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CLINICAL RESEARCH

Repeat catheter ablation after very late recurrence of atrial fibrillation after pulmonary vein isolation

Niklas Stauffer [1,2], Sven Knecht [1,2], Patrick Badertscher [1,2], Philipp Krisai [1,2], Elisa Hennings [1,2], Teodor Serban [1,2], Gian Voellmin [1,2], Stefan Osswald [1,2], Christian Sticherling [1,2], and Michael Kühne [1,2]*

[1]Department of Cardiology, University Hospital Basel, Petersgraben 4, 4031 Basel, Switzerland; and [2]Cardiovascular Research Institute Basel, University Hospital Basel, Spitalstrasse 2, 4056 Basel, Switzerland

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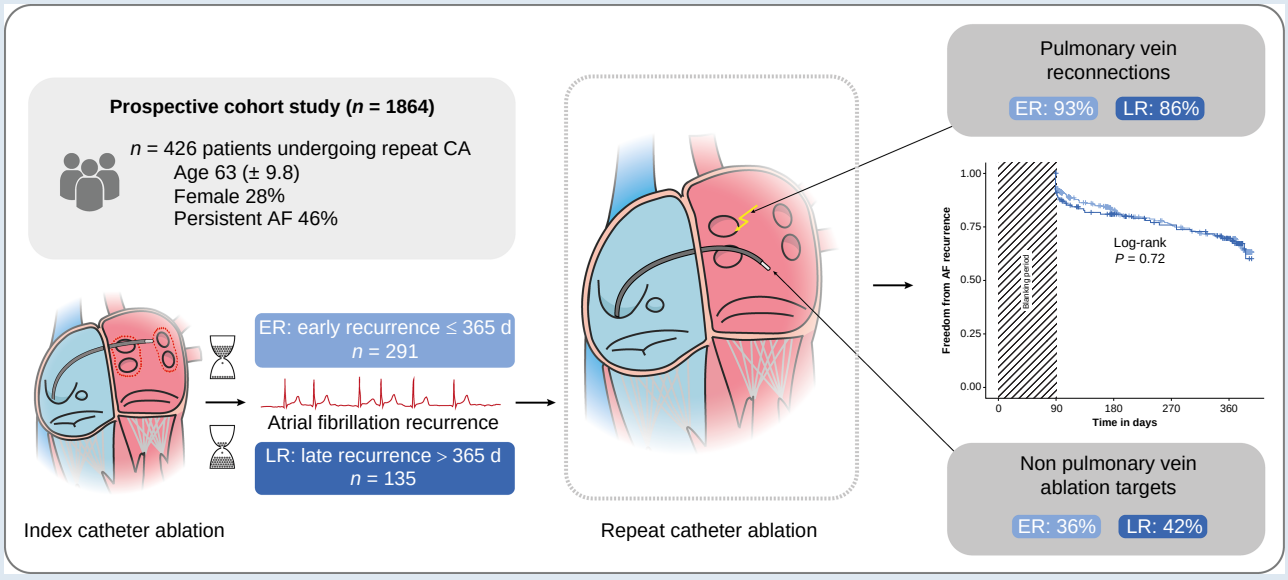
Aims Atrial fibrillation (AF) recurs in about one-third of patients after catheter ablation (CA), mostly in the first year. Little is known about the electrophysiological findings and the effect of re-ablation in very late AF recurrences (VLR) after more than 1 year. The aim of this study was to determine the characteristics and outcomes of the first repeat CA after VLR of AF after index CA.

Methods and results We analysed patients from a prospective Swiss registry that underwent a first repeat ablation procedure. Patients were stratified depending on the time to recurrence after index procedure: early recurrence (ER) for recurrences within the first year and late recurrence (LR) if the recurrence was later. The primary endpoint was freedom from AF in the first year after repeat ablation. Out of 1864 patients included in the registry, 426 patients undergoing a repeat ablation were included in the analysis (28% female, age 63 ± 9.8 years, 46% persistent AF). Two hundred and ninety-one patients (68%) were stratified in the ER group and 135 patients (32%) in the LR group. Pulmonary vein reconnections were a common finding in both groups, with 93% in the ER group compared to 86% in the LR group ($P = 0.052$). In the LR group, 40 of 135 patients (30%) had a recurrence of AF compared to 90 of 291 patients (31%) in the ER group (log-rank $P = 0.72$).

Conclusion There was no association between the time to recurrence of AF after initial CA and the characteristics and outcomes of the repeat procedure.

* Corresponding author. Tel: +41612652525. *E-mail address*: michael.kuehne@usb.ch

Graphical Abstract



Keywords Atrial fibrillation • Repeat ablation • Pulmonary vein isolation • Very late recurrence

What's new?

- In this large cohort study, there was no association between the time to recurrence of atrial fibrillation (AF) after an initial pulmonary vein isolation and the outcome of the first repeat catheter ablation.
- Pulmonary vein reconnections were a common finding, also in patients with a very late recurrence of AF after the index procedure.
- The findings were consistent in patients with paroxysmal and persistent AF and in patients undergoing radiofrequency ablation or cryo-ablation during the index procedure.

Introduction

Catheter ablation (CA) is a well-established treatment for atrial fibrillation (AF) improving quality of life and AF-related symptoms.[1] When compared with treatment with antiarrhythmic drugs (AADs), CA achieves a substantial reduction in recurrence of atrial arrhythmias and hospitalizations.[2,3] Because the pulmonary veins (PVs) are recognized as the major trigger of AF,[1,4,5] CA primarily aims at sustained electrical isolation of PV (PVI) from the left atrium. Despite evolving techniques and different sources of energy, arrhythmia recurrences after CA remain a clinical challenge.[6–9] Depending on the type of AF (persistent vs. paroxysmal) and patient characteristics, single-procedure success rates at 12 months vary between 52 and 88%[10–12] with most of the arrhythmia recurrences occurring in the first year after ablation.[13] Pulmonary vein reconnection is thought to be the predominant mechanism of recurrence, with lower rates in later recurrences.[13–16] While the clinical relevance of very late recurrences (VLRs) is increasingly recognized,[1,17,18] little is known about the electrophysiological findings and the effect of re-ablation in this setting.

The aim of this study was to determine the outcomes and characteristics (including PV reconnections) of the first repeat CA after VLR (>365 days) of AF after index CA procedure in comparison with repeat CA after earlier recurrences within the first year after index CA.

Methods

Study design and population

The study was conducted using the Swiss Atrial Fibrillation Pulmonary Vein Isolation (SWISS-AF PVI) registry (ClinicalTrials.gov identifier: NCT03718364), an ongoing prospective cohort study in Switzerland, enrolling adult patients with paroxysmal or persistent AF undergoing PVI. The study was approved by the local ethics committee (Ethikkommission Nordwest- und Zentralschweiz), and all patients provided their written consent. In our analysis, we included patients that underwent a first repeat ablation procedure between April 2010 and December 2021 at our institution. The index PVI procedure was performed using radiofrequency (RF) energy or cryo-energy. Patients that underwent a surgical index ablation procedure or an ablation procedure at an outside hospital were excluded.

Study procedures and catheter ablation

Repeat ablation procedures were conducted using RF energy and irrigated-tip ablation catheters in combination with a 3D electro-anatomic mapping system (Carto3, Biosense Webster, Inc., Irvine, CA, USA) and a multipolar mapping catheter (Pentaray, Biosense Webster, Inc., Irvine, CA, USA). Before the procedure, transoesophageal echocardiography was performed to rule out thrombus in the left atrial appendage. Antiarrhythmic drugs were stopped at the time of the procedure. To access the left atrium, a fluoroscopy-guided transseptal puncture was performed. The procedures focused on the identification and ablation of PV reconnections. Additional lesions [cavotricuspid isthmus line, mitral isthmus line, roof line, posterior box, superior vena cava isolation, vein of Marshall ethanol ablation, complex fractionated atrial electrogram (CFAE) ablation] were at the discretion of the operator. In the case of peri-mitral flutter, a mitral isthmus line was the standard approach. The position of the mitral isthmus line (antero-medial, antero-lateral, or postero-lateral) was at the discretion of the operator. Re-isolation of the PVs was confirmed by entrance block. If performed, bidirectional block across additional lines was confirmed by differential pacing.

Follow-up

Standard follow-up visits were scheduled at 3, 6, and 12 months after repeat ablation and included a detailed physical examination, a 12-lead

electrocardiogram (ECG), and a 7-day Holter ECG recording. Additionally, 12-lead ECGs and 7-day Holter recordings were performed in case of symptoms independent of the follow-up scheme.

Outcomes

The primary endpoint was the efficacy of the first repeat ablation defined as freedom from AF during the first year after repeat PVI procedure. Atrial fibrillation recurrence was defined according to the 2017 expert consensus statement on catheter and surgical ablation of AF[1] as any documented episode of AF, atrial flutter, or atrial tachycardia lasting longer than 30 s. According to current guidelines, we applied a blanking period of 90 days[1,19] after the ablation procedure.

Statistical analysis

The patients were stratified based on the time to the first recurrence of AF after the index procedure: in this analysis, ER was defined as a recurrence within the first year after index ablation, whereas a recurrence occurring after the first 365 days after index procedure was defined as a LR. These definitions deviate from the expert consensus statement,[1] where an ER denotes an AF recurrence within the first 3 months, a LR is defined as a recurrence between 90 days and 1 year after CA, and a VLR is defined as a recurrence >1 year after CA. Categorical variables were expressed as numbers (percentages) and compared using χ^2 tests and Fisher's exact tests as appropriate. Continuous variables were reported as means ± standard deviation (SD) or, if strongly skewed, median (interquartile range) and compared with Student's *t*-tests and Wilcoxon's rank sum tests, respectively. The primary outcome (freedom from AF) was calculated as the time from the repeat procedure in days until the first documented recurrence of AF. In the case of dropout or loss to follow-up, appropriate censoring was applied. The primary outcome was displayed using Kaplan–Meier curves and compared with a log-rank test. Cox proportional hazards models were fitted to identify associations between the outcome of the repeat procedure and the time to recurrence after the first ablation procedure. We used the dichotomized strata ER vs. LR in an unadjusted model (model 1) and in two corrected multivariable models (model 2: age, sex; model 3: age, sex, hypertension, type of AF, left ventricular ejection fraction, indexed left atrial volume). Additionally, we fitted an unadjusted model using the time to AF recurrence after index procedure and the time between index and repeat procedure as a continuous variable. The Cox proportional hazards assumption was verified using the Schoenfeld residuals. The presented *P*-values are two-sided. A *P*-value ≤0.05 was regarded as statistically significant. All analyses were performed using the statistical software R version 4.2.3.

Results

Study population

Out of 1864 patients undergoing CA for AF between April 2010 and December 2021, 557 patients underwent a first repeat procedure at our institution. Of these 557 patients, 33 patients were excluded because they underwent an index procedure at an outside hospital or had a prior surgical ablation procedure. Ninety-five patients were excluded because follow-up information was incomplete. Three patients were excluded, because the repeat procedure was performed without a 3D electro-anatomic mapping system using cryo-energy (*Figure 1*).

Baseline characteristics

Of the 426 patients included in the final analysis, 117 patients (28%) were female, the mean age was 63 (±9.8) years, and 195 patients (46%) had persistent AF. The patients were stratified into two groups: ER ($n = 291$, 68%) and LR ($n = 135$, 32%). The median time to AF recurrence after index intervention was 208 days (ER) and 867 days (LR). Except for differences in age and the prevalence of smoking, there were no differences in the baseline parameters (*Table 1*).

Pulmonary vein reconnections

At the repeat procedure, 378 patients (91%) had PV reconnections with a mean of two reconnected PVs (±1.1). In the ER group, 266 patients (93%) had PV reconnections, compared to 112 patients (86%) in the LR group ($P = 0.052$). Right inferior pulmonary vein was the most common PV to be reconnected in a total of 256 patients (61%, overall), in 175 patients (61%) in the ER group and in 81 patients (62%) in the LR group (*Table 2* and *Figure 2*). Although there was no difference in the number of patients with reconnected PVs after an index ablation using cryo-energy [97/112 patients (89%)] compared to RF energy [281/314 patients (91%)], there were significantly more reconnected PVs in patients after index procedures using RF energy with a mean of 2.1 (±1.1) reconnected PVs compared to a mean of 1.8 (±1.1) PVs after index procedures using cryo-energy ($P = 0.024$). Also, left superior pulmonary vein (LSPV) was more likely to be reconnected after index procedures using RF energy in 156 patients (50%) compared to 34 patients (31%) after index procedures using cryo-energy ($P = 0.001$) (see Supplementary material online, *Table S1*).

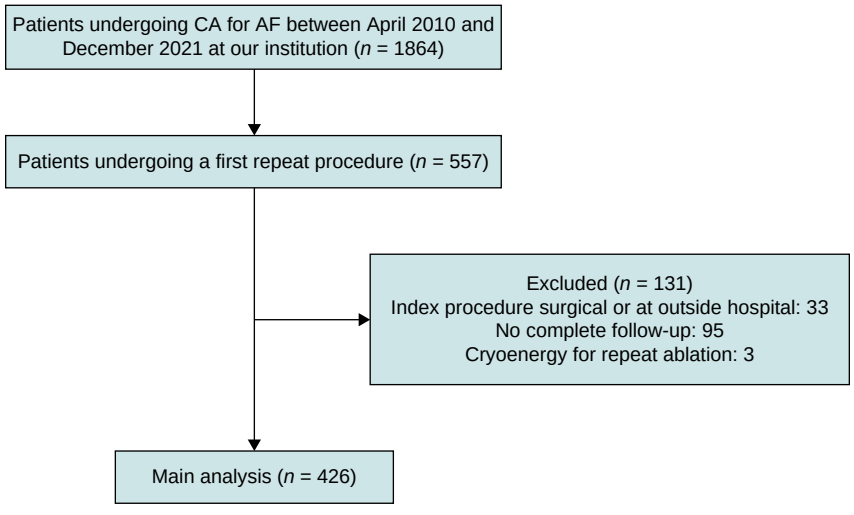


Figure 1 Patient flow diagram. AF, atrial fibrillation; CA, catheter ablation.

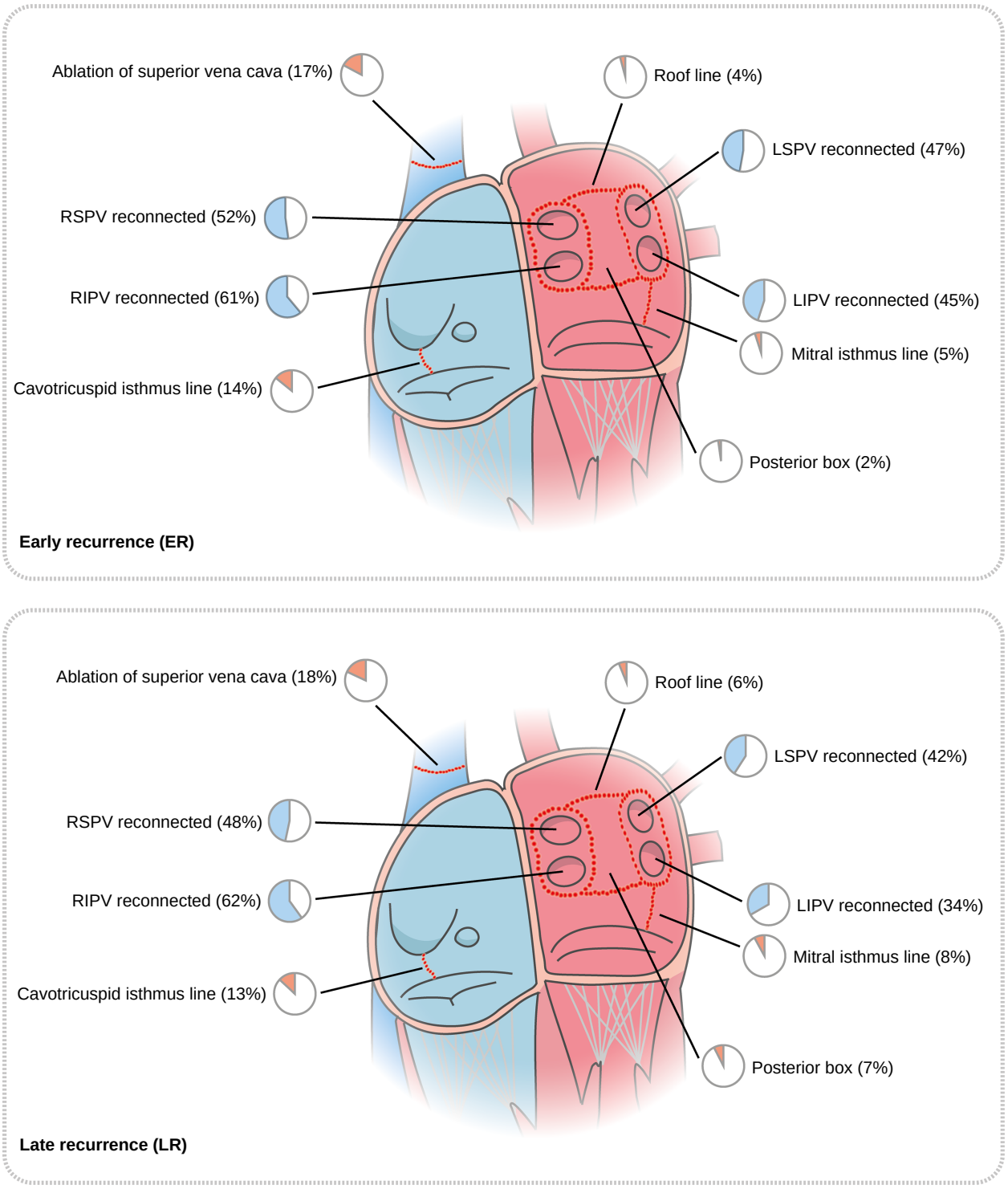


Figure 2 Procedural characteristics. Visualization of the rates of pulmonary vein reconnections and the location and rate of the ablation targets performed during the repeat procedures in the group ER and LR. The percentages are visualized by pie charts. For reasons of clarity, vein of Marshall, CFAEs, and other arrhythmia ablations are not shown. RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein; LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein. See *Table 2* for details.

Table 1 Baseline characteristics, overall and stratified by ER and LR

Variable	Overall	Early recurrence	Late recurrence	*P*
n	426	291	135	
Time to AF recurrence after index ablation [days] [median (IQR)]	208 (111–452)	141 (92–218)	867 (499–1382)	<0.001
Age, years [mean (SD)]	63 (9.8)	62 (9.9)	65 (9)	0.001
Female, *n* (%)	117 (28)	86 (30)	31 (23)	0.193
Smoking				0.008
– current, *n* (%)	40 (9.4)	21 (7.2)	19 (14)	
– past, *n* (%)	188 (44)	122 (42)	66 (49)	
– never, *n* (%)	196 (46)	147 (51)	49 (37)	
Body mass index, kg/m^2 [median (IQR)]	26 (24–30)	26 (24–30)	27 (25–30)	0.168
Non-paroxysmal AF, *n* (%)	196 (46)	128 (44)	68 (50)	0.260
EHRA score I/II vs. III/IV, *n* (%)	126/173 (42/58)	96/113 (46/54)	30/60 (33/67)	0.058
CHA_2DS_2-VASc [median (IQR)]	2 (1–3)	2 (1–3)	2 (1–3)	0.067
Hypertension, *n* (%)	261 (61)	169 (58)	92 (68)	0.060
Diabetes, *n* (%)	31 (7.3)	21 (7.2)	10 (7.4)	1.00
Echocardiographic findings				
LA size (PLAX) (mm) [mean (SD)]	42 (6.6)	42 (6.9)	43 (5.8)	0.183
LAVI, mL/m^2 [mean (SD)]	40 (12)	39 (12)	41 (12)	0.158
LVEF [%, median (IQR)]	60 (53–63)	59 (52–62)	60 (54–64)	0.177

Values are given as mean (±standard deviation), median (interquartile range), or numbers (percentage).
Early recurrence: AF recurrence in the first 365 days after previous procedure. Late recurrence: AF recurrence beyond the first 365 days after previous index intervention.
Missing values: smoking ($n = 2$), EHRA score ($n = 127$), CHA_2DS_2-VASc score ($n = 11$), LA ($n = 50$), LAVI ($n = 108$), LVEF ($n = 15$).
SD, standard deviation; IQR, interquartile range (25–75 percentile); AF, atrial fibrillation; EHRA score, European Heart Rhythm Association score: I = no symptoms, II = mild symptoms, III = severe symptoms, and IV = disabling symptoms; CHA_2DS_2-VASc score: congestive heart failure, hypertension, age ≥ 75 years (2 points), diabetes mellitus, prior stroke/transient ischaemic attack/thromboembolism (2 points), vascular disease, age 65–74 years, female sex; LA dimension (PLAX), left atrial dimension in the parasternal long axis; LAVI, indexed left atrial volume; LVEF, left ventricular ejection fraction.

Non-pulmonary vein ablation targets and electrocardiographic features

Overall, 161 patients (38%) underwent ablation of non-PV targets during the repeat procedure: 104 (36%) in the ER group and 57 (42%) in the LR group. The superior vena cava was the most common non-PV target [74 patients (17%)], and the cavotricuspid isthmus line was the second most commonly performed ablation lesion outside the PVs [58 patients (14%)]. For the ablation targets, there was no difference between the two groups except for the posterior box lesion, which was more likely to be performed in the LR group with 10 patients (7.4%) vs. 6 patients (2.1%) in the ER group ($P = 0.015$). There was also no difference in the electrocardiographic features between the two groups (*Table 2*).

Procedural complications

For all the repeat procedures, a total of four major complications that required a prolonged hospital stay occurred: two tamponades, one arteriovenous (AV) fistula, and one groin haematoma.

Atrial fibrillation recurrence after repeat procedure

A total of 130 patients (31%) had a recurrence of AF during a follow-up of 12 months after repeat ablation. In the LR group, 40 of 135 patients (30%) had a recurrence of AF compared to 90 of 291 patients (31%) in the ER group. There was no significant difference in freedom from AF recurrence between ER and LR (log-rank $P = 0.72$, *Figure 3*). The Cox proportional hazards models did not show an association of the time of the AF recurrence after the index procedure and the outcome of the repeat procedure (*Table 3*). Freedom from AF recurrence did not differ when comparing patients with paroxysmal to patients with persistent AF (see Supplementary material online, *Figure S2*) and when comparing patients undergoing RF ablation compared to cryo-ablation during the index procedure (see Supplementary material online, *Figure S3*). Also, there was no difference in outcomes when comparing patients with AF recurrence within 90 days compared to patients with a recurrence between 91 and 365 days and to patients with a LR (>365 days) (see Supplementary material online, *Figure S4*). Furthermore, there was no association between the time interval from index procedure to repeat procedure and the outcome of the repeat procedure when analysed as a continuous variable (see Supplementary material online, *Table S5*).

Discussion

To the best of our knowledge, this is the largest analysis of outcomes and characteristics of the first repeat CA after a VLR (>1 year) of AF after index PVI. Our main findings were as follows: first, the AF recurrence rate after repeat CA after index PVI was approximately 31%; second, the outcomes were independent of the time to AF recurrence after the index PVI with comparable recurrence rates in the ER and LR groups; third, PV reconnections were a common finding, also in patients with a VLR of AF after the index procedure; and fourth, these findings were consistent in patients with paroxysmal and persistent AF and in patients undergoing RF ablation or cryo-ablation during the index procedure.

Table 2 Procedural characteristics, overall and stratified by ER and LR

Variable	Overall	Early recurrence	Late recurrence	P
n	426	291	135	
Time interval between index and repeat procedure [days] [median (IQR)]	340 (IQR: 165 – 763)	218 (IQR: 140 – 357)	953 (IQR: 625 – 1510)	<0.001
Previous procedure using cryo-energy, *n* (%)	112 (26)	81 (28)	31 (23)	0.345
Pulmonary vein reconnections				
Number of reconnected PVs [mean (SD)]	2 (1.1)	2.1 (1.1)	1.9 (1.2)	0.143
No pulmonary vein reconnections, *n* (%)	39 (9.4)	21 (7.3)	18 (14)	0.052
≥1 reconnected pulmonary vein(s), *n* (%)	378 (91)	266 (93)	112 (86)	0.052
≥2 reconnected PV, *n* (%)	286 (69)	204 (71)	82 (63)	0.129
Left inferior pulmonary vein reconnected, *n* (%)	173 (41)	128 (45)	45 (34)	0.055
Left superior pulmonary vein reconnected, *n* (%)	190 (45)	135 (47)	55 (42)	0.373
Left common pulmonary vein reconnected, *n* (%)	14 (3.3)	10 (3.4)	4 (3)	1.00
Right inferior pulmonary vein reconnected, *n* (%)	256 (61)	175 (61)	81 (62)	0.953
Right superior pulmonary vein reconnected, *n* (%)	213 (51)	150 (52)	63 (48)	0.539
Non-pulmonary vein ablation targets				
Non-PV ablation targets, *n* (%)	161 (38)	104 (36)	57 (42)	0.239
Cavotricuspid isthmus line, *n* (%)	58 (14)	41 (14)	17 (13)	0.789
Mitral isthmus line, *n* (%)	26 (6.1)	15 (5.2)	11 (8.1)	0.325
Roof line, *n* (%)	19 (4.5)	11 (3.8)	8 (5.9)	0.456
Posterior box, *n* (%)	16 (3.8)	6 (2.1)	10 (7.4)	0.015
Ablation of superior vena cava, *n* (%)	74 (17)	49 (17)	25 (18)	0.773
Ablation of vein of Marshall, *n* (%)	3 (0.7)	1 (0.3)	2 (1.5)	0.494
Ablation of complex fractionated atrial electrograms (CFAE), *n* (%)	21 (4.9)	16 (5.5)	5 (3.7)	0.579
Ablation of other arrhythmias, *n* (%)	19 (4.5)	16 (5.5)	3 (2.2)	0.203
Electrocardiographic features				
Rhythm at admission for repeat ablation (%)				0.267
– Sinus rhythm, *n* (%)	265 (64)	181 (64)	84 (65)	
– AF, *n* (%)	117 (28)	77 (27)	40 (31)	
– Typical flutter, *n* (%)	7 (1.7)	7 (2.5)	0 (0)	
– Atypical flutter, *n* (%)	13 (3.2)	11 (3.9)	2 (1.6)	
– Other rhythm, *n* (%)	9 (2.2)	6 (2.1)	3 (2.3)	
PR interval, ms [mean (SD)]	178 (35)	178 (33)	178 (39)	0.980
QRS duration, ms [median (IQR)]	99 (IQR: 90 – 110)	98 (IQR: 88 – 108)	100 (IQR: 92 – 114)	0.064

Numbers are No. (%) unless otherwise noted. Early recurrence: AF recurrence in the first 365 days after previous procedure.
Late recurrence: AF recurrence beyond the first 365 days after previous index intervention.
Other arrhythmias: focal atrial tachycardia ($n = 13$), atrioventricular-node re-entry tachycardia ($n = 3$), left atrial micro-re-entry tachycardia ($n = 3$).
Missing values: pulmonary vein reconnections ($n = 9$), rhythm at admission for repeat ablation ($n = 15$), PR interval ($n = 169$), QRS duration ($n = 116$).
AF, atrial fibrillation; SD, standard deviation; IQR, interquartile range (25–75 percentile); PV, pulmonary vein; ECG, electrocardiogram.

Few other studies examined the relationship between the time to recurrence after the index procedure and outcomes after repeat CA. Recently, Choi *et al.*[20] found no relationship between the outcomes of repeat CA according to the time to recurrence after the index procedure in an observational study of 198 patients using RF energy including 98 patients after VLR of AF (>12 months). Daimee *et al.*[21] examined the outcomes of 300 repeat ablations and found no association between AF recurrence and the time interval between index and repeat ablation when comparing recurrences within 3 years to recurrences after more than 3 years. In contrast, Gaztañaga *et al.*[22] previously observed an association of the outcomes of the repeat procedure with the time to recurrence after the index procedure with better response to repeat ablation and to AAD treatment after a longer time to AF recurrence after ablation. However, the group undergoing repeat ablation after more than 12 months was relatively small ($n = 35$), the study was performed before the advent of contact-force sensing catheters, and they used an endpoint of 'AF control' defined as 'no or rare episodes of AF'. In our study, the success of the procedure was approximately 70% 1 year after repeat ablation. We did not observe a difference dependent on the time to recurrence after the index ablation procedure and included a substantially larger number of patients undergoing a repeat ablation after a VLR ($n = 135$). Our study included cryo- and RF index procedures, and there was no differential effect of the two energy sources on AF recurrence. This is consistent with previous work showing that there is no association of the index procedure modality with the outcome of the repeat procedure.[21,23] Due to the non-

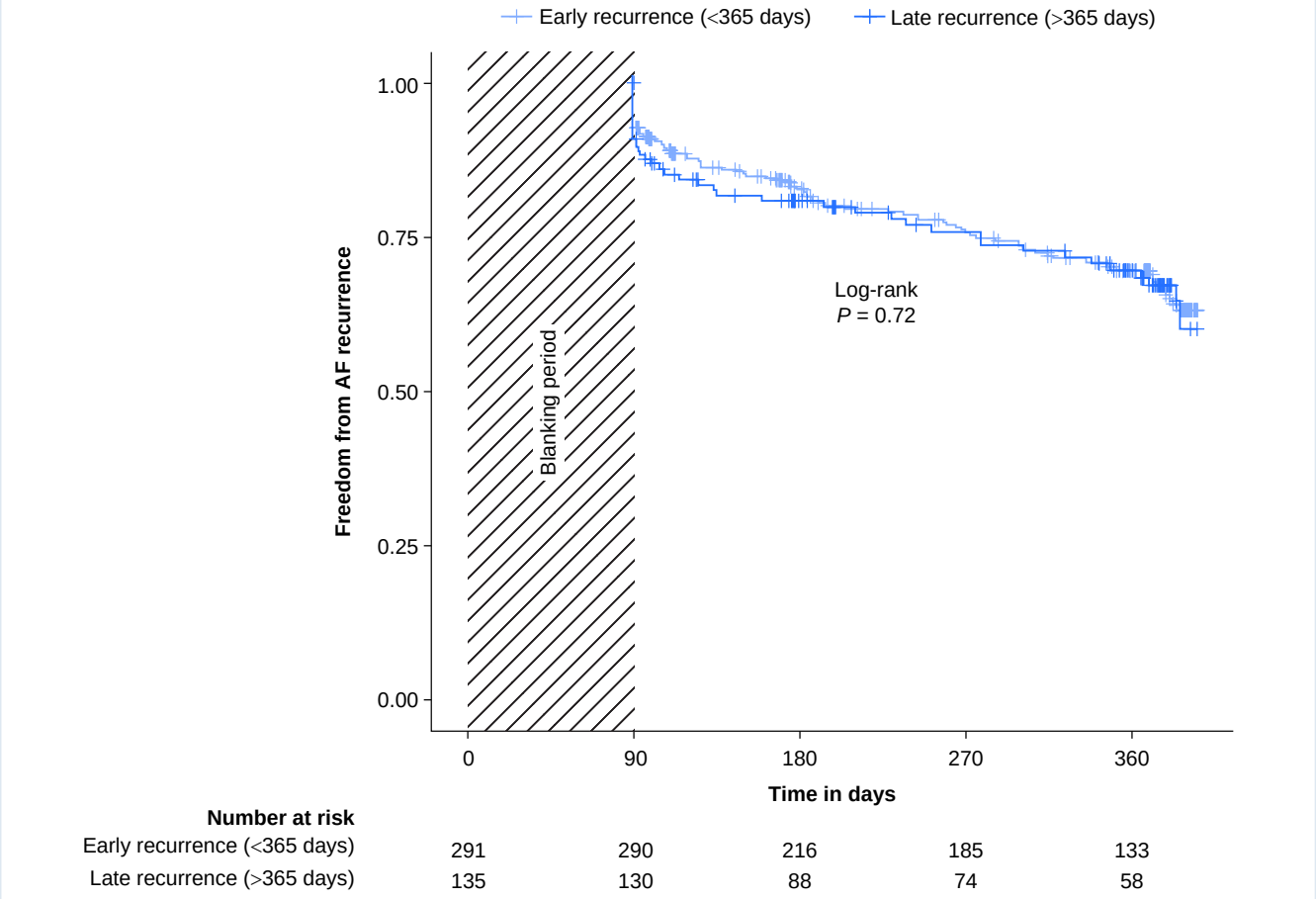


Figure 3 Kaplan–Meier plot for freedom from AF recurrence after repeat CA. Freedom from AF recurrence per follow-up days after repeat CA according to time to AF recurrence after index ablation. *P*-value was calculated by log-rank test. AF, atrial fibrillation.

randomized nature of our comparison, differences in ablation strategies during the repeat procedure may have impacted the outcomes in the two groups in our study. However, differences were minor with a similar rate of ablation of non-PV targets, except for a small but significant difference in the creation of a posterior box lesion (7.4% in the LR vs. 2.1% in the ER group).

The PVs have been reported to contain the triggers of AF mostly in patients with the paroxysmal form of the arrhythmia,[4,5] while with disease progression, atrial substrate caused by remodelling is believed to play a major role in maintaining AF.[24,25] The comparable procedural findings and ablation outcomes between the two groups in our analysis may suggest that the initial CA was indeed able to slow disease progression and atrial remodelling. Retrospective studies have shown that there is an association between a shorter diagnosis-to-ablation time and better outcomes of an initial CA,[26,27] although a recent randomized study did not confirm this finding, at least when comparing direct CA within one month to medical treatment and delayed CA after a time span of 1 year.[28] It is conceivable that relevant disease progression and changes in atrial substrate take a longer time to develop. For instance, the recently published 3-year follow-up of the EARLY-AF[29] study showed that patients with paroxysmal AF undergoing CA had a lower incidence of persistent AF or atrial tachyarrhythmia when compared with antiarrhythmic therapy.

In our study, we identified a high proportion of PV reconnections in both groups. Hussein *et al.*[13] found PV reconnections in all patients undergoing a repeat procedure after a recurrence within the first year ($n = 161$) and a recurrence later than 1 year ($n = 27$) after an initial RF procedure. Similarly, in an analysis by Shah *et al.*,[14] there were PV reconnections in all 18 patients undergoing a repeat ablation for recurrent AF after more than 1 year after an initial RF procedure. In contrast, Sotomi *et al.*[15] found a significant difference between the prevalence of reconnections in their retrospective study comparing patients with a VLR (>12 months, $n = 26$) to patients with a LR (3–12 months, $n = 124$) after initial RF ablation. The rate of reconnections in patients with a recurrence in the first year (90%) was comparable to our results (93%) in the ER group. In patients with a VLR (>12 months), the rate of reconnections was lower (69%) than in our corresponding LR group (86%). However, 3D mapping systems were only partly used in their study. It is conceivable that some PV signals may be missed without the systematic use of multipolar catheters for high-resolution mapping of the PVs and the left atrium and a clear voltage cut-off to distinguish between healthy and scar tissues. In our study, we systematically used high-resolution 3D mapping using a multipolar mapping catheter to determine PV reconnections. More recently, Erhard *et al.*[16] found significantly fewer PV reconnections in later recurrences when comparing repeat ablations after 3–24 months ($n = 47$, PV reconnections 97.9%), 2–5 years ($n = 29$, PV reconnections 72.4%), and > 5 years ($n = 34$, PV reconnections 55.9%) after an initial RF procedure. Compared to our study, different cut-offs for time to recurrence after the previous procedure were used. The longer time span may have allowed more subtle differences in atrial remodelling to become apparent. Shah *et al.*[30] examined the prevalence of PV reconnections and additional lesions in patients with a recurrence more than 3 years after

Table 3 Association of time to AF recurrence after initial ablation procedure and time to AF recurrence after repeat ablation

	Model 1: unadjusted HR (95% CI)	Model 2: age- and sex-adjusted HR (95% CI)	Model 3: multivariable adjusted HR (95% CI)
Early recurrence	Reference	Reference	Reference
Late recurrence	1.07 (0.74–1.56) $P = 0.7$	1.05 (0.72–1.52) $P = 0.8$	1.09 (0.73–1.65) $P = 0.7$

Model 3 adjusted for age, sex, hypertension, type of AF, left ventricular ejection fraction (LVEF), and indexed left atrial volume (LAVI).CI, confidence interval; HR, hazard ratio.

the last ablation procedure. Of the 137 patients enrolled in their observational study, 81% had at least one PV reconnection. Additional lesions were much more likely (93%) to be performed than in our study with 36% in the ER group and 42% in the LR group. The analysis was based on a highly selected cohort (137 of 10 378 patients), the time span to the recurrence after the previous procedure was longer, and multiple prior procedures were allowed, which may explain the different findings compared to our study.

In contrast to the studies mentioned, our analysis also included patients that underwent an index procedure using cryo-energy. Although, in our analysis, the rate of patients with reconnected PVs was similar between the types of energy used at the index procedure, the number of reconnected PVs was higher in patients that received an index procedure using RF energy. Specifically, the LSPV was more likely to be reconnected in patients after an index procedure using RF. The presence of reconnected PVs at the repeat procedure in around 90% of patients after cryoballoon (CB) index procedure was higher than in previous studies. Kuck *et al.*[31] reported reconnected PVs in 78% of patients, Heeger *et al.* reported 74[32] and 79%,[33] Bordignon *et al.*[34] reported 67%, and Ciconte *et al.*[35] found approximately 50% reconnected PVs. Differences in PV reconnection rates might be explained by heterogeneity of CB generations used and the resolution of electroanatomic mapping.

Strengths and limitations

The strengths of our analysis include the large cohort size and the standardized follow-up. Limitations of our study include the single centre and the observational nature. Due to methodical reasons, there may be a selection bias because we only included patients undergoing a repeat ablation. For our comparison, we used a definition of 'ER' and 'LR' with a cut-off between early and late at 1 year after ablation that deviates from the expert consensus statement.[1] We believe that this adequately reflects clinical routine. Finally, no findings from patients undergoing pulsed field ablation during the index procedure can be presented because the technology was not available at the time.

Further studies are needed including re-mapping studies in patients with and without AF recurrence and studies including novel energy sources (e.g. pulsed field ablation) to improve the understanding of the temporal relationship between AF diagnosis, index and repeat CA, the mechanisms of AF recurrence and the best ablation strategy at repeat procedure.

Conclusions

In patients undergoing repeat CA for recurrent AF, there was no association between the time to recurrence of AF after initial CA and the characteristics and outcomes of the repeat procedure. Therefore, the decision whether to perform a repeat ablation should not be based on the time to recurrence of AF after initial ablation.

Supplementary material

Supplementary material is available at *Europace* online.

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Data availability

The consent forms, as approved by the local ethics committee (Ethikkommission Nordwest- und Zentralschweiz), do not allow the data to be made publicly available. The data will be shared on reasonable request to the corresponding author.

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