Management of Ventricular Tachycardia in the Setting of a Dedicated Unit for the Treatment of Complex Ventricular Arrhythmias
Long-Term Outcome After Ablation

Paolo Della Bella, MD; Francesca Baratto, MD; Dimitris Tsiachris, MD; Nicola Trevisi, MD; Pasquale Vergara, MD; Caterina Bisceglia, MD; Francesco Petracca, MD; Corrado Carbucicchio, MD; Stefano Benussi, MD; Francesco Maisano, MD; Ottavio Alfieri, MD; Federico Pappalardo, MD; Alberto Zangrillo, MD; Giuseppe Maccabelli, MD

Background—We investigated the impact of catheter ablation on ventricular tachycardia (VT) recurrence and survival in a large number of patients with structural heart disease treated in the setting of a dedicated multiskilled unit.

Methods and Results—Since January 2007, we have implemented a multidisciplinary model, aiming for a comprehensive management of VT patients. Programmed ventricular stimulation was used to assess acute outcome. Primary end points were VT recurrence and the occurrence of cardiac and sudden cardiac death. Overall, 528 patients were treated by ablation (634 procedures; 1–4 procedures per patient). Among 482 tested with programmed ventricular stimulation after the last procedure, a class A result (noninducibility of any VT) was obtained in 371 patients (77%), class B (inducibility of nondocumented VT) in 12.4%, and class C (inducibility of index VT) in 10.6%. After a median follow-up time of 26 months, VT recurred in 164 (34.1%) of 472 patients. VT recurrence was documented in 28.6% of patients with a class A result versus 39.6% of patients with class B and 66.7% with class C result (log-rank P<0.001). The incidence of cardiac mortality was lower in class A patients than in those with class B and class C (8.4% versus 18.5% versus 22%, respectively; log-rank P=0.002). On the basis of multivariate analysis, postprocedural inducibility of index VT was independently associated both with VT recurrence (hazard ratio, 4.030; P<0.001) and with cardiac mortality (hazard ratio, 2.099; P=0.04).

Conclusions—Within a dedicated VT unit, catheter ablation prevents long-term VT recurrences, which may favorably affect survival in a large number of patients who have VT. (Circulation. 2013;127:1359-1368.)

Key Words: catheter ablation ◼ heart failure ◼ risk factors ◼ survival ◼ ventricular tachycardia

In patients with ventricular tachycardia (VT) and structural heart disease, an implantable cardioverter-defibrillator (ICD) provides significant protection against the risk of sudden death; however, it does not prevent arrhythmia recurrences or the occurrence of electrical storm (ES), which has been shown to be an independent predictor of cardiac mortality.1–7 A curative strategy is therefore required for the care of patients with recurrent ventricular arrhythmias.4–7

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The hospital admission and treatment of VT patients requires the management of a broad spectrum of clinical patterns, ranging from paroxysmal episodes to incessant VT and ES, leading to acute cardiac failure and cardiogenic shock.10 Catheter ablation (CA) plays a relevant role in the treatment of drug-refractory VT episodes, recurrent ICD shocks, and ES, lowering VT recurrence and improving quality of life.11–13

Data about the effects of CA on survival are controversial. In the Ventricular Tachycardia Ablation in Coronary Heart Disease (VTACH) study, no survival benefit was observed in ischemic patients treated by CA before ICD implantation, whereas in Substrate Mapping and Ablation in Sinus Rhythm to Halt Ventricular Tachycardia (SMASH VT) trial, there was a trend toward decreased mortality in the ablation group, although it was not statistically significant.11,12 Recently, Sauer et al13 reported a beneficial effect of CA on survival in patients according to CA result. On the basis of the complex nature of VT patients, we have implemented a multidisciplinary model, and within this expert environment, we investigated the impact of CA on VT recurrences, hospitalization, and survival in a large number of patients with structural heart disease.

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From the Arrhythmia Unit and Electrophysiology Laboratories (P.D.B., F.B., D.T., N.T., P.V., C.B., F. Petracca, G.M.), Heart Surgery Unit (S.B., F.M., O.A.), Department of Cardiology and Cardiothoracic Surgery, and Anesthesia and Intensive Care (F. Pappalardo, A.Z.), Ospedale San Raffaele, Milan, Italy; and Cardiac Arrhythmia Research Centre, Centro Cardiologico Monzino, IRCCS, Milan, Italy (C.C.).
Correspondence to Paolo Della Bella, MD, Arrhythmia Unit and Electrophysiology Laboratories, Ospedale San Raffaele, via Olgettina 60, Milan, Italy. E-mail dellabella.paolo@hsr.it

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Methods

Study Design
We implemented a dedicated unit, focused on the management of pa-
tients with VT and structural heart disease, with the purpose of pro-
viding assistance to patients from hospital admission to discharge and
follow-up, linking the electrophysiology laboratory to the emergency
area and intensive care unit (ICU), in close cooperation with the heart
failure unit and cardiac surgery. The VT unit (VTU) became opera-
tive in January 2007 in the arrhythmia unit at Centro Cardiologico
Monzino in Milan, Italy, and has been operational at San Raffaele
Hospital, Milan, since January 2010. To the best of our knowledge,
this strategy represents a unique experience of a unit dedicated to VT.

Physicians, hospitals, and ICUs throughout the country referred
patients to our VTU staff for admission, using a priority phone line
that was available 24 hours a day, 7 days a week. A heliport situated
nearby the hospital made the emergency transfer of unstable patients
possible. Twenty-four-hour continuous service of care was provided
by the arrhythmia staff, who were able to perform CA at any time of
the day or night.

Study Protocol

Risk Classification
On admission, patients underwent clinical examination, blood gas
analysis, ECG, chest radiography, and echocardiography. The ar-
rhythmia pattern was classified as paroxysmal episodes of VT, inces-
sant VT, or ES (≥3 episodes of VT separated by >5 minutes during
a 24-hour period). Hemodynamic state was evaluated with regard
to both VT tolerance and the circulatory state during sinus rhythm
(cardiogenic shock defined by prolonged phases of severe hypoten-
sion [<70 mm Hg] that persisted beyond the temporary resumption
of regular rhythm despite continuous infusion of pressor agents).

All patients with cardiogenic shock were considered high risk. Stepwise assessment of arrhythmia pattern, VT tolerance (any VT
causong hemodynamic compromise), and presence of major comor-
bidities (left ventricular ejection fraction ≤30% and history of chronic
kidney disease, defined as serum creatinine ≥1.5 mg/dL) or minor co-
morbidities (chronically occluded left anterior descending artery
and severe pulmonary disease based on the presence of Pco₂ >50 mm Hg)
were used to classify patients as being at high or low risk (Figure 1).
All high-risk patients were subsequently treated in the ICU and un-
derwent CA either at the same time or after correction of metabolic,
respiratory, and circulatory imbalances. Low-risk patients underwent
an electrophysiological evaluation and according to this evaluation
were electively considered for CA.

CA Procedure
All procedures were performed under general anesthesia and me-
chanical ventilation, with continuous monitoring of invasive arterial
pressure and oxygen saturation. In selected cases of patients with in-
cessant VT, CA was performed without general anesthesia. Written
informed consent was obtained from all patients. Patients with bun-
dle-branch reentry, focally triggered arrhythmias, and fascicular VTs
were excluded from the present analysis.

In the absence of contraaindications, the left ventricle was accessed
by transseptal and retrograde routes in all cases. A first-line com-
bined epicardial and endocardial mapping was routinely undertaken
in patients with VT and nonischemic causes (idiopathic dilated car-
diomyopathy, arrhythmogenic right ventricular cardiomyopathy, or
previous myocarditis) or when preprocedural imaging suggested the
epicardial origin of the reentrant circuit. Epicardial ablation was the
second treatment choice in case of clinical VT recurrence after a pre-
vious endocardial ablation. Surgical ablation was undertaken in case
of coexisting cardiac surgery indication or in the presence of VT that
proved to be resistant to endocardial and epicardial CA.

In all cases, we systematically implemented an ablation strategy
of substrate modification, independent from the VT inducibility, fo-
cused on abolition of late and fragmented activity. Specifically, all
patients underwent precise electroanatomical mapping in sinus rhythm
using the standard definition of scar and border zone. This was the
case even after termination of incessant VTs through activation map-
ning. Programmed ventricular stimulation with up to 4 extrastimuli
from the right ventricular apex and multiple left ventricular sites (in
case of VTs originating from left ventricle) was performed, and toler-
ated VTs were ablated through activation mapping. If nontolerated
VTs were induced, ablation was performed in sinus rhythm only.
Radiofrequency current was delivered with an irrigated-tip catheter
with the aim of completely abolishing abnormal activity at an ini-
tial power setting of 30 to 50 W, with a temperature limit of 43°C.
On the basis of the above, general anesthesia was preferred because

![Figure 1. Proposed algorithm for risk stratification of patients presenting with ventricular tachycardia (VT) based on arrhythmia pattern, VT tolerance, and presence of major comorbidities (chronically occluded left anterior descending coronary artery and history of chronic kidney disease, defined as serum creatinine ≥1.5 mg/dL) and minor comorbidities (left ventricular ejection fraction [LVEF] ≤30% and severe pulmonary disease, based on the presence of Pco₂ >50 mm Hg). ES indicates electrical storm.](http://circ.ahajournals.org/doi/abs/10.1161/CIRCULATIONAHA.113.001360?journalCode=circ)
impact of ventricular tachycardia ablation

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of enhanced patient comfort and minimized patient movement, and most importantly because it aids close monitoring and facilitates adjustment of metabolic, respiratory, and circulatory imbalances.

Programmed ventricular stimulation (up to 4 extrastimuli) was used to assess acute outcome. Prevention of inducibility of any VT was defined as complete success (class A); ablation of all previously documented VTs with persistent inducibility of any nondocumented sustained VTs or ventricular fibrillation was defined as partial success (class B). The inability to prevent reinduction of ≥1 previously documented VTs was considered as a failure (class C). In cases of early in-hospital VT recurrence, CA was repeated, and the long-term results refer to the period after the last procedure.

Follow-Up
After the procedure, all patients underwent a 5- to 7-day constant 12-lead ECG telemetry monitoring period in the VTU to assess for possible early VT recurrence. In cases with complete ablation success and an absence of VT recurrence, patients were discharged with therapy optimization discontinuing amiodarone administration.

Before discharge, all patients were scheduled for regular follow-up visits (at 3-month intervals) in the VT outpatient clinic or whenever any symptom occurred. All patients who underwent ICD implantation after 2010 at our center were additionally followed up by remote monitoring.

Primary end points of the study were the recurrence of sustained VT as documented by regular ICD interrogation or clinical events and the occurrence of cardiac death and sudden cardiac death (defined as death resulting from malignant ventricular arrhythmias that occurred within 1 hour of the onset of symptoms). Secondary end points were hospitalization for documented recurrence of VT, cardiac decompensation, or major medical treatments and interventions.

Statistical Analysis
Continuous variables are presented as either means (±SD) or medians (with interquartile ranges) and categorical variables as numbers and percentages. Comparisons between groups were performed by unpaired t test for continuous variables and by Fisher exact test or χ² test for proportions, as indicated. Event-free survival was estimated by the Kaplan-Meier method, and curves were compared with the log-rank test. Univariate and multivariate Cox proportional hazards analyses were used to assess the relationship between CA result and study end points. Differences were considered statistically significant at the 2-sided P<0.05 level. All statistical analyses were performed with SPSS version 15.0 statistical software (SPSS Inc, Chicago, IL).

Results
Study Population
Between 2007 and 2011, 616 consecutive patients (548 males, mean age 61±14 years), who had VT episodes caused by scar-related substrate were referred to the VT unit. An ICD had previously been implanted in 480 patients; 31 underwent ICD implantation after ablation, and 105 were treated by ablation and did not receive an ICD. At the time of admission, 58 patients (9.4%) were in incessant VT, 151 (24.5%) had experienced an ES, and 407 patients had recurrent paroxysmal VT (88 of these 407 experienced their first VT episode). Catheter ablation was performed in 528 of these 616 patients. Tolerated VT was present in 62.9% of ablated patients (Table 1).

Among patients with a first-onset VT, an ICD was implanted in 35 and CA was offered to 19 as a further option because of the inducibility of tolerated VTs under antiarrhythmic treatment. Moreover, 16 of 88 patients with a first-onset VT underwent ventricular mapping but were not treated by ablation because of the absence of pathological substrate and VT inducibility, whereas in the remaining 37, VT was not inducible, and they were treated with medical therapy.

One hundred eight patients (20%) of the 528 patients who received CA, were referred from other ICUs; mean hospital stay was 15±10 days. Four hundred twenty-one patients (80%) had already experienced at least 1 hospitalization for VT in a different hospital (210 patients in the preceding 6 months); an attempt at CA had been performed in 56 of them (13%).

Risk Stratification and Initial Management
On the basis of the above-mentioned method (Figure 1), patients were classified into high-risk (n=221, 36%) and low-risk (n=395, 64%) categories. Among high-risk patients, 53 were directly admitted to the ICU because of the extreme instability of the arrhythmia pattern (ongoing ES in 40, incessant VT in 13) and 18 because of cardiogenic shock during sinus rhythm that required circulatory support (either intraaortic balloon counterpulsation or extracorporeal membrane oxygenation); concomitant ventilatory support was provided in 10 patients with respiratory failure and hemodialysis in 3 for acute renal failures. Hemodynamic stabilization was achieved in all patients. All high-risk patients underwent CA, as did 307 (77.7%) of 395 low-risk patients.

Table 1: Baseline Clinical Characteristics of Patients Who Underwent Ablation of VT

<table>
<thead>
<tr>
<th>Underlying heart disease</th>
<th>n (%)</th>
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<tbody>
<tr>
<td>Ischemic dilated cardiomyopathy</td>
<td>290 (54.9)</td>
</tr>
<tr>
<td>Idiopathic dilated cardiomyopathy</td>
<td>109 (20.6)</td>
</tr>
<tr>
<td>Arrhythmogenic right ventricular cardiomyopathy</td>
<td>34 (6.4)</td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td>15 (2.8)</td>
</tr>
<tr>
<td>Hypertrophic cardiomyopathy</td>
<td>8 (1.5)</td>
</tr>
<tr>
<td>Previous myocarditis</td>
<td>24 (4.5)</td>
</tr>
<tr>
<td>Congenital heart disease</td>
<td>9 (1.7)</td>
</tr>
<tr>
<td>Myocardial benign tumors</td>
<td>3 (0.6)</td>
</tr>
<tr>
<td>Storage diseases</td>
<td>3 (0.6)</td>
</tr>
<tr>
<td>Other diseases</td>
<td>33 (6.3)</td>
</tr>
<tr>
<td>Age, y</td>
<td>62±14</td>
</tr>
<tr>
<td>Males/females, n</td>
<td>473/55</td>
</tr>
<tr>
<td>Left ventricular ejection fraction, %</td>
<td>38±13</td>
</tr>
<tr>
<td>Left ventricular ejection fraction ≤30%</td>
<td>190 (36)</td>
</tr>
<tr>
<td>New York Heart Association class</td>
<td></td>
</tr>
<tr>
<td>Class I</td>
<td>183 (34.7)</td>
</tr>
<tr>
<td>Class II</td>
<td>194 (36.7)</td>
</tr>
<tr>
<td>Class III</td>
<td>129 (24.4)</td>
</tr>
<tr>
<td>Class IV</td>
<td>22 (4.2)</td>
</tr>
<tr>
<td>Prior amiodarone therapy</td>
<td>410 (77.7)</td>
</tr>
<tr>
<td>Amiodarone adverse reaction</td>
<td>79 (19)</td>
</tr>
<tr>
<td>Renal disease</td>
<td>117 (22.2)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>124 (23.5)</td>
</tr>
<tr>
<td>Implantable cardioverter defibrillator</td>
<td>432 (81.8)</td>
</tr>
<tr>
<td>Nontolerated VT</td>
<td>196 (37.1)</td>
</tr>
<tr>
<td>Electrical storm</td>
<td>151 (28.6)</td>
</tr>
<tr>
<td>Incessant VT</td>
<td>58 (11)</td>
</tr>
<tr>
<td>High risk/low risk, n</td>
<td>221/307</td>
</tr>
</tbody>
</table>

VT indicates ventricular tachycardia.

Values are n (%), mean±SD, or number of patients.
CA Acute Results

Overall, among 528 patients treated by ablation, 634 procedures were performed (range 1–4 procedures per patient); mean duration of the procedure was 220±75 minutes, mean fluoroscopy time was 36±13 minutes, and mean radiofrequency time was 1320±470 seconds. The first procedure was endocardial in 348 patients (66%), endocardial-epicardial in 156 (29.5%), and surgical in 21 (4.0%). In 3 patients, the epicardium was accessed in the electrophysiology laboratory through a surgical subxiphoid window. In 69 patients, ablation was repeated because of in-hospital recurrence of VT during the same hospitalization.

At the end of the last ablation procedure, 482 patients underwent postablation programmed ventricular stimulation, whereas inducibility was not tested in 46 patients (8.7%) because of absence of VT inducibility at baseline programmed ventricular stimulation (n=39) or severe acute complications (n=7). A class A result was obtained in 371 patients (77%), class B in 60 patients (12.4%), and class C in 51 patients (10.6%). Class A acute results were more prevalent in low-risk than in high-risk patients (81.1% versus 71.1%, P=0.01), whereas the prevalence of a class B (10.3% versus 15.4%, P=0.09) and class C (8.5% versus 13.4%, P=0.08) result was marginally but not statistically different between low- and high-risk patients.

Among 60 class B patients, polymorphic VT that degraded to VF was induced in 22 patients; a VT with a different morphology was induced in 28 patients with a previously available ECG of the index VT, whereas a VT with a difference in cycle length ≥50 ms was defined as a class B result in 10 patients with previously available stored ICD electrograms and correspondent cycle length of the initially induced VT. Inducibility of VF was more prevalent in high-risk than in low-risk patients with a class B result (48.4% versus 24.1%, P=0.05).

Regarding patients with acute VT recurrence and a second ablation procedure in the same hospitalization (n=69), a class A acute result had been registered after the first ablation in 32 patients, class B in 21 patients, and class C in 16 patients. Accordingly, after the second procedure, class A was achieved in 41 patients, class B in 10, and class C in 14, whereas VT inducibility was not tested in 4 patients.

Amiodarone was maintained in 167 patients (31.6%) after discharge because of ablation failure, in-hospital VT recurrence, or atrial fibrillation; 357 patients (67.6%) were prescribed β-blocker therapy at the highest tolerated dose.

Complications

Intraprocedural electromechanical dissociation was observed in 3 patients; 2 were supported by extracorporeal membrane oxygenation and treated by ablation, recovering uneventfully, whereas 1 patient died. Three patients experienced intraprocedural acute heart decompensation, 1 had transient total atrioventricular block, and 1 had permanent left bundle branch block.

Major vascular complications (arteriovenous fistula/pseudoaneurysm) that required surgical repair occurred in 23 patients (4%) and minor vascular complications in 38 (7%). Pericardial effusion occurred in 17 patients (3%), which required drainage because of tamponade in 11 patients (2%). Late tamponade after removal of the pericardial sheath (24 hours after the procedure) occurred in only 2 cases of endocardial-epicardial CA.

Retroperitoneal hematoma was evident in 1 patient that was caused by acute anemia and treated by surgical repair of the hypogastric artery (endocardial procedure). One patient underwent periprocedural percutaneous coronary intervention because of acute myocardial ischemia (endocardial procedure). An abdominal hematoma, caused by the puncture of a small diaphragmatic artery, occurred in 2 patients during subxiphoid puncture, requiring surgical repair in 1 patient; both patients recovered uneventfully.

In-Hospital Follow-up

Mean hospitalization time in the VTU was 8±3 days (range, 5–16 days). Nine patients died of refractory heart failure. In 3 patients, a left ventricular assist device was implanted. In-hospital recurrence of paroxysmal VT was experienced by 96 patients (18%).

VT Recurrence

After a median follow-up of 26 months (interquartile range, 13–46 months), follow-up of arrhythmia recurrences was available in 472 patients (47 were lost to follow-up, and 9 experienced in-hospital death without experiencing VT recurrence in this short postablation period). No differences were observed between patients lost to follow-up and the final study population in any of the assessed clinical characteristics, whereas CA acute results appeared to be more favorable in patients lost to follow-up (class A, 83.7% versus 76.7%; class B, 14% versus 12.2%; and class C, 2.3% versus 11.1%), although this did not reach statistical significance.

VT recurred in 164 patients (34.0%) and median recurrence survival time was 44.2 months (95% confidence interval, 41.5–46.9 months). Forty patients experienced at least 1 hospitalization because of VT during the first 6 months after ablation (compared with 210 hospital admissions for VT in the preceding 6 months, P<0.001). VT recurrence was documented in 95 (28.6%) of 332 patients with a class A result in the last ablation procedure versus 21 (39.6%) of 53 patients with a class B result and 32 (66.7%) of 48 with a class C result (log-rank P<0.001), as well as in 13 of 39 patients not tested (33%; Figure 2).

Univariate analysis, VT recurrence was predicted by both postprocedural inducibility of previously documented VT (class C versus A and B; hazard ratio [HR] 4.485, P<0.001) and class A (versus B and C) result (HR=0.418, P<0.001), as well as by ES as the presenting pattern, presence of nontolerated VT, New York Heart Association class, idiopathic dilated cardiomyopathy as the VT substrate, left ventricular ejection fraction, and postablation amiodarone therapy. After multivariate analysis was performed, only failed CA (class C versus A and B, HR=4.030, P<0.001), presence of nontolerated VT (HR=1.553, P=0.012), and postablation amiodarone therapy (HR=1.492, P=0.024) predicted VT recurrence (Table 2).

Additionally, we analyzed the characteristics of VT recurrence separately for high- and low-risk patients. Among 175 high-risk patients, VT recurred in 37.4% (46/123) of patients...
with class A, 33.3% (9/27) with class B, and 84% (21/25) of patients with postprocedural inducibility of index VT (log-rank \( P<0.001 \)). The incidence of VT recurrence was significantly lower in class A (23.4%, 49/209) than class B (46.2%; 12/26) and class C (47.8%; 11/23) among low-risk patients (log-rank \( P<0.001 \)). The absence of any postprocedural inducibility (class A versus B and C, HR=0.439, \( P=0.002 \)) instead of the presence of CA failure was associated with VT recurrence in low-risk patients. In contrast, postprocedural inducibility of index VT (class C versus A and B, HR=5.880, \( P<0.001 \)), presence of nontolerated VT (HR=1.710, \( P=0.032 \)), presence of idiopathic dilated cardiomyopathy (HR=1.747, \( P=0.035 \)), and postablation amiodarone therapy (HR=1.810, \( P=0.019 \)) predicted VT recurrence in high-risk patients (Table 3; Figure 2).

**Heart Failure**

At least 1 episode of heart failure occurred in 41 patients, which led to death in 12 patients. New York Heart Association class was a strong predictor of the occurrence of an acute heart failure episode (HR=1.874, \( P=0.002 \)), along with the presence of functional class, type of cardiomyopathy, and administration of amiodarone at discharge, in the entire study population (A) and in low- (B) and high-risk (C) patients.

**Table 2. Univariate and Multivariate Cox Regression Analysis of VT Recurrence**

<table>
<thead>
<tr>
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<th>Univariate Analysis</th>
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<th>Multivariate Analysis</th>
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<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td></td>
<td>HR (95% CI)</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>1.004 (0.992–1.015)</td>
<td>0.532</td>
<td>1.192 (0.904–1.572)</td>
<td>0.214</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.013 (0.604–1.698)</td>
<td>0.962</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NYHA class</td>
<td>1.367 (1.146–1.631)</td>
<td>0.001</td>
<td>1.902 (0.569–1.489)</td>
<td>0.735</td>
</tr>
<tr>
<td>Class A (vs B and C)</td>
<td>0.418 (0.298–0.585)</td>
<td>&lt;0.001</td>
<td>4.030 (2.277–7.134)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td>0.978 (0.966–0.991)</td>
<td>0.001</td>
<td>1.000 (0.980–1.020)</td>
<td>0.982</td>
</tr>
<tr>
<td>Nontolerated VT</td>
<td>1.541 (1.122–2.117)</td>
<td>0.008</td>
<td>1.553 (1.100–2.193)</td>
<td>0.012</td>
</tr>
<tr>
<td>Electrical storm</td>
<td>1.690 (1.226–2.331)</td>
<td>0.001</td>
<td>1.315 (0.916–1.888)</td>
<td>0.138</td>
</tr>
<tr>
<td>Incessant VT</td>
<td>0.927 (0.544–1.578)</td>
<td>0.779</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal disease</td>
<td>1.209 (0.834–1.752)</td>
<td>0.317</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>1.102 (0.770–1.577)</td>
<td>0.594</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idiopathic dilated cardiomyopathy</td>
<td>1.737 (1.230–2.454)</td>
<td>0.002</td>
<td>1.396 (0.960–2.031)</td>
<td>0.081</td>
</tr>
<tr>
<td>Amiodarone therapy</td>
<td>1.619 (1.183–2.216)</td>
<td>0.003</td>
<td>1.492 (1.055–2.112)</td>
<td>0.024</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; Class A, noninducibility of any ventricular tachycardia; Class B, inducibility of nondocumented ventricular tachycardia; Class C, inducibility of index ventricular tachycardia; HR, hazard ratio; NYHA, New York Heart Association; and VT, ventricular tachycardia.

**Figure 2.** Kaplan-Meier curves of freedom from recurrence of ventricular tachycardia (VT) according to catheter ablation acute result, adjusted for arrhythmia pattern, VT tolerance, ejection fraction, functional class, type of cardiomyopathy, and administration of amiodarone at discharge, in the entire study population (A) and in low- (B) and high-risk (C) patients.
of idiopathic dilated cardiomyopathy (HR=2.234, \(P=0.028\)) and ES (HR=2.207, \(P=0.028\)).

Of the 18 patients admitted with cardiogenic shock, 2 died in the hospital of heart failure, and 1 patient experienced in-hospital ES recurrence and died; a left ventricular assist device was implanted in 3 patients, and 1 died of graft rejection after heart transplantation; among the 14 patients who lived, VT recurred in 1 patient during long-term follow-up.

**Survival**

Seventy-five (15.6%) of the 482 patients who were tested with programmed ventricular stimulation died during follow-up: 22 died of sudden cardiac death (13 of coronary artery disease, 7 of idiopathic dilated cardiomyopathy, 1 of arrhythmogenic right ventricular dysplasia, and 1 of hypertrophic cardiomyopathy), 34 of heart failure (22 of coronary artery disease, 10 of idiopathic dilated cardiomyopathy, 1 of valvular disease, and 1 of hypertrophic cardiomyopathy), and 19 of noncardiac causes. The incidence of the combined end point of cardiac death and sudden cardiac death was lower in patients with a class A acute result than in those with a class B or class C result (8.4% versus 18.5% versus 22%, respectively; log-rank \(P=0.002\)), whereas it reached 18% among nontested patients because of baseline noninducibility (Figure 3).

On the basis of multivariate analysis, cardiac mortality was strongly associated with New York Heart Association class (HR=2.771, \(P<0.001\)), presence of ES on admission (HR=2.624, \(P=0.002\)), chronic kidney disease (HR=2.060, \(P=0.016\)), and postprocedural inducibility of index VT (class C versus A and B, HR=2.099, \(P=0.041\); Table 4).

Among low-risk patients, the incidence of combined cardiac mortality was significantly lower in patients with a class A (versus B and C) acute result (3.4% versus 10.2%, log-rank \(P=0.031\)). Furthermore, in the high-risk group, the incidence of combined cardiac mortality was significantly increased in patients with a class C (versus A and B) acute result (33.4% versus 18.2%, log-rank \(P=0.05\)). Multivariate analysis indicated that New York Heart Association class (HR=2.532, \(P<0.001\)), presence of ES on admission (HR=3.532, \(P=0.009\)), chronic kidney disease (HR=2.330, \(P=0.018\)), and class C were also independent predictors of cardiac mortality in high-risk patients (HR=2.284, \(P=0.045\)), in contrast to low-risk patients, for whom only New York Heart Association class predicted cardiac mortality (Table 5, Figure 3).

**Analysis of First Ablation Procedures**

To investigate the net predictive value of noninducibility of any VT after the first procedure, we reanalyzed the data considering
Table 4. Univariate and Multivariate Cox Regression Analysis of Cardiac Mortality

<table>
<thead>
<tr>
<th></th>
<th>Univariate Analysis</th>
<th>Multivariate Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>P</td>
</tr>
<tr>
<td>Age, y</td>
<td>1.055 (1.027–1.084)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female sex</td>
<td>0.897 (0.358–2.249)</td>
<td>0.816</td>
</tr>
<tr>
<td>NYHA class</td>
<td>3.770 (2.747–5.173)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Class A</td>
<td>0.389 (0.221–0.686)</td>
<td>0.001</td>
</tr>
<tr>
<td>Class C</td>
<td>2.565 (1.310–5.022)</td>
<td>0.005</td>
</tr>
<tr>
<td>Ejection fraction, %</td>
<td>0.926 (0.900–0.952)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nontolerated VT</td>
<td>1.272 (0.743–2.175)</td>
<td>0.380</td>
</tr>
<tr>
<td>Electrical storm</td>
<td>5.305 (3.049–9.232)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Incessant VT</td>
<td>1.308 (0.592–2.889)</td>
<td>0.507</td>
</tr>
<tr>
<td>Renal disease</td>
<td>3.590 (2.119–6.081)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>1.842 (1.066–3.185)</td>
<td>0.029</td>
</tr>
<tr>
<td>Idiopathic dilated cardiomyopathy</td>
<td>1.696 (0.959–2.999)</td>
<td>0.069</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; Class A, noninducibility of any ventricular tachycardia; Class B, inducibility of nondocumented ventricular tachycardia; Class C, inducibility of index ventricular tachycardia; HR, hazard ratio; NYHA, New York Heart Association; and VT, ventricular tachycardia.

Discussion
The present study reports the 5-year experience of the VTU, the first model implemented to provide a state-of-the-art, cooperative, 24-hour-availability service for the admission and treatment of patients with VT. The present results showed that a successful VT ablation procedure (based on noninducibility of any VT) decreased arrhythmia recurrence and cardiac mortality in the largest series of VT patients with structural heart disease to date.

The use of ICDs is consistently being expanded on the basis of the results of randomized clinical trials demonstrating a greater life expectancy in patients with an increased risk or a history of malignant ventricular arrhythmias, however, patients who experience ICD shocks have a decreased quality of life if >5 shocks per year are delivered, and a pooled analysis of all randomized ICD trials indicated an ICD-unresponsive sudden cardiac death rate of 5%. Catheter ablation has been shown to reduce arrhythmia recurrence in patients with VT; however, no study has been powered to test whether prevention or a significant reduction of ICD therapies by CA improves survival. In the early Cooled RF trial, which included only patients with hemodynamically stable VT, CA was successful, as defined by elimination of all mappable VTs, in 41%. VT recurred in 46% of patients, and the mortality rate was 25% after 1 year. In the Thermocool trial, ablation of all inducible VTs was accomplished in 49% of patients; VT recurred in 53% after a 6-month follow-up, but the frequency of VT was reduced by >75% in 67% of patients. The 1-year mortality rate was 18%, with low left ventricular ejection fraction and arrhythmia recurrence being among the predictors of an adverse outcome. In the EuroVT study, a successful procedure was defined by termination and noninducibility of all clinically relevant VTs (cycle length greater than or equal to the index VT) and this was accomplished in 81% of the patients. VT recurrence was 49%, and a significant reduction of ICD therapies occurred in 79%. Of course, in all these studies, any beneficial effect of CA may be influenced by drug therapy. In patients with incessant VT, CA is the only treatment option, with a recurrence of the same clinical pattern in 24% and of paroxysmal VT in another 24%. Additionally, when the presenting arrhythmia is ES, a frightening event...
with poor short- and long-term prognosis, we have previously demonstrated the favorable role of successful CA, together with pharmacological therapy, on arrhythmia recurrence and overall cardiac mortality.8

Early CA, before or after the first ICD shock, was performed in the SMASH trial and led to a 73% reduction of ICD shocks and a trend toward improved survival in ablated patients.11 In the VTACH trial, CA was applied after the first tolerated VT episode, prolonging the time to VT recurrence and reducing its incidence, although no survival benefit was observed in the ablation group.12 Lastly, in a CA study that focused on long-term mortality, Sauer et al13 indicated as independent predictors the presence of renal disease, poor left ventricular ejection fraction, advanced age, VT tolerance, and VT inducibility. Notably, VT ablation performed after the year 2003 (with the implementation of electroanatomic mapping and irrigated radiofrequency technologies) was demonstrated to be more effective than previously in achieving a satisfying long-term outcome.13

In the present study, we present the impact of CA on the largest series of patients to date with all clinical patterns of VT presentation and all types of structural heart disease. The present study population was characterized by a high proportion of first VT ablation procedures (87%) and tolerated VT (62.9%). The latter could be attributed to the different definition used in previous studies, in which nonreproducible and pleomorphic VTs were included together with hemodynamically nontolerated VTs, as well as to the inclusion of multiple causes of structural heart disease.13,14,17 The relatively high success rate of CA (90% of patients with class A or B) could be attributed to the comprehensive multiskilled management of the patients and the systematic implementation of an ablation strategy that focused on endocardial-epicardial substrate modification independent of VT inducibility and tolerance. This approach enabled us to achieve a prolongation of time to first recurrence and a reduction in short-term hospitalization caused by VT. Moreover, a successful CA procedure based on different classifications of noninducibility of any VT was associated with a lower arrhythmia recurrence rate in both high- and low-risk patients independent of VT pattern, tolerance, and type of underlying heart disease, whereas amiodarone, administered only after failed CA, predicted recurrence predominantly in less successfully ablated high-risk patients. The independent predictive value of amiodarone might be considered a surrogate for ablation failure, indicating the inefficacious role of amiodarone in preventing reentrant VTs. Notably, in low-risk patients, postprocedural noninducibility per se appears to provide a better outcome, whereas in high-risk patients, noninducibility of the index VT is associated with lower arrhythmia recurrence rate. The presence of more advanced cardiac disease and the use of a more aggressive stimulation protocol (up to a fourth extrastimulus) may explain the induction of nonspecific VT, leading to a class B result, in the present high-risk population.18

Table 6. Multivariate Cox Regression Analysis of VT Recurrences and Cardiac Mortality According to Baseline Noninducibility After First Ablation Procedure

<table>
<thead>
<tr>
<th>HR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VT recurrence</strong></td>
<td></td>
</tr>
<tr>
<td>NYHA class</td>
<td>1.323 (1.042–1.681)</td>
</tr>
<tr>
<td>Noninducibility</td>
<td>0.516 (0.387–0.688)</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>1.002 (0.985–1.019)</td>
</tr>
<tr>
<td>Nontolerated VT</td>
<td>1.089 (0.808–1.468)</td>
</tr>
<tr>
<td>Electrical storm</td>
<td>1.227 (0.895–1.681)</td>
</tr>
<tr>
<td>Idiopathic dilated cardiomyopathy</td>
<td>1.512 (1.098–2.082)</td>
</tr>
<tr>
<td>Amiodarone therapy</td>
<td>1.311 (0.976–1.761)</td>
</tr>
<tr>
<td><strong>Cardiac mortality</strong></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>1.023 (0.990–1.056)</td>
</tr>
<tr>
<td>NYHA class</td>
<td>2.875 (1.845–4.481)</td>
</tr>
<tr>
<td>Noninducibility</td>
<td>0.539 (0.301–0.966)</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>0.994 (0.958–1.031)</td>
</tr>
<tr>
<td>Electrical storm</td>
<td>2.735 (1.529–4.894)</td>
</tr>
<tr>
<td>Renal disease</td>
<td>2.013 (1.165–3.476)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>1.030 (0.585–1.813)</td>
</tr>
</tbody>
</table>

LVEF indicates left ventricular ejection fraction; NYHA, New York Heart Association; and VT, ventricular tachycardia.
The salient finding of the present study is the significant reduction of the incidence of the combined end point of cardiac death and sudden cardiac death in VT patients with a class A acute result compared with those with a class B and class C result (8.4% versus 18.5% versus 22%); results were similar when we compared noninducible patients after the first procedure versus inducible patients and those with unknown status. Moreover, postprocedural inducibility of a previously documented VT predicted mortality in high-risk patients and in the whole study population.10 The predictive value of postprocedure stimulation with regard to VT recurrence and mortality has been examined previously in several studies with contradictory results.13,15,19 Indeed, the ability to render an inducible VT noninducible may simply be a marker for better outcomes and characterize patients who are healthier at baseline. However, independent of the classification used regarding postablation noninducibility, this was accompanied by reduced morbidity and mortality. Remarkably, patients in whom VT was noninducible at baseline, presumed to have a healthier status, exhibited a recurrence rate of 33% and an incidence of cardiac mortality of 18%.

The purpose of the study was not to demonstrate the superiority of our multisiskilled approach to the treatment of VT patients (dedicated VTU, risk classification approach, endocardial-epicardial ablation performed in general anesthesia and based on substrate modification) compared with other strategies. We consider it extremely important, however, to describe the complexity of patients with VT beyond CA, focusing on the necessity for global management. Given the present results, CA might be proposed as treatment for high-risk patients with VT who previously were not considered candidates for invasive therapy (ie, patients with hemodynamic instability, ES, or renal disease), because noninducibility of index VT is not only life-saving acutely but can also modify the survival curve of this population. Evolution of techniques and expertise, as well as hemodynamic assistance, are pivotal to provide safe and effective procedures in this setting.14 The subsequent hospitalization rate was also markedly decreased compared with the preablation period. One may suggest that the central management of progressively increasing numbers of VT patients may reduce the public health costs for VT treatment in the long term.

Complications
The reported acute mortality rate in the 2 US multicenter trials and in the EURO-VT trial ranged from 0% to 3%. In the present study cohort, only 1 patient (0.2%) died during the procedure because of electromechanical dissociation, whereas observed in-hospital mortality was 1.7%. Major complications occurred in 9 patients (2%), and late tamponade occurred in only 2 cases after removal of the pericardial sheath. Compared with previous reports (from 0%–7.3%), our complication rate shows that in an experienced unit focused on VT treatment, CA (including epicardial CA) is a safe procedure. Moreover, in case of hemodynamic instability, acute hemodynamic support was instituted, and no procedures were aborted; substrate modification during sinus rhythm also allowed effective and safe ablation in these patients.

Study Limitations
This study was a prospective analysis of the short- and long-term outcome in patients with VT treated by CA, not a randomized controlled trial comparing CA with other forms of treatment for VT or a control group. Moreover, 9% of patients were lost to follow-up, including a disproportionately higher number of patients who were initially found to be rendered noninducible during ablation. On the other hand, the large size of the study population, the prolonged follow-up period with a significant incidence of events, and the discontinuation of amiodarone in successfully ablated patients constitute strengths of the present study.

Conclusions
This is the largest clinical experience evaluating the potential benefit of CA for the treatment of VT in patients with any type of structural heart disease, independent of the arrhythmia pattern and VT tolerance. We implemented a dedicated unit focused on the treatment and care of these patients from their admittance to the electrophysiological procedure, therapy optimization, and close follow-up and linked the electrophysiology procedure to the emergency area and ICU, in close cooperation with the heart failure unit and cardiac surgery. Within this expert environment, the results of the present study indicate that CA favorably affects VT recurrence, hospitalization, and survival in a large cohort of patients with VT. This study supports the implementation of a multidisciplinary unit dedicated to the treatment of VT.

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Disclosures
Dr Della Bella is a consultant for St. Jude Medical and has received honoraria for lectures from Biosense Webster, St. Jude Medical, and Biotronik. The other authors report no conflicts.

References
Catheter ablation plays a relevant role in the treatment of drug-refractory ventricular tachycardia (VT) episodes, recurrent implantable cardioverter-defibrillator shocks, lowering VT recurrence and improving quality of life. Data about the effects of catheter ablation on survival are still controversial. We implemented a multidisciplinary model, aiming for multiskilled management of this critical population from patients’ admittance to electrophysiological procedure, therapy optimization, and close follow-up. We provide the largest clinical experience to date investigating the potential benefit of catheter ablation for the treatment of VT in patients with any type of structural heart disease. Risk stratification on admission was the first step of our approach to VT management, and it allowed the identification of patients at high risk of developing an adverse outcome, which was treated subsequently by a comprehensive and multidisciplinary approach. Five hundred twenty-eight patients were treated by ablation; after a median follow-up of 26 months, VT recurrence rate and cardiac mortality were significantly lower in patients without any VT inducibility at programmed stimulation after the procedure than in those with induction of nonclinical VT and those with persistence of clinical VT inducibility. On the basis of multivariate analysis, postprocedural inducibility of index VT was independently associated with both VT recurrence and cardiac mortality. Catheter ablation favorably affects VT recurrence, hospitalization, and survival in a large cohort of patients with VT; therefore, it might be proposed as elective treatment for VT even in patients with advanced heart disease and severe comorbidities.
Management of Ventricular Tachycardia in the Setting of a Dedicated Unit for the Treatment of Complex Ventricular Arrhythmias: Long-Term Outcome After Ablation
Paolo Della Bella, Francesca Baratto, Dimitris Tsiachris, Nicola Trevisi, Pasquale Vergara, Caterina Bisceglia, Francesco Petracca, Corrado Carbucicchio, Stefano Benussi, Francesco Maisano, Ottavio Alfieri, Federico Pappalardo, Alberto Zangrillo and Giuseppe Maccabelli

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