European Heart Journal (2014) **35**, 1479–1485
doi:10.1093/eurheartj/ehu040

Radio-frequency ablation as primary management of well-tolerated sustained monomorphic ventricular tachycardia in patients with structural heart disease and left ventricular ejection fraction over 30%

Philippe Maury[1]*, Francesca Baratto[2], Katja Zeppenfeld[3], George Klein[4], Etienne Delacretaz[5], Frederic Sacher[6], Etienne Pruvot[7], Francois Brigadeau[8], Anne Rollin[1], Marius Andronache[9], Giuseppe Maccabelli[2], Marcin Gawrysiak[3], Roman Brenner[5], Andrei Forclaz[6], Jürg Schlaepfer[7], Dominique Lacroix[8], Alexandre Duparc[1], Pierre Mondoly[1], Frederic Bouisset[1], Marc Delay[1], Meleze Hocini[6], Nicolas Derval[6], Nicolas Sadoul[9], Isabelle Magnin-Poull[9], Didier Klug[8], Michel Haïssaguerre[6], Pierre Jaïs[6], Paolo Della Bella[2], and Christian De Chillou[9]

[1]Department of Cardiology, University Hospital Rangueil, 31059 Toulouse Cedex 09, France; [2]Ospedale San Raffaele, Milano, Italy; [3]University Hospital Leiden, Leiden, Netherlands; [4]University of Western, London, ON, Canada; [5]University Hospital, Berne, Switzerland; [6]University Hospital Haut-Leveque, Pessac, France; [7]Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland; [8]University Hospital Lille, Lille, France; and [9]University Hospital Nancy, Nancy, France

Received 30 May 2013; revised 5 January 2014; accepted 22 January 2014; online publish-ahead-of-print 16 February 2014

See page 1433 for the editorial comment on this article (doi:10.1093/eurheartj/eht559)

Aims Patients with well-tolerated sustained monomorphic ventricular tachycardia (SMVT) and left ventricular ejection fraction (LVEF) over 30% may benefit from a primary strategy of VT ablation without immediate need for a 'back-up' implantable cardioverter-defibrillator (ICD).

Methods and results One hundred and sixty-six patients with structural heart disease (SHD), LVEF over 30%, and well-tolerated SMVT (no syncope) underwent primary radiofrequency ablation without ICD implantation at eight European centres. There were 139 men (84%) with mean age 62 ± 15 years and mean LVEF of 50 ± 10%. Fifty-five percent had ischaemic heart disease, 19% non-ischaemic cardiomyopathy, and 12% arrhythmogenic right ventricular cardiomyopathy. Three hundred seventy-eight similar patients were implanted with an ICD during the same period and serve as a control group. All-cause mortality was 12% (20 patients) over a mean follow-up of 32 ± 27 months. Eight patients (40%) died from non-cardiovascular causes, 8 (40%) died from non-arrhythmic cardiovascular causes, and 4 (20%) died suddenly (SD) (2.4% of the population). All-cause mortality in the control group was 12%. Twenty-seven patients (16%) had a non-fatal recurrence at a median time of 5 months, while 20 patients (12%) required an ICD, of whom 4 died (20%).

Conclusion Patients with well-tolerated SMVT, SHD, and LVEF > 30% undergoing primary VT ablation without a back-up ICD had a very low rate of arrhythmic death and recurrences were generally non-fatal. These data would support a randomized clinical trial comparing this approach with others incorporating implantation of an ICD as a primary strategy.

Keywords Ventricular tachycardia • Implantable cardioverter defibrillator • Sudden death • Radio-frequency • Ablation

* Corresponding author. Tel: +33 5 61 32 30 54, Fax: +33 5 61 32 22 46, Email: mauryjphil@hotmail.com

Introduction

The occurrence of a sustained monomorphic ventricular tachycardia (SMVT) in patients with underlying structural heart disease (SHD) has traditionally been considered to carry a poor prognosis based on historical data in patients treated with anti-arrhythmic drugs.[1–3] Subsequently, randomized trials have proven the lifesaving benefit of an implantable cardioverter-defibrillator (ICD) compared with anti-arrhythmic drug therapy in patients with sustained ventricular arrhythmias and SHD.[4–8] However, patients included in these trials presented with aborted cardiac arrest or poorly tolerated VT causing syncope or severe haemodynamic compromise—all conditions known to carry a poor prognosis[9]—while patients with well-tolerated VT were excluded.

Based on these trials and a subsequent meta-analysis,[8] ICD implantation is currently recommended after the occurrence of a SMVT in patients with SHD whether the arrhythmia is tolerated or not, even in the presence of normal or near-normal ventricular systolic function.[10] It is intuitively reasonable that the patients with well-tolerated VT and preserved ventricular function will have a better prognosis than the contrary and would be more likely to present again with well-tolerated VT in case of recurrence. Such patients were arguably underrepresented in the pivotal ICD trials and subgroup analysis in all these trials supported the supremacy of ventricular function in prognosis with most ICD benefit occurring in the groups with poorest ejection fraction ($\leq$30%).

Radiofrequency (RF) ablation of VT has progressed substantively since the initial pivotal ICD secondary prevention trials but is currently only indicated in patients at low risk for died suddenly (SD).[11] Radiofrequency ablation without ICD has been reported anecdotally in patients with SHD and SMVT.[12–15] A strategy of primary RF ablation without concurrent ICD implantation in the subgroup of patients with well-tolerated VT and preserved left ventricular systolic function has obvious potential advantages but has never been assessed systematically.

We performed a retrospective European multicentre study on the follow-up of patients with SHD with a left ventricular ejection fraction (LVEF) over 30% presenting with a well-tolerated first episode of SMVT who were discharged after RF ablation as a primary strategy without a concomitant ICD. We hypothesized that such patients would have a relatively favourable prognosis and that recurrences, if they occurred, would be non-fatal.

Methods

We reviewed consecutive SHD patients with LVEF over 30% admitted for the occurrence of one or several well-tolerated first episode(s) of SMVT and who were treated by RF ablation as a first choice therapy at eight European tertiary reference centres (University Hospital Rangueil, Toulouse, France; Ospedale San Raffaele, Milano, Italy; University Hospital, Berne, Switzerland; University Hospital Haut-Leveque, Bordeaux-Pessac, France; University Hospital Leiden, Netherlands; Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland; University Hospital Lille, France; University Hospital Nancy, France) between 2005 and 2010 and who were discharged without ICD implantation. Structural heart disease was defined by the existence of a chronic pathological process generating an electrophysiological substrate for ventricular arrhythmias—i.e. scar-related SMVT. Well-tolerated SMVT was defined by the lack of syncope or cardiac collapse at the time of SMVT presentation. Updated follow-up was performed mid-2011 after reviewing hospitalization and consultations reports, ICD interrogations (for the patients eventually implanted during the follow-up), calling the cardiologists and/or physicians about the vital status of the patients and checking death certificates when needed.

We collected clinical parameters, electrophysiological characteristics of the clinical arrhythmias, details of the ablation procedure cause of death, and recurrences of SMVT.

Died suddenly was defined as instantaneous or unexpected death occurring less than 1 h after onset of symptoms, or death while sleeping or unwitnessed.[16] 'Died suddenly' was attributed to ventricular arrhythmia unless otherwise documented. Deaths in patients with end-stage heart failure were classified as 'non-sudden' regardless of terminal ventricular tachyarrhythmias. Recurring SMVT was defined as 'recurrence' regardless of similarity to presenting VT.

The main endpoints of the study were mortality and VT recurrence rates in non-implanted patients; thus follow-up was 'officially' terminated at the time of ICD implantation if eventually required. Nonetheless, survival and occurrence of appropriate therapies for ventricular arrhythmias as retrieved from ICD memories continued to be documented in the latter group.

Patients with SHD with LVEF $>$ 30% and similar SMVT (no syncope) implanted with an ICD at our eight centres during the same period of time served as a control group.

Statistics

Continuous variables were reported as means $\pm$ SD or medians (range) as appropriate. Comparisons of continuous variables between groups were performed with Student's *t*-test or the non-parametric Mann Whitney test as suitable. Categorical variables were compared with the Chi-square test.

Univariate and multivariate Cox regression models were used to investigate the association between variables and mortality or SMVT recurrences during the follow-up and to determine hazard ratios (HR) and 95% confidence intervals (95% CI). All variables associated with a *P*-value $<$ 0.1 in univariate analysis were introduced in a multivariate Cox model. The proportional-hazard assumption was tested for each covariate by the 'log–log' method, plotting ($-\ln[-\ln(\text{survival})]$) for each category of a nominal covariate vs. ln(analysis time). A backward procedure was applied to assess variables that were significantly and independently associated with mortality or SMVT recurrence. All tests were two-tailed, and a *P*-value $<$0.05 was considered to indicate statistical significance.

Results

Clinical and electrophysiological characteristics

From 2005 to 2010, 166 consecutive SHD patients with well-tolerated SMVT and LVEF over 30% were treated by RF ablation without implantation of an ICD at our eight centres. Clinical parameters of the study population and characteristics of the SMVT are depicted in *Tables 1* and *2*.

The majority had only palpitations (93 patients, 56%) and two were completely asymptomatic. Others had pre-syncope (35 patients, 21%), congestive heart failure (24 patients, 14%, one with cardiogenic shock), and chest pain (15 patients, 9%). Outside the fact that SMVT was well-tolerated together with a LVEF $>$ 30% and the success of the ablation procedure, the main other reasons for not implanting

Table 1 Clinical parameters of the study population ($n = 166$)

Male gender	139 patients	84%
Age (years)	62 ± 15 (17–89)	
LVEF (%)	50 ± 10 (31–73)	
LVEF >30 and <45%	50 patients	30%
LVEF ≥45 and <55%	63 patients	38%
LVEF ≥55%	53 patients	32%
NYHA class		
Class I	77 patients	53%
Class II	60 patients	41%
Class III (data not available in 20 patients)	9 patients	6%
Underlying structural heart diseases		
Ischaemic heart disease[a]	91 patients	55%
Non-ischaemic cardiomyopathy	31 patients	19%
Arrhythmic right ventricular cardiomyopathy	20 patients	12%
Valvular heart disease	6 patients	3.5%
Congenital heart disease[b]	5 patients	3%
Post-myocarditis	5 patients	3%
Hypertrophic cardiomyopathy	2 patients	5%
Undetermined cardiomyopathy	2 patients	
Amyloidosis	1 patient	
Idiopathic left ventricular diverticle	1 patient	
Post traumatic/surgery	1 patient	
Left ventricular myxoma	1 patient	
Antiarrhythmic therapy at the time of VT occurrence		
Beta-blockers	50 patients	30%
Amiodarone	21 patients	13%
Beta-blockers + amiodarone	31 patients	19%
Sotalol	11 patients	7%
Class 1 drug + beta-blockers	2 patients	1%
Class 1 drug + sotalol	1 patient	0.5%
No drug (data not available in 2 patients)	48 patients	29%

[a]Remote myocardial infarction (median 78 months before, one week to 33 years).
[b]Repaired tetalogy of Fallot in three, pulmonary atresia in one, and complex congenital cardiomyopathy in one.

Table 2 Characteristics of the sustained monomorphic ventricular tachycardia

Number of episodes[a]	Median 2 (1–14)	
multiple (precise data NA)	15 patients	9%
Incessant	17 patients	10%
Electrical storm[b]	20 patients	12%
VT rate	Median 160 bpm (100–270 bpm)	
VT rate ≥ 200 bpm	25 patients	15%
VT rate ≤ 200 and >150 bpm	88 patients	53%
VT rate ≤ 150 and >120 bpm	45 patients	27%
Slow VT (≤120 bpm)	9 patients	5%
Incessant slow VT	2 patients	1%
VT morphology		
One VT morphology	154 patients	93%
Two VT morphologies	11 patients	6.5%
>2 morphologies	1 patient (5 different VT morphologies)	

[a]Consecutive episodes occurring in a short lapse of time before referral.
[b]Defined by the occurrence of at least three SMVT episodes over 24 h (comprising patients with incessant VT).

Table 3 Characteristics and results of the ablation procedure for sustained monomorphic ventricular tachycardia (SMVT)

Inducible SMVT before ablation	149/166	90%
Number of different induced SMVT	median 1 (1–6)	
Entrainment mapping	76/149	51%
SMVT termination during ablation	83/132[a]	63%
Pace mapping	131/164	80%
Percutaneous epicardial ablation	22/163	13%
Linear ablation	66/166	40%
Ablation of post-systolic potentials	73/165	44%
Tridimensional navigation system	116/166	70%
Irrigated catheter	153/165	93%
Procedural duration (min)	158 ± 66 (40–430)	
Fluoroscopy time (min)	27 ± 14 (1–70)	
Radiofrequency application (min)	13 ± 10 (1–60)	
All clinical/inducible SMVT targetted	144/162	89%
No SMVT inducible after RF	137/158	87%
SMVT still inducible after RF	21/158	13%
Clinical SMVT	6/21	
Non-clinical VT	15/21 (fast SMVT or VF in11)	
No electrophysiological testing after RF	6/166	3.5%

[a]When radiofrequency was delivered during SMVT.

an ICD were an 'advanced' age (>75 years old in 18 patients, 11%), significant comorbidities and/or limited life esperancy in 7 (4%), patients decision in 8 (5%), an electrical storm or multi-recurrent VT ($n = 21$, 13%) or slow VT ($n = 2$) successfully stopped by the ablation, or a young age in 2. The remaining cases do not have any reason but the ones mentioned above.

Radiofrequency ablation

One hundred eighty-seven RF ablation procedures were performed (15 and 3 patients needed two and three procedures, respectively). Characteristics and results of the ablation procedure are depicted in *Table 3*.

Procedure-related complications were reported in 11 patients (6.5%), including tamponade (3) and atrio-ventricular block (2) and pericardial effusion (1), groin haematoma (4) and femoral peudo-aneurysm (1). One of the two patients with atrio-ventricular block required a pacemaker. There was no mortality directly or indirectly related to the ablation procedure.

At discharge, amiodarone was prescribed to 8 patients, beta-blockers to 72, amiodarone + beta-blockers to 28, sotalol to 16, and class 1 drugs with or without beta-blockers to 5. No antiarrhythmic drugs were prescribed for 37 patients.

Follow-up

The mean follow-up was 32 ± 27 months (1 week to 134 months), leading to a cumulative follow-up of 437 patient-years. Follow-up duration in living patients was never less than 6 months except for 5 patients early implanted after discharge (see below). No patient was lost to follow-up.

Mortality

Twenty patients died (all-cause mortality 12%—i.e. 4.5% annual mortality rate) at a median time of 25 months after catheter ablation (1 week to 83 months). Actuarial survival curve for all-cause mortality is shown in *Figure 1*.

Of these 20 patients, 8 (40%) died from non-cardiovascular causes (1 week to 36 months, median 18), 8 (40%) died from non-arrhythmic cardiovascular causes (6–83 months, median 27), and 4 patients (20%) died suddenly (1–75 months, median 37); none with recurrent SMVT before the fatal event. No patient with end-stage heart failure had documented terminal VT. Details related to mortality rates and causes of death are depicted in *Tables 4* and *5*. Actuarial survival curve for SD is shown in *Figure 2*.

Parameters significantly related to all-cause mortality in univariate and multivariate are listed in *Table 6*.

A total of 378 patients were implanted for well-tolerated MSVT and LVEF > 30% at our eight centres during the same period of time (86% men, 63 ± 13 years old, 76% ischaemic heart disease, LVEF 43 ± 10%). All-cause mortality in the comparison group for the same follow-up duration was 12% (46 patients).

Ventricular tachycardia recurrences

Sustained monomorphic ventricular tachycardia recurred in 27 patients after the initial RF ablation (16%, i.e. 6% mean annual recurrence rate) at a median time of 5 months after the procedure (3 days to 41 months). Actuarial survival curve without SMVT recurrence is shown in *Figure 3*.

Table 4 Mortality rates and causes of deaths in the patient's population (n = 166)

All-cause mortality	20/166 (12%)
Non-cardiac mortality	8/166 (4.8%)
Neoplasy	2
Renal failure	1
Pulmonary cause	2
Neurologic deterioration	1
Cachexy	1
Exact cause NA	1
Cardiac non-arrhythmic mortality	8/166 (4.8%)
Refractory heart failure	7
Electro-mechanical dissociation	1
Sudden death	4/166 (2.4%)

Table 5 Details about the four patients presenting with sudden death during the follow-up

Delay after ablation (months)	1	33	42	75
Underlying heart disease	Valvular	Ischaemic	Ischaemic	Ischaemic
Gender	Male	Male	Male	Male
Age	77	76	60	81
LVEF (%)	65	50	50	43
VT rate (bpm)	140	170	160	135
Symptoms	Palpitations	Near syncope	Chest pain	Near syncope
Inducible after ablation	NA	No	No	Fast VT

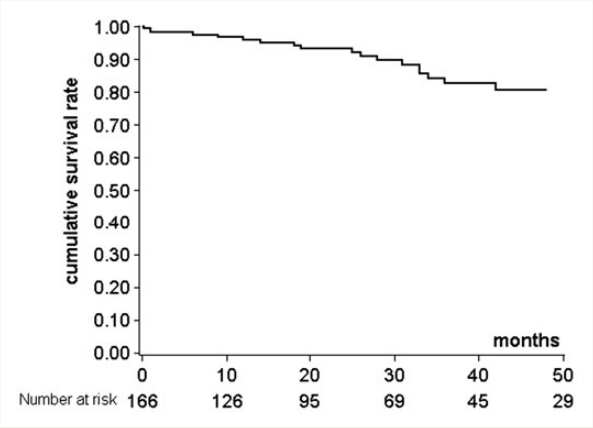

Figure 1 Actuarial survival curve for all-cause mortality.

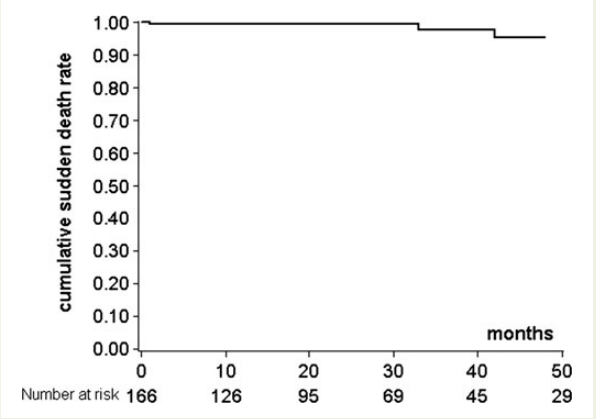

Figure 2 Actuarial survival curves for sudden death.

Table 6 Parameters significantly related to all-cause mortality in univariate and multivariate analysis

Parameter	Non adjusted HR	95% CI	*P*	Adjusted HR	95% CI	*P*
Age*	1.14	1.08–1.21	<0.0001	1.12	1.05–1.20	0.0007
All SMVT not targetted	5.82	2.26–14.94	0.0003	3.89	1.20–12.64	0.02
NYHA class						
III vs. I	7.19	1.92–27.02	0.003	–	–	–
III vs. II	5.59	1.57–20.00	0.008	–	–	–
LVEF ≤ 45%	3.70	1.51–9.09	0.004	0.6	0.21–1.74	0.35
Female gender	3.10	1.08–8.92	0.03	3.09	0.97–9.81	0.05
SMVT rate**	1.02	1.00–1.03	0.04	1.002	0.98–1.02	0.8
Slow SMVT	3.36	0.97–11.63	0.05	–	–	–
Congestive heart failure	2.47	0.93–6.55	0.07	1.05	0.27–4.04	0.9
Electrical storm	2.37	0.86–6.54	0.09	2.62	0.83–8.26	0.1

There was a 14% increase in all-cause mortality for each year more (*) and a 2% increase in all-cause mortality for each bpm less (**). Slow SMVT not included in the model because of redundancy with SMVT rate, NYHA class also not included because of incomplete data.

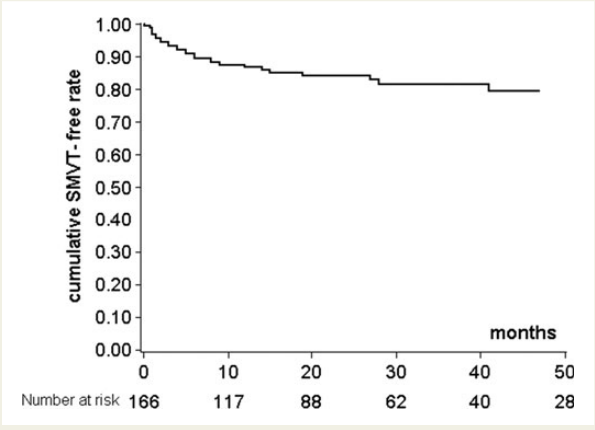

Figure 3 Actuarial survival curve for recurrence of sustained monomorphic ventricular tachycardia after the initial ablation procedure.

Recurrent SMVT was similar in morphology and rate to the ablated one in 17 patients (63%), different in 8 (30%), and not available in 2. Recurrence was not statistically associated with all-cause mortality. Recurrence was correlated only with female gender with borderline significance (HR 2.20, 95% CI 0.92–5.23, $P = 0.07$).

Of these 27 patients, 5 had ICD implanted at this time, 8 were discharged without further RF ablation or ICD (1 non-sudden cardiac death, no SMVT recurrence), while 14 patients underwent a second RF ablation. Six of these 14 patients were finally implanted because of failure of the second procedure, recurring SMVT, or further recurrences despite repeated ablation procedures. From this group of 14 patients, none of the ablated patients without ICD died during the follow-up. The follow-up of patients with recurring MSVT is summarized in *Figure 4*.

There was no significant differences in mortality or recurring SMVT rates according to the main underlying heart diseases: 14% mortality (3 SD) and 15% SMVT recurrences for ischaemic heart disease, 13% mortality (no SD) and 26% SMVT recurrences for non-ischaemic cardiomyopathy, and no mortality and 25% SMVT recurrence for arrhythmogenic right ventricular cardiomyopathy (P = ns).

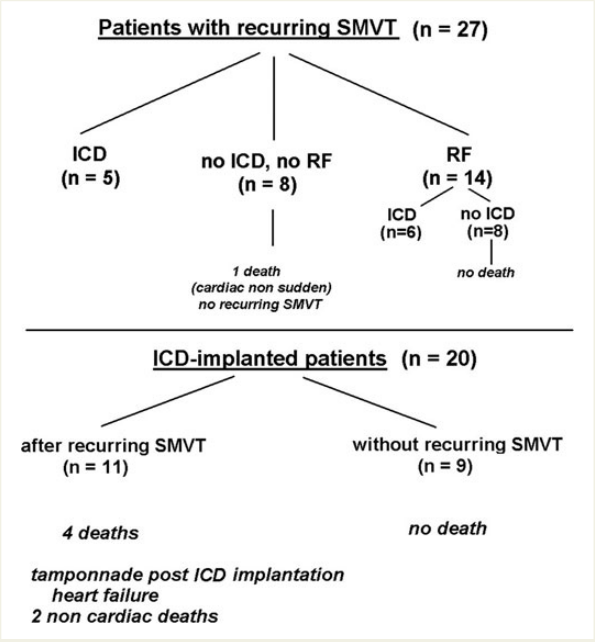

Figure 4 Summary of the follow-up of patients with recurring sustained monomorphic ventricular tachycardia (upper) and of implanted patients (lower).

Implantable cardioverter-defibrillator implantation

During the follow-up, 20 patients (12%) were implanted with an ICD: 11 after SMVT recurrences (see above) and 9 without any

recurrence. The latter were implanted because of inducible SMVT during electrophysiological study performed during the follow-up at some centres (six cases), need for resynchronization therapy (one case), and implantation in patients followed later on at other centres (two cases). Median time to implantation was 6 months (1–114).

Recurring arrhythmias with appropriate ICD therapies occurred in 50% (4/8) of the implanted patients without SMVT recurrence after ablation and in 78% (7/9) of the patients implanted because of SMVT recurrences following ablation (NA in three cases) ($P = 0.23$). The recurring arrhythmias were monomorphic ventricular tachycardia in all but one case (ventricular fibrillation).

Four of the 20 implanted patients died during the follow-up (1 from tamponade complicating the ICD implantation, 1 from intractable heart failure, and 2 from non-cardiac causes 25, 12, and 31 months after ablation, respectively), all of them having been implanted after SMVT recurrence. The follow-up of implanted patients is summarized on *Figure 4*.

All-cause mortality in non-implanted patients (20/146, 14%) was lower than in implanted patients (4/20, 20%) although non-significantly ($P = 0.45$).

Discussion

All-cause mortality, sudden death, and recurrences after radiofrequency ablation of sustained monomorphic ventricular tachycardia

This study suggests that a strategy of catheter ablation with a deferral of ICD implantation is reasonable for the patient presenting with well-tolerated SMVT related to structural disease with LVEF > 30%. All-cause mortality was 12% over a mean follow-up of 32 months, with a median time to death of 23 months. Importantly, only four patients died suddenly (2.4% of the study population).

Even if no comparison could be made due to the lack of randomization, it should be noted that the all-cause mortality rate in the control group of implanted patients presenting with SMVT and sharing similar clinical characteristics was very similar (12%). These data further compare most favourably with mortality rate in a similar group of patients with SHD and stable SMVT included in the AVID registry (of whom one-third were implanted with an ICD).[17] In a small recent retrospective series of coronary artery disease patients with SMVT, the 4-year mortality rate of 26 ablated patients without ICD was even lower than that of 19 similar patients who were later implanted because of inducibility at control testing.[15] The sudden death rate was reassuringly low in our population, comparing favourably with the sudden death rates in treated groups of large primary prevention trials.[18–20] Hence, 162 of 166 patients (97.6%) would have not benefited from initial implantation of an ICD in this population. Of note, the patients included in this study underwent successful ablation and presented with well-tolerated VT (no syncope) and with moderately altered left ventricular function, representing a selected subgroup felt to be at relatively low risk and carrying a probable better outcome. Moreover, some had additional reasons for not being implanted (see results). These results can clearly not be extrapolated to the broader population of SHD patients with SMVT.

The SMVT recurrence rate was 16% with a median time to recurrence of 5 months after the RF ablation procedure. None of the 27 patients with documented recurring SMVT suffered a cardiac arrest at the time of relapse and none of the 4 patients with SD did present with recurring SMVT before. It is impossible to determine if a relapse of the clinical-ablated SMVT was linked to the fatal event in the four patients who experienced SD, but the chronological occurrence of SD and SMVT was clearly different (all but one SMVT occurred during the first 30 months, all but one SD occurred after the 30th month) (see survival curves). Therefore, we hypothetized that SD were not caused by recurrences of ablated MSVT, but were more probably linked to the evolution of the underlying heart disease (acute coronary event, decreased EF, and so on). In view of our results however, the implantation of an ICD appears warranted after a first relapse of SMVT since repeated RF ablation was less likely to be successful.

The prognosis following SMVT in patients with underlying SHD has repetitively been considered to be poor. In historical series of patients under various antiarrhythmic drugs, high recurrence and mortality rates were observed.[1–3] However, the risk of death of patients with SHD and SMVT may not be as high as previously thought and should not be assumed to be similar to the risk following resuscitated SD.[12] Indeed, low SD rates (<3% annual) in patients with coronary artery disease and haemodynamically stable SMVT or preserved LVEF were observed with anti-arrhythmic drugs even before the era of the ICD.[9,21,22] Although haemodynamically tolerated SMVT was associated with a high mortality rate in the AVID registry, mortality of these patients was high in spite of the fact that approximately one-third of the patients were given ICDs and details about SD rate in non-implanted patients are missing.[17] Our results extend former observations reporting that mortality in patients with haemodynamically tolerated SMVT was mainly due to non-arrhythmic causes[12] and possibly not preventable by ICD implantation.

We can observe that the 4.5% all-cause-mortality annual rate in our non-implanted patients treated by RF ablation is lower than that of implanted patients in secondary prevention trials[5–7] as well as to that of patients implanted for SMVT in a more recent study[23] and to that of ablated and mostly implanted patients with SMVT in a recent large registry.[24] However, LVEF was lower and haemodynamical tolerance of the SMVT was poor or not detailed in all these studies. The SD rate in this study is even substantively lower than the arrhythmic death rate observed in implanted patients in primary prevention trials.[18–20]

Implantable cardioverter-defibrillator implantation

Only 20 patients (12%) eventually required an ICD in this study. The implantation of an ICD after the occurrence of a sustained ventricular arrhythmia in patients with SHD is supported by prospective trials[4–8] and current guidelines.[10]

Nonetheless, these trials predominantly included patients with resuscitated cardiac arrest or with VT causing symptoms of serious haemodynamic compromise. The improved outcome after ICD

implantation in subgroup analysis was confined largely to patients with LVEF $< 35\%$[8] or in patients <75 years old.[25] The latter support a differential approach to management of patients presenting with VT based on risk stratification.[12] A strategy of primary ablation with deferral of ICD implantation in our patient population is consistent with this view and is supported by the low sudden death rate in our cohort.

Withholding ICD therapy in the lower risk subgroups to which this strategy is applicable has merit well beyond potential cost savings. Although ICDs are life-saving in the appropriate patients, it is well appreciated that ICDs still involve significant morbidity and even mortality in their own right.[15,23,26–32]

The role of catheter ablation in the patient with sustained monomorphic ventricular tachycardia

Catheter ablation has a well-established role in managing recurrent VT to reduce shocks in patients with ICDs. Advances in catheter ablation promise to expand its role as an early treatment or even alternative to ICD placement in selected individuals.[12–14,33,34]

Conclusion

These data support the view that a lower risk subgroup of patients presenting with SMVT in the context of SHD can be identified and that a uniform management imperative of an ICD may not be optimal. Patients with LVEF $> 30\%$ and well-tolerated VT in our cohort undergoing a primary VT ablation strategy had a low sudden death rate compared with that observed in the treatment arms of primary prevention trials and that VT recurrences were predominately non-fatal. A prospective randomized clinical trial to evaluate the potential benefit and cost-effectiveness of an initial strategy of catheter ablation with deferral of ICD implantation after a first episode of well-tolerated SMVT in patients with moderate SHD would be ethical and appropriate.

Limitations

This is a retrospective cohort analysis with all the inherent limitations of such a study. The study was multicentre with no single ablation strategy enforced. The follow-up is relatively short. Nonetheless, it is the largest series to address the question and the sudden death rate potentially arrhythmic was impressively low. This suggests that a subgroup of patients with well-tolerated VT and non-severely depressed ventricular function can be identified and managed safely by a strategy of catheter ablation with deferral of ICD therapy to a later stage in the management process if it becomes obvious that it is necessary.

Conflict of interest: none declared.

References

1. Greene HL. The efficacy of amiodarone in the treatment of ventricular tachycardia or ventricular fibrillation. *Cardiovasc Dis* 1989;**31**:319–354.
2. Leclercq JF, Coumel P, Denjoy I, Maisonblanche P, Cauchemez B, Chouty F, Leenhardt A, Slama R. Long-term follow-up after sustained monomorphic ventricular tachycardia: causes, pump failure, and empiric antiarrhythmic therapy that modify survival. *Am Heart J* 1991;**121**:1685–1692.
3. Mason JW. A comparison of seven antiarrhythmic drugs in patients with ventricular tachyarrhythmias. Electrophysiologic Study versus Electrocardiographic Monitoring Investigators. *N Engl J Med* 1993;**329**:452–458.
4. Wever EF, Hauer RN, van Capelle FL, Tijssen JG, Crijns HJ, Algra A, Wiesfeld AC, Bakker PF, Robles de Medina EO. Randomized study of implantable defibrillator as first-choice therapy versus conventional strategy in postinfarct sudden death survivors. *Circulation* 1995;**91**:2195–2203.
5. Antiarrhythmics Versus Implantable Defibrillators (AVID) Investigators. A comparison of antiarrhythmic-drug therapy with implantable defibrillators in patients resuscitated from near-fatal ventricular arrhythmias. *N Engl J Med* 1997;**337**:1576–1583.
6. Kuck KH, Cappato R, Siebels J, Rüppel R. Randomized comparison of antiarrhythmic drug therapy with implantable defibrillators in patients resuscitated from cardiac arrest: the Cardiac Arrest Study Hamburg (CASH). *Circulation* 2000;**102**:748–754.
7. Connolly SJ, Gent M, Roberts RS, Dorian P, Roy D, Sheldon RS, Mitchell LB, Green MS, Klein GJ, O'Brien B. Canadian implantable defibrillator study (CIDS): a randomized trial of the implantable cardioverter defibrillator against amiodarone. *Circulation* 2000; **101**:1297–1302.
8. Connolly SJ, Hallstrom AP, Cappato R, Schron EB, Kuck KH, Zipes DP, Greene HL, Boczor S, Domanski M, Follmann D, Gent M, Roberts RS, on behalf of the Investigators of the AVID, CASH and CIDS studies. Meta-analysis of the implantable cardioverter defibrillator secondary prevention trials. *Eur Heart J* 2000;**21**:2071–2078.
9. Brugada P, Talajic M, Smeets J, Mulleneers R, Wellens HJ. The value of the clinical history to assess prognosis of patients with ventricular tachycardia or ventricular fibrillation after myocardial infarction. *Eur Heart J* 1989;**10**:747–752.
10. ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices) developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2008;**51**:e1–e62.
11. ACC/AHA/ESC 2006 Guidelines for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death: a report of the American College of Cardiology/American Heart Association Task Force and the European Society of Cardiology Committee for Practice Guidelines (writing committee to develop Guidelines for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death): developed in collaboration with the European Heart Rhythm Association and the Heart Rhythm Society. *Circulation* 2006;**114**:e385–e484.
12. Almendral J, Josephson ME. All patients with hemodynamically tolerated postinfarction ventricular tachycardia do not require an implantable cardioverter-defibrillator. *Circulation* 2007;**116**:1204–1211.
13. Della Bella P, De Ponti R, Uriarte JA, Tondo C, Klersy C, Carbucicchio C, Storti C, Riva S, Longobardi M. Catheter ablation and antiarrhythmic drugs for haemodynamically tolerated post-infarction ventricular tachycardia; long-term outcome in relation to acute electrophysiological findings. *Eur Heart J* 2002;**23**:414–424.
14. Borger van der Burg AE, de Groot NM, van Erven L, Bootsma M, van der Wall EE, Schalij MJ. Long-term follow-up after radiofrequency catheter ablation of ventricular tachycardia: a successful approach? *J Cardiovasc Electrophysiol* 2002;**13**:417–423.
15. Pauriah M, Cismaru G, Magnin-Poull I, Andronache M, Sellal JM, Schwartz J, Brembilla-Perrot B, Sadoul N, Aliot E, De Chillou C. A stepwise approach to the management of post-infarct ventricular tachycardia using catheter ablation as the first line treatment: a single center experience. *Circ Arrythm Electrophysiol* 2013;**6**:351–356.
16. Hinkle LE Jr, Thaler HT. Clinical classification of cardiac deaths. *Circulation* 1982;**65**:457–464.
17. Raitt MH, Renfroe EG, Epstein AE, McAnulty JH, Mounsey P, Steinberg JS, Lancaster SE, Jadonath RL, Hallstrom AP; Antiarrhythmics Versus Implantable Defibrillators Investigators. 'Stable' ventricular tachycardia is not a benign rhythm: insights from the antiarrhythmics versus implantable defibrillators (AVID) registry. *Circulation* 2001;**103**:244–252.
18. Buxton AE, Lee KL, Fisher JD, Josephson ME, Prystowsky EN, Hafley G. A randomized study of the prevention of sudden death in patients with coronary artery disease. Multicenter Unsustained Tachycardia Trial Investigators. *N Engl J Med* 1999;**341**:1882–1890.
19. Greenberg H, Case RB, Moss AJ, Brown MW, Carroll ER, Andrews ML; MADIT-II Investigators. Analysis of mortality events in the Multicenter Automatic Defibrillator Implantation Trial (MADIT-II). *J Am Coll Cardiol* 2004;**43**:1459–1465.
20. Packer DL, Prutkin JM, Hellkamp AS, Mitchell LB, Bernstein RC, Wood F, Boehmer JP, Carlson MD, Frantz RP, McNulty SE, Rogers JG, Anderson J, Johnson GW, Walsh MN, Poole JE, Mark DB, Lee KL, Bardy GH. Impact of implantable cardioverter-defibrillator, amiodarone, and placebo on the mode of death in stable patients with heart failure: analysis from the sudden cardiac death in heart failure trial. *Circulation* 2009;**120**:2170–2176.

21. Olson PJ, Woelfel A, Simpson RJ Jr, Foster JR. Stratification of sudden death risk in patients receiving long-term amiodarone treatment for sustained ventricular tachycardia or ventricular fibrillation. *Am J Cardiol* 1993;**71**:823–826.
22. Sarter BH, Finkle JK, Gerszten RE, Buxton AE. What is the risk of sudden cardiac death in patients presenting with hemodynamically stable sustained ventricular tachycardia after myocardial infarction? *J Am Coll Cardiol* 1996;**28**:122–129.
23. Glikson M, Lipchenca I, Viskin S, Ballman KV, Trusty JM, Gurevitz OT, Luria DM, Eldar M, Hammill SC, Friedman PA. Long-term outcome of patients who received implantable cardioverter defibrillators for stable ventricular tachycardia. *J Cardiovasc Electrophysiol* 2004;**15**:658–664.
24. Sacher F, Tedrow UB, Field ME, Raymond JM, Koplan BA, Epstein LM, Stevenson WG. Ventricular tachycardia ablation: evolution of patients and procedures over 8 years. *Circ Arrhythmia Electrophysiol* 2008;**1**:153–161.
25. Healey JS, Hallstrom AP, Kuck KH, Nair G, Schron EP, Roberts RS, Morillo CA, Connolly SJ. Role of the implantable defibrillator among elderly patients with a history of life-threatening ventricular arrhythmias. *Eur Heart J* 2007;**28**:1746–1749.
26. Reynolds MR, Cohen DJ, Kugelmass AD, Brown PP, Becker ER, Culler SD, Simon AW. The frequency and incremental cost of major complications among medicare beneficiaries receiving implantable cardioverter-defibrillators. *J Am Coll Cardiol* 2006;**47**:2493–2497.
27. Poole JE, Johnson GW, Hellkamp AS, Anderson J, Callans DJ, Raitt MH, Reddy RK, Marchlinski FE, Yee R, Guarnieri T, Talajic M, Wilber DJ, Fishbein DP, Packer DL, Mark DB, Lee KL, Bardy GH. Prognostic importance of defibrillator shocks in patients with heart failure. *N Engl J Med* 2008;**359**:1009–1017.
28. Larsen GK, Evans J, Lambert WE, Chen Y, Raitt MH. Shocks burden and increased mortality in implantable cardioverter-defibrillator patients. *Heart Rhythm* 2011;**8**:1881–1886.
29. Sweeney MO, Sherfesee L, DeGroot PJ, Wathen MS, Wilkoff BL. Differences in effects of electrical therapy type for ventricular arrhythmias on mortality in implantable cardioverter-defibrillator patients. *Heart Rhythm* 2010;**7**:353–360.
30. Saxon LA, Hayes DL, Gilliam FR, Heidenreich PA, Day J, Seth M, Meyer TE, Jones PW, Boehmer JP. Long-term outcome after ICD and CRT implantation and influence of remote device follow-up: the ALTITUDE survival study. *Circulation* 2010;**122**:2359–2367.
31. Moss AJ, Schuger C, Beck CA, Brown MW, Cannom DS, Daubert JP, Estes NA 3rd, Greenberg H, Hall WJ, Huang DT, Kautzner J, Klein H, McNitt S, Olshansky B, Shoda M, Wilber D, Zareba W; MADIT-RIT Trial Investigators. Reduction in inappropriate therapy and mortality through ICD programming. *N Engl J Med* 2012;**367**:2275–2283.
32. Germano JJ, Reynolds M, Essebag V, Josephson ME. Frequency and causes of implantable cardioverter-defibrillator therapies: is device therapy proarrhythmic? *Am J Cardiol* 2006;**97**:1255–1261.
33. Reddy VY, Reynolds MR, Neuzil P, Richardson AW, Taborsky M, Jongnarangsin K, Kralovec S, Sediva L, Ruskin JN, Josephson ME. Prophylactic catheter ablation for the prevention of defibrillator therapy. *N Engl J Med* 2007;**357**:2657–2665.
34. Kuck KH, Schaumann A, Eckardt L, Willems S, Ventura R, Delacrétaz E, Pitschner HF, Kautzner J, Schumacher B, Hansen PS; VTACH study group. Catheter ablation of stable ventricular tachycardia before defibrillator implantation in patients with coronary heart disease (VTACH): a multicentre randomised controlled trial. *Lancet* 2010;2:**375**:31–40.