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Different impact of female gender on the outcome of catheter ablation between paroxysmal and persistent atrial fibrillation

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Abstract

Background The impacts of gender on the outcome of atrial fibrillation (AF) ablation have been studied previously with contradictory results. Given the heterogeneities in clinical and pathophysiological characteristics between paroxysmal and persistent AF, gender impacts on post-ablation recurrence might differ depending on the type of AF.

Aims This study aimed to investigate the differing impacts of female gender on catheter ablation outcomes between paroxysmal and persistent AF.

Methods and results A total of 857 patients (537 (62.7%) males and 320 (37.3%) females) undergoing de novo catheter ablation of AF were included in this retrospective study. Gender differences in ablation outcomes for different types of AF were compared. Of all patients, 476 were diagnosed with paroxysmal AF (PAF) and 381 with persistent AF (PeAF). Compared to male patients, female patients were older (64.0 ± 8.9 vs. 59.5 ± 10.7 years, $P<0.001$), and more likely to have PAF (64.4% vs. 50.3%, $P<0.001$). During a median follow-up of 53 [37–72] months, the total atrial tachyarrhythmia (ATa) recurrence rate after a single procedure was 35.4%, with no difference between male and female patients (34.5% vs. 36.9%, $P=0.473$). For PAF, the recurrence was slightly higher in males than in females (37.4% vs. 30.1%, $P=0.096$). On the contrary, for PeAF, females had a significantly higher risk of recurrence than males (49.1% vs. 31.5%, $P=0.001$). The multivariate Cox regression analysis showed that female gender was an independent predictor of post-ablation recurrence only in PeAF (HR = 1.686; 95% CI 1.196–2.377, $P=0.003$).

Conclusions The female gender had different impacts on the outcome of catheter ablation between PAF and PeAF. The ATa recurrence was significantly higher in females than males only for PeAF.

Clinical trial number Not applicable.

Keywords Atrial fibrillation, Radiofrequency catheter ablation, Recurrence, Gender, female

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Introduction

Atrial fibrillation (AF) represents the most prevalent cardiac arrhythmia in clinical practice, with catheter ablation serving as a cornerstone therapeutic intervention for effective rhythm control [1]. Gender differences in epidemiology, pathophysiology, clinical presentation, and prognosis of AF have been recognized [2, 3]. Previous studies have investigated the impacts of gender on the outcomes of AF catheter ablation and generated controversial results. Some studies indicated that females experienced more post-ablation recurrence than males [4–10], while others found no significant difference between genders [11–16]. Given the heterogeneities in pathophysiological basis and recurrence mechanisms between paroxysmal AF (PAF) and persistent AF (PeAF), gender impacts on post-ablation recurrence might differ depending on the type of AF, which needs further study. Hence, we sought to explore the different impacts of female gender on the long-term outcome after catheter ablation between PAF and PeAF through a retrospective cohort study.

Methods

Patient population

Patients with AF who underwent de novo catheter ablation at Xuzhou Central Hospital from May 2013 to April 2021 were included in this retrospective study. The criteria for exclusion were as follows: (1) individuals who had previously received catheter ablation for AF; (2) those with severe concurrent structural heart disease; (3) those with incomplete clinical and procedure data; and (4) those lost to follow-up after the procedure. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Xuzhou Central Hospital and written informed consent was obtained from all participants.

Definitions

AF was defined as paroxysmal or persistent according to the guidelines [1]. AF duration was assessed as the time interval (in months) from initial diagnosis to catheter ablation. Left atrial volume (LAV) was measured intraprocedurally using the CARTO 3D electroanatomic mapping system (Biosense Webster, USA). Real-time 3D models of the left atrium were reconstructed from multipolar catheter-acquired anatomical points, and LAV was automatically calculated by the system software. LAVI was derived as the ratio of LAV to body surface area to account for body size variability.

Ablation protocol

All patients underwent transesophageal echocardiography or computed tomography (CT) to exclude left atrial thrombus within 24 h before the procedure. Antiarrhythmic drugs except amiodarone were discontinued for at least five half-lives before the procedure.

The procedures were performed under local anesthesia, combined with intravenous morphine. After performing double transseptal punctures, two 8.5 F SL1 sheaths (St. Jude Medical, St. Paul, MN) were advanced into the left atrium (LA). Systemic anticoagulation was achieved by intravenous administration of heparin, maintaining an activated clotting time (ACT) of 300–350 s throughout the procedure. Through a transseptal sheath, a circular mapping catheter (Lasso, Biosense-Webster, Diamond Bar, CA) was introduced into the left atrium to record pulmonary vein (PV) potentials. An irrigated contact force–sensing catheter (ThermoCool SmartTouch or ThermoCool SmartTouch SF, Biosense Webster, Diamond Bar, CA) was used for mapping and ablation. The ablation procedure was performed under the guidance of an electroanatomic mapping system (CARTO 3, Biosense Webster). Linear point-by-point lesions were placed in the PV antra with the endpoint of electrical isolation. Radiofrequency energy was delivered with 30 W on the posterior wall and 35 W on the anterior wall. The temperature of the radiofrequency energy was limited to 43 °C, with irrigation rates of 17 to 30 ml/min. If AF persisted after complete electrical isolation of all PVs, sinus rhythm (SR) was restored by direct current (DC) cardioversion. The conduction block between the LA and PV was confirmed by the disappearance of PV potential or the appearance of spontaneous potential. If AF converted to regular atrial tachycardia (AT) during ablation, the LA and RA activation map was conducted. Only when cavotricuspid isthmus (CTI) dependent atrial flutter was identified ablation along the CTI was performed; otherwise, AT was terminated by DC cardioversion. Ablation of extraPV triggers was guided by the presence or absence of spontaneous AF, AT, or frequent atrial ectopic beats.

Postprocedural management and follow-up

All patients were required to take novel oral anticoagulants (NOACs) or warfarin. The antiarrhythmic drugs (amiodarone, or propafenone) were used during the 3-month blanking period unless there existed bradyarrhythmia. Regular telephone and clinic follow-ups were provided for all patients. A physical examination and a 12-lead ECG were recorded at each visit, and 24-hour ECG Holter monitoring was performed at 3, 6, and 12 months and then every 6 months thereafter. Loss to follow-up was defined as failure to establish clinical contact for more than 12 consecutive months. The primary endpoint of our study was the recurrence of atrial tachycardia arrhythmia (ATa) after a single ablation procedure, defined as any recorded episode of ATa lasting more than 30 s beyond the 3-month blanking period.

Statistical analysis

Normally distributed continuous variables were expressed as mean ± standard deviation (SD) and compared by the Student t-test; non-normally distributed data were presented as the median with interquartile range [IQR: Q1-Q3] and compared by the Mann-Whitney U test. Categorical variables were described in numbers or percentages and compared through the χ^2 test. Univariate and multivariate Cox regression models were used to evaluate independent predictors of arrhythmia recurrence. The significant covariates ($P < 0.05$) identified in the univariate analyses were included in a multivariable Cox regression model. Arrhythmia-free survival was estimated using Kaplan-Meier curves with right censoring applied at the date of last verified clinical contact for patients meeting the predefined lost-to-follow-up criteria (≥ 12 months without contact), and differences between genders and AF types were compared using log-rank statistics with censoring-adjusted variance estimation.

To account for potential confounding variables (age, AF duration, comorbidities, extra-PV ablation and LAVI), propensity score matching (PSM) with a nearest neighbor matching algorithm was performed as a sensitivity analysis. A 1:1 female-to-male matching was implemented using a caliper value of 0.02 to balance covariate distributions.

A two-sided test was used in this study, and a P-value less than 0.05 was considered statistically significant. The statistical analyses were performed using R 4.3.2 (The R Project for Statistical Computing, www.r-project.org).

Results

Baseline clinical and procedural characteristics of all the patients by gender

918 AF patients underwent CA during the study period. The study flow chart is shown in Fig. 1. Twenty-five patients were excluded due to loss to follow-up after catheter ablation (CA), while ten others were excluded for incomplete clinical information. Furthermore, eleven patients with valvular heart disease or a prosthetic heart valve were excluded, and fifteen additional patients with prior ablation procedures were excluded to ensure homogeneity in the study population. As a result, a total of 857 patients were included in the analysis, with a median age of 61.4 ± 10.2 years. Of those patients, 320 (37.3%) were female, and 476 (55.5%) had PAF. The basic clinical characteristics of all the patients by gender are shown in Table 1. Compared to male patients, female patients were older (64.0 ± 8.9 vs. 59.5 ± 10.7 years, $P < 0.001$), and more likely to have PAF (64.4% vs. 50.3%, $P < 0.001$).

Successful PV isolation was achieved in all patients. The average procedure time was 118 [90–162] min, with no difference between genders. Ablation of extraPV triggers was more common in female patients (20.3% vs. 14.7%, $P = 0.038$) (see Table 1).

Baseline clinical and procedural characteristics of patients with PAF or PeAF by gender

Comparisons between genders in patients with PAF or PeAF are summarized in Tables 2 and 3, respectively. In the patients with PAF, there was no significant difference in LAVI between genders (46.5 [41.2–56.8] vs. 47.1 [39.3–55.3], $P = 0.444$). In contrast, among patients with PeAF, LAVI was significantly higher in females than in males (65.8 [55.6–79.2] vs. 62 [53-75.3], $P = 0.016$).

Follow-up and clinical outcomes in males and females

During a median follow-up of 53 [37–72] months, 303 patients (35.4%) suffered from an ATa recurrence, including 185 (34.5%) in males and 118 (36.9%) in females ($P = 0.473$). Kaplan-Meier survival curve analysis demonstrated that there was no significant difference in the

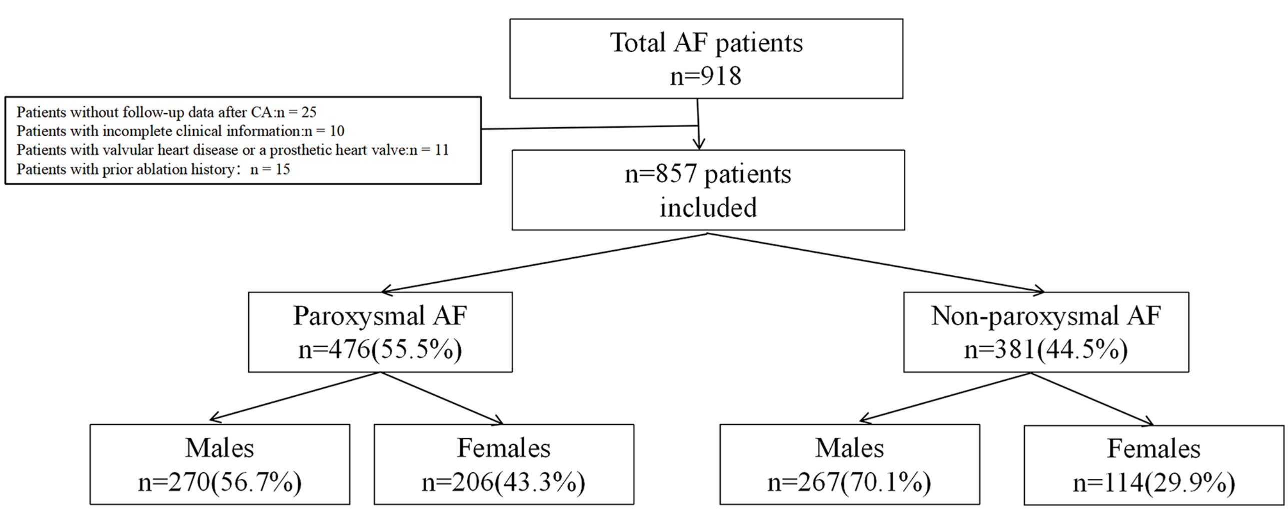

Fig. 1 Study flow chart

Table 1 Baseline characteristics by sex in total cohort

Variables	Total (*n* = 857)	Male (*n* = 537)	Female (*n* = 320)	*P* value
Age, years, Mean (SD)	61.4 ± 10.2	59.5 ± 10.7	64.0 ± 8.9	< 0.001
BMI, kg/m^2, Mean (SD)	25.3 ± 3.5	25.4 ± 3.4	24.5 ± 3.7	0.264
AF duration, m (IQR)	12 (4–48)	12 (4–48)	12 (3.8–48)	0.420
Type of AF, n (%)				< 0.001
Paroxysmal	476 (55.5)	270 (50.3)	206 (64.4)	
Persistent	381 (44.5)	267 (49.7)	114 (35.6)	
Concomitant medical history, n (%)				
Hypertension	384 (44.8)	231 (43)	153 (47.8)	0.178
Diabetes mellitus	94 (11)	53 (9.9)	41(12.8)	0.214
History of stroke/TIA	57 (6.7)	39 (7.3)	18 (5.6)	0.397
Chronic heart failure	54 (6.3)	37 (6.9)	17 (2)	0.387
Coronary artery disease	160 (18.7)	97 (18.1)	63 (19.7)	0.587
AAD post-ablation, n (%)	745 (86.9)	468 (87.2)	277 (86.6)	0.805
Amiodarone, n (%)	720 (84)	453 (84.4)	267 (83.4)	0.722
propafenone, n (%)	29 (3.4)	18 (3.4)	11 (3.4)	0.947
LAD, mm, Mean (SD)	36.6 ± 6.6	37.4 ± 6.4	35.3 ± 6.6	< 0.001
LVEDD, mm, Mean (SD)	48.3 ± 5.0	49.3 ± 5.0	46.4 ± 4.4	< 0.001
LVEF, %, Mean (SD)	55.9 ± 5.9	55.5 ± 6.5	56.5 ± 3.54.6	0.190
Ablation time, min (IQR)	118 (90-161.5)	118 (92–161)	117.5 (88-163.8)	0.711
LAV, ml (IQR)	96 (76.9-118.9)	99 (81-125.5)	89.1 (73-109.9)	< 0.001
LAVI, ml /m^2 (IQR)	54 (43-66.6)	53.8 (42.9–67.2)	54.2 (43.7–65.3)	0.936
extraPV ablation, n (%)	144 (16.8)	79 (14.7)	65 (20.3)	0.038
Follow-up, m (IQR)	53 (37–72)	51 (37–72)	53 (37–72)	0.606
ATa recurrence, n (%)	303 (35.4)	185 (34.5)	118 (36.9)	0.473

AF: atrial fibrillation; LAD: left atrial diameter; LVEDD: left ventricular end-diastolic diameter; LAV: left atrial volume; LVAI: left atrial volume index; extraPV: extra-pulmonary vein; ATa: atrial tachycardia arrhythmias; BMI: Body mass index; AAD: Anti-arrhythmia drug

cumulative ratio of freedom from recurrence between males and females (log-rank $P = 0.551$) (Fig. 2). To address potential confounding, a propensity score-matched (PSM) analysis was performed, adjusting for age, AF duration, comorbidities, extraPV ablation, and LAVI. The matched cohort ($n = 542$) demonstrated a similar ATa recurrence between genders (Supplementary Table S1 and figure S1).

Table 2 Baseline characteristics by sex in paroxysmal AF

Variables	Total (*n* = 476)	Male (*n* = 270)	Female (*n* = 206)	*P* value
Age, years, Mean (SD)	62.1 ± 10.2	60.7 ± 11	63.8 ± 8.8	0.003
BMI, kg/m^2, Mean (SD)	25 ± 3.5	25 ± 3.4	25 ± 3.6	0.757
AF duration, m (IQR)	12 (6–48)	16.5 (6–60)	12 (4–48)	0.376
Concomitant medical history, n (%)				
Hypertension	214 (45)	120 (44.4)	94 (45.6)	0.853
Diabetes mellitus	48 (10.1)	18 (6.7)	30 (14.6)	0.006
History of stroke/TIA	25 (5.3)	15 (5.6)	10 (4.9)	0.837
Chronic heart failure	7 (1.5)	3 (1.1)	4 (1.9)	0.473
Coronary artery disease	96 (20.2)	54 (20)	42 (20.4)	1.000
AAD post-ablation, n (%)	408 (85.7)	231 (85.6)	177 (85.9)	0.910
amiodarone, n (%)	394 (82.8)	225 (83.3)	169 (82.0)	0.711
propafenone, n (%)	14 (2.9)	6 (2.2)	8 (3.9)	0.288
LAD, mm, Mean (SD)	33.8 ± 5.6	34.4 ± 5.5	33 ± 5.5	0.013
LVEDD, mm, Mean (SD)	47.6 ± 4.5	48.7 ± 4.6	46.2 ± 4	< 0.001
LVEF, %, Mean (SD)	57.3 ± 4.1	57.1 ± 4.8	57.5 ± 3	0.578
Ablation time, min (IQR)	116 (87.3–157)	116.5 (86–157)	114 (89–157)	0.835
LAV, ml (IQR)	82 (69–99)	85.6 (72–101)	78 (65.4–96)	< 0.001
LAVI, ml /m^2 (IQR)	47.1 (40.2–56.6)	47.1 (39.3–55.3)	46.5 (41.2–56.8)	0.444
extraPV ablation, n (%)	83 (16.8)	42 (15.6)	41 (19.9)	0.225
Follow-up, m (IQR)	55 (38–73)	55 (38–74)	54.5 (38–72)	0.796
ATa recurrence, n (%)	163 (34.2)	101 (37.4)	62 (30.1)	0.096

Annotations are the same as those in Table 1

In patients with PAF, 163 (34.2%) experienced recurrences. The recurrence rate was slightly higher in males than in females (37.4% (101/270) vs. 30.1% (62/206), $P = 0.096$). There were no apparent differences between genders in the Kaplan-Meier survival analysis (log-rank $P = 0.081$) (Fig. 3B). After PSM to adjust for baseline covariates, the results remained unchanged (Supplementary Table S2 and figure S2).

In patients with PeAF, the overall recurrence rate was 36.7% (140/381). Compared to males, recurrences were more common in females (49.1% (56/114) vs. 31.5% (84/267), $P = 0.001$). The Kaplan-Meier survival analysis indicated that the cumulative rate of freedom from recurrence was significantly lower in females than in males (log-rank $P = 0.001$) (Fig. 3A). After applying PSM to account for baseline variables, the primary outcomes maintained their statistical significance without alteration (Supplementary Table S3 and figure S3).

The multivariate Cox regression analysis revealed that AF duration (HR = 1.002; 95% confidence interval [CI] 1.000–1.004, $P = 0.04$) and LAVI (HR = 1.015; 95% CI 1.008–1.021, $P < 0.001$) were independently associated with ATa recurrence in total patients. In patients with

Table 3 Baseline characteristics by sex in persistent AF

Variables	Total (*n* = 381)	Male (*n* = 267)	Female (*n* = 114)	*P* value
Age, years, Mean (SD)	60.6 ± 10.3	59.1 ± 10.4	64.2 ± 9.1	< 0.001
BMI, kg/m^2, Mean (SD)	25.6 ± 3.5	25.7 ± 3.4	25.5 ± 3.8	0.491
AF duration, m (IQR)	12 (3–48)	12 (3–48)	12 (3–36)	0.579
Concomitant medical history, n (%)				
Hypertension	170 (44.6)	111 (41.6)	59 (51.8)	0.072
Diabetes mellitus	46 (12.1)	35 (13.1)	11 (9.6)	0.394
History of stroke/TIA	32 (8.4)	24 (9)	8 (7)	0.687
Chronic heart failure	47 (12.3)	34 (12.7)	13 (11.4)	0.865
Coronary artery disease	160 (18.7)	97 (18.1)	63 (19.7)	0.587
AAD post-ablation, n (%)	337 (88.5)	237 (88.8)	100 (87.7)	0.770
amiodarone, n (%)	326 (85.6)	228 (85.4)	98 (86)	0.884
propafenone, n (%)	15 (3.9)	12 (4.5)	3 (2.6)	0.570
LAD, mm, Mean (SD)	40.1 ± 6.0	40 ± 5.8	39.5 ± 6.4	0.178
LVEDD, mm, Mean (SD)	49 ± 5.4	50 ± 5.3	46.9 ± 5.1	< 0.001
LVEF, %, Mean (SD)	54.1 ± 7.2	53.9 ± 7.6	54.6 ± 6.2	0.823
Ablation time, min (IQR)	120 (92.5–169)	120 (94–167)	122 (87–180)	0.969
LAV, ml (IQR)	114 (96-139.1)	115.5 (96.3-142.1)	113.5 (95–134)	0.225
LAVI, ml /m^2 (IQR)	62.8 (53.8–77.7)	62 (53-75.3)	65.8 (55.6–79.2)	0.016
extraPV ablation, n (%)	61 (16)	37 (13.9)	24 (21.1)	0.093
Follow-up, m (IQR)	50 (36–71)	48 (36-69.5)	52.5 (35–74)	0.557
ATa recurrence, n (%)	140 (36.7)	84 (31.5)	56 (49.1)	0.001

Annotations are the same as those in Table 1

PAF, LAVI (HR = 1.019; 95% CI 1.009–1.029, *P* = 0.001) was identified as the only independent risk factor. In patients with PeAF, AF duration (HR = 1.003; 95% CI 1.000–1.006, *P* = 0.037), LAVI (HR = 1.010; 95% CI 1.002–1.019, *P* = 0.016), and female gender (HR = 1.686; 95% CI 1.196–2.377, *P* = 0.003) were found to related to recurrence independently (see Table 4). Following adjustment for baseline covariates via PSM, the study findings exhibited stability across all key analyses (Supplementary Table S4).

Discussion

The main finding of our study was that the impact of gender on the outcomes of AF ablation was different between PAF and PeAF. In PeAF patients, females were significantly more likely to suffer from post-ablation recurrence than males. However, in patients with PAF, the recurrence rate was slightly higher in males than females.

Previous studies have investigated the impact of gender on recurrence following catheter ablation of AF, yielding mixed results. Some studies indicated that females experienced higher recurrence rates than males [4–10], while others have found no significant gender differences [11–16]. Notably, most of these studies did not analyze PAF and PeAF separately, which may have contributed to the conflicting outcomes. Given the different clinical characteristics, pathogenesis, and recurrence causes associated with different types of AF, gender's influence on post-ablation recurrence may vary as well. To better understand the impact of gender on recurrence after AF ablation, we need to analyze PAF and PeAF separately.

In this study, we discovered that the recurrence rate after ablation was higher in females than in males with PeAF. These results align with those reported by Sugumar et al. [17] and Zhang et al. [18]. In contrast, Singh et al. reported no significant differences in post-ablation recurrence rates of PeAF between genders [19]. Regarding PAF, our findings indicated that males had a slightly higher recurrence rate than females. Some earlier studies supported our findings [20, 21], while others suggested that females had a higher recurrence rate than males [7, 22, 23]. The differences in these results might stem not only from the low sample size but also from variations in catheter ablation strategies. In some previous studies, a high proportion of patients underwent ablation other than PVI, including complex fractionated atrial electrograms and/or linear ablation [18, 19, 23]. However, most of our patients received only PVI, with just 16% undergoing ablation of extraPV triggers. Therefore, our research mainly focuses on the impact of gender on the recurrence rate of different types of AF after receiving only PVI.

The difference in the influence of gender on post-ablation recurrence of different types of AF should be related to the differences in pathophysiological characteristics and recurrence causes between PAF and PeAF. Patients with PAF typically exhibit relatively mild atrial remodeling, with post-ablation recurrence primarily resulting from PV reconnections. As the atrial wall thickness in males is greater than in females [20, 24], it is relatively less likely to form transmural damage. Therefore, reconnections are more likely to occur after PVI. Previous studies have displayed that during a second procedure, the PV reconnection rate in females was lower compared to males [7, 21, 25], which could explain why the recurrence rate is slightly higher in males than in females with PAF in the current study. In contrast, atrial remodeling is more pronounced in patients with PeAF, so the role of PV reconnections in post-ablation recurrence is relatively weak, while changes in the electrophysiological and structural substrate of the atrium play a more prominent

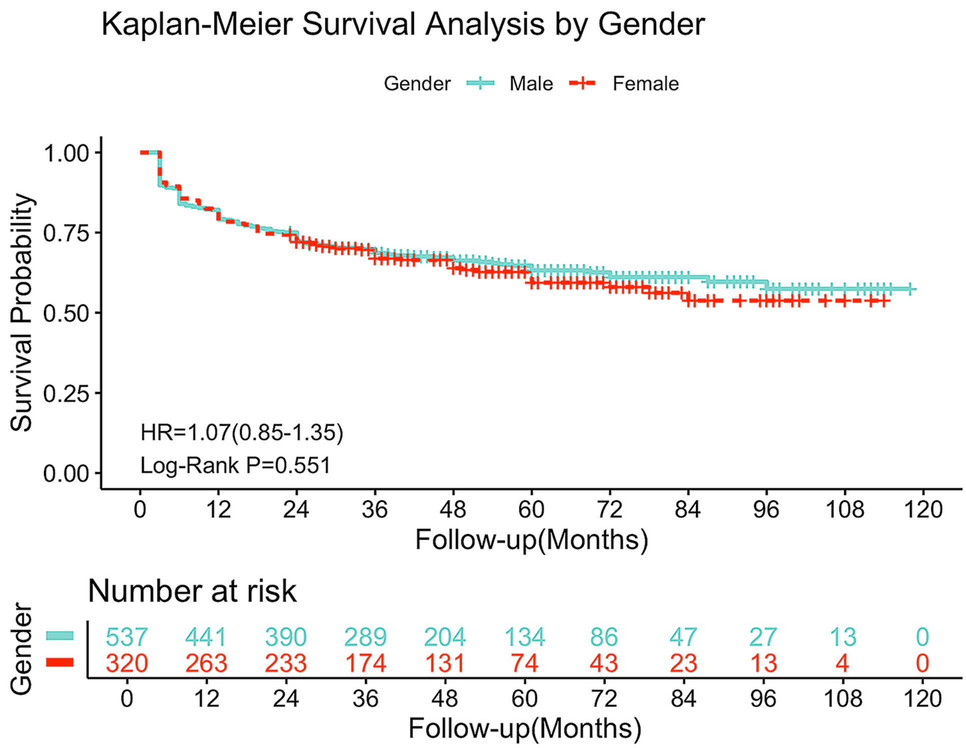

Fig. 2 Kaplan-Meier analysis of ATa-free survival after the initial ablation procedure in the total cohort

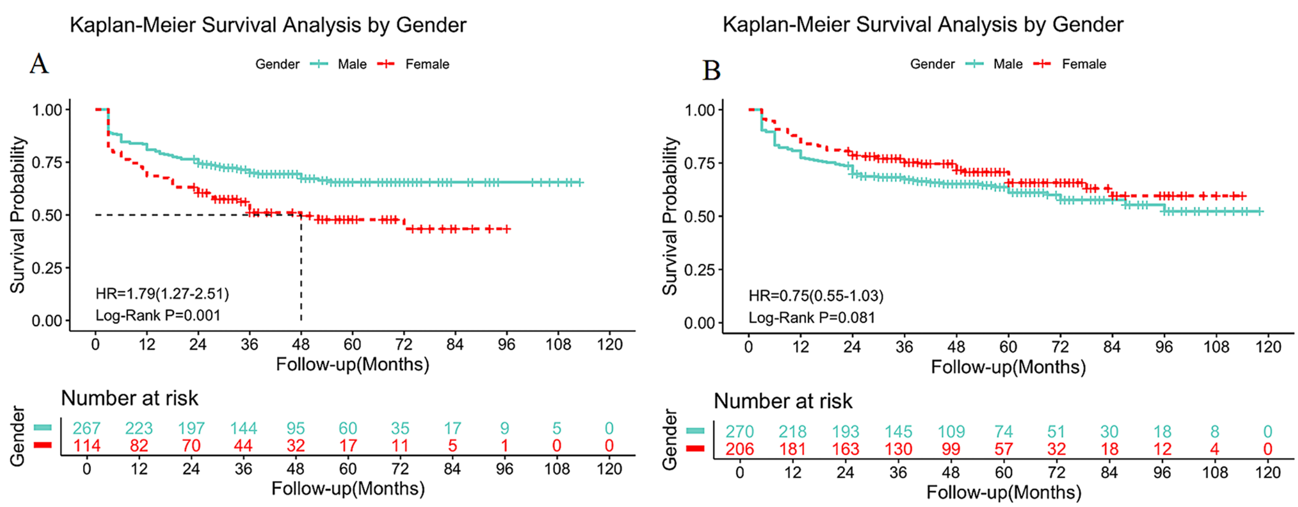

Fig. 3 Kaplan-Meier analysis of ATa-free survival after the initial ablation procedure in (**A**) Persistent AF; (**B**) Paroxysmal AF

role. Compared to males, atrial remodeling is more common in females, including low voltage zones, delayed enhancement on cardiac magnetic resonance imaging, and extraPV triggers [4, 25, 26]. In this study, female patients required extraPV ablation more frequently than males (20.3% vs. 14.7%, $P=0.038$), indicating potential sex-specific arrhythmogenic substrates. Although additional ablation did not disproportionately affect short-term outcomes in females (see Supplementary Analyses), a trend toward higher long-term recurrence rates was observed. This phenomenon may be attributed to: (1) Substrate heterogeneity: histopathological data indicate sex-specific collagen deposition patterns, with females showing more diffuse interstitial fibrosis [27]. Diffuse fibrosis in females may create complex regions of electrical conduction barriers, necessitating broader ablation coverage to target latent reentrant pathways; (2) Hormonal influences: Preclinical models demonstrate that estrogen deficiency (e.g., post-menopause) accelerates collagen synthesis via activation of the TGF-β/Smad signaling pathway, while estrogen replacement therapy significantly attenuates fibrotic progression [28].

Table 4 Multivariable Cox analysis of risk factors for ATa recurrence in total cohort

	Variables	*P* value	HR	95%CI	
Total cohort					
	AF duration	**0.040**	**1.002**	**1.000**	**1.004**
	Hypertension	0.120	1.198	0.954	1.505
	LAVI	**< 0.001**	**1.015**	**1.008**	**1.021**
	Female	0.620	1.061	0.839	1.343
	AF type	0.468	0.907	0.697	1.181
	AAD	0.456	1.138	0.809	1.601
Paroxysmal AF					
	Female	0.110	0.771	0.561	1.061
	Hypertension	0.216	1.215	0.892	1.655
	extraPV ablation	0.129	0.700	0.442	1.110
	AF duration	0.409	1.001	0.998	1.004
	LAVI	**0.001**	**1.019**	**1.009**	**1.029**
Persistent AF					
	Female	**0.003**	**1.686**	**1.196**	**2.377**
	extraPV ablation	0.762	0.932	0.590	1.471
	AAD	0.691	0.902	0.542	1.501
	AF duration	**0.037**	**1.003**	**1.000**	**1.006**
	LAVI	**0.016**	**1.010**	**1.002**	**1.019**

Annotations are the same as those in Table 1

The bold values indicate the values of $p < 0.05$

In our cohort, post-menopausal females (85% of female participants) had higher LAVI than pre-menopausal females (57.8 ± 19.3 ml/m^2 vs. 51.9 ± 19.8 ml/m^2, $P = 0.05$), suggesting a potential hormonal contribution to atrial remodeling.

LAVI is an important indicator reflecting atrial remodeling and is associated with post-ablation recurrence. According to our findings, LAVI was an independent factor linked to recurrence in both PAF and PeAF. Previous studies have shown that LAVI is generally larger in females than males [25, 29]. However, in this study, we found that only patients with PeAF exhibited a significantly greater LAVI in females compared to males. In contrast, patients with PAF showed no significant difference in LAVI between genders. This suggested that only for PeAF was atrial remodeling more pronounced, leading to a higher recurrence rate in females than in males. Conversely, the difference in LA remodeling between genders was less significant in patients with PAF, resulting in a relatively weak impact on post-ablation recurrence.

Our study identified significant gender disparity in ablation uptake (male: 62.7% vs. female: 37.3%), consistent with prior reports of reduced ablation rates in women despite higher symptom burden [30]. The recent study by Gangadharan et al. [31] further elucidates that this disparity predominantly arises during referral to electrophysiologists rather than final treatment decisions. Notably, our data revealed comparable AF duration between genders, suggesting equivalent access pathways once entering specialty care. Our results extend the observations of Gangadharan et al. by demonstrating that while referral disparities persist, equitable access to ablation is achievable once patients enter the electrophysiology care pathway. This dichotomy underscores the need for targeted interventions to address upstream barriers (e.g., improving AF recognition in women, enhancing primary care provider education on gender-neutral referral criteria).

Limitations

This study has several limitations. First, post-ablation echocardiographic data, quality of life (QoL) assessments, and objective measures of AF burden (e.g., continuous rhythm monitoring) were not systematically collected. These parameters could provide critical insights into structural remodeling, patient-centered outcomes, and arrhythmia recurrence patterns, which were not captured in our current analysis. Future studies incorporating longitudinal imaging, patient-reported outcomes, and detailed rhythm surveillance will further elucidate the holistic impact of catheter ablation. Secondly, it is a single-center, retrospective observational analysis with a relatively small sample size. Additionally, some patients were excluded due to incomplete clinical and procedural data or loss of follow-up, which may introduce some bias. Furthermore, data such as atrial voltage and conduction velocity could not be obtained for analysis due to the lack of high-density electro-anatomical mapping during sinus rhythm in most patients. Lastly, since only 24-hour ECG Holter monitoring was utilized to assess arrhythmia recurrences, the actual recurrence rate may have been underestimated. However, this limitation likely affected all patients equally, so it should have little impact on the overall results.

Conclusions The impact of female gender on catheter ablation outcomes differed between PAF and PeAF. The ATa recurrence was significantly higher in females than males for PeAF not for PAF.

Abbreviations

AF	atrial fibrillation
PAF	paroxysmal AF
PeAF	persistent AF
CA	catheter ablation
ATa	atrial tachyarrhythmia
CT	computed tomography
LA	left atrium
ACT	activated clotting time
SR	sinus rhythm
PV	pulmonary vein
DC	direct current
CTI	cavotricuspid isthmus
NOACs	novel oral anticoagulants
IQR	interquartile range
LAD	left atrial diameter
LVEDD	left ventricular end-diastolic diameter

LAV left atrial volume
LAVI left atrial volume index
extraPV extra-pulmonary vein

Supplementary Information

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Supplementary Material 1

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Author contributions

BH designed the study and conceived the paper. WD performed statistical analysis and drafted the manuscript. WZ and HY were responsible for the methodology and investigation. QD and YF arranged the data and performed visualization. XL contributed to validation. SL critically revised the manuscript, and all authors read and approved the final manuscript.

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Data availability

The data presented in this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethical Committee of Xuzhou Central Hospital. All participants provided written informed consent as there were no interventions.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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