequency of VT episodes after ablation, as in our study. Similar results were confirmed in the redo procedures. The study of Marchlinski et al<sup>14</sup> underlined a significant reduction in VT incidence and improvement in quality of life at 6 months in ischemic patients after ablation. Muser et al<sup>17</sup> also demonstrated a substantial improvement in VT burden in patients with nonischemic dilated cardiomyopathy.

Another significant appreciable finding of our study was the possibility of withdrawing amiodarone therapy in a notable number of patients. This has allowed us to reduce the number of patients exposed to the side effects of amiodarone, which, given the relatively young age of the study population, acquires even greater importance, as amiodarone has been related to increased mortality in VT patients in some randomized trials.<sup>2</sup>

### VT recurrence predictors

In multivariable analysis, we found that noncomplete elimination of LPs heavily correlated with VT recurrence.



**Figure 3** Kaplan-Meier curve of VT-free survival in patients with complete and incomplete (residual) isolated late potential (ILP) abolition during the VT ablation procedure. VT = ventricular tachycardia.

This is in accordance with previously reported studies in which persistence of LPs after ablation was found to be the most powerful predictor of recurrence.<sup>18</sup> In addition, although it has always been proposed that recurrence is related to disease progression, some studies have shown that, in the redo procedures, VT is the same as in the index procedure in many patients.<sup>19</sup> Altogether, the ablation index must focus on eliminating the full substrate, and, based on our results and those of previous studies, LP abolition (not only lack of inducibility) seems to be the best endpoint in this regard. In addition, LVEF and LV end-diastolic volume have been shown to be predictive of VT recurrence at long-term follow-up, confirming published data,<sup>20</sup> and may be related to more advanced cardiac disease.

In univariable analysis, unlike previously reported data<sup>21</sup> VT recurrence in our study did not seem to be different in non-ischemic patients than in those with ischemic substrate. Nonetheless, we can speculate that this finding could be related to the small sample size.

Other predictors have been found, such as advanced New York Heart Association functional class and chronic kidney disease, confirming previously reported data.<sup>4</sup> Both parameters suggest that frail patients with very advanced

heart disease present a high risk of VT recurrence, so the cost-effectiveness of the procedure should be well evaluated.

### Study limitations

The major limitation of our study is that it is a retrospective analysis. Although we acknowledge this limitation, the follow-up was prospective and highly detailed, thus increasing the quality of data from this observational study.

A second limitation is that all procedures were performed by highly experienced electrophysiologists. In this sense, the results are applicable only to highly experienced centers. Moreover, the generalization of this study is limited by the single-center nature of this registry and the lack of a control group.

Another important limitation is the study of VT incidence before the ablation procedure. The timing of the VT ablation procedure is influenced by clinical and procedural planning factors, so the incidence of VT episodes over time before ablation can greatly differ across patients. Patients who experienced the first episode of VT and subsequently underwent the ablation procedure within a short period of time could not have a reduction in VT burden as high as in patients with a high VT burden before VT ablation. An additional



limitation is that the decrease in VT burden hypothetically could be overestimated due to some patients with extremely high VT burden before the ablation that resolves after the procedure. To avoid this overestimation effect, the median (which is less affected by extreme values than the mean) has been used to evaluate VT burden reduction.

Finally, the low percentage use of high-density mapping catheters and force sensor ablation catheters because of the period of the study could have affected the ablation results.

## Conclusion

The results of substrate-based VT ablation are fairly favorable in terms of reduction of VT episodes and ICD therapy and illustrate clinical benefit more clearly than consideration of VT recurrence as a dichotomous variable. Patient clinical characteristics and procedural VT ablation factors can predict VT recurrence during a long follow-up period, thus helping to identify patients at high risk for VT recurrence.

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