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Sinus rhythm duration after DC cardioversion for persistent atrial fibrillation and long-term outcomes after subsequent catheter ablation

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ABSTRACT (300/300 words)

Background: Patients undergoing catheter ablation (CA) for persistent atrial fibrillation (PsAF) experience high rates of AF recurrence. Direct current cardioversion (DCCV) is often performed prior to CA, with variable post-DCCV duration of sinus rhythm (SR).

Objective: We aimed to determine whether shorter SR duration after DCCV is associated with AF recurrence after subsequent CA.

Methods: We performed an international multicentre retrospective study of patients undergoing first-time CA for PsAF between 2015-2024 with a prior DCCV. SR duration after the last DCCV preceding CA was recorded. The primary outcome was freedom from atrial arrhythmia after CA (after a 56-day post-ablation blanking period).

Results: 938 patients undergoing first-time CA for PsAF were identified from six centres and categorized by post-DCCV SR duration: <7 days (group 1, n=212); 7-31 days (group 2, n=236); and >31 days (group 3, n=490). Over median post-CA follow-up of 511 days, 512 patients (55%) experienced atrial arrhythmia recurrence. There was no significant between-group difference in freedom from atrial arrhythmia (log rank p=0.10). When analysed as a continuous variable in a Cox regression model, there was no association between post-DCCV SR duration and time to first recurrence of atrial arrhythmia (hazard ratio [HR] per 10-day increment 1.00, 95% confidence intervals 1.00-1.01, p=0.07). In secondary analyses, there were significantly more blanking period arrhythmias in groups 1 and 2 compared with group 3 (both pairwise p<0.001), and presentation for CA in persistent atrial arrhythmia was associated with a time-dependent increased risk of atrial arrhythmia recurrence compared with presentation in SR.

Conclusion: In this large multicentre cohort, shorter duration of SR after DCCV was associated with blanking period arrhythmia after subsequent CA, but we did not find evidence of an association with long-term AF recurrence. Clinicians should consider these findings when making decisions regarding suitability for CA or predicting long-term CA success.

Keywords: Persistent atrial fibrillation, catheter ablation, direct current cardioversion, patient selection, atrial remodelling

KEY MESSAGES

What is already known on this topic: Catheter ablation (CA) is an effective treatment for atrial fibrillation (AF), but better patient selection for CA of persistent AF is needed. It is not known whether the duration of sinus rhythm (SR) after DC cardioversion (DCCV), a commonly performed intervention prior to CA, predicts CA success.

What this study adds: In this multicentre, international cohort study, we did not observe an association between the duration of SR after DCCV prior to CA and CA success. However, shorter duration of SR after DCCV was associated with atrial arrhythmias during the post-CA blanking period. Furthermore, we observed that blanking period arrhythmia (including its timing) and presenting rhythm at the time of CA appeared to be associated with long-term CA success.

How this study might affect research, practice, or policy: Clinicians should not use duration of SR after DCCV in isolation to predict long-term CA success, or when making decisions regarding suitability of CA. Our other findings, such as the association between presenting rhythm at time of CA and CA success, may warrant further research testing strategies of SR maintenance prior to CA.

INTRODUCTION

Atrial fibrillation (AF) affects >59 million individuals worldwide.[1] It is associated with significant morbidity and premature mortality related to symptoms, stroke, and heart failure.[2,3] Catheter ablation (CA) is indicated for treatment of symptomatic AF when pharmacological therapies have not been tolerated or provided inadequate symptom control, and for severe left ventricular systolic dysfunction secondary to AF.[4] Despite technical advances, high rates of arrhythmia recurrence are observed after CA for persistent AF (PsAF),[5] highlighting a need for better patient selection.

Direct current cardioversion (DCCV) is commonly performed prior to CA in PsAF, and holds a class IIa recommendation for rhythm control and assessment of symptomatic benefit in sinus rhythm (SR).[4] However, AF commonly recurs after DCCV.[6] Numerous characteristics (clinical [obesity, sleep apnoea, prior duration of AF];[7-9] electrocardiographic [p-wave duration, AF cycle length];[10,11] echocardiographic [indexed left atrial {LA} volume][12]) have been reported to be associated with earlier AF recurrence after DCCV. These are either associated with or indicative of atrial remodelling, suggesting that shorter SR duration after DCCV reflects a more advanced substrate for AF, which could influence the outcome of CA.

We aimed to test this hypothesis by investigating the relationship between SR duration after DCCV for PsAF, and the outcome of subsequent CA.

METHODS

Study Population

We conducted an international multicentre retrospective cohort study across six electrophysiology departments at tertiary centres. Patients meeting inclusion criteria were identified: age >18 years; first-time CA for PsAF between 2015-2024; DCCV for PsAF prior to ablation, with contemporaneously documented post-DCCV SR duration; >90 days' documented follow-up post-ablation. All patients provided written informed consent. Data collection was locally approved and conducted by members of the clinical care team.

Study Procedures

DCCV and CA were performed according to local protocols and contemporary guidelines.[13,14] Antiarrhythmic drug (AAD) use at DCCV was at the discretion of the clinical team: patients were considered not to be on an AAD if this had been discontinued >5 half-lives beforehand. The ablation strategy employed (energy source, lesion sets) was at operator discretion. Generally, pre-existing AADs were continued after CA until review at 3 months.

In the event of symptom recurrence, patients were advised to seek medical attention for a 12-lead ECG and clinical review, and to contact their local cardiac rhythm management service. Most patients were routinely followed up in clinic with a 12-lead ECG at three months, and one year. Ambulatory monitoring was performed when clinically indicated.

Data Collection

Data were collected at each site and collated centrally. The index DCCV was defined as the last DCCV for PsAF prior to first-time CA for PsAF. SR duration post-DCCV was determined by review of contemporaneous records, and was analysed both by dividing the population into three groups (<7, 7-31, and >31 days), and as a continuous variable. Groups were defined based on the existing literature showing that a significant proportion of AF recurrence post-cardioversion occurs within 7 days,[15,16] and subsequently within the first month.[9,16] LA size was defined using LA indexed volume (or LA diameter if not available) based on published reference values.[17,18]

The primary endpoint was freedom from atrial arrhythmia after CA, not including atrial arrhythmias isolated to an 8-week post-ablation blanking period, in line with recent multisociety consensus.[19] Atrial arrhythmia included AF, flutter, or tachycardia, and had to be recorded on a 12-lead ECG or for >30 seconds on implanted or ambulatory monitoring, including single-lead devices, to qualify. All available patient records after CA were reviewed until final follow-up, defined as the last recorded clinical contact. Data on early recurrence of atrial tachyarrhythmia (ERAT) during the blanking period, repeat DCCV, and repeat CA were collected. Rhythm status and symptom scores were documented for final follow-up.

Statistical Analyses

The primary analysis was the relationship between SR duration after the index DCCV and freedom from atrial arrhythmia post-CA. Freedom from atrial arrhythmia was estimated using the Kaplan-Meier method, and its association with post-DCCV SR duration compared between groups using non-parametric log-rank tests. Bonferroni corrections were applied to pairwise comparisons. We performed a pre-specified sensitivity analysis for AAD use at cardioversion, by excluding such patients.

Secondary analyses included the relationship between the primary outcome and SR duration after DCCV as a continuous variable using a Cox regression model, adjusted analyses with a multivariable Cox regression model (using the "Enter" method; see ***Supplement***), and for the relationships between the following factors and the primary outcome: i. ERAT during the blanking period; ii. timing of ERAT; iii. presenting rhythm at ablation. ERAT[20,21] and rhythm at ablation[22,23] have both been reported to be associated with long-term outcomes after ablation. For ERAT, all recurrences during the blanking period were reviewed, and the timing of the last episode used. Patients with ERAT who exited the blanking period in AF were excluded. For the analysis of presenting rhythm, patients were categorised as being in atrial arrhythmia or SR on the day of ablation.

Post-ablation interventions were compared. Repeat DCCVs were compared using negative binomial regression modelling (due to high prevalence of zero-event subjects and overdispersion) and the likelihood ratio test. Zero-inflated models were utilised in sensitivity analyses. The prevalence of pulmonary vein (PV) reconnection at first repeat ablation was compared.

Statistical analyses were performed using StatPlus:mac (v7.1.1.0), Microsoft Excel (v16.80), and R (v4.3.1). For survival analyses, participants were observed from index CA until primary outcome occurrence, or censoring at last clinical follow-up or death. Given a low incidence of competing events, competing risks analyses were not utilised. The proportional hazards assumption was assessed using Schoenefeld residual plots with time-dependent effect modelling for violations; linearity for quantitative predictors was assessed using penalised splines within the Cox model. Parametric continuous variables are shown as mean (standard deviation), non-parametric continuous variables as median (interquartile range), and categorical variables as frequency (percentage). Normality was assessed by inspection of histograms and Q-Q plots, and homogeneity of variance using Levene’s test. Normally distributed data were compared using one-way analyses of variance (ANOVA), unless where variance was unequal when Welch’s ANOVA was used. Non-normally distributed unpaired data were compared using the Kruskal-Wallis test. Proportions were compared using the Chi-square test, unless >20% of cells had an expected value <5 or any single expected count was

<1, when the Fisher's exact test was used. All tests were two-tailed, and p-values <0.05 were considered significant.

Patient and public involvement

None.

RESULTS

Baseline characteristics

938 patients were identified, with mean age 62.5 (10.9) years, 75% male, and median CHA_2DS_2-VASc score 2 (1-3; **Table 1**). SR was achieved acutely after 909 (97%) DCCVs. The median time in SR after DCCV was 36 (7-91) days (**Figure 1**).

Patients were divided into three groups based on the duration of SR observed after cardioversion (group 1, <7 days; group 2, 7-31 days; group 3, >31 days). Patients in group 1 had a lower prevalence of heart failure and hypertension, and a greater proportion underwent single DCCV prior to CA. A greater proportion of patients in group 3 were on amiodarone at index DCCV (**Table 1**).

Catheter Ablation

Most patients presented on the day of CA in atrial arrhythmia (666, 71%), including a higher proportion of patients in groups 1 and 2 (88%), as expected (**Table 2**). Most patients underwent PV isolation only (PVI; a higher proportion in group 1) using radiofrequency ablation (**Table 2**). There was a high acute procedural success rate (>99%). The incidence of complications was low, with the most common being access-site-related vascular events (2%).

244 patients (26%) experienced ERAT within 8 weeks post-ablation. The proportion of patients experiencing ERAT was significantly higher in groups 1 and 2 compared with group 3 after applying a *post hoc* Bonferroni correction for pairwise testing (both $p<0.001$; **Table 3**).

Primary Outcome: Freedom from Atrial Arrhythmia after the Blanking Period

Over median follow-up of 511 (351-1113) days after CA, recurrence of atrial arrhythmia after the blanking period was observed in 512 (55%) patients (**Table 3**). 426 (45%) were censored: 9 for death, and the remainder at last follow-up without occurrence of the primary endpoint. The median time free from atrial arrhythmia recurrence was 497 (95% CI 436-596) days. There was no significant difference in the time to the first recurrence of atrial arrhythmia after the blanking period among the three groups (p=0.10; **Figure 2**), including on pairwise testing (Bonferroni-adjusted p-values: 1 vs 2 p=1.00, 1 vs 3 p=0.14, 2 vs 3 p=0.41); a secondary analysis including only AF and flutter recurrences likewise showed no differences (p=0.19; ***Figure S1***). When duration of SR after DCCV was analysed as a continuous variable, there was no significant effect on the time to first recurrence of atrial arrhythmia after the blanking period (hazard ratio [HR] 1.00 per ten-day increment in post-DCCV SR duration, 95% CI 1.00-1.01, p=0.07). Although Schoenfeld residual plots suggested a minor violation of the proportional hazards assumption (***Figure S2A***, p=0.02), modelling as a time-dependent effect resulted in similar effect sizes (***Table S1***). Adjustment in a multivariable Cox regression model also showed no significant effect (HR 1.00, 95% CI 1.00-1.00, p=0.42; ***Table S2***).

Repeat Interventions

569 post-ablation DCCVs were performed in 325 patients (35%; **Table 3**; ***Figure S3***), with an overall incidence rate of 0.29 DCCVs/patient-year. The incidence rate of post-ablation DCCVs was similar between groups (likelihood ratio test p=0.17), with no significant differences on Bonferroni-adjusted pairwise testing.

346 repeat catheter ablations were performed in 303 patients (32%). Procedural data for the first repeat ablation was available for 301/303 procedures. PV reconnection was noted in 189/301 (63%), with no significant between-group difference (p=0.37; **Table 3**).

Follow-Up

At final follow-up, 46% (435/938) of the cohort were in SR off AADs, which was similar across groups (p=0.54; **Table 3**). AADs were otherwise continued in 25% (237/938). Symptoms relative to pre-ablation status, graded as improved (complete or partial resolution), or no improvement (unchanged or worsened), were available for 869/938 patients. Most patients reported improved symptoms (797/869, 92%), with no significant between-group difference (p=0.41).

Sensitivity Analysis Excluding AAD Use

We performed a pre-specified sensitivity analysis for AAD use at cardioversion, by excluding all such patients across the three groups (***Tables S3, S4***). Over median post-ablation follow-up of 512 (355-1182) days, atrial arrhythmia recurred in 246/450 (55%) patients, with no significant between-group difference (p=0.24; **Figure 3**).

Rhythm at Time of Ablation

Data were available for 936 patients. Presentation for ablation in persistent atrial arrhythmia was associated with a significantly increased risk of atrial arrhythmia recurrence when compared with presentation in SR (p<0.001; **Figure 4**). Due to violation of the proportional hazards assumption (***Figure S2B***), presenting rhythm was modelled as a time-dependent variable, demonstrating an early effect of presentation in persistent atrial arrhythmia, which attenuated over time and crossed HR=1 at 668.5 days (adjusted HR [95% CI] at six months: 1.67 [1.35-2.07]; one year: 1.27 [1.01-1.59]; ***Table S1***, ***Figure S4***).

Blanking Period: Implications of Timing and Removal

Finally, we sought to examine the relevance of timing of ERAT within the blanking period, and the implications of removing the blanking period. 830 patients were included in the analysis of the impact of ERAT timing on long-term recurrence (***Table S5***). Patients were excluded because of insufficient data on ERAT (n=8) and exit from the blanking period in atrial arrhythmia (n=100). The presence of ERAT (compared with no ERAT) was associated with a significantly increased risk of long-term recurrence of atrial arrhythmia (HR 2.13, 95% CI 1.70-2.66, p<0.001). Its timing was important, with later recurrence conferring greater risk (compared with no ERAT: ERAT within 28 days [HR 1.63, 95% CI 1.20-2.23, p=0.002], 29-56 days [HR 3.11, 95% CI 2.31-4.17, p<0.001]; **Figure 5**). A separate *post hoc* survival analysis without any blanking period showed that post-DCCV SR duration was associated with time to first recurrence of atrial arrhythmia after CA (***Figure S5***).

DISCUSSION

Here, we report the results of an international multicentre cohort study of patients undergoing CA for PsAF with prior DCCV. Although we demonstrate that shorter duration of SR after DCCV is associated with ERAT after subsequent CA, we did not find evidence of an association with long-term AF recurrence. These findings were replicated in a sensitivity analysis that excluded patients on AADs at the time of cardioversion. Finally, we noted that presentation for CA with persistent atrial arrhythmia, and ERAT, were associated with greater probability of long-term AF recurrence.

There may be a tendency for clinicians managing patients with PsAF to incorporate SR duration following DCCV into the decision-making process for CA. However, these data indicate that there is no clinically significant association between early recurrence of AF post-DCCV and suboptimal outcome following subsequent AF ablation. Patients with PsAF who experience recurrence of AF soon after DCCV may do so due to an advanced atrial substrate, but equally may also do so due to a high burden of atrial or PV ectopy,[24] which may drive ERAT after CA during the consolidation phase of PVI. This might explain the increased incidence of ERAT in groups 1 and 2. Whilst the former (advanced atrial substrate) implies a lower success rate of CA, PVI would be expected to have a high rate of success in the latter (atrial or PV ectopy). Hence, duration of SR maintenance after DCCV should not, in isolation, influence decision-making regarding suitability for CA or be used to predict long-term CA success.

DCCV in Persistent AF

The role of post-DCCV SR duration in predicting CA success for PsAF has not been well-studied. One study reported that patients who maintained SR for >24 hours after DCCV were more likely to remain free of AF after CA.[25] However, this was a small single-centre study (n=195), and the mean AF duration at enrolment was 25 months, suggesting a high proportion of long-standing PsAF. Patients were dichotomized at 24 hours' post-DCCV SR, but our data show post-DCCV SR varies widely. Finally, only half of the patients undergoing DCCV proceeded to CA, and those who had recurrence of AF within 24 hours were less likely to undergo CA, highlighting existing clinical biases.

Conversely, another study reported that CA in 60 patients with PsAF despite AAD therapy and at least one prior DCCV with recurrent AF, was associated with significant reduction in AF burden, suggesting that patients with pharmacological and DCCV-resistant AF may still benefit from CA.[26] Beyond DCCV, the success of amiodarone therapy in maintaining SR in patients with AF prior to CA does not appear to be associated with successful CA.[27] Taken together, these results support the notion that the results of pre-ablation rhythm control may not correlate well with subsequent CA success in PsAF.

The Post-Ablation Blanking Period

We report that ERAT is associated with long-term atrial arrhythmia recurrence, and that later timing of ERAT is associated with greater risk of long-term recurrence. Traditionally, ERAT has been considered to represent transient pro-arrhythmia after LA ablation, with no long-term implications. However, mounting evidence suggests that ERAT is partially associated with long-term recurrence,[20,21] which may aid identification of patients where ablation lesion sets have failed (PV reconnection) or been insufficient (non-PV triggers, LA flutter), who might benefit from early re-intervention. Our data are consistent with the notion that ERAT, including its timing, carries prognostic implications for long-term ablation success.[20,21] Future studies may seek to clarify the optimal duration of the blanking period, and features of ERAT (e.g. number of episodes,[28] burden[29]) to refine patient selection for re-intervention.

While our *post hoc* analysis without a blanking period suggested that post-DCCV SR duration was associated with recurrence of atrial arrhythmia after CA, it is important to note that this is not recommended reporting practice: the blanking period still holds clinical value for balancing the benefits of early re-intervention against its risks and potential transience of arrhythmia. Other outcomes reported here (repeat intervention, final follow-up symptom/rhythm/AAD status) may provide a more holistic, patient-centred set of endpoints.

Rhythm at Ablation

We observed that presentation for ablation in SR was associated with greater freedom from AF recurrence, in keeping with previous studies.[22,23] Presentation in SR may be a surrogate for more sustained periods of SR between DCCV and CA, associated with greater positive atrioventricular remodelling,[30] leading to improved outcomes. Our observation that this is a time-dependent attenuating effect is biologically plausible, as pre-CA remodelling likely predominantly determines early post-CA atrial substrate, being gradually superseded by post-CA exposures; nevertheless, a strategy delivering improved early post-CA SR maintenance may still be of clinical value.

Limitations

Although this was a large multicentre study, its retrospective design means the possibilities of residual confounding and treatment bias remain, and an *a priori* sample size calculation was not undertaken. Some between-group differences were observed: more patients in group 1 had prior cardioversions, underwent PVI only, and had radiofrequency ablation. Whether this reflects underlying biological differences between groups is unclear; ablation energy and strategy have not consistently been shown to affect outcomes, and we did not find an effect of SR duration when analysed as a continuous variable, including after multivariable adjustment. In our study, rhythm monitoring was performed in line with local protocols, consisting of clinical follow-up with a 12-lead ECG two to three months and one year post-ablation, with symptom-led application of extended rhythm monitoring; recurrences were also detected through patient-led re-presentations. This approach is in keeping with real-world practice and consensus recommendations.[14,19] While the incidence of recurrent atrial arrhythmias in this cohort after CA[5,30] and SR duration post-DCCV[6-12,15,16,25] are consistent with the published literature, our study is limited by the lack of universal application of extended rhythm monitoring, and potential differences in utilisation. These are challenging to implement across large populations but increase detection of post-ablation atrial arrhythmia recurrence. While data on post-CA pharmacological cardioversions were not available, there was no difference in AAD use at final follow-up or utilisation of other rhythm control measures. Finally, it was not possible to determine the total number of patients undergoing DCCV across the included centres, as patients also underwent DCCV at outside referral centres.

CONCLUSION

In this large multicentre contemporary cohort, shorter duration of SR after DCCV for PsAF was associated with blanking period arrhythmia after CA, but we did not find an association with long-term AF recurrence. Clinicians should consider these findings when assessing suitability for CA.

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DATA AVAILABILITY STATEMENT

The data underlying this article will be shared on reasonable request to the corresponding author.

CONTRIBUTORSHIP STATEMENT

PTT, RSW, and MRG were responsible for the original conception and design of the study, which was supplemented by all other authors (AA, GV, JHC, JH, KEJ, HE, CAR, RLMG, AH, ML, SK, SA, MA, BM, NA, RA, RJH, HV, KA, SH, TRB, MP, KR, YB). All authors (PTT, AA, GV, JHC, JH, KEJ, HE, CAR, RLMG, AH, ML, SK, SA, MA, BM, NA, RA, RJH, HV, KA, SH, TRB, MP, KR, YB, RSW, MRG) were involved in extraction of raw data from the involved centres. PTT performed statistical analyses and wrote the first draft. All authors critically revised the manuscript for important intellectual content including revisions, additional analyses, and discussion. AA contributed to substantial revisions of the paper. RSW and MG are joint senior authors and provided overall supervision. PTT is the guarantor of the article. All authors read and approved the final manuscript.

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TABLE LEGENDS

Table 1. Clinical Characteristics of Patients at Index DC Cardioversion.

Baseline demographics and cardioversion characteristics of overall patient cohort and patients grouped by duration of sinus rhythm post-DC cardioversion (Group 1, <7 days; Group 2, 7-31 days; Group 3, >31 days). CVA, cerebrovascular accident; DCCV, DC cardioversion; IQR, interquartile range; PsAF, persistent AF; SD, standard deviation; TIA, transient ischemic attack.

Table 2. Details of Ablation for Persistent AF.

Ablation details for patients grouped by duration of sinus rhythm post-DC cardioversion. Acute procedural success was defined as the successful delivery of ablation to achieve pulmonary vein isolation and exit from the electrophysiology laboratory in sinus rhythm. CFAE, complex fractionated atrial electrograms; CS, coronary sinus; CTI, cavotricuspid isthmus; PVI, pulmonary vein isolation; PVI+, pulmonary vein isolation and other targets; PWI, posterior wall isolation.

Table 3. Outcomes of Ablation Through to Final Follow-Up.

Ablation outcomes for patients grouped by duration of sinus rhythm post-DC cardioversion.

FIGURE LEGENDS

Figure 1. Post-DC Cardioversion Duration of Sinus Rhythm.

Cumulative proportion of patients remaining in sinus rhythm after index DC cardioversion over time. Shaded area represents the 95% confidence band.

Figure 2. Post-DC Cardioversion Duration of Sinus Rhythm and Freedom from Atrial Arrhythmia after Catheter Ablation.

Kaplan-Meier curves comparing freedom from the primary endpoint between groups as categorized by duration of sinus rhythm after DC cardioversion.

Figure 3. Post-DC Cardioversion Duration of Sinus Rhythm and Freedom from Atrial Arrhythmia after Catheter Ablation Excluding Patients on Anti-Arrhythmic Drugs at time of DC Cardioversion.

Kaplan-Meier curves comparing freedom from the primary endpoint between groups as categorized by duration of sinus rhythm after DC cardioversion for patients not on anti-arrhythmic drugs at time of index cardioversion.

Figure 4. Association between Presenting Rhythm at Catheter Ablation and Survival free from Atrial Arrhythmia after the Blanking Period.

Kaplan-Meier curves comparing freedom from the primary endpoint based on rhythm at time of catheter ablation.

Figure 5. Timing of Early Recurrence of Atrial Fibrillation During the Blanking Period and Freedom from Atrial Arrhythmia after Catheter Ablation.

Kaplan-Meier curves comparing freedom from the primary endpoint between groups based on the presence and timing of early recurrence of atrial arrhythmia during the 8-week blanking period.

Table 1. Clinical Characteristics of Patients at Index DC Cardioversion.

Characteristic	Overall (n=938)	Group 1 (n=212)	Group 2 (n=236)	Group 3 (n=490)	P value
Baseline demographics (at time of index DCCV)					
Mean age, years (SD)	62.5 (10.9)	62.1 (9.6)	63.1 (10.9)	62.3 (11.4)	0.614
Female gender, n (%)	236 (25)	57 (27)	60 (25)	119 (24)	0.762
Median time since PsAF diagnosis, years (IQR)	0.7 (0.3-1.5)	0.7 (0.4-1.5)	0.6 (0.3-1.1)	0.7 (0.3-1.6)	0.077
Median duration of PsAF episode at time of DCCV, years (IQR)	0.2 (0.0-0.5)	0.3 (0.1-0.6)	0.1 (0.0-0.4)	0.1 (0.0-0.4)	<0.001
Mean body mass index, kg/m^2 (SD)	29.7 (5.4)	29.5 (5.3)	29.9 (5.7)	29.6 (5.3)	0.772
Heart failure, n (%)	173 (18)	26 (12)	52 (22)	95 (19)	0.021
Hypertension, n (%)	452 (48)	87 (41)	124 (53)	241 (49)	0.042
Diabetes mellitus, n (%)	110 (12)	20 (9)	31 (13)	59 (12)	0.455
Previous TIA/CVA, n (%)	52 (6)	16 (8)	17 (7)	19 (4)	0.065
Vascular disease, n (%)	83 (9)	22 (10)	20 (9)	41 (8)	0.672
Median CHA_2DS_2-VASc (IQR)	2 (1-3)	2 (0.75-3)	2 (1-3)	2 (1-3)	0.326
Left ventricular ejection fraction <35%, n (%)	121 (13)	19 (9)	36 (15)	66 (13)	0.121
Left atrial size					
Normal, n (%)	181/648 (28)	60/173 (35)	32/152 (21)	89/323 (28)	0.109
Mild enlargement, n (%)	169/648 (26)	40/173 (23)	47/152 (31)	82/323 (25)	
Moderate enlargement, n (%)	138/648 (21)	38/173 (22)	29/152 (19)	71/323 (22)	
Severe enlargement, n (%)	160/648 (25)	35/173 (20)	44/152 (29)	81/323 (25)	
No data, n	290	39	84	167	N/A
Index DCCV Characteristics					
Median prior cardioversions (IQR)	0 (0-1)	1 (0-1)	0 (0-1)	0 (0-1)	<0.001
First-time cardioversion, n (%)	501 (53)	104 (49)	152 (64)	245 (50)	<0.001
Antiarrhythmic drug use					
Amiodarone, n (%)	356 (38)	80 (38)	72 (31)	204 (42)	0.015
Sotalol, n (%)	62 (7)	11 (5)	18 (8)	33 (7)	0.576
Flecainide/other class I antiarrhythmic, n (%)	74 (8)	19 (9)	21 (9)	34 (7)	0.528
Cardioversion Modality					
External, n (%)	816 (87)	189 (89)	209 (89)	418 (85)	0.348

Internal (including via implanted device), n (%)	33 (4)	9 (4)	8 (3)	16 (3)	
No data	90 (10)	15 (7)	19 (8)	56 (11)	N/A
Median shocks delivered (IQR)	1 (1-1)	1 (1-2)	1 (1-1)	1 (1-1)	0.001
Restoration of sinus rhythm after single shock, n (%)	592/701 (84)	107/153 (70)	163/191 (85)	321/359 (89)	<0.001
Median time from index DCCV to ablation, days (IQR)	149 (68-293)	152 (70-260)	106 (50-226)	170 (76-381)	<0.001
Median diagnosis to ablation time, years (IQR)	1.2 (0.8-1.4)	1.2 (0.8-2.5)	1.0 (0.7-1.9)	1.4 (0.8-2.7)	<0.001

Table 2. Details of Ablation for Persistent AF.

Characteristic	**Group 1 (n = 212)**	**Group 2 (n = 236)**	**Group 3 (n = 490)**	**P value**
Presenting Rhythm				
Any atrial arrhythmia, n (%)	186/212 (88)	208/235 (89)	272/489 (56)	<0.001
Sinus rhythm, n (%)	26/212 (12)	27/235 (11)	217/489 (44)	
Unknown, n (%)	0	1	1	
Ablation Strategy/Lesions				
PVI, n (%)	164/211 (78)	129/235 (55)	285/485 (59)	<0.001
PVI +, n (%)	47/211 (22)	106/235 (45)	200/485 (41)	
Linear ablations, n (%)	24 (11)	27 (11)	36 (7)	Not performed
CFAE, n (%)	3 (1)	2 (0.8)	8 (2)	
PWI, n (%)	21 (10)	81 (34)	158 (32)	
CS ablation, n (%)	1 (0.5)	6 (3)	2 (0.4)	
Focal ablation, n (%)	6 (3)	8 (3)	12 (2)	
CTI ablation, n (%)	25 (12)	25 (11)	32 (7)	
No data, n (%)	1	1	5	
Ablation Technology				
Radiofrequency ablation, n (%)	178 (84)	150 (64)	323 (66)	<0.001
Cryoballoon ablation, n (%)	20 (9)	24 (10)	62 (13)	
Pulsed field ablation, n (%)	11 (5)	62 (26)	105 (21)	
Laser balloon ablation, n (%)	3 (1)	0	0	
Acute Procedural Success				
Success, n (%)	210 (99)	236 (100)	489 (99.8)	N/A
Failure, n (%)	2 (1)	0	1 (0.2)	
Sinus rhythm restored during ablation, n (%)	27 (13)	65 (28)	138 (28)	<0.001
Complications				
Access site complications, n (%)	7 (3)	6 (3)	8 (2)	Not performed
Major bleeding, n (%)	0	0	1 (0.2)	
Pericardial effusion/tamponade, n (%)	2 (0.9)	3 (1)	5 (1)	
Stroke, n (%)	0	0	1 (0.2)	
Atrio-oesophageal fistula, n (%)	0	0	0	

Table 3. Outcomes of Ablation Through to Final Follow-Up.

Characteristic	Group 1 (n = 212)	Group 2 (n = 236)	Group 3 (n = 490)	P value
Follow-Up				
Median follow-up, days (IQR)	468 (360-1018)	493 (341-899)	548 (350-1219)	0.285
Atrial arrhythmia during blanking period, n (%)	88 (42)	64 (27)	92 (19)	<0.001
Atrial arrhythmia after blanking period, n (%)	121 (57)	134 (57)	257 (52)	N/A
*Atrial fibrillation, n**	103	107	216	
*Atrial flutter, n**	10	8	20	
*Atrial tachycardia, n**	18	30	40	
Post-Ablation Rhythm Interventions				
DC cardioversion after index ablation, n (%)	87 (41)	83 (35)	155 (32)	N/A
Total DC cardioversions after index ablation, n	142	139	288	N/A
Incidence of DC cardioversions after index ablation, n/patient-year	0.33	0.31	0.27	0.167
Repeat catheter ablation, n (%)	63 (30)	88 (37)	152 (31)	0.157
Pulmonary vein reconnection at first repeat ablation, n (%)	40/63 (63)	50/88 (57)	99/150 (66)	0.365
Data unavailable	0	0	2	N/A
Total repeat ablation, n	73	94	179	N/A
Final Follow-Up: Rhythm, Symptoms, Antiarrhythmic Drug Use				
Sinus rhythm without intervention <6 months, off antiarrhythmics, n (%)	101 (48)	115 (49)	219 (45)	0.544
Antiarrhythmic Use at Final Follow-up				
Amiodarone, n (%)	15 (7)	41 (17)	83 (17)	0.001
Sotalol, n (%)	10 (5)	6 (3)	24 (5)	0.316
Flecainide/other class I antiarrhythmic, n (%)	13 (6)	13 (6)	33 (7)	0.811
Symptomatic Change				
Symptoms improved, n (%)	181/202 (90)	202/217 (93)	414/450 (92)	0.413
No symptom improvement, n (%)	21/202 (10)	15/217 (7)	36/450 (8)	
No data, n	10	19	40	N/A
Mortality	5 (2)	4 (2)	8 (2)	N/A

*In some cases, multiple types of recurrent arrhythmias documented.