Early Referral for Ablation of Scar-Related Ventricular Tachycardia Is Associated with Improved Acute and Long-Term Outcomes: Results from the Heart Center of Leipzig Ventricular Tachycardia Registry

**Running title:** Dinov et al.; Benefits of earlier VT ablation

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**Journal Subject Codes:** [22] Ablation/ICD/surgery
Abstract:

Background - The effects of time to referral for catheter ablation (CA) of scar-related ventricular tachycardia (VT) on acute success, VT recurrence and cardiac mortality are unclear.

Methods and Results - We investigated 300 patients after CA of sustained VT. CA was performed within 30 days after the first documented VT in 75 (25%) patients (group 1); between 1 month and 1 year in 84 (28%) patients (group 2); and more than 1 year after the first VT occurrence in 141 (47%) patients (group 3). The end points were non-inducibility of any VT after CA (acute success), VT-recurrence and cardiac mortality after 2 years. Acute success was achieved in 66 (88%) patients in group 1; 68 (81%) in group 2, and in 99 (70.2%) in group 3 (p=0.008). During the 2-years follow-up period, VT recurred in 28 (37.3%) patients in group 1; 52 (61.9%) patients in group 2; and 91 (64.5%) patients in group 3 (p<0.0001). Recurrence-free survival was higher in group 1, as compared to group 2 (HR=1.85; p=0.009) and group 3 (HR=2.04; p=0.001). No survival difference was observed between groups 1 and 2 (HR=0.85; p=0.68), and groups 1 and 3 (HR=1.13, p=0.73). Beta-blocker therapy, VT of ischemic origin, and complete success were associated with VT-free survival. VT recurrence (HR=1.91; p=0.037) predicted cardiac mortality.

Conclusions - CA of scar-related VT performed within 30 days after the first documented VT was associated with improved acute and long-term success. VT recurrence, but not the early referral for CA, was associated with cardiovascular mortality.

Key words: ablation, ventricular tachycardia, structural heart disease, early
Catheter ablation (CA) of ventricular tachycardia (VT) has proved to be an effective strategy to achieve short-term electrical stability in patients with structural heart disease, however, VT recurrences are not uncommon. In patients with ischemic cardiomyopathy (ICM), recurrent sustained VT’s may provoke ischemia in areas of critically reduced microvascular perfusion, leading to cell necrosis and replacement fibrosis. Evidences of elevated serum troponin after supra-ventricular and ventricular tachycardias suggest myocytes death even in the absence of coronary artery disease. A recurrent VT itself may change the electrophysiological properties of the myocardium, predisposing the occurrence and stabilization of new VT re-entry circuits in non-homogeneous tissue.

In VTACH trial, CA performed after the first episode of sustained VT of ischemic origin was associated with a prolonged time to VT recurrence. A small retrospective study suggested that earlier referral for VT ablation had superior 1-year VT-free survival compared to delayed ablation. In addition, animal experiments revealed early formation of arrhythmogenic substrate after induced myocardial infarction and suggested better outcomes after immediate ablation. 

We hypothesized that the arrhythmia substrate evolves in the time, partially driven by the VT itself. Therefore, we aimed to determine if CA in earlier stages of ventricular remodeling may improve the outcomes, compared to VT ablation performed as a treatment of last resort in patients with advanced stage structural heart disease.

Methods

Patient Population

Between January 2008 and March 2012, 300 patients with ICM and non-ischemic dilated cardiomyopathy (NIDCM) were ablated for sustained VT. No patients in this group had been previously ablated. All medical records were carefully examined to identify the first documented
sustained VT and to calculate the time from the first VT occurrence to the first CA. Depending on this, patients were divided into three groups: early ablation strategy (group 1), consisting of patients ablated within 30 days after the first documented VT; delayed ablation strategy (group 2) – patients ablated between 1 month and 1 year after the initial VT; very late ablation strategy (group 3) – CA was performed more than 1 year after the first documented VT.

Due to the differences in the VT-burden all patients were further divided into two subgroups. The high VT-burden group consisted of patients referred for CA due to: 1) electrical storm, 2) incessant VT’s, or 3) more than 5 VTs, requiring Implantable Cardioverter Defibrillator (ICD) therapies, inclusive shocks in the last 6 months before ablation.12 The low VT-burden group consisted of patients: 1) referred for CA due to recurrent VT’s terminated through Antitachycardia Pacing (ATP) or a single ICD shock or 2) or without an ICD, requiring external defibrillation, but in sinus rhythm at the time of hospitalization.

**Catheter Ablation Procedure**
All patients signed an informed consent before the CA and were prepared according to the clinical routine of our institution. The procedure was performed under conscious sedation. A transseptal puncture using a steerable introducer (Agilis™, St. Jude Medical, St. Paul, MN, USA) was performed to access the left ventricle. After entering the left ventricular cavities, heparin was administered to maintain an activation clotting time of over 300 seconds. In cases with suspected epicardial VT, a subxyphoid puncture was performed prior to the transeptal puncture in order to avoid inadvertent bleeding complications.

Catheter mapping was facilitated by fluoroscopy in combination with electronatomical mapping systems (Carto 3 or Carto-RMT, Biosense Webster Inc., CA, USA or EnSite NavX, St. Jude Medical Inc, St. Paul, MN, USA). In patients in sinus rhythm we performed voltage maps.
Areas with peak-to-peak amplitudes < 0.5 mV were defined as scar and areas demonstrating local bipolar electrograms ≥ 1.5 mV were defined as healthy. All fragmented, late potentials and appropriate pace mapping sites were annotated. In patients with hemodynamically stable VTs, activation and entrainment mapping were performed to localize the exit sites and critical isthmuses. Radiofrequency energy was delivered using open-irrigated tip catheters (Navistar Thermocool or Navistar Thermocool-RMT, Biosense Webster Inc, Diamond bar, CA, USA) with power settings of up to 50 W and irrigation rates of up to 30 ml/min. In cases where Coolflex catheters (St. Jude Medical Inc, St. Paul, MN, USA) were used the irrigation rate was reduced to 17 ml/min.

After the CA, programmed electrical stimulation (PES) from right ventricular apex and outflow tract was used to assess the procedure success. We used four different drive cycle lengths (500, 430, 370, 330 ms) and introduction of up to 3 extrastimuli until the ventricular refractory period or coupling interval of 200 ms were reached. Ablation of the clinical VT only, determined from the available ECGs and EGM recordings, was defined as partial success. Non-inducibility of any clinical or non-clinical monomorphic sustained VT at the end of the procedure was defined as complete success.

After ablation, the antiarrhythmic drugs (AAD) were usually discontinued in cases of complete VT non-inducibility. In cases of partial success or failure, the AAD therapy was maintained with the majority of patients receiving amiodarone.

**Patient Follow-up**

Following the ablation procedure, all patients were continuously monitored until hospital discharge. Patients without ICDs at admission received ICD devices before discharge. Patients with preserved EF and non-inducible VT's after ablation received implantable loop recorders.
(ILR). After discharge, patients were evaluated in our Pacemaker/ICD outpatient clinic at 3
month intervals and in cases of ICD shock delivery.

Primary end points of the study were: (1) the recurrence of sustained VT as documented
by ICD/ILR interrogation and (2) the occurrence of cardiac death. The secondary end points
were acute success and procedure-related complications. The follow-up for the clinical events
(VT recurrence and mortality) was limited to 2 years. All patients completed the follow-up.

Statistical Analysis

For the continuous variables with normal distribution, the mean values and standard deviations
are reported. For variables with skewed distribution, non-parametric tests were used to compare
the groups. For categorical variables, absolute numbers and proportions are used. Student’s t test,
one-way ANOVA, chi-square test, and Fischer exact test were used to compare differences across
different groups. Event-free survival was estimated by the Kaplan-Meier method, and log-rank
statistics was used to compare the groups. The potential confounders were subsequently entered
into the Cox proportional hazard model based on univariable association (2-sided p<0.20) and
known clinical relevance. Multivariable Cox regression analysis was used for identifying
significant predictors of VT recurrence and cardiac mortality while controlling for the relevant
covariates. All tests were two-sided and p value of < 0.05 was considered statistically significant.
The statistical analysis was performed using SPSS 17.0 (IBM, Armonk, NY, USA).

Results

Baseline Characteristics

Three hundred patients (of them 262 male, mean age 65±12 y) with ICM or NIDCM were
included in the study. ICM was the underlying cause in 204 (68%) patients. Forty-seven (15.7%)
patients had no ICD at the time of admission and ablation was performed due to VT recurring
after at least 1 external defibrillation. At the time of admission, 37 (12.3%) patients had incessant
VT; 119 (39.7%) had experienced electrical storm, and 168 (56%) had experienced at least one
ICD shock. Seventy-five patients (25%) were classified as early ablation (group 1). Eighty-four
(28%) patients were allocated to delayed ablation group (group 2). One hundred and forty-one
patients (47%) underwent a very late VT ablation (group 3). At admission, 133 (44.3%) patients
were on AAD, of them 27 (36%) patients in group 1, 36 (42.9%) patients in group 2 and 70
(49.6%) patients in group 3; p=0.43. Most of them (117, 39%) were treated with amiodarone; 23
(30.7%) patients in group 1; 32 (38.1%) in group 2; and 62 (44%) in group 3. (Table1).

Impact of Time to Referral for Ablation on Acute Procedural Outcomes: Complications
and In-Hospital Mortality

Among 300 patients, 268 (89.3%) were ablated endocardially and 32 (10.7%) patients were
ablated both endo- and epicardially. Median of 2 VT (IQR 2) per patient were induced and
targeted for ablation. Acute complete success was achieved in 231 (77.3%) patients. Partial
success was additionally achieved in 50 (16.6%) patients.

Patients in group 1 had significantly better LV ejection fraction, lower VT-burden and
lower number of VT’s inducible using PES. Complete acute success was achieved in 66 (88.0%)
patients in group 1, 68 (81%) cases in group 2, and in 99 (70.2%) patients in group 3 (p=0.008).
Partial success was achieved in 8 (10.7%) patients in group 1; 12 (14.3%) patients in group 2,
and in 29 (20.6%) patients in group 3 (p=0.14). Procedure failure was observed in 1 (1.3%)
patient in group 1, 4 (4.8%) patients in group 2, and in 13 (9.2%) patients in group 3 (p=0.057).
In-hospital death occurred in 5 patients (6.7%) in group 1; 2 patients (2.4%) in group 2; 4
patients (2.8%) in group 3 (p=0.28). Procedure-related complications were observed in 3 patients
(4.0%) in group 1; 6 patients (7.1%) in group 2; 10 patients (7.1%) in group 3 (p=0.63).
After hospital discharge, 100 (33.3%) patients received AAD; 18 (24%) patients in group 1; 27 (32.1%) patients in group 2 and 55 (39%) patients in group 3, p=0.31. Most patients (83; 27.7%) were treated with amiodarone; 17 (20.5%) patients in group 1; 21 (25.3%) cases in group 2 and 45 (31.9%) patients in group 3. Baseline procedural and post-procedural characteristics are presented in table 2.

**Impact of Time to Referral for Ablation on VT Recurrence**

During 2-years of follow-up, VT recurrence occurred in 28 (37.3%) patients in group 1, in 52 (61.9%) patients in group 2, and in 91 patients (64.5%) in group 3 (p<0.0001).

In univariable analysis, delayed and very late referral for ablation, presence of NIDCM, VT non-inducibility at the beginning of the procedure, absence of beta-blocker therapy, and failure to eliminate all inducible VT’s were predictors of VT recurrence (Table 3). The probability for VT-free survival was significantly higher in the group 1 as compared to group 2 (HR=1.85 for 2 vs. 1; p=0.009) and group 3 (HR=2.04 for 3 vs. 1; p=0.001) (Figure 1).

In the multivariable analysis after adjustment for age, sex, ICM, arterial hypertension, NYHA class, coronary artery bypass grafting, VT-burden, ejection fraction, number of inducible VTs, mapping approach, use of beta-blockers and amiodarone after ablation, and acute complete success, delayed and very late referral for ablation (HR=1.95 for 2 vs. 1; p=0.007 and HR=1.96 for 3 vs. 1; p=0.004), were independently associated with VT recurrence. Additionally, absence of beta-blocker therapy (HR=1.77; p=0.033), prior coronary artery bypass grafting operation (HR=1.48; p=0.04), and persistent VT inducibility (partial success or ablation failure) (HR=1.54; p=0.032) were associated with VT recurrence (Table 3).

**Impact of Time to Referral for Ablation on the Cardiac Mortality**

Twelve patients (16%) in group 1; 12 (14.3%) patients in group 2; and 26 (18.4%) patients in
group 3 died during the follow-up period (p=0.71). In the multivariable analysis after adjustment for age, sex, ICM, arterial hypertension, diabetes mellitus, NYHA class, ejection fraction, atrial fibrillation, VT-burden, coronary artery bypass grafting, number of VTs, procedure time, therapy with amiodarone, beta-blockers, acute complete success and VT recurrence, the early ablation strategy was not associated with improved survival (Figure 2). The older age (HR=1.04; p=0.02), lower ejection fraction (HR=0.97; p=0.046), VT recurrence (HR=2.3; p=0.021), and absence of beta-blocker (HR=2.69; p=0.031) were the only predictors for cardiac mortality (Table 4).

Sub-group Analysis of the Impact of Time to Ablation on VT Recurrence

The high VT-burden group consisted of 171 patients (57%) and the low VT-burden group consisted of 129 patients (43%). In the low VT-burden population, the probability for VT recurrence was significantly higher in group 3 (very late ablation) and 2 (delayed ablation) as compared to group 1 (early ablation): HR=1.91 for 2 vs.1; p=0.038 and HR=2.22 for 3 vs 1; p=0.013. On the contrary, in the high VT-burden population, a significant difference in the VT recurrence could not be demonstrated, although there was a tendency for more VT recurrence in groups 2 and 3: HR=1.71 for group 2 vs. 1, p=0.14 and HR=1.80 for group 3 vs 1, p=0.078. Additionally, differences in the probability of VT recurrence between groups 2 and 1, as well as between groups 3 and 1, was observed in both ICM and NIDCM; only in men; and in patients with EF ≤ 35%.

Time to Ablation in Relation to Outcomes after CA

In patients with complete success, median time from the first documented VT to ablation was 9 (IQR 46) months, as compared to 31 (IQR 80) months in patients with partial success (p=0.001). There was no significant difference in the time to ablation between patients who suffered procedure-related complications and those who did not: 11 (IQR 53) months vs. 12 (IQR 53.5)
months respectively, p=0.99. The time from the first documented VT to ablation was 6 (IQR 45.5) months in patients without VT recurrence, as compared to 19 (IQR 60) months in patients with VT recurrence (p=0.005). There was no significant difference in the time to ablation between patients who died and the survivors: 16 months (IQR 59) vs. 12 months; (IQR 53) respectively, p=0.53 (Figure 3).

Discussion

Up until now, limited data on the appropriate timing for VT ablation have been available with only two prospective studies suggesting benefits from earlier ablation in patients with coronary artery disease. Due to its complexity, VT ablation is usually performed in high-volume centers, in patients with high arrhythmia burden and after failure to achieve effective suppression of the VT using AAD. That is why, the majority of the patients experiencing VT's are referred relatively late for CA. However, recent studies in animals and humans demonstrated that the electro-anatomical substrate for VT develops very early after myocardial infarction.

In our study, we observed that patients referred for VT ablation within 30 days after the first documented VT had higher acute success rates compared to patients who underwent ablation later, with similar complications and in-hospital mortality rates. This may suggest that the early CA, performed within 30 days after the first documented VT, was not only as safe as the more conservative and delayed CA strategies, but also associated with improved acute outcomes. Previously, Frankel et al. reported on higher procedural success in patients ablated within 30 days after first documented VT, as compared to those ablated later. However, the differences were not statistically significant, either due to the much lower number of patients included in the study, or the higher number of repeated procedures per patient. The observed improved acute success rates in earlier ablated patients can be explained by the lower number of
inducible VT’s per patient, the better LV ejection fraction, and lower VT-burden, suggesting less arrhythmogenic substrate in these patients.

In the study, the long-term outcomes after early VT ablation were significantly better as compared to the outcomes after delayed VT ablation. This observation is in accord with the findings of the VTACH trial, where CA after the first tolerated VT was associated with prolonged time to VT recurrence. In the SMASH VT trial, early ablation after the first ICD shock led to a reduction in the ICD shocks afterwards. Interestingly, the long-term benefit from CA was observed only in group 1, but not in groups 2 and 3, suggesting lack of additional benefit if the procedure was performed later than 30 days after the first documented VT. In addition to the time to ablation referral, VT of ischemic origin, beta-blocker therapy and successful elimination of all inducible VT’s were independently associated with VT-free survival. Recently, Della Bella et al. demonstrated that patients with hemodynamically well-tolerated VT’s, better EF, and absence of major co-morbidities had better VT-free survival, provided a complete VT non-inducibility was achieved. These findings, along with our observations, suggest that successful CA performed as a first-line therapy in earlier stages of cardiac remodeling may improve VT-free survival.

An important novel finding in the study was that time to CA referral was associated with favorable long-term outcomes not only in patients with ICM, but also in those with NIDCM. Considering the higher rates of VT recurrence in NIDCM, an earlier referral for CA can possibly improve the long-term outcomes in these patients.

A concern in our study design was the influence of VT-burden on the long-term outcomes, since patients with electrical storm, incessant VTs, or frequent ICD shocks may be referred earlier for CA, and thus may experience a preferential selection bias. Consequently, we
performed a sub-group analysis separately for the low and high VT-burden patients. The benefits of early ablation were attenuated in the high VT-burden group, but remained significant in the sub-group with lower VT-burden. We suggested that this discrepancy may be related to differences in the stage of electro-anatomical remodeling, with an earlier and more abundant substrate development in the high VT-burden patients.

Even though, early referral for CA was associated with improved acute and long-term procedural outcomes, the cardiac mortality was not influenced by the timing of ablation. This was not an unexpected finding, given that the VTACH study could not demonstrate a reduction in mortality in patients with early VT ablation either. Nevertheless, VT recurrence was an independent predictor of mortality as shown in the Multicenter Thermocool study. Therefore, it is expected that reduction of the VT recurrence through an earlier referral for ablation may result in improved survival at longer follow-up. Further studies, however, are warranted to test this hypothesis.

Two randomized multicenter studies (NCT01576042 and NCT01557842) had been designed to elucidate whether earlier ablation strategy is more effective than medical therapy alone in improving outcomes and reducing mortality in patients with VT of ischemic origin. Given that both have not started yet with patient’s recruitment our trial is currently the largest one substantiating the benefits of early CA of VT in both ICM and NIDCM. Our findings may encourage clinicians to refer patients with sustained VT’s earlier for CA, especially if the EF ≤ 35%, and even if they have lower VT-burden. More evidence is necessary to support or renounce the benefits of an earlier ablation strategy. However, this study may serve as the scientific basis for future trials.
Study limitations

This study was a retrospective analysis of the influence of timing to ablation on the short- and long-term outcomes in patients with VT treated by CA. The large size of the study population with a significant incidence of events allowed for adjustment for many significant and clinically relevant confounders. However, certain residual confounding due to some differences in the baseline characteristics may influence the outcomes. For example, the referral for ablation can be influenced by the severity of the symptoms (incessant VT or electrical storm) and the time of their occurrence. Therefore, we tried to isolate the effects of the VT burden on the decision for ablation performing subgroup analysis for the patients with low and high VT-burden separately.

The results are derived from a high-volume center, and may not be directly applicable to low-volume centers without sufficient expertise and well-developed facilities for VT ablation. Since most patients already had ICD’s implanted before ablation, we could not perform MRI to compare the extent of underlying electro-anatomical substrate and correlate it with the outcomes.

Conclusion

CA of scar-related VT performed within 30 days after the first documented VT was safe and associated with better acute success. At 2 years of follow-up, the VT-free survival after early CA was significantly higher, however no mortality difference was observed. The benefits from earlier CA were observed in patients with low VT-burden and severely depressed LV systolic function.

Conflict of Interest Disclosure: None.
References:


### Table 1: Baseline Clinical Characteristics

<table>
<thead>
<tr>
<th>Clinical characteristics</th>
<th>All N=300</th>
<th>Group1 N=75</th>
<th>Group2 N=84</th>
<th>Group3 N=141</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>65±11.7</td>
<td>66.92 ± 11.58</td>
<td>62.68 ± 12.91</td>
<td>65.65 ± 10.84</td>
<td>0.057</td>
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<tr>
<td>Gender</td>
<td>262 (87.3)</td>
<td>62 (82.7)</td>
<td>78 (92.9)</td>
<td>122 (86.5)</td>
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<tr>
<td>ICM</td>
<td>204 (68.0)</td>
<td>57 (76)</td>
<td>59 (70.2)</td>
<td>88 (62.4)</td>
<td>0.11</td>
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<td>Arterial hypertension</td>
<td>211 (70.3)</td>
<td>56 (74.7)</td>
<td>52 (61.9)</td>
<td>103 (73)</td>
<td>0.13</td>
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<td>Diabetes mellitus</td>
<td>111 (37.0)</td>
<td>26 (34.7)</td>
<td>28 (33.3)</td>
<td>57 (40.4)</td>
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<td>Atrial fibrillation</td>
<td>117 (39.0)</td>
<td>27 (36.0)</td>
<td>31 (36.9)</td>
<td>59 (41.8)</td>
<td>0.63</td>
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<td>Heart failure NYHA &gt;II</td>
<td>146 (48.7)</td>
<td>28 (37.3)</td>
<td>41 (48.8)</td>
<td>77 (54.6)</td>
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<td>Coronary artery bypass</td>
<td>101 (33.7)</td>
<td>30 (40)</td>
<td>21 (25)</td>
<td>50 (35.7)</td>
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<td>ICD at admission</td>
<td>254 (84.7)</td>
<td>36 (48)</td>
<td>78 (92.9)</td>
<td>140 (99.3)</td>
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<td>Electrical storm</td>
<td>119 (39.7)</td>
<td>22 (29.3)</td>
<td>34 (40.5)</td>
<td>63 (44.7)</td>
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<td>AAD at admission</td>
<td>133 (44.3)</td>
<td>27 (36.0)</td>
<td>36 (42.9)</td>
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<td>23 (30.7)</td>
<td>32 (38.1)</td>
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<td>Class IB or C</td>
<td>11 (3.7)</td>
<td>3 (4.0)</td>
<td>3 (3.6)</td>
<td>5 (3.5)</td>
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<td>Sotalol</td>
<td>5 (1.7)</td>
<td>0 (0)</td>
<td>2 (1.4)</td>
<td>3 (2.1)</td>
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<tr>
<td>Incessant VT</td>
<td>37 (12.3)</td>
<td>15 (20)</td>
<td>9 (10.7)</td>
<td>13 (9.2)</td>
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<td>LV EF, %</td>
<td>32.6±11.1</td>
<td>35.60 ± 13.31</td>
<td>32.57 ± 10.75</td>
<td>31.01 ± 9.75</td>
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<tr>
<td>High VT burden</td>
<td>171 (57)</td>
<td>33 (44)</td>
<td>48 (57)</td>
<td>90 (63.8)</td>
<td>0.020</td>
</tr>
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</table>

Continuous variables are presented as mean (±SD) and median (IQR); categorical variables are presented as numbers and proportions; ICM indicates ischemic cardiomyopathy; AAD - antiarrhythmic drugs; VT - ventricular tachycardia
Table 2: Procedural and Post-procedural Characteristics

<table>
<thead>
<tr>
<th>Clinical characteristics</th>
<th>All N=300</th>
<th>Group 1 N=75</th>
<th>Group 2 N=84</th>
<th>Group 3 N=141</th>
<th>P</th>
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<td>Operator</td>
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<tr>
<td>Operator 1</td>
<td>216 (72)</td>
<td>57 (76.0)</td>
<td>61 (72.6)</td>
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<tr>
<td>Others</td>
<td>84 (28)</td>
<td>18 (24)</td>
<td>23 (27.4)</td>
<td>43 (30.5)</td>
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<td>Inducible or ongoing</td>
<td>269 (89.3)</td>
<td>66 (88)</td>
<td>73 (86.9)</td>
<td>129 (91.5)</td>
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<td>Clinical VT CL, ms</td>
<td>375±90.8</td>
<td>373 ± 79.47</td>
<td>368.5 ± 95.50</td>
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<td>Number VTs</td>
<td>2.05 ± 1.29</td>
<td>1.65 ± 1.05</td>
<td>2.1 ± 1.32</td>
<td>2.23 ± 1.36</td>
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<tr>
<td>Epicardial ablation</td>
<td>32 (10.7)</td>
<td>6 (8)</td>
<td>8 (9.5)</td>
<td>18 (12.8)</td>
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<tr>
<td>Substrate mapping</td>
<td>252 (84.0)</td>
<td>58 (77.3)</td>
<td>72 (85.7)</td>
<td>124 (87.9)</td>
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<td>Activation mapping</td>
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<td>44 (58.7)</td>
<td>40 (47.6)</td>
<td>62 (141)</td>
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<td>RMN</td>
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<td>13 (17.3)</td>
<td>14 (16.7)</td>
<td>34 (24.1)</td>
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<td>Complete success</td>
<td>231 (77.3)</td>
<td>66 (88)</td>
<td>68 (81)</td>
<td>99 (70.2)</td>
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<td>Partial success</td>
<td>50 (16.6)</td>
<td>8 (10.7)</td>
<td>12 (14.3)</td>
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<tr>
<td>Failure</td>
<td>18 (6.0)</td>
<td>1 (1.3)</td>
<td>4 (4.8)</td>
<td>13 (9.2)</td>
<td>0.057</td>
</tr>
<tr>
<td>Procedure time, min</td>
<td>151 (70)</td>
<td>150 (60)</td>
<td>165 (63)</td>
<td>165 (70)</td>
<td>0.041</td>
</tr>
<tr>
<td>Ablation time, sec.</td>
<td>1551 (1263)</td>
<td>1326 (1211)</td>
<td>1542 (1400)</td>
<td>1695 (1484)</td>
<td>0.012</td>
</tr>
<tr>
<td>Complications</td>
<td>19 (6.3)</td>
<td>3 (4.0)</td>
<td>6 (7.1)</td>
<td>10 (7.1)</td>
<td>0.63</td>
</tr>
<tr>
<td>Vascular</td>
<td>7 (2.3)</td>
<td>1 (1.3)</td>
<td>2 (2.4)</td>
<td>4 (2.8)</td>
<td></td>
</tr>
<tr>
<td>Tamponade</td>
<td>5 (1.7)</td>
<td>1 (1.3)</td>
<td>2 (2.4)</td>
<td>2 (1.4)</td>
<td></td>
</tr>
<tr>
<td>TIA</td>
<td>1 (0.3)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.7)</td>
<td></td>
</tr>
<tr>
<td>ARDS</td>
<td>2 (0.7)</td>
<td>1 (1.3)</td>
<td>0 (0)</td>
<td>1 (0.7)</td>
<td></td>
</tr>
<tr>
<td>EMD</td>
<td>2 (0.7)</td>
<td>0 (0)</td>
<td>1 (1.2)</td>
<td>1 (0.7)</td>
<td></td>
</tr>
<tr>
<td>Liver haematoma</td>
<td>1 (0.3)</td>
<td>0 (0)</td>
<td>1 (1.2)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>AV Block III</td>
<td>1 (0.3)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.7)</td>
<td></td>
</tr>
<tr>
<td>In-hospital death</td>
<td>11 (3.7)</td>
<td>5 (6.7)</td>
<td>2 (2.4)</td>
<td>4 (2.8)</td>
<td>0.28</td>
</tr>
<tr>
<td>ICD at discharge</td>
<td>286 (95.3)</td>
<td>64 (85.3)</td>
<td>81 (96.4)</td>
<td>141 (100)</td>
<td>0.0001</td>
</tr>
<tr>
<td>ILR at discharge</td>
<td>12 (4.0)</td>
<td>9 (12.0)</td>
<td>3 (3.6)</td>
<td>0 (0.0)</td>
<td>0.0001</td>
</tr>
<tr>
<td>AAD at discharge</td>
<td>100 (33.3)</td>
<td>18 (24.0)</td>
<td>27 (32.1)</td>
<td>55 (39.0)</td>
<td>0.31</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>83 (27.7)</td>
<td>17 (20.5)</td>
<td>21 (25.3)</td>
<td>45 (31.9)</td>
<td></td>
</tr>
<tr>
<td>Class IC</td>
<td>9 (3.0)</td>
<td>1 (1.3)</td>
<td>3 (3.6)</td>
<td>5 (3.5)</td>
<td></td>
</tr>
<tr>
<td>Sotalol</td>
<td>8 (2.7)</td>
<td>0 (0)</td>
<td>3 (3.6)</td>
<td>5 (3.5)</td>
<td></td>
</tr>
<tr>
<td>BB at discharge</td>
<td>271 (90.3)</td>
<td>68 (90.7)</td>
<td>76 (90.5)</td>
<td>127 (90.1)</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Continuous variables are presented as mean (±SD) and median (IQR); categorical variables are presented as numbers and proportions; AAD - antiaarrhythmic drugs; VT CL - ventricular tachycardia cycle length; RMN- remote magnetic navigation; ICD- implantable cardioverter defibrillator; ILR - implantable loop recorder; BB – beta blocker; EMD – electro-mechanical dissociation; ARDS – acute respiratory distress syndrome; TIA – transient ischemic attack.

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Table 3: Univariate and Multivariate Cox Regression Analysis of VT Recurrence

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariable</th>
<th>Multivariable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95%;CI)</td>
<td>P</td>
</tr>
<tr>
<td>Delayed vs. early</td>
<td>1.85 (1.17-2.93)</td>
<td>0.009</td>
</tr>
<tr>
<td>Very late vs. early</td>
<td>2.04 (1.34-3.12)</td>
<td>0.001</td>
</tr>
<tr>
<td>NIDCM</td>
<td>1.57 (1.16-2.14)</td>
<td>0.005</td>
</tr>
<tr>
<td>CABG</td>
<td>1.19 (0.82-1.53)</td>
<td>0.480</td>
</tr>
<tr>
<td>Absence of beta-blocker</td>
<td>1.91 (1.21-3.03)</td>
<td>0.006</td>
</tr>
<tr>
<td>Complete success</td>
<td>1.59 (1.02-2.50)</td>
<td>0.042</td>
</tr>
</tbody>
</table>

HR indicates hazard ratio; CI indicates confidence interval; NIDCM indicates non-ischemic dilated cardiomyopathy; CABG indicates coronary artery bypass grafting.

Table 4: Univariate and Multivariate Cox Regression Analysis of Cardiovascular Mortality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariable</th>
<th>Multivariable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95%;CI)</td>
<td>P</td>
</tr>
<tr>
<td>Age, y</td>
<td>1.03 (1.003-1.06)</td>
<td>0.031</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td>0.96 (0.93-0.99)</td>
<td>0.005</td>
</tr>
<tr>
<td>Absence of Beta-blocker</td>
<td>2.14 (1.003-4.56)</td>
<td>0.049</td>
</tr>
<tr>
<td>VT recurrence</td>
<td>1.89 (1.03-3.47)</td>
<td>0.039</td>
</tr>
</tbody>
</table>
Figure Legends:

**Figure 1:** Kaplan-Meier curves of VT-free survival according to time to CA. Patients referred earlier for ablation (group 1; dotted line) have better long term VT-free survival as compared to those with delayed (group 2; continuous line), p=0.009, and very late ablation (group 3; dashed line), p=0.001.

**Figure 2:** Kaplan-Meier curves for death from cardiac reasons according to time to referral for ablation. No difference in cardiac mortality between group 1 (dotted line), group 2 (continuous line), group 3 (dashed line) was observed.

**Figure 3:** Showing the median, IQR (Q3-Q1) and range for time from first VT to ablation, depending on the acute outcome, complications, VT recurrence and cardiac mortality. The time from the first VT to CA was significantly shorter in patients with complete success and without VT recurrence.
HR 2 vs. 1 = 1.851 (1.168-2.933); p=0.009
HR 3 vs. 1 = 2.043 (1.337-3.122); p=0.001

Cum VT-free survival %

Time to first VT recurrence, days

N at risk 1 75 46 33 22 19
2 84 43 23 15 12
3 141 68 44 33 25

Ablation < 30 days (1)
Ablation 30 days-12 months (2)
Ablation > 12 months (3)
HR 2 vs. 1 = 0.848 (0.381-1.887); p=0.686
HR 3 vs. 1 = 1.125 (0.568-2.230); p=0.735

Cumulative Survival %

Time to death, days

N at risk 1 75 61 51 38 34
2 84 70 61 46 42
3 141 117 95 81 70

Ablation 30 days-12 months (2)
Ablation < 30 days (1)
Ablation > 12 months (3)
Early Referral for Ablation of Scar-Related Ventricular Tachycardia Is Associated with Improved Acute and Long Term Outcomes: Results from the Heart Center of Leipzig Ventricular Tachycardia Registry
Borislav Dinov, Arash Arya, Livio Bertagnolli, Valentina Schirripa, Katharina Schoene, Philipp Sommer, Andreas Bollmann, Sascha Rolf and Gerhard Hindricks

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