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Ventricular tachycardia ablation in structural heart disease: Impact of ablation strategy and non-inducibility as an end-point on long term outcome☆,☆☆,★

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ABSTRACT

Background: To investigate the long term outcomes after catheter ablation (CA) of ventricular tachycardia (VT) in the context of structural heart disease in a multicenter cohort. The impact of different ablation strategies (substrate ablation versus activation guided versus combined) and non-inducibility as an end-point was evaluated.
Methods: Data was pooled from prospective registries at 5 centres over a 5 year period. Success was defined as survival free from recurrent ventricular arrhythmias (VA). Multivariate analysis of factors predicting survival free from VA was analysed by Cox regression.
Results: Five hundred sixty-six patients underwent CA for VT. Patients were 64 ± 15 years. Left ventricular ejection fraction was 35 ± 15% and 66% had ischaemic heart disease. At 2.3 (IQR 1.0–4.2) years, success was achieved in 44% after a single procedure, rising to 60% after repeat procedures. Mortality at final follow up was 22%. Multivariate analysis showed that higher left ventricular ejection fraction, younger age, ischaemic heart disease, and non-inducibility of VA predicted long term survival free from VA (all $p < 0.05$). There was no impact of the approach to ablation.
Conclusion: CA eliminates VT in a large proportion of patients long term. Ablation strategy did not impact outcome and hence substrate ablation is a reasonable initial strategy. Non-inducibility of VA predicted survival free from VA and may be worth pursuing as a procedural end-point.

1. Introduction

Ventricular arrhythmias (VA) cause significant morbidity and mortality in patients with structural heart disease (SHD). Implantable cardioverter-defibrillators (ICD) prevent sudden cardiac death but do not prevent recurrent VA. Management of patients with recurrent VA and ICD shocks remains a challenge. Shocks are unpleasant and these patients are prone to VT storm, have increased heart failure hospitalisations and higher mortality [1].

Catheter ablation (CA) of ventricular tachycardias (VT) is being utilized increasingly in the context of SHD [2,3]. Approaches to CA are based partly or wholly on substrate modification, whereby surviving myocardial fibres within areas of scar are ablated to interrupt critical isthmi for re-entrant VT [2,4]. CA reduces the burden of VT and ICD shocks [5].

There are limited data investigating the long-term outcome after CA of VA in SHD and the available published data originates mostly from a small number of world leading centres [4–7]. Furthermore, there remains uncertainty as to the safest and most effective approach as well as the usefulness of procedural end-points such as non-inducibility of VA. The present study investigated the impact of VT ablation on long term outcome in a large cohort of patients with SHD of mixed

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aetiologies in a multi-centre registry. The impact of ablation strategy and non-inducibility of VA as a procedural end-point was assessed in terms of (i) procedural safety, (ii) long tern efficacy, and (iii) long term mortality.

2. Methods

2.1. Study design and patient sample

A multicenter registry was compiled from a collaborative group of UK tertiary centres experienced in VT ablation. Independent prospective registries were held for consecutive patients undergoing catheter ablation of VT, including baseline demographics, procedural data, complications and follow-up. All consecutive patients were included over a 5 year period (01/01/2010–31/12/2014).

Of patients undergoing catheter ablation of VT the sole inclusion criteria was structural heart disease which was defined as (i) significantly impaired left ventricular function (ejection fraction < 45%), (ii) a formal diagnosis of a cardiomyopathy or (iii) evidence of late gadolinium enhancement in either ventricle. Patients with structural heart disease were included regardless of the aetiology.

2.2. Ablation procedure

All procedures were performed either under conscious sedation or under general anaesthesia. The route to access the endocardial left ventricle was at the operator's discretion and involved either the transseptal route, retrograde access through the arterial system, or both. Epicardial access was obtained where necessary using a Seldinger approach. Where it was thought necessary, epicardial access was sought at the index procedure and this was not deferred to a second or staged procedure.

Electroanatomic mapping systems were used with irrigated catheters to deliver radiofrequency energy in all cases. Multipolar mapping catheters, steerable or robotic sheaths, and contact-force sensing ablation catheters were used at the discretion of the operator when they were available. The ablation power ranged from 30 to 50 W. Where contact force sensing catheters were used operators aimed for 5–40 g of contact force.

2.3. Ablation strategy

The approach to ablation of VT was at the discretion of the treating physician and included both substrate based modification performed in sinus rhythm or activation mapping of VT, or both. Substrate modification involved voltage mapping in sinus rhythm with identification of sites of late activation as demonstrated by split, fractionated or isolated late potentials which were targeted for ablation. Ablation was delivered focally to abolish these signals, often in clusters or lines, but there was no attempt to create lines of block or to isolate areas of tissue.

Activation mapping was performed for either spontaneous or induced VT. In cases where activation mapping was performed, the aim was to identify and ablate the diastolic pathway, or failing this to ablate the exit site. Pace mapping was utilized in many patients as an adjunct to activation mapping to help to localize the VT exit site.

2.4. Programmed ventricular stimulation and non-inducibility of VA as a procedural end-point

All 5 centres participating in this study routinely perform programmed ventricular stimulation at the end of VT ablation procedures. This was not performed in all cases, for example where there was no realistic prospect of having achieved non-inducibility, or where patients were unwell and unlikely to tolerate further VT/cardioversion well. Otherwise programmed ventricular stimulation was performed with the rationale that it might (a) reveal a mapable VT that could be targeted, (b) prompt the operator to map and ablate epicardialy if they had not already done so, or (c) provide prognostically useful information. Programmed ventricular stimulation was routinely performed from two different locations with two different cycle lengths and three successive extrastimuli at decreasing intervals until reaching ventricular refractoriness. Whether the VA induced was 'clinical' or not is often unclear, particularly when the indication for the procedure is ICD shocks as is often the case. Given the lack of clarity over this and the multicentre nature of the study we did not distinguish between induced VA being clinical or not. Inducibility of VA was therefore considered a binary endpoint (i.e. VA inducible or not).

2.5. Follow-up and endpoints

A majority of patients were followed up in the ICD clinic. Patients without implanted devices were followed up in conventional outpatient clinics. Patients who had not been seen recently were contacted for follow up data.

It was not thought possible to eradicate all VA over long term follow up including non-sustained episodes. Furthermore, much of the study period was before the landmark MADIT-RIT trial, and hence use of ATP was initially more liberal [8]. We therefore used a composite primary end-point of death or recurrent VA similar to that reported in recent trials. Recurrent VA (including both VT and VF) was defined as (i) receiving an appropriate ICD shock for VA, (ii) VA storm, defined as three or more episodes of VA requiring appropriate ICD therapies (whether ATP or shocks) within 24 h, or (iii) VA requiring hospital admission, a change in anti-arrhythmic drug treatment or catheter ablation. Episodes of non-sustained VT not meeting these criteria, including those treated with ATP, were not counted as failure.

2.6. Complications

All complications were prospectively recorded in the respective institutional registries but were reviewed so as to allow the application of a rigorous consensus definition compatible with guidelines [9]. Bleeding complications were considered to be major complications if they were considered to be life threatening, necessitating intervention (including thrombin injection, placement of a drain or surgery), transfusion, or causing prolongation of hospitalization or re-attendance to hospital following discharge.

2.7. Statistical analysis

Continuous variables are reported as mean ± standard deviation, or median (range or interquartile range where stated) if not normally distributed. Continuous data were compared by Student's *t*-test if normally distributed or Man-Whitney *U* test if not normally distributed. Categorical data were compared by chi-squared test. Kaplan-Meier curves were used to analyse survival free from VA. Groups were compared using the log-rank test.

Multivariate analysis of factors predicting long term mortality and a composite of recurrent VT or death was by Cox regression and included the following factors: Age, gender, left ventricular ejection fraction, ischaemic heart disease (IHD), dilated cardiomyopathy, use of contact force sensing catheters, the ablation strategy used (substrate guided ablation only, activation mapping only, or a combined approach), demonstration of non-inducibility of VA, and the centre in which the ablation was performed. These were all included as categorical covariates, with the exception of age and left ventricular ejection fraction which were included as continuous covariate. Variables were then removed stepwise from the model when the *p*-value exceeded 0.10, and variables with $p < 0.05$ in the final model were considered to be significant predictors of recurrent VA and death. A similar analysis of factors predicting 30 day mortality was performed using binary logistic regression. Analysis was performed using SPSS 16 (SPSS, Inc., Chicago, IL).

3. Results

3.1. Study population

Baseline characteristics of the patients are summarized in Table 1. Five hundred sixty-six patients underwent CA for VA. Patients were aged 64 ± 15 years and the majority (72%) were male. The aetiology of structural heart disease was ischemic in 66%, dilated cardiomyopathy in 14% and other cause in 21% (Table 1). Mean LVEF was 35 ± 15%. An ICD or CRT-D had been implanted prior to catheter ablation in 78% of the patients. More than three quarters of the study population were

Table 1
Patient demographics.

Number of patients [*N*]	566
Age [years]	64 ± 15
Male/female gender [%]	72/28
Underlying heart disease	
Ischaemic	373 (66%)
Prior stenting	162 (29%)
Prior CABG	132 (23%)
Dilated cardiomyopathy	77 (14%)
Sarcoid-associated cardiomyopathy	12 (2%)
Arrhythmogenic ventricular cardiomyopathy	29 (5%)
Hypertrophic cardiomyopathy	11 (2%)
Other	64 (11%)
Left ventricular ejection fraction (LVEF)	35 ± 15%
Device	
ICD	308 (54%)
CRT-D	136 (24%)
No ICD	122 (22%)
Hypertension	185 (33%)
Type 2 diabetes	80 (14%)
eGFR	68 ± 26
Beta-blocker	474 (84%)
ACE-I or ARB	429 (76%)
Sotalol	59 (10%)
Calcium channel blocker	21 (4%)
Flecainide	9 (2%)
Amiodarone	244 (43%)
Anticoagulation	183 (32%)

on treatment with beta-blockers and ACE-inhibitors/angiotensin-receptor blockers at baseline and 43% were already taking amiodarone.

3.2. Procedure characteristics

566 patients underwent a total of 761 catheter ablation procedures for VT (Table 2). Of these, 74% of patients had one procedure only, 19% underwent a second procedure, 5% underwent a third, and <2% of patients underwent 4 or more procedures. In 333/566 patients (59%), the procedure was performed on an urgent basis on patients who had been admitted to hospital with VA, whereas in 233/566 (41%) the procedure was performed on an elective basis. 379/566 patients (67%) had access to the endocardial left ventricle via a transseptal approach whereas 273/566 (48%) had a retrograde, transaortic approach. A contact force sensing catheter was used in a third of the patients (33%).

3.3. Ablation strategy and non-inducibility as an end-point

The approach to CA was solely activation mapping in 146/566 subjects (26%; Table 2), substrate ablation in 163/566 patients (29%), and a combination of these two approaches in 257/566 patients (45%). Programmed ventricular stimulation to induce VA was performed at the end of the procedure in 398/566 patients (70%); non-inducibility of VA was demonstrated in 322/566 patients (57%).

3.4. Success following VT ablation

The single procedure success rate using the composite endpoint of death or recurrent VA was 61% at 1 year (Fig. 1A & B) and 44% at a final follow up of 2.3 years (IQR 1.0–4.2 years). Allowing for repeated procedures, the success rate increased to 78% at 1 year and 60% at final follow-up. A total of 127 patients (22%) died during follow up (Fig. 1C & D). Success at final follow up was achieved in 71/163 (44%) who had substrate guided ablation only (HR on univariate analysis 0.99, 95% CI 0.78–1.27, $p = 0.957$) compared to 62/146 (43%) of those who had activation guided ablation only (HR 0.97, CI 0.76–1.25, $p = 0.814$) and 115/257 (45%) of those who had a combined approach (HR 1.03, CI 0.83–1.28, $p = 0.798$). In patients in whom non-inducibility of VA was achieved at the end of the procedure long-term success was achieved in 161/322 (50%) patients (HR on univariate analysis 0.70, CI 0.56–0.87, $p = 0.001$).

Table 2
Procedural data.

Procedure number	1 (IQR 1–3)
1 procedure	420 (74%)
2 procedures	110 (19%)
3 procedures	27 (5%)
4 procedures	6 (1%)
5 procedures	2 (0.4%)
6 procedures	1 (0.1%)
Procedure time	189 ± 68 min
Fluoroscopy time	25 ± 20 min
Radiation dose	2507 ± 3885 cGycm^2
Access	
Transseptal puncture	379 (67%)
Retrograde	273 (48%)
Epicardial	52 (9%)
Contact force sensing catheters	189 (33%)
Activation guided ablation only	146 (26%)
Substrate guided ablation only	163 (29%)
Activation and substrate guided ablation	257 (45%)
VT stimulation study at end of procedure	398 (70%)
VT non-inducibility demonstrated	322 (57%)
Major complications	
Haematoma	10 (1.8%)
Tamponade	20 (3.5%)
Stroke or TIA	3 (0.5%)
Complete heart block	3 (0.5%)
Other major	20 (3.5%)
Death within 24 h	5 (0.8%)
Death within 30 days	15 (2.7%)
Any major complication up to 30 days	68 (12.0%)

3.5. Predictors of recurrent VT and death

Fig. 2A shows a multivariate analysis of factors predicting the primary end point of recurrent VA or death; notably there was no impact of the ablation approach although the impact of non-inducibility of VA was significant (for Kaplan-Meier analyses see Fig. 1A and B). After stepwise removal of factors with a $p > 0.10$, those relevant factors remaining were increasing age (HR 1.012 per year of increasing age, 95% CI 1.002–1.022, $p = 0.022$), higher LVEF (HR 0.989 per percentage point increase in ejection fraction, 95% CI 0.980–0.997, $p = 0.011$), IHD (HR 0.597, 95% CI 0.447–0.797, $p < 0.001$), non-inducibility of VA at the end of the procedure (HR 0.700, 95% CI 0.539–0.908, $p = 0.007$), the use of contact force sensing catheters (HR 0.782, 95% CI 0.600–1.020, $p = 0.070$), and the centre at which the procedure was performed (overall effect $p = 0.043$). Notably, there was no impact of the ablation strategy on outcome.

3.6. Predictors of long term mortality following VT ablation

Fig. 2B shows a multivariate analysis of the factors predicting death over long term follow up after VT ablation. Notably there was no impact of the approach to ablation, although the impact on non-inducibility of VA was significant (see also Kaplan Meier analyses in Fig. 1C & D). After stepwise removal of factors with a $p > 0.10$ those relevant factors remaining were age (HR 1.054 per year of increasing age, 95% CI 1.034–1.074, $p < 0.001$), LVEF (HR 0.966 per percentage point increase in ejection fraction, 95% CI 0.950–0.983, $p < 0.001$), the presence of dilated cardiomyopathy (HR 1.684, 95% CI 1.021–2.777, $p = 0.041$), non-inducibility of VA (HR 0.407, 95% CI 0.267–0.621, $p < 0.001$) the use contact force sensing catheters (HR 0.592, 95% CI 0.381–0.919, $p = 0.020$), and the centre at which the ablation was performed (overall effect $p = 0.002$).

3.7. Procedural complications and mortality

Major complications occurred in 12% of patients (Table 2). A significant proportion of these were made up of haematoma at the access site (1.8%) and tamponade requiring drainage in 3.5%. Both atrioventricular block and TIA/stroke were infrequent at 0.5% each. The mortality rate was low at 24 h (0.5%) although this increased to 2.7% when including all deaths up to 30 days. Notably, all the deaths occurred in patients who underwent the CA procedure on an urgent basis having been admitted to hospital for VA (333 of 566 patients, 59%). If considered separately this would give a 30 day mortality of 0% when VT ablation was performed electively compared to 4.5% (15/333) when performed as an emergency ($p < 0.001$). Fig. 2C shows a multivariate analysis of the factors predicting 30 day mortality after VT ablation. After stepwise removal of factors with a $p > 0.10$ those remaining were higher age (HR 1.078, 95% CI 1.013–1.147, $p = 0.019$) and lower LVEF (HR 0.904, 95% CI 0.839–0.974, $p = 0.008$), IHD (HR 0.113, 95% CI 0.025–0.512, $p = 0.005$), and dilated cardiomyopathy (HR 0.184, 95% CI 0.026–1.310, $p = 0.091$), and non-inducibility of the VA (HR 0.134, 95% CI 0.028–0.638, $p = 0.012$). There was no impact of ablation strategy or the centre at which the ablation was performed.

3.8. Differences between centres

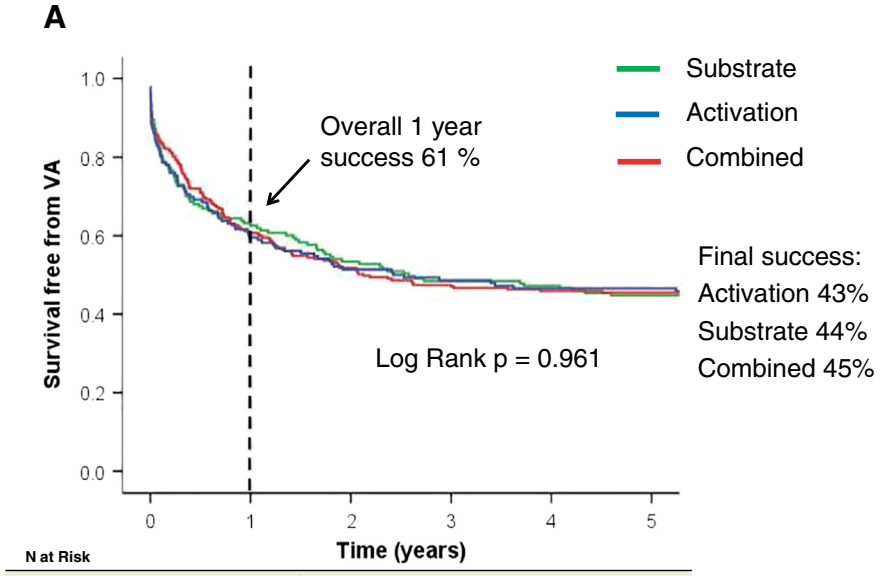
Overall, the centre at which the procedure was performed had a significant impact on the long term composite of recurrent VA or death and also mortality during follow up, but not on 30 day mortality (Fig. 2A–C). One centre had a lower occurrence of the combined end point during

follow up which did not translate to an impact on mortality. Another centre had a higher mortality during long term follow up without affecting the composite end point. There was no difference between centres in the 30 day mortality.

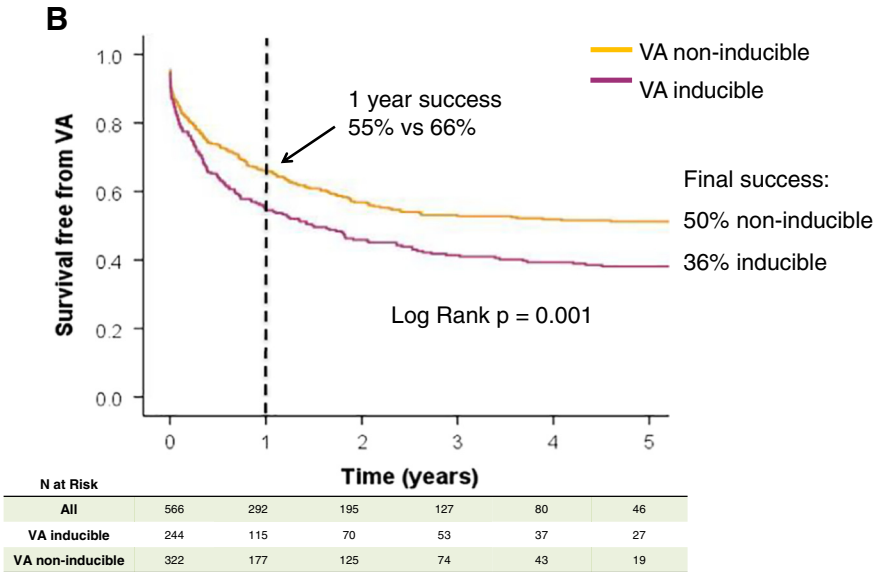
There was significant variation between centres in the proportion of procedures performed using contact force sensing catheters, ranging from 14 to 63% of procedures (mean 32 ± 20%, $p < 0.001$). There was also significant variation in the ablation strategy between centres: the proportion undergoing ablation guided by activation mapping alone was 1–55% (mean 25 ± 19%, $p < 0.001$); the proportion guided by substrate mapping alone was 1–51% (mean 31 ± 19%, $p < 0.001$); and the proportion guided by a combined approach was 14–97% (mean 44 ± 32%, $p < 0.001$).

4. Discussion

This multicentre registry of VT ablation in patients with SHD is one of the largest and has one of the longest follow up periods reported to date. Survival free from VA was 44% after a single procedure, or 60% if allowing for repeat procedures at 2.3 years. Although mortality within 24 h was low at 0.5% this increased to 2.7% at 30 days; notably all deaths occurred in the 59% of patients admitted to hospital with VA and having procedures as an emergency. The approach to ablation in terms of being guided by substrate mapping, activation mapping or a combined approach had no demonstrable effect on long term success, long term mortality, or 30 day mortality, accepting the limitations of this retrospective analysis. Non-inducibility of VA at the end of the procedure

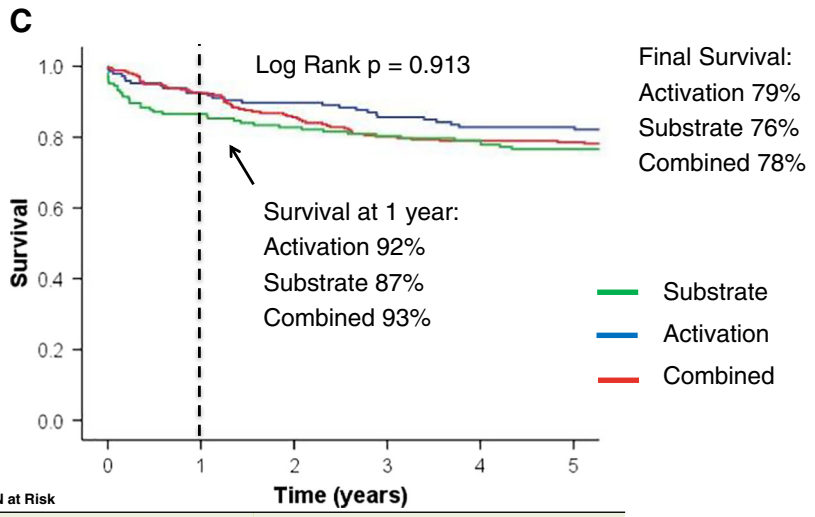


N at Risk						
All	566	292	195	127	80	46
Activation	146	73	52	41	30	23
Substrate	163	89	53	34	20	10
Combined	257	130	90	52	30	13

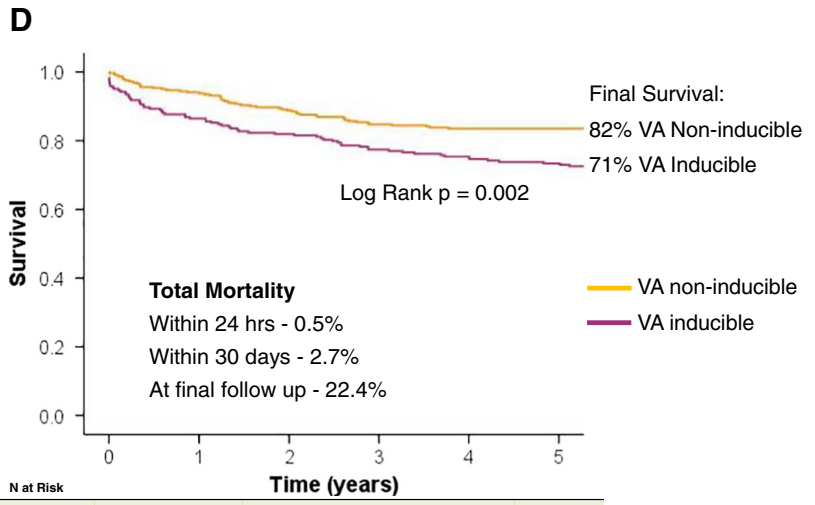


N at Risk						
All	566	292	195	127	80	46
VA inducible	244	115	70	53	37	27
VA non-inducible	322	177	125	74	43	19

Fig. 1. A–D. Figures show Kaplan-Meier curves. The number at risk is shown at the bottom. Curves are compared using the Log Rank test.



N at Risk						
All	566	404	288	178	115	52
Activation	146	109	84	61	44	27
Substrate	163	113	69	42	25	8
Combined	257	182	135	75	46	17



N at Risk						
All	566	404	288	178	115	52
VA inducible	244	166	116	80	56	28
VA non-inducible	322	238	172	98	59	24

Fig. 1 (*continued*).

was associated with a higher long term success rate, lower long term mortality, and lower 30 day mortality.

4.1. Outcome after VT ablation

Two randomised trials comparing catheter ablation to AADs at the time of ICD implantation for VT in the context of IHD found survival free from VA in 47% and 79%, both at 1.9 years [4,5]. The VANISH trial randomised 132 patients with IHD to ablation, achieving VA free survival in 41% at 2.3 years [10]. We report survival free from VA after a single ablation procedure of 45% at 2.3 years, rising to 61% if allowing for repeat procedures. Data from this and other large 'real world' multicentre registries show that similar results can be achieved to those reported in randomised trials in which conditions may be controlled and patients selected. However, there is still certainly scope to improve outcomes with new techniques and technologies. Furthermore, 22% of patients died during follow-up, highlighting the need for ongoing treatment of the underlying heart disease, management of heart failure and selection for other therapies such as transplant or ventricular assist devices.

4.2. Impact of non-inducibility of VA

Non-inducibility of VA at the end of the procedure has been shown to predict freedom from VA and survival, albeit mostly in the context of IHD [2,11,12]. In a single centre registry of 160 patients with IHD, non-inducibility predicted freedom from VA and survival [11]. Similarly, in the multicentre Thermocool Ventricular Tachycardia Ablation Trial of 231 post-myocardial infarction patients' non-inducibility predicted freedom from VA [2]. These studies were included in a recent meta-analysis of 736 patients undergoing VT ablation which found a favourable effect of non-inducibility [12].

The current study reports outcomes in almost as many patients as the recent meta-analysis over a longer period of follow up and confirms a protective effect of non-inducibility in a mixed cohort of patients with

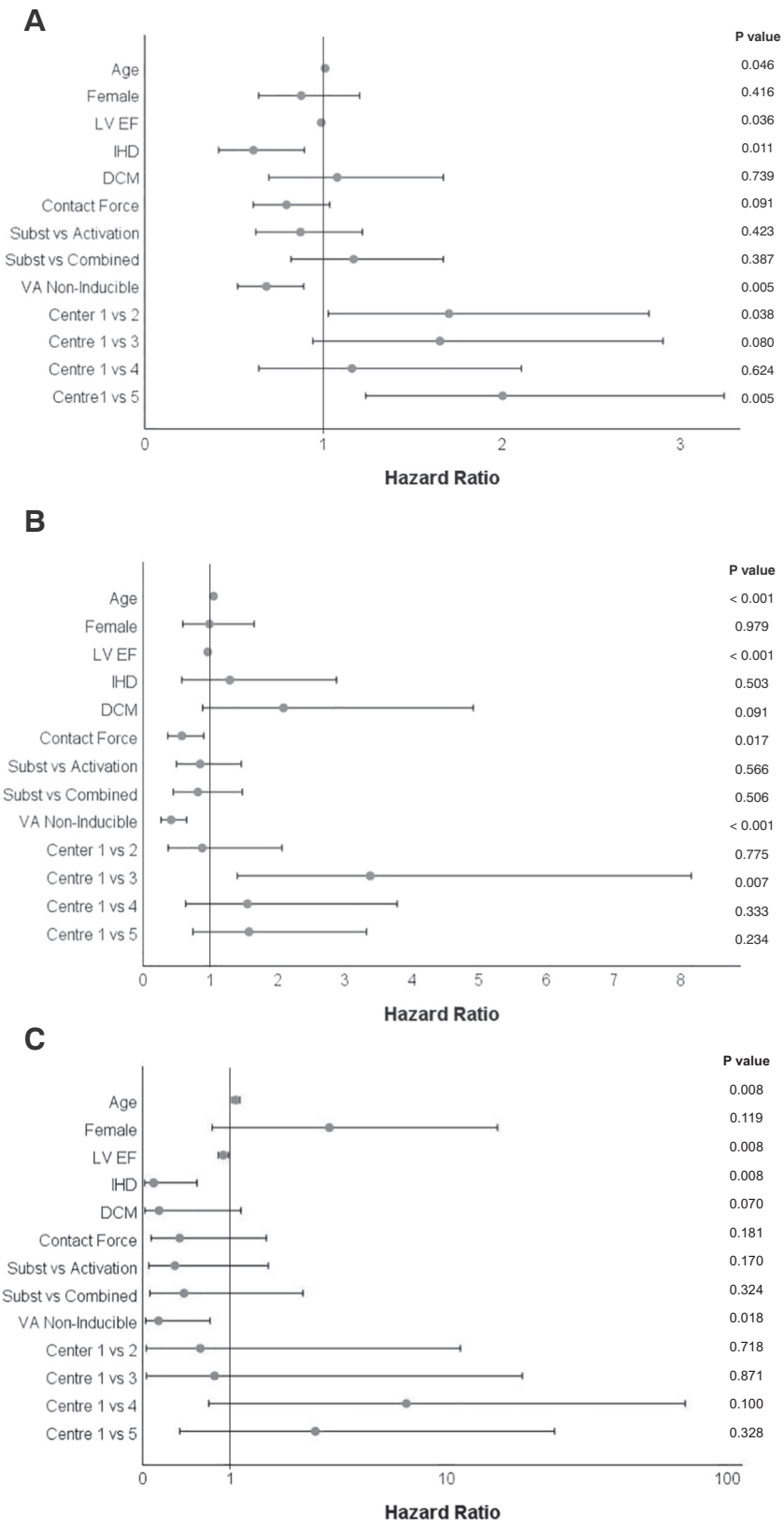


Fig. 2. A–C. Figures shows hazard ratio and 95% confidence intervals. 'Subst' denotes a substrate ablation strategy. For analysis of ablation strategy, a hazard ratio below 1 favours a substrate ablation strategy. For analysis of centre a hazard ratio below 1 favours centre 1.

ischaemic and non-ischaemic aetiologies. Non-inducibility of VA was one of the strongest predictors of 30 day mortality, long term mortality and freedom from VA. This association may partly reflect the extent of underlying cardiac pathology which may convey some of the prognostic advantage with non-inducibility. However, the size of this cohort has allowed a meaningful multivariate analysis to control for other factors and showed that non-inducibility of VA independently predicted freedom from VA and mortality.

These data suggests that non-inducibility of VA is desirable and is reasonable to pursue as a procedural end-point. Nevertheless, randomised trials are needed to confirm whether pursuing this as an end-point really improves outcomes. Furthermore, non-inducibility can be difficult to achieve in the context of advanced heart disease and it remains to be seen whether aggressive approaches utilizing haemodynamic support are warranted.

4.3. Impact of approach to ablation

Activation mapping requires VT to be sustained, consistent and haemodynamically tolerated. Ablation guided by activation mapping may only eliminate one of many potential VTs. Several studies have utilized substrate-based VT ablation targeting channels within scar in sinus rhythm, often with good effect and low complication rates [4,5,13]. Although this is intended as a 'gentler' approach, there is concern that this may lead to more extensive ablation in patients with already poor ventricular function and also may miss critical areas. There are currently little data comparing the safety and efficacy of these techniques and no consensus as to the ideal approach to VT ablation.

Two meta-analyses studied the impact of ablation strategy on outcome [13,14]. Kumar et al. included 6 studies comprised of 403 patients and reported no difference in outcomes with either approach [15]. Briceño et al. also included 6 studies comprised of 396 patients and reported better outcomes with a substrate modification strategy [13,14]. This study is the largest yet to compare the safety and efficacy of these ablation strategies, comprising more patients than either of these meta-analyses and testing this across multiple centres and aetiologies. There was no difference in 30 day mortality, long term survival or freedom from VA when comparing patients having substrate based ablation versus activation guided or a combined approach. However, this data is not a randomised controlled trial and needs to be interpreted with caution. Cases may have started with one approach for well-founded clinical reasons before 'crossing over' to a combined approach if VA remained inducible, potentially disadvantaging the combined group. Nevertheless, these data may be reassuring to those physicians who favour substrate ablation as an initial standalone strategy, accepting that cross over may be required to achieve non-inducibility. Further randomised controlled trials are required to better define the ideal ablation strategy. The advent of ultra-high-density mapping techniques using the current generation of multipolar mapping catheters and systems such as Rhythmia may also impact on the effectiveness of substrate ablation being performed today.

4.4. Other factors predicting outcome

A higher LVEF and younger age predicted 30 day survival, long term survival and survival free from VA. The association between poor LV function and a worse outcome has been demonstrated previously [5–7], and the link with age is not surprising. IHD predicted 30 day survival, long term survival free from VA, but not long term survival, perhaps suggesting that VA may be more straight forward to eliminate with this aetiology but that death may still occur in a significant proportion long-term due to disease progression. Scarring in non-ischemic heart disease may be less extensive but is often patchy and located epicardialy or mid-myocardialy [16]. Furthermore, there may also be a higher incidence of seemingly focal VT in non-ischemic heart disease [17]. Studies comparing outcome of VT ablation in patients with IHD and non-ischemic aetiologies favour the outcome in IHD [18].

The use of contact force sensing catheters was associated with better outcome. This is a novel finding but in the context of registry data ought to be regarded as hypothesis generating. There may be important regional differences in contact force achieved endocardialy and contact epicardialy may be directed away from the myocardium [19]. This may limit identification of targets for ablation as well as lesion formation [20]. It is conceivable that use of contact force sensing catheters could help to overcome these challenges. Data on ideal contact force targets, ablation powers, and ablation output using measures such as force time integral or ablation index are needed to maximise any benefit from using contact force sensing catheters. Further data examining this association is desirable and ultimately randomised controlled trials are needed to define the optimal technologies and strategies.

Notably all deaths within 30 days occurred in patients admitted to hospital with VA having emergency procedures, giving a mortality of 4.5% in this group. This cohort is likely to be sicker than those undergoing elective VT ablation and may be under represented in randomised trials. Centres performing VT ablation should be aware of this, should anticipate problems and manage patients in a high dependency setting. However, elective VT ablation had a 0% mortality. Taken together with the recent VANISH trial, these data raise the question as to whether VT should be ablated early prior to developing VT storm [10].

4.5. Limitations

Registry data can be incomplete and may be biased. Nevertheless, the data were collected prospectively and the complication and success rates are very comparable to other prospective studies. Although cases were categorised based on the ablation approach, this may have been affected by the clinical scenario and it is likely that many 'crossed over' to the combined approach group particularly if VT were inducible on programmed electrical stimulation. Although it is useful to see that patients did not appear disadvantaged with a substrate modification approach, these data on ablation strategy ought to be interpreted with caution and are no substitute for further randomised trials.

The association between non-inducibility of VA and improved outcomes may relate partly to the degree of underlying heart disease and it is recognised that multivariate analysis may not fully account for confounding factors. Randomised trials are needed to investigate the impact of different ablation approaches and to determine whether striving for non-inducibility as an end-point improves outcome.

5. Conclusions

These data highlight the prognostic impact of achieving non-inducibility of VA as a procedural end-point. Outcomes with substrate ablation were comparable to that with other strategies, although the data regarding ablation strategy needs to be interpreted with caution and further randomised studies are needed to confirm the optimal ablation strategy. The 30 day mortality following VT ablation for electrical storm is appreciable and highlights the need for aggressive care in this sub-group. Early ablation of VA in an elective setting is safer and should be considered. The long-term mortality is significant in these sick patients and they are likely to benefit from ongoing treatment of their underlying heart disease and heart failure.

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