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Study of left heart parameters related to recurrence in patients with atrial fibrillation after radiofrequency ablation by ultrasonography

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Abstract

This study evaluates the value of transesophageal echocardiography (TEE) combined with speckle tracking imaging in predicting the recurrence of atrial fibrillation (AF) after radiofrequency ablation. A total of 269 patients with paroxysmal AF were divided into 2 groups according to the clinical follow-up results: the recurrence group (n = 79) and the non-recurrence group (n = 190). Left atrial appendage flow velocity was measured by TEE, left atrial anteroposterior diameter, left atrial volume index and CAAP-AF score were measured by conventional TEE, and left atrial reservoir phase strain, left atrial pipeline phase strain and left atrial pump phase strain were measured by speckle tracking imaging. The correlation between each parameter and recurrence was compared. Logistic regression analysis showed that left atrial reservoir strain and left atrial appendage flow velocity were sensitive indicators to predict the recurrence of paroxysmal AF after radiofrequency ablation. Ultrasound parameters can be used to screen the patients who are prone to recurrence after operation and provide reference for clinical treatment to reduce the recurrence rate.

Abbreviations: AF = atrial fibrillation, CA = catheter ablation, LA = left atrium, LAA = left atrial appendage, LAA-v = left atrial appendage flow velocity, LAD = left atrial anteroposterior diameter, LASr = left atrial reservoir phase strain, LAVI = left atrial volume index, RFCA = radiofrequency catheter ablation, TEE = transesophageal echocardiography.

Keywords: atrial fibrillation, echocardiography, radiofrequency ablation, relapse

1. Introduction

With the continuous improvement in the efficacy and safety of catheter ablation (CA) for atrial fibrillation (AF), the 2021 expert consensus proposed by the European Society of Cardiology recommends CA as a Class I treatment for symptomatic paroxysmal AF and persistent AF following failed pharmacological therapy.[1] Clinically, circumferential pulmonary vein isolation is commonly used as the foundation combined with multiple ablation strategies, yet the postoperative recurrence rate remains relatively high. Some validated methods for assessing AF recurrence after ablation, such as the CAAP-AF score,[2] evaluate postoperative recurrence and prognosis by integrating various risk factors associated with AF development. However, echocardiographic parameters are less frequently incorporated into existing scoring systems like CAAP-AF. This study aims to explore the predictive value of echocardiographic parameters in AF patients undergoing CA, providing clinical preoperative reference.

2. Study objects and methods

2.1. Study objects

This study enrolled 269 patients scheduled to undergo first-time transcatheter radiofrequency ablation for AF at our hospital from January 2021 to November 2021.

Inclusion criteria: Patients with AF confirmed by electrocardiogram with clinical diagnosis of AF; patients who received first-time radiofrequency ablation candidates (including paroxysmal and persistent AF), and failure to spontaneously revert to sinus rhythm during hospitalization.

Patients who undergo preoperative transesophageal echocardiography showing no thrombi in the left atrium (LA) or left atrial appendage (LAA).

Exclusion criteria: Patients who undergo non-first-time radiofrequency ablation; Patients with congenital heart disease, valvular disease and other organic cardiac diseases; Patients with a history of pacemaker implantation; Patients with

All the patients have signed the informed consent.

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

The study has been approved by the ethics committee of General Hospital of Northern Theater Command.

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hyperthyroidism, cerebral apoplexy in the last 3 months, and secondary AF and patients with left auricular thrombosis.

2.2. General data and ultrasonic image collection

2.2.1. General information of patients. Age, gender, medical history (coronary artery disease, hypertension, renal insufficiency, and diabetes), and the CAAP-AF score for AF recurrence risk was calculated.

2.2.2. Ultrasound image acquisition and parameter measurement. All patients underwent transthoracic echocardiography before their first radiofrequency CA (RFCA). Examinations were performed using a Philips EPIQ 7C color Doppler ultrasound system with an X5-1 transducer (frequency range: 1–5 MHz, frame rate: 50–90 frames/s). Patients were placed in the left lateral decubitus position with continuous electrocardiogram monitoring. Dynamic 2D images, color Doppler, spectral Doppler, and tissue Doppler imaging were acquired, with 3 consecutive cardiac cycles recorded and stored for offline analysis. Calculated and stored parameters: body surface area, left atrial anteroposterior diameter (LAD), left atrial end-diastolic volume, left atrial end-systolic volume, left atrial volume index (LAVI) = maximum left atrial volume/body surface area, left atrial appendage flow velocity (LAA-v): Measured via real-time three-dimensional transesophageal echocardiography using pulsed-wave Doppler, with the sample volume positioned at the orifice of the LAA (Fig. 1).

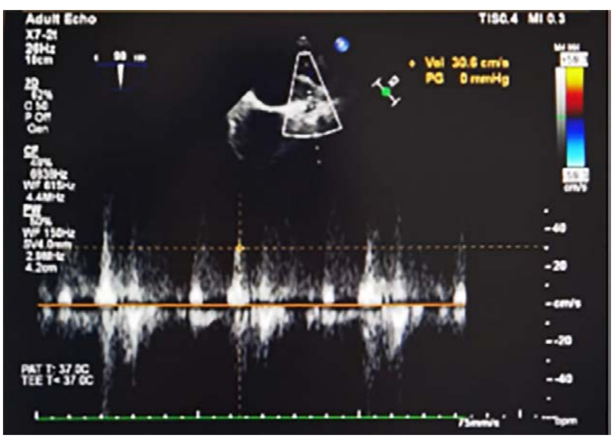

Figure 1. Left atrial appendage blood flow velocity (LAA-v) in patients with non-recurrence paroxysmal atrial fibrillation before surgery.

Left atrial strain curve was obtained using 2D speckle tracking imaging. Left atrial reservoir strain (LASr): Calculated as the strain difference between mitral valve opening and left ventricular end-diastole (Fig. 2). Left atrial conduit strain: Defined as the strain difference between atrial contraction onset and mitral valve opening. Left atrial contraction strain: Calculated as the strain difference between left ventricular end-diastole and atrial contraction onset.

2.3. Statistical analysis

SPSS 25.0 software was used for statistical analysis. The measurement data were expressed as ($\bar{x} \pm s$). The counting data were represented by examples and percentages. Independent sample t test was used for comparison of measurement data, and x2 test was used for comparison of counting data between 2 groups. All hypothesis tests were bilateral tests, and $P < .05$ was statistically significant. *t*-Test was used to screen the indicators related to recurrence in the persistent and paroxysmal AF group and the paroxysmal AF group, and the parameters of univariate analysis $P < .05$ were included in the multivariate model analysis, and the sensitive indicators for predicting the recurrence of persistent and paroxysmal AF were screened by multivariate Logistic regression analysis.

3. Results

3.1. General information

A total of 269 patients were ultimately included in this study. Seventy-nine patients (29%) who experienced atrial tachycardia, atrial flutter, or AF lasting > 30 seconds during the 4 to 6 months post-RFCA were classified as the recurrence group, while the remaining 190 patients (71%) with successful outcomes were designated as the control group. The recurrence group was further subdivided into persistent AF recurrence (n = 43, 54%) and paroxysmal AF recurrence (n = 36, 46%) based on AF type.

There were no significant differences in the mean age, gender, and combined diseases between the recurrence group and the non-recurrence group ($P > .05$) (Table 1).

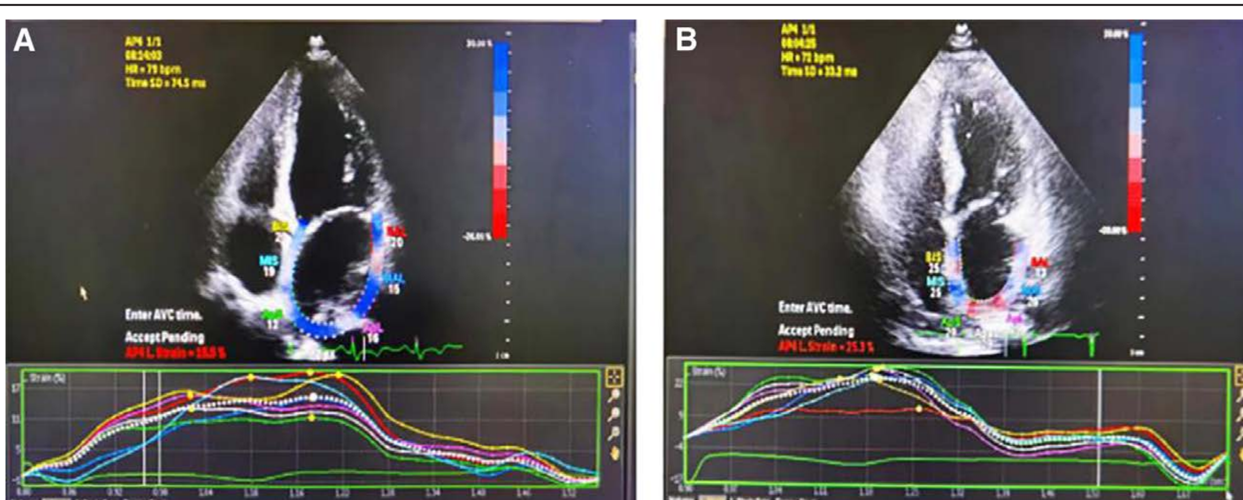

Figure 2. Left atrial strain during reservoir phase (LASr) of patients with paroxysmal atrial fibrillation before surgery. (A) Recurrence patient; (B) non-recurrence patient.

3.2. Comparison of ultrasound parameters of LA and LAA between recurrence group and non-recurrence group

The LAVI and LAD in the recurrence group were higher than those in the non-recurrence group, and the LASr and LAA blood flow velocity were lower than those in the non-recurrence group, and the differences were statistically ($P < .05$) (Table 2).

3.3. Comparison of ultrasound parameters between persistent AF recurrence group and non-recurrence group

Univariate analysis of variables with significant differences in clinical and imaging characteristics showed that the persistent AF recurrence group had larger LAD, LAVI, E/e', and CAAP-AF scores ($P < .05$), and lower LASr and LAA-v ($P < .001$) compared to the non-recurrence group (Table 3).

Multivariate Logistic regression analysis adjusted for age and gender showed that LASr and LAA-v were sensitive indicators to predict the recurrence in persistent AF patients after RFCA ($P < .05$) (Table 4).

3.4. Comparison of ultrasound parameters between paroxysmal AF recurrence group and non-recurrence group

Univariate analysis of variables with significant differences in clinical and imaging characteristics demonstrated no significant differences in LAD or LAVI between the paroxysmal AF recurrence and non-recurrence groups ($P > .05$). However, the paroxysmal AF recurrence group showed higher CAAP-AF scores and lower LASr, LAA-v, and left ventricular global longitudinal strain ($P < .05$, Table 5).

Multivariate Logistic regression analysis adjusted for age and gender showed that LASr and LAA-v were sensitive indicators to predict the recurrence in paroxysmal AF patients after RFCA ($P < .05$), while other clinical general parameters, blood biochemical parameters and ultrasound parameters could not predict the recurrence in paroxysmal AF patients after RFCA (Table 6).

4. Discussion

Although RFA is a crucial treatment for AF, the postoperative recurrence rate remains as high as 30% to 50%.[3,4] Identifying effective predictors of AF recurrence holds significant clinical value for diagnosis and treatment. This study focuses on the predictive role of echocardiographic parameters in AF recurrence following RFA.

4.1. Discussion on LAVI and LAA diameter differences and similarities

1.Statistical differences between recurrence and non-recurrence groups in LAVI and LAA diameter.

The observed statistical differences in LAVI and LAA diameter between the recurrence and non-recurrence groups, as presented in Table 2, are of great significance. LAVI is an important parameter reflecting left atrial remodeling. A recent study by Kranert et al[5] demonstrated that increased LAVI is associated with a higher risk of AF recurrence. In our study, the recurrence group showed a significantly larger LAVI compared to the non-recurrence group. This could be attributed to the fact that left atrial remodeling, manifested by an enlarged LAVI, creates an electrophysiological substrate conducive to the maintenance and recurrence of AF. The enlarged atrium may have abnormal electrical conduction, leading to reentry circuits that trigger AF recurrence. Regarding the LAA diameter, a study[6] reported that a larger LAA diameter is related to thrombus formation and a higher likelihood of AF recurrence. In our results, the recurrence group also had a significantly larger LAA diameter. The larger LAA diameter may result in slower blood flow velocity within the LAA, promoting thrombus formation. Thrombi in the LAA can then potentially embolize, causing stroke or other thromboembolic events. Additionally, the mechanical and hemodynamic changes associated with an enlarged LAA may further disrupt the normal atrial electrophysiology, contributing to AF recurrence.

Multivariate logistic regression analysis revealed that LASr and LAA-v are predictors of AF recurrence after ablation. Recurrence patients exhibited lower LASr compared to non-recurrence patients, likely due to more severe left atrial interstitial fibrosis and increased left atrial wall stiffness in the recurrence group. LASr reflects left atrial reservoir function,

Table 1

Baseline information between recurrence and non-recurrence groups.

Item	Recurrence group (n = 79)	Non-recurrence group (n = 190)	P value
Age (year)	53.12 ± 11.81	54.52 ± 11.94	.255
Male [(n)%]	62 (79.82%)	69 (79.84%)	.791
Complications			
Hypertension [(n)%]	63 (80.12%)	74 (85.27%)	.200
Diabetes [(n)%]	3 (4.22%)	4 (4.65%)	.837
Dyslipidemia [(n)%]	31 (39.46%)	36 (41.86%)	.468
Coronary heart disease [(n)%]	15 (19.28%)	17 (20.16%)	.832
Renal insufficiency [(n)%]	4 (5.12%)	6 (7.00%)	.418

(n)%: Percentage of the cases.

Table 2

Comparison of ultrasound parameters between recurrence group and non-recurrence group.

Ultrasound parameters	Recurrence group (n = 70)	Non-recurrence group (n = 190)	P value
Left atrial volume index (mL/m^2)	21.81 ± 17.04	17.04 ± 10.66	.004
Left atrial appendage diameter (mm)	38.88 ± 4.70	36.76 ± 3.19	<.001
Left atrial strain during reservoir phase (%)	21.50 ± 6.30	25.50 ± 5.12	<.001
Left atrial strain during conduit phase (%)	–10.63 ± 6.25	–12.36 ± 4.13	.601
Left atrial strain during contraction phase (%)	–11.90 ± 4.78	–12.17 ± 3.62	.677
Left atrial appendage blood flow velocity (cm/s)	23.26 ± 5.40	37.54 ± 10.42	<.001
Left atrial end diastolic volume (mL)	54.01 ± 23.45	52.92 ± 20.37	.749
Left atrial end systolic volume (mL)	34.80 ± 20.29	31.43 ± 21.88	.307
CAAP-AF score	3.82 ± 1.05	2.98 ± 1.17	<.001

Table 3

Comparison of ultrasound parameters between persistent atrial fibrillation recurrence group and non-recurrence group.

Ultrasound parameters	Persistent atrial fibrillation recurrence group (n = 43)	Non-recurrence group (n = 190)	P value
Left atrial volume index (mL/m²)	22.58 ± 7.32	17.04 ± 10.66	.003
Left atrial appendage diameter (mm)	40.30 ± 5.22	36.76 ± 3.19	<.001
Left atrial strain during reservoir phase (%)	20.77 ± 7.32	25.50 ± 5.12	<.001
Left atrial appendage blood flow velocity (cm/s)	24.28 ± 6.66	37.54 ± 10.42	<.001
CAAP-AF score	3.96 ± 1.14	2.98 ± 1.17	<.001

Table 4

Multivariate logistic analysis between persistent atrial fibrillation recurrence group and non-recurrence group.

Variables	OR	95%CI	P value
Left atrial appendage diameter (mm)	1.165	0.18–1.988	.425
Left atrial volume index (mL/m²)	1.052	0.877–1.261	.586
Left atrial strain during reservoir phase (%)	0.183	0.641–1.078	.831

OR = odds ratio, 95%CI = 95% confidence interval.

Table 5

Comparison of ultrasound parameters between paroxysmal atrial fibrillation recurrence group and non-recurrence group.

Ultrasound parameters	Paroxysmal atrial fibrillation recurrence group (n = 36)	Non-recurrence group (n = 190)	P value
Left atrial volume index (mL/m²)	19.51 ± 13.65	17.04 ± 10.66	.275
Left atrial appendage diameter (mm)	37.22 ± 3.38	36.76 ± 3.19	.476
Left atrial strain during reservoir phase (%)	22.36 ± 4.81	25.50 ± 5.12	<.001
Left atrial appendage blood flow velocity (cm/s)	22.86 ± 3.33	37.54 ± 10.42	<.001
CAAP-AF score	1.165	0.18–1.988	.402

Table 6

Multivariate logistic analysis between paroxysmal atrial fibrillation recurrence group and non-recurrence group.

Variables	OR	95%CI	P value
Left atrial strain during reservoir phase (%)	1.472	1.157–1.871	.002
Left atrial appendage blood flow velocity (cm/s)	2.860	2.009–4.071	.004
CAAP-AF score	0.649	0.216–1.951	.441

OR = odds ratio, 95%CI = 95% confidence interval.

which is significantly influenced by AF-induced electrical and mechanical remodeling and may occur earlier than left atrial enlargement.[7] Following AF onset, structural remodeling of the left atrial myocardium, autonomic nerve activation, and fibroblast proliferation lead to increased myocardial stiffness and reduced deformability.[8,9] LASr, measured via 2D-STE, represents the strain generated during left atrial filling from pulmonary venous flow in ventricular systole and serves as a valuable parameter for predicting AF ablation success.[10] LAA-v is a marker of LAA hemodynamics and the severity of left atrial remodeling,[11] positively correlated with left atrial voltage and negatively correlated with left atrial volume. Enlarged LA in recurrence patients alters the LAA pressure-volume relationship. A decline in LAA-v reflects impaired left atrial contraction and reservoir function,[12] indicating poor LAA contractility and serving as a reliable predictor of AF recurrence.

CAAP-AF Score: This study found higher CAAP-AF scores in recurrence patients compared to non-recurrence patients. The CAAP-AF score incorporates 6 parameters: LAD, coronary artery disease, age, AF type, number of failed antiarrhythmic drugs, and female sex,[8] demonstrating predictive value for AF recurrence after RFCA. A high score (≥8 points) indicates increased recurrence risk associated with left atrial scarring and low-voltage zones.

Based on the above difference between the non-recurrence group and the recurrence group, in order to further explore the characteristics of postoperative recurrence of different types of AF, patients were divided into paroxysmal AF group and persistent AF group according to the type of AF. Paroxysmal AF is self-limiting, while persistent AF lasts > 7 days and rarely terminates spontaneously. Differences in pathophysiological mechanisms and disease progression between AF types justify subgroup analyses to refine the predictive utility of echocardiographic parameters.[13]

Comparison between paroxysmal AF group and non-recurrence group: Recurrence paroxysmal AF patients showed reduced LASr, LAA-v, and left ventricular global longitudinal strain, and elevated CAAP-AF scores. Paroxysmal AF patients are in the early stage of left atrial remodeling, where chronic pressure overload drives left atrial enlargement.[14] Left atrial dysfunction precedes structural enlargement, and declines in LASr and LAA-v reflect impaired left atrial function and remodeling,[1] which were sensitive predictors of post-ablation recurrence in paroxysmal AF.

Comparison between persistent AF group and non-recurrence group: Recurrence persistent AF patients exhibited larger LAD, LAVI, and higher CAAP-AF scores, and lower LASr and LAA-v compared to non-recurrence patients. Persistent AF involves more complex and heterogeneous atrial remodeling. Diverse underlying etiologies and comorbidities (e.g., heart failure with elevated atrial pressure/volume contribute to severe atrial remodeling) resulting in increased LAVI and LAA diameter.[15] In addition, the duration of AF also affects the atrial remodeling degree, the patients with prolonged duration have larger LAVI and LAA diameters. Similarities between groups and reasons: Comparisons across the non-recurrence group, recurrence group, paroxysmal AF group, and persistent AF group showed similar results, and indicated that LASr and LAA-v and other parameters were associated with AF recurrence. This is because the development and progression of AF – whether in the overall AF population or in subgroups categorized as paroxysmal and persistent AF – are accompanied by processes of atrial electrical remodeling and mechanical remodeling. Structural and functional alterations in the LA manifest across different AF subtypes, with these changes being closely associated with AF recurrence. LA dysfunction-related parameters such as LASr and LAA-v can sensitively reflect pathophysiological changes in the atria, thereby demonstrating predictive value for AF recurrence in comparative analyses across different subgroups.

Limitations of this study: (1) Due to the epidemic situation, there were many cases lost to follow-up in this study, patients were lost at different time periods, and the single-center small sample factor may lead to biased results; (2) Patients with early recurrence of AF (within 3 months after surgery) were not independently grouped, and right heart function was not included in the study; and (3) Due to time constraints, patients over 6 months after surgery were not included in this study, and the long-term postoperative status assessment of patients was unknown.

5. Conclusions

1. Ultrasound parameters can be combined with multiple indicators to screen patients prone to postoperative recurrence, provide reference for clinical treatment, and reduce the recurrence rate of surgery.
2. Compared with non-recurrence patients, patients with recurrence AF had more significant impairment of left atrial reservoir function, left ventricular global systolic function and diastolic function.
3. Logistic regression analysis showed that LAsr and LAA-v were predictive indicators of recurrence of AF after radiofrequency ablation.

Author contributions

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Writing – review & editing: Jing Yun Wang, Nan Nan Liu, Ming Liang, Zu Lu Wang, Wei Wei Zhou, Yu Xin Su.

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