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Catheter ablation of atrial fibrillation in patients with heart failure: impact of maintaining sinus rhythm on heart failure status and long-term rates of stroke and death

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Aims Catheter ablation of atrial fibrillation (AF) in patients with heart failure (HF) can improve left ventricular (LV) function and HF symptoms. We aimed to investigate whether long-term maintenance of sinus rhythm impacts on hard outcomes such as stroke and death.

Methods and results An international multicentre registry was compiled from seven centres for consecutive patients undergoing catheter ablation of AF. Long-term freedom from AF was examined in patients with and without HF. The impact of maintaining sinus rhythm on rates of stroke and death was also examined. A total of 1273 patients were included: 171 with HF and 1102 without. Median follow-up was 3.1 years (IQR 2.0–4.3). The final procedure success rate was no different for paroxysmal AF (PAF) (78.7 vs. 85.7%, $P = 0.186$), but significantly different for persistent AF (57.3 vs. 75.8%, $P < 0.001$). Multivariate analysis showed that HF independently predicted recurrent arrhythmia [hazard ratio (HR) 1.7, 95% confidence interval (CI) 1.2–2.4, $P = 0.002$]. New York Heart Association class decreased from 2.3 ± 0.7 at baseline to 1.5 ± 0.8 at follow-up ($P < 0.001$). Left ventricular ejection fraction (LVEF) increased from 34.3 ± 9.0 to $45.8 \pm 12.8\%$ ($P < 0.001$). Recurrent AF was strongly predictive of stroke or death in HF patients (HR 8.33, 95% CI 1.86–37.7, $P = 0.001$).

Conclusion Long-term success rates for persistent (but not paroxysmal) AF ablation are significantly lower in HF patients. Left ventricular function and HF symptoms were improved following ablation. In HF patients, recurrent arrhythmia strongly predicted stroke and death during follow-up.

Keywords AF • Catheter ablation • Heart failure • Outcome • Mortality • Stroke

Introduction

Atrial fibrillation (AF) can exacerbate heart failure (HF) and increases mortality.[1–3] Despite these findings, a large trial comparing rate control with conventional rhythm control in patients with AF and HF found no difference in outcomes.[4] This might be explained by the difficulty maintaining sinus rhythm using drugs and Direct current (DC) cardioversion alone. Several studies have since demonstrated the superiority of catheter ablation over medical therapy in maintaining sinus rhythm, albeit mostly in those with structurally normal hearts.[5,6]

Randomized studies have shown that catheter ablation of AF in patients with HF can improve left ventricular (LV) function and HF symptoms.[7–9] Data from these studies and others suggest that

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What's new?

- Success rates for catheter ablation are markedly lower for patients with persistent (but not paroxysmal) atrial fibrillation in the context of heart failure (HF).
- Heart failure is independently predictive of recurrent arrhythmia.
- Patients with HF who maintain sinus rhythm have improved HF symptoms and left ventricular function long term.
- Maintenance of sinus rhythm post-catheter ablation is associated with a substantial reduction in long-term rates of stroke and death.

the safety and efficacy of catheter ablation in this context are very similar to that in patients with structurally normal hearts.[10–12] This raises the question, if sinus rhythm can be safely and effectively restored in HF patients, might it improve hard outcomes in terms of stroke and death over the long term?

Registry data suggest that successful restoration of sinus rhythm by catheter ablation is associated with very low rates of subsequent stroke and death.[13,14] Several retrospective studies of HF patients have suggested an association between maintenance of sinus rhythm and improved HF symptoms and survival,[3,15,16] although this remains controversial. We examined an international multicentre registry of consecutive patients undergoing catheter ablation of AF to examine the safety and long-term efficacy of catheter ablation in patients with HF compared with those with structurally normal hearts, and the impact of maintaining sinus rhythm on outcome in terms of stroke and death.

Methods

A multicentre registry was compiled from a collaborative group in the UK and Australia. Independent prospective registries were held for consecutive patients undergoing catheter ablation of AF (paroxysmal or persistent), including baseline demographics, echocardiographic data, procedural data, complications and follow-up.

Definitions of heart failure

The definition used for HF was evidence of LV systolic dysfunction [left ventricular ejection fraction (LVEF) $\leq$45%], which had been symptomatic in terms of HF at some stage. This definition therefore included patients that were treated medically for HF and became asymptomatic prior to ablation.

Dilated cardiomyopathy was defined as a dilated impaired left ventricle without another clear cause. It is recognized that there may be a component of tachycardia-mediated cardiomyopathy in many patients with AF and HF. For the purposes of this study, a heart rate of $\geq$110 beats per minute on a resting ECG pre-ablation was considered potentially contributory and outcomes in this subgroup were specifically assessed.

Peri-procedural management and anticoagulation

The peri-procedural management, procedural techniques, and follow-up varied between centres, although there were certain commonalities. All patients underwent transoesophageal echocardiography pre-procedure to rule out intra-cardiac thrombus. Patients had warfarin stopped 5 days pre-procedure and had bridging with low-molecular-weight heparin after the procedure until INR was therapeutic. Patients were anticoagulated intra-procedurally with heparin. Patients remained on oral anticoagulation for at least 3 months post-procedure. Subsequent advice regarding anticoagulation was guided by thromboembolic risk rather than freedom from AF, as per guidelines.[17]

Catheter ablation procedures

All procedures included pulmonary vein isolation as a procedural endpoint. A majority of patients underwent wide area circumferential ablation guided by a 3D mapping system, although a variety of techniques were used including segmental ostial isolation, cryo-balloon ablation (Arctic Front, Medtronic, CA, USA), and robotic ablation with the Hansen robot (Hansen Medical, Inc., Mount View, CA, USA). Lesions were also not limited to pulmonary vein isolation and included targeting of fractionated electrograms and linear ablation, particularly for persistent AF. Notably, these procedures were performed before the availability of contact force sensing catheters.

Patient follow-up

A 3-month blanking period was observed during which patients were managed medically and repeat intervention avoided. Patients were followed up at 3 and 6 months, with a period of ambulatory monitoring. Patients with persistent AF/atrial tachycardia or symptomatic paroxysmal AF (PAF) at 3 months or after were offered a repeat procedure where clinically indicated. Follow-up after 6 months varied between institutions and included clinic visits, telephone appointments, follow-up with local cardiologists and open access to arrhythmia nurse specialists. Attempts were made to contact patients to update follow-up, but where this was not possible, final follow-up was taken from the point of last patient contact.

As catheter ablation of AF carries a small procedural risk, to discern any long-term impact on outcomes a minimum period within which to derive benefit must be allowed. Therefore, registry data were included for consecutive cases up to 1 year before data analysis for the current study began. Analysis of rates of stroke and death were following the first procedure in an intention to treat fashion.

Assessment of safety and efficacy in heart failure and non-heart failure populations

The major complication rate is compared for HF and non-HF populations. Success in terms of maintaining sinus rhythm was defined as freedom from documented AF/atrial tachycardia lasting $\geq$30 s following the 3-month blanking period as per current guidelines,[17] and is reported following a single procedure and following the final procedure.

Since HF is associated with conditions that might also impact on future maintenance of sinus rhythm, a multivariate analysis was conducted to see if HF independently predicted recurrent arrhythmia following the final procedure. The factors included in this multivariate analysis were the presence of HF, whether AF was persistent, gender, age, left atrial diameter, the presence of ischaemic heart disease, hypertension, and diabetes.

The impact of ablation on left ventricular function and heart failure symptoms

The impact of an ablation strategy was assessed by comparing LV function at baseline with that at follow-up in the HF cohort. This was assessed by transthoracic echocardiography using Simpson's biplane method. The impact on HF symptoms was assessed by comparing New York Heart Association (NYHA) score at baseline and final follow-up.

Impact of maintaining sinus rhythm on rates of stroke and death

Rates of stroke and death were examined in HF and non-HF cohorts over long-term follow-up. The impact of maintaining sinus rhythm on rates of stroke and death was examined. The survival in the HF group might be expected to depend on several factors including age, LV function, NYHA class, and the cause of HF. Therefore, to control for the effect of these other factors, a multivariate analysis was conducted to determine whether maintenance of sinus rhythm independently predicted stroke-free survival. The factors included in this multivariate analysis were as follows: freedom from AF following the last procedure, age, gender, whether AF was initially persistent, the presence of ischaemic heart disease at baseline, LVEF at baseline, and NYHA class at baseline.

Statistics

Continuous variables are reported as mean ± standard deviation, or median (interquartile range) if not normally distributed. Continuous data were compared by Student's *t*-test if normally distributed or Mann–Whitney *U* test if not normally distributed. Categorical data were compared by χ^2 test.

The Kaplan–Meier curves were used to analyse freedom from AF, and groups were compared using the log-rank test. The multivariate analyses described (the first examining factors predicting failure after the last procedure and the second examining factors predicting stroke-free survival) was by Cox regression. Variables were 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. Analysis was performed using SPSS 16 (SPSS, Inc., Chicago, IL).

Results

Patients

A total of 1273 patients were included, and their demographics are shown in *Table 1*. Overall, 56% of the cohort had PAF. Of the 44% of patients with persistent AF, almost all had long-standing persistent AF (i.e. >1 year), and hence these are reported together with the 2% of patients with persistent AF of <1 year duration.

There were 171 patients with a history of HF and 1102 with no history of HF. Patients in the two groups were of a similar age and were both predominantly male, but HF patients more likely to have persistent AF, were more often hypertensive, were more often diabetic, were more likely to have ischaemic heart disease, and had a higher CHADS VASc score at baseline (all $P < 0.01$; *Table 1*).

Table 1 Patient demographics

N	HF 171	No HF 1102	*P*-value
Age	58.2 ± 11.0	58.4 ± 10.6	0.901
Male gender	145 (84.8%)	792 (71.9%)	<0.001
AF type			
PAF	61 (35.7%)	656 (59.5%)	<0.001
Persistent AF	6 (3.5%)	21 (1.9%)	0.246
Long-lasting persistent AF	104 (60.8%)	425 (38.6%)	<0.001
Hypertension	88 (51.5%)	449 (40.8%)	0.010
Diabetes	16 (9.4%)	44 (4.0%)	0.005
Stroke	6 (3.5%)	62 (5.6%)	0.3587
Ischaemic heart disease	38 (22.2%)	74 (6.7%)	<0.001
CHADS VASc score	2.4 ± 1.3	1.2 ± 1.2	<0.001
LA diameter	43.0 ± 6.2	40.0 ± 8.2	0.418
LVEF	36.8 ± 10.6	59.6 ± 6.0	<0.001
HF aetiology			
Ischaemic heart disease	29%	–	–
Previous coronary stent	15%		
CABG	12%		
DCM	67%	–	–
Other	11%	–	–
NYHA class	2.3 ± 0.7	–	–
NYHA I	13%		
NYHA II	43%		
NYHA III	42%		
NYHA IV	2%		
HF treatment			
ACE-I or ARB	84%	–	–
Beta-blocker	72%	–	–
Aldosterone antagonist	29%	–	–
Loop diuretic	52%	–	–
ICD	19%	–	–
CRT device	9%	–	–

Proportions are given as a percentage; otherwise, numbers are presented as mean ± SD if normally distributed.
CHADS VASc score, the scoring system for stratification of stroke risk (C = congestive heart failure, H = hypertension, A = age >75 years, D = Diabetes mellitus, S = stroke, V = vascular disease, A = age >65 years, Sc = sex category female); LA, left atrial; CABG, coronary artery bypass graft; DCM, dilated cardiomyopathy; NYHA, New York Heart Association; ACE-I, Angiotensin Converting Enzyme - Inhibitor; ARB, Angiotensin Receptor Blocker; ICD, implantable cardioverter defibrillator; CRT, cardiac resynchronization therapy.

Procedures performed

In total, 2261 procedures were performed. A majority of patients underwent more than one procedure over the long term. For PAF, there was no difference in the number of patients requiring repeat procedures in the HF and non-HF groups (1.54 ± 0.79 procedures for HF patients versus1.67 ± 0.82 for those without HF; $P = 0.169$; *Table 2*). For persistent AF, there were a significantly greater number of repeat procedures in the HF group (2.05 ± 0.90 procedures for the HF group compared with 1.90 ± 0.96 procedures in the non-HF group; $P = 0.038$; *Table 2*).

Procedural safety

Overall, the rate of major complications was similar in the HF and non-HF groups: there were 16 major complications in 320 procedures (5.0% per procedure) in the HF group vs. 106 in 1941 procedures in the non-HF group (5.5% per procedure, $P = 0.894$). This was comprised mostly of stroke or TIA (0.9% per procedure in the HF group and 1.0% in the non-HF group) and tamponade (2.5% per procedure in the HF group compared with 3.2% in the non-HF group).

There were no procedural deaths, although 2 patients died within 30 days of their procedure. One patient in the non-HF group had a procedural stroke, and died 5 days later from a myocardial infarction due to in-stent thrombosis (on a background of IHD and previous

Table 2 Outcomes of AF ablation

	HF	No HF	*P*-value
Single procedure success			
Total	44/171 (25.7%)	441/1102 (40.0%)	<0.001
PAF	28/61 (45.9%)	268/656 (40.8%)	0.497
Including AADs	29/61 (47.5%)	296/656 (45.1%)	0.783
Persistent AF	14/110 (12.7%)	122/446 (27%)	0.001
Including AADs	15/110 (13.6%)	145/446 (32.5%)	<0.001
Final procedure success			
Total	111/171 (64.9%)	900/1102 (81.7%)	<0.001
Including AADs	125 (73.1%)	1020 (92.6%)	<0.001
PAF	48/61 (78.7%)	562/656 (85.7%)	0.186
Including AADs	52 (85.2%)	623 (95.0%)	0.006
Persistent AF	63/110 (57.3%)	338/446 (75.8%)	<0.001
Including AADs	73 (66.4%)	397 (89.0%)	<0.001
Procedure number			
Mean	1.87 ± 0.89	1.76 ± 0.89	0.075
Mean for PAF	1.54 ± 0.79	1.67 ± 0.82	0.169
Mean for persistent AF	2.05 ± 0.90	1.90 ± 0.96	0.038
1 procedure	69 (40.4%)	515 (46.7%)	0.138
2 procedures	64 (37.4%)	400 (36.3)	0.798
3 procedures	31 (18.1%)	138 (12.5%)	0.052
4 procedures	5 (2.9%)	34 (3.1%)	1.000
5 procedures	2 (1.2%)	14 (1.3%)	1.000
6 procedures	0	1 (0.1%)	1.000

Breakdown of success rates for paroxysmal and persistent AFs after a single and multiple procedures. The proportion remaining free but still taking antiarrhythmic medication (AAD) is also provided.

coronary stents). The second was in the HF group and had a history of IHD and severe LV systolic dysfunction, had a tamponade drained at the time of their procedure, and despite being well initially died from a combination of hospital acquired pneumonia and cardiac failure at 10 days.

Freedom from atrial fibrillation

The median follow-up duration was significantly longer in the HF group 3.6 years (IQR 2.6–4.6) vs. 3.1 (IQR 2.0–4.2) years in the non-HF group ($P < 0.001$). *Figure 1* shows a Kaplan–Meier analysis of freedom from atrial arrhythmia during long-term follow-up. The overall success rate following the final procedure off antiarrhythmic drugs (AADs) was lower in the HF group compared with the non-HF group (64.9 vs. 81.7% respectively, $P < 0.0001$). A more detailed breakdown of the freedom from atrial arrhythmia on and off AADs following the first and last procedures, for paroxysmal and persistent AFs is shown in *Table 2*.

Although there was no significant difference in the success rate after a single procedure or repeat procedures for PAF, there was a marked difference between groups for persistent AF. The single procedure success off AADs at long-term follow-up was only 12.7% in the HF group compared with 27.0% in the non-HF group

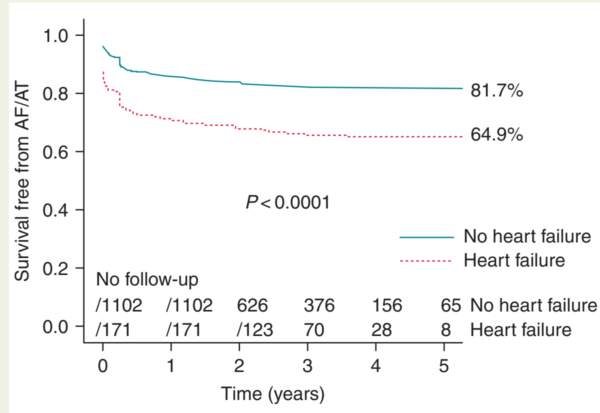

Figure 1 Freedom from AF. The Kaplan–Meier curve showing freedom from AF following the last procedure for patients with and without HF.

($P = 0.001$). The success rate off AADs after the final procedure was 57.3% in the HF group compared with 75.8% in the non-HF group for persistent AF ($P < 0.001$).

Cardiac failure was associated with recurrence of AF after the final procedure on univariate analysis (hazard ratio (HR) 1.65; 95% confidence interval (CI) 1.16–2.35; $P = 0.005$) as shown in *Figure 2*. After stepwise removal from the model of covariates with $P > 0.10$, the variables remaining were cardiac failure (HR 1.71; 1.22–2.41; $P = 0.002$), persistent AF (HR 2.08, 1.54–2.81; $P < 0.001$), female gender (HR 1.48; 1.07–2.04; $P = 0.017$), age (HR 1.19 for each advancing decade, 1.03–1.37; $P = 0.016$), and LA diameter (HR 1.16 for each centimetre increase; 0.98–1.36; $P = 0.087$).

Impact of ablation on left ventricular function and heart failure symptoms

The NYHA class decreased from 2.3 ± 0.7 at baseline to 1.5 ± 0.8 at follow-up ($P < 0.001$). For the 87% of the HF group who had symptomatic HF at the time of their first ablation, NYHA class decreased by 0.9 ± 0.7. In those with symptoms of HF at baseline, the change in NYHA class was greater in those who maintained freedom from AF (−1.1 ± 0.6) compared with those with recurrent arrhythmia (−0.6 ± 0.8; $P < 0.001$).

There were follow-up echocardiographic data for 152 of the 171 HF patients (88.9%), which was performed at 10 (IQR 8–20) months. In these patients, LVEF increased from 34.3 ± 9.0 to 45.8 ± 12.8% ($P < 0.001$). The change in LVEF was greater in those who maintained sinus rhythm (14.8 ± 9.9%) compared with those with recurrent AF (5.1 ± 11.5%, $P < 0.001$).

Impact of heart failure aetiology and tachycardia-mediated cardiomyopathy on outcome

Eighteen patients (10.5% of the HF cohort) had a resting heart rate of ≥110 beats per minute and were considered to have an element of tachycardia-mediated cardiomyopathy. Fourteen of these

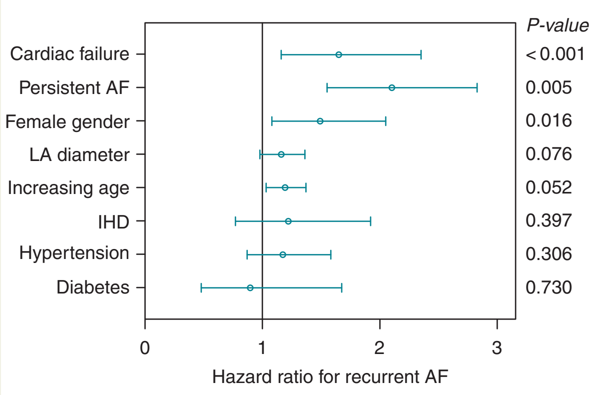

Figure 2 Factors predicting recurrent AF. Multivariate analysis of factors predicting recurrent arrhythmia. The figure shows HR and 95% CIs.

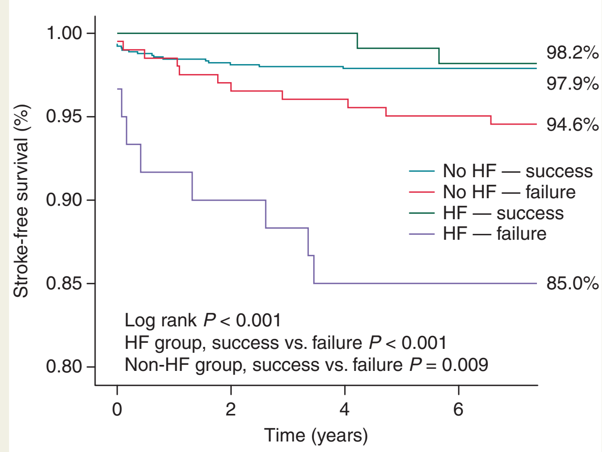

Figure 3 Impact of recurrent AF and HF on rate of stroke and death. The Kaplan–Meier curve shows freedom from the combined endpoint of stroke or death. The population is divided based on whether they had HF at baseline and whether they had recurrent arrhythmia at follow-up.

Table 3 Rates of stroke and death in patients with or without HF

	HF	No HF	*P*-value
Stroke	4 (2.3%)	16 (1.5%)	0.331
Death	7 (4.1%)	16 (1.5%)	0.026
Death cardiovascular	6 (3.5%)	10 (0.9%)	0.014
Stroke or death	11 (6.4%)	30 (2.7%)	0.0178

The raw number of strokes, deaths, and deaths attributable to cardiovascular causes in the HF and non-HF groups.

patients also met our criteria for dilated cardiomyopathy (12.3% of the dilated cardiomyopathy cohort).

The outcome in terms of freedom from AF following the last procedure was no different in those with tachycardia-mediated cardiomyopathy compared with those without (72.2 vs. 64.1%; $P = 0.492$). The composite of stroke or death occurred in 1 patient with tachycardia-mediated cardiomyopathy (a death from HF) compared with 10 patients without (5.5 vs. 6.5%; $P = 0.873$). This translates to 1 death amongst the 5 patients with tachycardia-mediated cardiomyopathy who had recurrent arrhythmia post ablation (20%).

The increase in LVEF was no different in those with tachycardia-mediated cardiomyopathy compared with those without (10.9 ± 10.5 vs. $11.5 \pm 11.5\%$; $P = 0.993$). However, there was a greater increase in LVEF in those with a dilated cardiomyopathy compared with those without (14.2 ± 11.5 vs. $5.8 \pm 8.9\%$; $P < 0.001$). Conversely, the increase in LVEF was smaller in those with a history of ischaemic heart disease compared with those without (6.0 ± 8.8 vs. $13.7 \pm 11.6\%$; $P < 0.001$).

Freedom from atrial fibrillation and survival

Table 3 shows the crude number of strokes and deaths occurring in the HF and non-HF groups. The Kaplan–Meier analysis of

Table 4 The impact of recurrent arrhythmia on the risk of adverse events in HF and non-HF populations

	HF	Non-HF
Stroke or death	8.33 (1.86–37.30) $P = 0.001$	2.58 (1.25–5.34) $P = 0.008$
Death	11.10 (1.37–90.06) $P = 0.004$	5.73 (2.16–15.2) $P < 0.001$
Cardiac death	9.25 (1.106–77.37) $P = 0.012$	2.97 (0.846–10.429) $P = 0.075$
Stroke	5.55 (0.59–52.20) $P = 0.091$	1.028 (0.296–3.575) $P = 0.965$

The number shown is the HR with 95% CIs for the adverse event listed in those with recurrent arrhythmia.

stroke-free survival is shown in *Figure 3* with both HF and non-HF groups divided according to whether they had recurrent arrhythmia following the final procedure. For the non-HF group, the HR for stroke or death in those with recurrent arrhythmia was 2.58 (95% CI 1.25–5.34, $P = 0.008$). In the HF group, the HR for stroke or death in those with recurrent arrhythmia was far higher at 8.33 (95% CI 1.86–37.30, $P = 0.001$). *Table 4* shows the HR for adverse events in those with recurrent arrhythmia broken down into stroke, death, and death from cardiovascular causes. The combined endpoint appears to be driven by a reduction in death from cardiovascular causes. Stroke alone has a low event rate, and there is only a trend towards an effect of recurrent arrhythmia. In the HF group, 67% of patients remained on oral anticoagulant therapy at final follow-up compared with 33% of the non-HF group ($P < 0.001$).

Figure 4 shows the results of a multivariate analysis of the factors predicting the combined endpoint of stroke or death. After stepwise removal from the model of covariates with $P > 0.10$, the variables remaining were recurrent AF (HR 7.82, 95% CI 1.68–36.39;

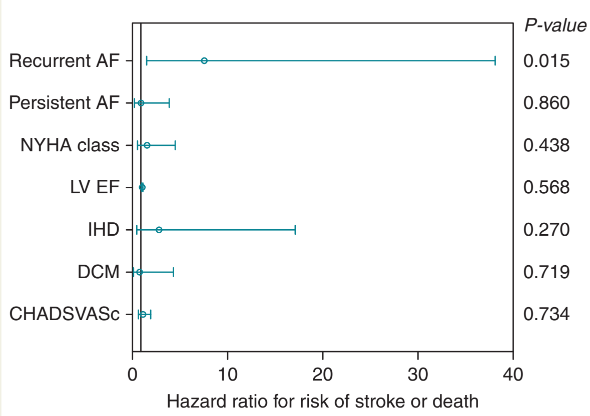

Figure 4 Factors predicting stroke and death during long-term follow-up. Multivariate analysis of factors predicting stroke or death during follow-up. The figure shows HR and 95% CIs.

$P = 0.009$) and IHD as aetiology of HF 3.89 (95% CI 1.13–13.36; $P = 0.031$).

Discussion

In this large multicentre registry, catheter ablation of AF in patients with HF had a similar major complication rate to that in patients with structurally normal hearts. Although for PAF outcomes were similar for patients with and without HF, for persistent AF there was a marked difference in success rates. For patients with HF and persistent AF, the single procedure success rate off AADs was 13% at long-term follow-up, increasing to 66% allowing for repeat procedures and the use of AADs. Heart failure was an independent predictor of recurrent arrhythmia on multivariate analysis. Restoration of sinus rhythm was associated with marked improvements in HF symptoms and LVEF. Freedom from AF in the HF patients was strongly associated with stroke-free survival. Recurrent arrhythmia was an independent predictor of stroke and death in HF patients.

Safety and efficacy of atrial fibrillation ablation in heart failure

Several studies have suggested that catheter ablation of AF in the context of HF is relatively safe. This multicentre registry confirms that the complication rate was not different from that in patients with structurally normal hearts.

Although the success rate for catheter ablation of PAF was similar in HF patients compared with non-HF patients, the success rates for persistent AF were markedly worse. In randomized studies, the success rate following a single procedure has been reported at 38–68%, rising to 50–88% after repeated procedures at 6–12 months.[7–9,18] These results are perhaps as one might expect with ongoing recurrences up to a follow-up of 3.6 (IQR 2.6–4.6) years. Other registries have placed the success rate at long-term follow-up slightly higher than this.[10,11] Our results are likely explained by an AF duration in the persistent group of 30 (IQR 24–48) months and longer follow-up than earlier reports.

The lower success rate for catheter ablation of persistent AF in the HF group is likely multifactorial. Both HF and the conditions leading to HF increase left atrial pressure and wall stress, which causes remodelling of the atria.[19] Left ventricular dilatation also causes progressive mitral regurgitation, which further impacts on left atrial pressure and remodelling. The disease processes affecting the left ventricle such as ischaemia and cardiomyopathy may also affect the atria to some extent. The result of these factors is a more scarred and remodelled atria, which are more inclined to support AF.[20]

Improvement in left ventricular function and heart failure symptoms

The current study showed a significant improvement in NYHA class and LVEF in the HF group compared with baseline. This was evident in the cohort as a whole but was most marked in those who maintained sinus rhythm. This is compatible with the findings of smaller randomized studies.[7–9] This finding is important in the current study as it provides a plausible mechanism by which restoration of sinus rhythm might convey a prognostic benefit. The finding that LVEF improves so markedly after restoration of sinus rhythm (ejection fraction increased 14.8 ± 9.9%) has important implications regarding the need for ICD or CRT device therapies in a HF population. Arguably in this cohort a rhythm control strategy should be considered and the impact on LV function assessed before making decisions regarding device implantation.

The presence of a tachycardia-mediated cardiomyopathy (defined as a resting heart rate of ≥110 beats per minute at baseline) did not impact significantly on the outcome of catheter ablation and did not predict an improvement in LV function. It is possible that a higher resting heart rate still may have been more predictive of LV remodelling, but the numbers of such patients were very small. It is noteworthy that patients with a dilated cardiomyopathy were much more likely to improve LV function following ablation, whereas those with ischaemic heart disease were much less likely to do so. These data suggest that AF can significantly impact on LV function through mechanisms other than a rapid ventricular response and that patients with HF and no suspicion of a tachycardia-mediated cardiomyopathy may still benefit significantly from restoration of sinus rhythm. The difference in response between patients with dilated cardiomyopathy and those with ischaemic heart disease is consistent with that observed in other studies and may help inform patient selection for catheter ablation.[7,10]

Atrial fibrillation as a predictor of stroke and death in heart failure

Although the consequences of poor rate control for LV function are widely understood, the impact of an irregular ventricular filling time and the loss of atrial contraction on LV function have also been well documented. Cardioversion to sinus rhythm improves cardiac function, and several retrospective studies have suggested an association between the subsequent maintenance of sinus rhythm and improved HF symptoms and survival.[3,15,16] Despite this, the largest trial to compare rate control to rhythm control in patients with AF and HF found no benefit in aggressively pursuing sinus rhythm.[4] This might be explained by the difficulty maintaining sinus rhythm in this cohort using medication and DC cardioversion alone. Furthermore, the adverse effects of AADs may negate the benefits of restoring sinus rhythm.

Small randomized controlled trials comparing catheter ablation to restore sinus rhythm with a rate control strategy have shown improvements in LV function, functional capacity and HF symptoms with ablation.[7–9] Larger registries and meta-analyses of non-randomized studies have had similar findings.[10–12,21]

This is the first study to examine specifically the impact of maintaining sinus rhythm on rates of stroke and death after catheter ablation of AF in patients with HF. Previous analysis of this cohort showed that successful restoration of sinus rhythm by catheter ablation was associated with very low rates of stroke and death, comparable with that in the general population.[13] Studies by others have shown similarly low rates of stroke and death after successful ablation of AF, even in high-risk cohorts.[14] The inter-mountain group have recently published registry data looking at 5-year outcomes after catheter ablation of AF in HF patients.[12] They compared outcomes to matched patients with AF and HF treated medically, and a third cohort of patients with HF but no AF. These authors found the lowest mortality was in the ablated group. Furthermore, rates of HF hospitalizations were lower in the ablated group, and there was a trend towards lower stroke rates.

The current study compares outcome in terms of stroke in death in patients with recurrent AF compared with those who maintained sinus rhythm. The finding that recurrent arrhythmia is strongly associated with stroke and death (HR 8.3) supports the notion that successful restoration of sinus rhythm may have prognostic implications for patients with HF. This was powered mostly by the higher cardiovascular mortality in those with recurrent arrhythmia. The most likely explanation for this is the improvement in HF status following restoration of sinus rhythm. There was only a trend towards a reduction in the rate of stroke in HF patients. However, the event rate was low owing to the high proportion of patients who remained anticoagulated post ablation.

Limitations

Although these data suggest an association between successful restoration of sinus rhythm by ablation and freedom from stroke and death in patients with HF, it is recognized that this does not constitute proof. Registry data are prone to bias and the multivariate analyses may not fully account for confounding factors. Nevertheless, these findings are compatible with those of recent randomized studies showing improved LV function, functional capacity and HF symptoms after restoration of sinus rhythm in HF patients.[7–9] Data are awaited from studies such as the Catheter Ablation versus Standard conventional Treatment in patients with LEft ventricular dysfunction and AF trial (CASTLE AF), which may provide more definitive answers regarding any impact on hard outcomes.

It is possible that different techniques and technologies may have yielded different outcomes. Advances in technology (such as contact force sensing catheters) and changes to practice such as performing procedures on uninterrupted oral anticoagulation may have improved procedural safety and success rates for procedures being performed today.

Conclusion

Although the safety and efficacy of catheter ablation for PAF are similar for HF and non-HF patients, success rates are markedly lower for persistent AF in HF (albeit mostly long-standing persistent AF in this cohort). Heart failure is independently predictive of recurrent arrhythmia. Maintenance of sinus rhythm post-catheter ablation is associated with a substantial reduction in long-term rates of stroke and death, which is likely attributable to improved HF status. Randomized studies are needed to confirm these potentially important findings.

Conflict of interest: none declared.

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Repetitive inappropriate implantable cardioverter-defibrillator shocks due to insulation failure with externalized conductor cables of a Biotronik Linox SD ICD lead

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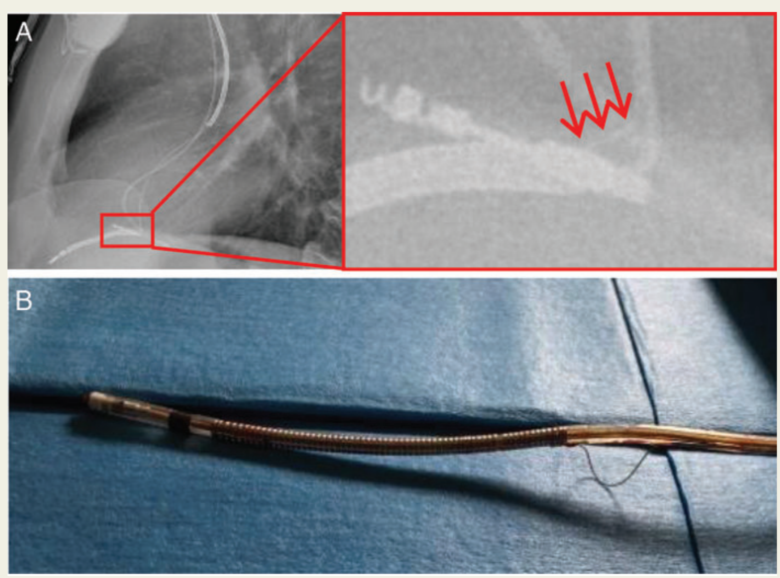
A 54-year-old man with non-ischaemic dilated cardiomyopathy and implantation of an implantable cardioverter-defibrillator (ICD) utilizing a Biotronik Linox SD 65/16 lead 8 years before presented with 17 ICD shocks. Interrogation of the ICD showed noise on the ventricular lead triggering repetitive ICD shocks. Device interrogation showed ventricular sensing of 11.3 mV, pacing impedance of 490 Ω, and shock impedance of 40 Ω, all consistent with prior testing. Pacing threshold could not be determined because pacing resulted in significant ventricular noise. On chest X-ray, an externalized conductor cable proximal to the distal coil was suspected (*Panel A*, arrows). A lead extraction was performed and inspection of the easily extractable lead showed an insulation failure with externalized pace-sense conductor cable (*Panel B*) proximal to the distal coil as the putative source of noise.



Unexpected ICD lead failures (e.g. Medtronic Sprint Fidelis and St Jude Medical Riata) have caused serious problems in the past. This case report is one of few in the literature describing inappropriate ICD shocks due to insulation failure with externalized conductor cables of a defibrillator lead from the Biotronik Linox family, launched in 2006 with over 150 000 leads implanted worldwide. Although the mechanism of failure remains unclear, a heightened awareness with Biotronik Linox leads seems warranted.

The full-length version of this report can be viewed at: http://www.escardio.org/Guidelines-&-Education/E-learning/Clinical-cases/Electrophysiology/EP-Case-Reports.