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Two-Year Outcomes and Predictors of Recurrence After High-Power Radiofrequency Ablation for Atrial Fibrillation: A Single-Center Experience With 480 Patients

ABSTRACT

Background: Atrial fibrillation (AF) catheter ablation is a cornerstone rhythm-control intervention in symptomatic patients. Despite technological improvements, recurrence remains a critical determinant of long-term success, particularly in persistent AF. This study aimed to evaluate the 2-year clinical outcomes of high-power radiofrequency (RF) ablation performed in a high-volume single center and to identify predictors of AF recurrence in patients undergoing catheter ablation.

Methods: This retrospective observational study included 480 consecutive adults who underwent RF catheter ablation for AF between January 2021 and December 2024. The patients were categorized based on AF recurrence, defined as >30-second episodes detected during 48- to 72-hour Holter at 6, 12, 24, and 36 months.

Results: The cohort had a mean age of 59.8 ± 11.5 years, 56.3% were male, and 55.2% had persistent AF. The overall recurrence rate was 14.5% over an average follow-up duration of 23.8 ± 9.2 months. The recurrence rate was 9.2% in paroxysmal AF and 20% in persistent AF. The left atrial diameter was significantly larger in recurrence-positive patients (43.1 ± 6.5 mm vs 41.4 ± 5.5 mm, $P = .023$). Additionally, mitral regurgitation (MR) was more prevalent in the recurrence-positive group, particularly in patients with ≥grade 3 MR (18.6% vs. 6.4%, $P = .004$). Independent predictors of recurrence were symptom duration (odds ratio [OR] = 1.01, $P = .006$, 95% CI: 1.00-1.02) and prior direct current cardioversion (OR = 3.12, $P < .001$, 95% CI: 2.34-4.10). The complication rate was 2.0%.

Conclusion: High-power RF ablation in an experienced center resulted in high sinus rhythm maintenance and low recurrence at 2 years. Individualized treatment strategies may have contributed to the low recurrence rates.

Keywords: Atrial fibrillation, radiofrequency ablation, high-power short duration

INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia and remains a major contributor to morbidity despite ongoing advances in rhythm-control strategies. Recurrent symptoms, limitations of antiarrhythmic drug therapy, and the progressive nature of atrial remodeling frequently necessitate interventional treatment. Therefore, catheter ablation has become a central component of rhythm control, and the *European Society of Cardiology* guidelines emphasize that pulmonary vein isolation (PVI) is an effective strategy after antiarrhythmic drug failure and may also be considered as a first-line treatment option in selected patients.[1]

Cryoballoon ablation is widely used as a standardized single-shot PVI technique with well-established efficacy.[2,3] Radiofrequency (RF) ablation remains the most frequently utilized alternative owing to its precision, adaptability, and compatibility with contemporary electroanatomic mapping systems.[4-6] Technological refinements, such as contact-force sensing and high-power, short-duration energy delivery, have further enhanced lesion durability and procedural outcomes.[4,5] Pulse-field ablation, a non-thermal modality with promising safety and

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efficiency, is also rapidly gaining adoption in modern electrophysiology laboratories.[7]

Despite advancements in ablation strategies, real-world outcomes vary substantially based on AF type, atrial substrate, and operator experience. Two-year recurrence rates after RF ablation have been reported to range from 15% to 48%, being generally lower in paroxysmal AF (≈14-35%) and higher in persistent AF (≈36-60%).[8-12] Identifying predictors of recurrence, such as left atrial (LA) size, AF chronicity, valvular disease, and prior rhythm-control attempts, remains essential to optimize patient selection and procedural strategy.[10-13] Single-center studies utilizing uniform workflows and consistent operators offer valuable insight by reducing heterogeneity related to technique, experience, and procedural approach.

In this study, the center's experience with RF catheter ablation in 480 patients is presented, evaluating procedural success, recurrence rates, complications, and clinical predictors of AF recurrence in a high-volume electrophysiology setting.

Study Population

This retrospective, single-center study included consecutive patients who underwent RF ablation for AF at the center between January 2021 and December 2024. Patients aged 18-82 years who were followed up for at least 12 months with a diagnosis of paroxysmal or persistent AF were included in the study. The patients were classified into 2 groups based on the presence or absence of AF recurrence. Patients with reversible causes of AF, postoperative AF, documented intra-atrial thrombus, or cardiac tumor, myocardial infarction within the previous 3 months, or percutaneous coronary intervention within the previous 3 months were excluded.

The study protocol was approved by the local ethics committee, and the study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines.

Procedural Strategies and Techniques

Before the procedure, all patients underwent detailed evaluation, including laboratory tests, transthoracic echocardiography, and 12-lead electrocardiography to exclude secondary causes of AF. According to institutional workflow, all cases were discussed in a multidisciplinary cardiology-cardiovascular surgery council, and ablation was performed under general anesthesia following anesthesiology approval.

HIGHLIGHTS

- In 480 patients with atrial fibrillation (AF) who were treated with high-power radiofrequency (RF) ablation, the 2-year recurrence rate was 14.5% (9.2% for paroxysmal AF, 20% for persistent AF), and 85.5% remained in sinus rhythm.
- Procedural safety was favorable, with 2.0% complications and low fluoroscopy times in a high-volume center.
- Longer AF symptom duration and prior direct current cardioversion independently predicted recurrence.
- These data support early ablation and individualized lesion sets to improve long-term rhythm control.

Vascular access was obtained through the right femoral vein using the Seldinger technique, and 2 6-F and 1 8-F sheaths were introduced. A coronary sinus catheter was positioned first, followed by a single transseptal puncture using an SL1 sheath and a Brockenbrough needle to access the LA. High-density (HD) mapping catheters were used for electroanatomic mapping.

If a stable atrial flutter with a constant tachycardia cycle length was present at the beginning of the procedure, late activation mapping was performed and a right atrial map was generated. In patients presenting in atrial flutter or in AF at the start of the procedure, scar assessment was performed using a bipolar voltage scale of 0.1-0.3 mV. In these cases, circumferential PVI was completed after ablating the critical isthmus of the arrhythmia. In patients in sinus rhythm, a bipolar voltage scale of 0.2-0.5 mV was used.

In cases with concentric activation indicating typical cavotricuspid isthmus (CTI)-dependent flutter, entrainment was used for confirmation. Cavotricuspid isthmus ablation and restoration of sinus rhythm were performed first, followed by transseptal puncture and LA mapping.

After voltage mapping, additional ablation beyond PVI was individualized, regardless of AF type. Decisions were based on predefined parameters: AF symptom duration, AF type (paroxysmal or persistent), anterior LA scarring related to mitral regurgitation (MR), patient age, and overall LA scar burden. According to these findings, posterior wall isolation, anterior mitral line, or scar homogenization was applied when indicated.

Open-irrigated RF catheters with contact-force sensing were used (Thermocool® SmartTouch®, Biosense Webster; TactiCath™, Abbott). HD mapping was performed using PENTARAY® NAV ECO or Advisor™ HD Grid Mapping Catheters. All LA lesions were delivered using a high-power, short-duration strategy. Right atrial ablation was performed at 40 W.

Pulmonary veins were isolated using a contiguous lesion set with an approximate lesion width of 3 mm. Lesion continuity was confirmed at a 2-mm resolution, and additional "touch-up" ablation was applied even when an entrance block was present.

In patients with documented AF and concomitant typical flutter at the beginning of the procedure, CTI ablation was performed first, followed by PVI and the additional LA ablation lesions. After first-pass isolation and restoration of sinus rhythm (spontaneously or via cardioversion), the LA was remapped using a bipolar voltage scale of 0.2-0.5 mV. Residual potentials within the pulmonary veins or posterior wall (when applicable) were targeted with additional RF applications at 35-40 W, irrespective of exit block, until residual electrical activity was eliminated.

After PVI or PVI plus posterior box isolation, programmed stimulation and burst pacing were performed. Empirical anterior mitral line ablation was not routinely performed in the absence of low-voltage areas or inducible flutter. In

both paroxysmal and persistent AF, LA mapping and ablation were performed first, followed by right atrial mapping. Cavotricuspid isthmus ablation and right atrial scar homogenization were performed when indicated.

Clinical Follow-up and Study Endpoints

All patients underwent 24-hour post-procedural monitoring and transthoracic echocardiography at 24 hours. In the absence of contraindications, amiodarone was administered during the blanking period. The blanking period was defined as the first 90 days after ablation, and any documented episode of AF, atrial flutter, or atrial tachycardia lasting >30 seconds during this period was classified as recurrence for the study analysis.

Oral anticoagulation was continued for at least 4 months in all patients and for at least 1 year in those with a CHA_2DS_2-VASc score of >2. Outpatient follow-ups, including electrocardiogram, echocardiography, and laboratory testing, were performed at week 1, month 1, and month 3 after the procedure. All patients underwent 48-72 hour Holter monitoring at 6, 12, 24, and 36 months.

During the blanking period, amiodarone therapy was administered to prevent arrhythmia recurrence unless contraindicated or not tolerated. After the blanking period, amiodarone was discontinued in patients who remained in sinus rhythm, and treatment was continued with beta-blocker therapy alone according to symptom status and clinical need. In patients who experienced arrhythmia recurrence during the blanking period, amiodarone or flecainide was continued at the discretion of the treating physician.

Arrhythmia Center Characteristics and Operator Experience

The institution has a dedicated arrhythmia center within the cardiology department that performs a broad spectrum of electrophysiological procedures. The center manages more than 1,000 arrhythmia procedures annually, including AF ablation and complex arrhythmias such as endocardial and epicardial ventricular tachycardia ablation.

The arrhythmia team consists of 5 interventional electrophysiologists with an average experience of approximately 8 years in invasive electrophysiology and catheter ablation. All operators are actively involved in both basic and complex arrhythmia procedures. Each operator performs at least 100 complex arrhythmia procedures annually.

Treatment strategies, procedural workflows, and patient management algorithms are standardized within the center and applied consistently among operators to ensure uniform decision-making and procedural reproducibility.

Statistical Analysis

Statistical analyses were performed using SPSS, version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Continuous variables were tested for normality using the Kolmogorov–Smirnov test and for homogeneity of variance. Normally distributed continuous variables were compared using the independent-samples *t*-test, whereas non-normally distributed variables were compared using the Mann–Whitney *U*-test. Categorical variables were compared using the chi-square test. Normally distributed continuous variables are presented as mean ± SD, non-normally distributed variables as median (interquartile range, Q1-Q3), and categorical variables as counts and percentages.

To identify predictors of AF recurrence, univariate and multiple logistic regression analyses were performed. Variables significant in univariate analysis were entered into a multiple model using a stepwise selection method. Receiver operating characteristic (ROC) curve analysis was performed to determine optimal cut-off values, sensitivity, and specificity for independent predictors. A 2-tailed *P*-value of <0.05 was considered statistically significant.

RESULTS

A total of 480 patients who underwent RF ablation for AF were included in the study. The mean age of the cohort was 59.76 ± 11.51 years, with 270 patients (56.25%) being male and 210 (43.75%) being female. Of all patients, 215 had paroxysmal AF and 265 had persistent AF. Atrial flutter was observed in 31 of the 265 patients with persistent AF. In patients with paroxysmal AF who presented with ongoing AF before the procedure or developed AF during the procedure, as well as in all patients with persistent AF, sinus rhythm was successfully restored by cardioversion under sedation. Procedure-related complications occurred in 9 patients (2.0%).

The mean follow-up duration was 23.8 ± 9.2 months. During follow-up, AF recurrence was documented in 70 patients (14.5%). The overall sinus rhythm maintenance rate was 85.5%, with rates of 92.1% in the paroxysmal AF group and 80.0% in the persistent AF group. Among patients who experienced recurrence, the median time to the first documented arrhythmia was 2 months (range: 1-60 months). Twenty patients (28.6%) experienced recurrence within the first month, and 40 patients (57.1%) within the first 3 months. In the analysis excluding the blanking period, recurrence was observed in 48 patients (10%) in the entire study population, in 14 patients (6.5%) in the paroxysmal AF group, and in 34 patients (12.8%) in the persistent AF group.

Demographic characteristics and medication histories of patients with and without recurrence are presented in Table 1. There were no statistically significant differences between the groups in demographic or medication-related variables.

Laboratory and echocardiographic parameters are compared in Table 2. LA diameter and the presence of MR, particularly grade 3 MR, showed statistically significant differences between the recurrence and non-recurrence groups. No significant differences were observed in other laboratory or echocardiographic parameters.

Clinical AF-related characteristics and procedural variables are shown in Table 3. The ratio of paroxysmal to persistent AF was 0.93 in the non-recurrence group compared with 0.32 in the recurrence group ($P < .001$). AF symptom duration, history of cardioversion, time elapsed after ablation, and procedure duration were all significantly different between the

Table 1. Demographic Characteristics and Medication Use of the Study Cohort

	Patients Without AF Recurrence n = 410	Patients with AF Recurrence n = 70	*P*
Age (years)	62 (19-84)	58.5 (20-79)	.086
Sex (F/M)	184/226	26/44	.228
Body mass index (kg/m^2)	27 (19-47)	28.9 (22.4-49.3)	.194
Hypertension, n (%)	215 (44.8)	29 (41.4)	.089
Diabetes mellitus, n (%)	91 (18.9)	13 (18.5)	.723
Medical treatment			
Beta-blocker, n (%)	338 (82.4)	60 (85.7)	.501
Calcium channel blockers, n (%)	53 (12.9)	9 (12.8)	.987
Propafenone, n (%)	101 (24.6)	10 (14.2)	.058
Amiodarone, n (%)	116 (28.3)	24 (34.2)	.528
Apixaban, n (%)	57 (13.9)	14 (20)	.184
Edoxaban, n (%)	75 (18.3)	11 (15.7)	.597
Rivaroxaban, n (%)	183 (44.6)	30 (42.8)	.782

AF, atrial fibrillation; F, female; M, male.

Table 2. Comparison of Laboratory and Echocardiographic Parameters Between the Study Groups

	Patients Without AF Recurrence (n = 410)	Patients with AF Recurrence (n = 70)	*P*
Hemoglobin (g/dL)	13.7 (8.1-20.1)	14.2 (10-17.2)	.155
White blood cell count (×10^9/L)	7.44 (3.55-62.46)	7.25 (2.86-21.62)	.979
Neutrophil count (×10^9/L)	4.42 (1.45-11.87)	4.37 (1.49-18.4)	.535
Lymphocyte count (×10^9/L)	2.14 (0.87-54.14)	2.11 (0.98-4.29)	.247
Platelet count (×10^9/L)	241 (58-515)	238 (164-454)	.937
NT-proBNP (pg/mL)	320 (5.37-6 472)	323 (16-4 408)	.486
Creatine (mg/dL)	0.89 (0.38-4.2)	0.88 (0.57-1.66)	.862
GFR	84 (10-140)	87 (42-122)	.219
Sodium (mmol/L)	140 (122-160)	140 (132-145)	.361
Potassium (mmol/L)	4.36 (2.88-6.32)	4.49 (3.3-5.76)	.152
HgA1C (%)	5.75 (4.7-9.5)	5.6 (5-9.4)	.222
LV-EF (%)	65 (15-65)	65 (20-65)	.218
LV-EDD (mm)	47 (32-69)	48 (38-70)	.421
LV-ESD (mm)	30 (16-62)	30 (22-60)	.811
IVS (mm)	11 (7-13)	11 (7-15)	.844
LA size (mm)	41.4 ± 5.5	43.1 ± 6.5	.023
sPAP (mm Hg)	30 (18-70)	30 (16-90)	.576
Tricuspid regurgitation, n (%)			.101
Absent, n (%)	69 (16.8)	5 (7.1)	.058
Grade 1	200 (48.7)	34 (48.5)	.974
Grade 2	110 (26.8)	21 (30)	.582
Grade 3	25 (6)	7 (10)	.226
Grade 4	6 (1.5)	3 (4.2)	.108
Mitral regurgitation, n (%)			.040
Absent	67 (16.3)	8 (11.4)	.295
Grade 1	211 (51.4)	28 (40)	.076
Grade 2	105 (25.6)	24 (34.2)	.130
Grade 3	25 (6)	10 (14.2)	.015
Grade 4	2 (0.4)	0 (-)	.558

AF, atrial fibrillation; GFR, glomerular filtration rate; HgA1C, hemoglobin A1C; IVS, interventricular septum; LA, left atrium; LV-EDD, left ventricular end-diastolic diameter; LV-EF, left ventricular ejection fraction; LV-ESD, left ventricular end-systolic diameter; NT-proBNP, N-terminal pro–b-type natriuretic peptide; sPAP, systolic pulmonary artery pressure.

2 groups. In the overall cohort, the median procedure duration was 104 minutes (range: 23-589 minutes; mean: 111.9 minutes), and the median fluoroscopy time was 8.75 minutes (range: 0.9-65 minutes; mean: 10.95 minutes).

Univariate and multiple logistic regression analyses evaluating predictors of AF recurrence are presented in Table 4. In univariate analysis, paroxysmal AF ($P < .001$), MR ($P = .008$), AF symptom duration ($P = .006$), history of cardioversion ($P < .001$), and LA diameter ($P = .021$) were identified as significant predictors of recurrence. In multiple regression, AF symptom duration (odds ratio [OR]= 1.01, $P = .006$, 95% CI: 1.00-1.02) and a history of cardioversion (OR = 3.12, $P < .001$, 95% CI: 2.34-4.10) remained independent predictors of AF recurrence.

ROC curve analysis showed that an LA diameter cut-off value of 41.5 mm predicted AF recurrence with an AUC = 0.597, $P = .037$, 95% CI: 0.509-0.685, a sensitivity of 57.8%, and a specificity of 57.9% (Figure 1).

DISCUSSION

In this study, approximately 24-month outcomes of 480 patients who underwent RF catheter ablation for AF were evaluated. The overall AF recurrence rate was 14.5%, which is notably lower than the recurrence rates reported in contemporary literature, where 2-year recurrence typically ranges between 15% and 48.3% (6,8). Recurrence rates in paroxysmal AF cohorts are generally reported between 14% and 34.5%,[4,5] whereas they range from 36% to 59.8% in persistent AF cohorts.[9,10] In the study, both the paroxysmal cohort (7.9%) and the persistent cohort (20%) demonstrated recurrence rates substantially below these ranges. In the study, atrial flutter was identified in 31 patients within the persistent AF group, and ablation was performed using 3-dimensional electroanatomic mapping in these cases. Macroreentrant atrial tachycardias such as atrial flutter are frequently encountered in conjunction with AF, and contemporary evidence suggests that addressing both arrhythmias during the ablation procedure may improve overall procedural success and long-term rhythm outcomes.[14]

When recurrence timing was analyzed, 28% of recurrences occurred within the first month and 57% within the first 3 months. The predominance of early recurrences suggests

Table 3. Comparison of Clinical Features and Ablation Parameters Between the Study Groups

	Patients Without AF Recurrence (n = 410)	Presence of AF Recurrence (n = 70)	*P*
Paroxysmal/persistent AF, n	198/212	17/53	<.001
AF symptom duration (months)	15 (1-236)	30 (3-129)	.001
Prior DC-CV, n (%)	144 (35.1)	52 (74.8)	<.001
Restoration of sinus rhythm via DC-CV, n (%)	134 (32.6)	46 (65.7)	<.001
Pre-procedural DC-CV, n (%)	111 (27)	23 (32.8)	.319
Duration after ablation (months)	21 (6-49)	26 (12-81)	<.001
Fluoroscopy dose (mGy)	344 (5-2,998)	456 (49-3,591)	.139
Fluoroscopy time (minutes)	8 (1-41.5)	10.9 (0.9-65)	.023
Procedure time (minutes)	101 (23-589)	116.5 (60-260)	.008

AF, atrial fibrillation; DC-CV, direct current cardioversion.

that many events occurred during the blanking period, when electrophysiological instability due to edema, inflammation, and autonomic fluctuations may result in transient arrhythmogenicity. Although arrhythmias during blanking remain controversial in terms of classification,[15,16] the high proportion of early recurrences in the cohort suggests that the true long-term recurrence rate may be even lower.

Although the analysis is limited to a single center, this design also confers methodological advantages. Previous multicenter studies have demonstrated that operator variability, including learning curves, technique heterogeneity, and procedural inconsistencies, significantly affect AF ablation outcomes.[11] In the study, all procedures were performed in a high-volume center by the same experienced operators using a uniform ablation workflow, which reduced variability related to operator-dependent factors and enhanced internal validity.

All patients in the cohort underwent RF ablation. Although cryoballoon ablation and RF ablation are the 2 most widely used PVI techniques, pulse-field ablation has recently emerged as a promising non-thermal alternative. Randomized trials and meta-analyses have shown comparable success rates between RF and cryoballoon ablation, with no clear superiority of either strategy.[3,17] However, in the previously published single-center cryoballoon AF ablation study, success rates were 85.6% for paroxysmal AF and 61.8% for persistent AF.[18] In that study, the mean procedure times for recurrence-positive and recurrence-negative patients were 116.8 and 115.8 minutes, respectively, with mean fluoroscopy times of 26.4 and 29.2 minutes. In contrast, in the present RF cohort, the mean procedure time was 111.9 minutes, and the mean fluoroscopy time was only 10.95 minutes. Thus, compared with the own cryoballoon experience, RF ablation yielded similar procedure duration but markedly lower radiation exposure, with similar complication rates.[18] Although the literature often shows shorter procedure duration but higher phrenic nerve injury rates with cryoballoon ablation,[3] the findings suggest that RF ablation performed by highly experienced operators can achieve comparable efficiency. Moreover, RF ablation offers greater flexibility for individualized lesion sets enabled by advanced 3-dimensional mapping capabilities.

Pulse-field ablation continues to gain widespread adoption, and early studies suggest that it may ultimately offer procedural and safety advantages over both RF and cryoablation.[7] However, its rapid evolution complicates direct comparison with established modalities.

Among echocardiographic parameters, LA diameter and the presence of MR, particularly grade 3, were significantly associated with recurrence. Left atrial size has long been recognized as one of the strongest predictors of AF recurrence, and this relationship has been consistently supported by meta-analyses.[12] Initially, the association between MR and AF recurrence was believed to be mediated by LA enlargement.[13] However, more recent evidence indicates that moderate-to-severe MR independently predicts AF recurrence, regardless of LA size.[19] MR leads to pressure and volume overload of the atrium, promoting structural remodeling and atrial cardiomyopathy through electromechanical alterations.[20] Consequently, in patients with clinically relevant MR, anterior LA low-voltage areas adjacent to the mitral annulus are frequently observed. In such patients, incorporation of personalized lesion sets (posterior wall isolation, anterior mitral line, or targeted homogenization of low-voltage regions) may be beneficial. In the cohort, even patients with

Table 4. Results of Univariate and Multiple Regression Analyses Showing the Relationship Between AF Recurrence and Investigated Parameters

	Univariable			Multiple		
Variables	OR	95% CI	*P*	OR	95% CI	*P*
Paroxysmal AF, n	0.34	0.19-0.61	<.001	0.55	0.22-1.11	.442
Mitral regurgitation, n	1.50	1.11-2.02	.008	1.35	0.82-1.89	.420
AF symptom duration (months)	1.01	1.00-1.02	.006	1.01	1.00-1.02	.006
Prior DC-CV, n	5.33	3.01-9.46	<.001	3.12	2.34-4.10	<.001
LA size (mm)	1.01	1.00-1.01	.021	1.00	0.99-1.01	.396

AF, atrial fibrillation; CI, confidence interval; DC-CV, direct current cardioversion; LA, left atrium; OR, odds ratio.

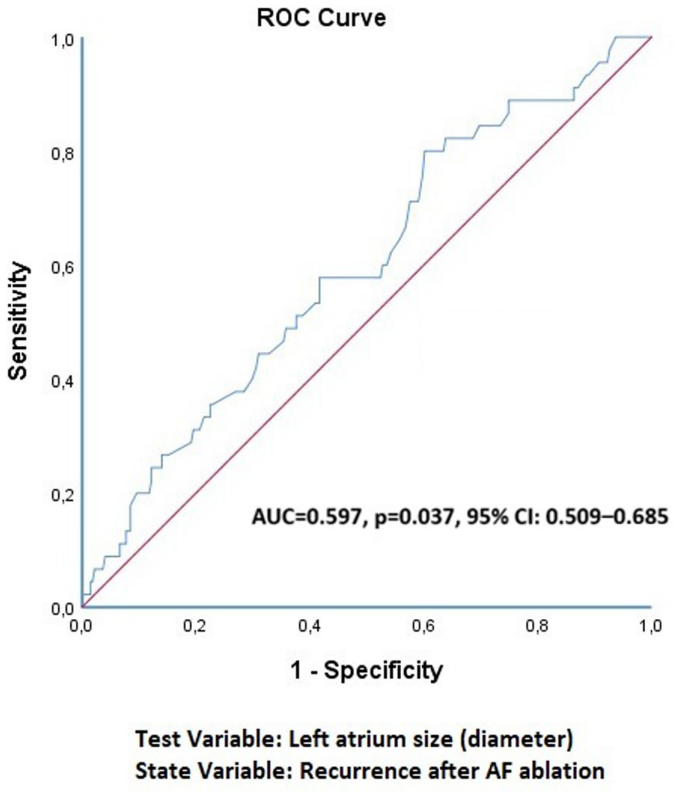

Figure 1. Receiver operating characteristic curve of left atrial size for predicting atrial fibrillation (AF) recurrence.

paroxysmal AF frequently underwent right atrial scar assessment and homogenization, which may partly explain the low recurrence rates. Larger prospective studies are needed to validate this observation.

Regarding AF type distribution, 44.8% of the patients had paroxysmal AF and 55.2% had persistent AF. Large contemporary AF ablation cohorts typically include 55-70% paroxysmal AF cases.[21] Thus, despite the cohort having a relatively high proportion of persistent AF, traditionally associated with higher recurrence, the overall recurrence rates remained lower than expected. This may reflect the detailed, standardized lesion formation strategy used in the center. This approach includes reduced lesion spacing, additional ablation applications at sites with incomplete isolation identified during post-ablation assessment with a HD catheter, and individualized adjunctive lesions (posterior wall box, scar homogenization, or anterior mitral line) when appropriate. Moreover, although earlier multicenter studies suggested that additional lesions did not reduce recurrence but increased procedure and fluoroscopy time, these studies predated zero-fluoroscopy and HD mapping technologies. In the experience, right atrial scar heterogeneity assessment and homogenization were systematically performed in all patients regardless of AF type. In many patients with paroxysmal AF, atrial runs detected during programmed or burst pacing resolved after right atrial homogenization, suggesting a potential mechanistic benefit. This observation is supported by prior work showing the relevance of right atrial remodeling in paroxysmal AF recurrence.[22] These findings highlight the potential role of bi-atrial substrate modification in select patients and warrant further prospective investigation.

AF symptom duration was also significantly longer in the recurrence group and emerged as an independent predictor of recurrence in multiple analyses. This aligns with prior findings by Sairaku et al, demonstrating that longer symptom duration predicted post-ablation recurrence.[23] AF diagnosis-to-ablation time, which is closely correlated with symptom duration, has similarly been shown in multiple recent systematic reviews and meta-analyses to be strongly associated with recurrence risk.[24,25]

A history of direct current cardioversion was also significantly more common among patients with recurrence and remained an independent predictor in multiple analyses. While this may partially reflect longer AF duration or more symptomatic disease prompting repeated cardioversions, its independent association suggests that prior direct current cardioversion may serve as a clinical marker of atrial substrate vulnerability.

Although LA diameter was significantly associated with AF recurrence, ROC analysis demonstrated limited discriminatory ability (area under the curve: 0.597), indicating poor predictive performance. These findings suggest that LA size alone is insufficient for risk stratification and should be interpreted in conjunction with other clinical and procedural variables.

Limitations of the Study

This study has several limitations that must be acknowledged. First, the retrospective and single-center design inherently limits the generalizability of the findings. Second, despite structured follow-up that included 48-72 hour Holter recordings, asymptomatic subclinical AF episodes may have been missed. Continuous monitoring (e.g., implantable loop recorders) would have provided more precise measurement of AF recurrence and burden. Third, procedural decisions regarding additional lesions (posterior wall isolation, anterior mitral line, and right atrial homogenization) were individualized based on operator assessment, introducing operator-dependent variability. Fourth, subgroup analyses comparing outcomes between PVI-only and PVI plus additional ablation strategies were not performed in the present study. Future studies incorporating such subgroup data from other centers and additional clinical experience may further contribute to the literature. Finally, although multiple regression identified independent predictors of AF recurrence, residual confounding from unmeasured variables such as autonomic factors, genetic predisposition, or inflammatory processes cannot be excluded.

CONCLUSION

In this study, RF ablation for AF performed in a high-volume, experienced electrophysiology laboratory demonstrated high procedural success and low recurrence rates over approximately 24 months of follow-up. The treatment was associated with low complication rates, short fluoroscopy times, and a high rate of sinus rhythm maintenance. A high

level of operator experience combined with individualized ablation strategies may have contributed to the improved treatment outcomes.

Ethics Committee Approval: This study was approved by the Ethics Committee of Koşuyolu High Specialization Training and Research Hospital (Approval No: 2023/12/711, Date: 18.07.2023).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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