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RESEARCH

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Predictive value of the left atrioventricular coupling index for recurrence after radiofrequency ablation of paroxysmal atrial fibrillation

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Abstract

Background Although patients with paroxysmal atrial fibrillation (PAF) are preferred to undergo catheter ablation (CA), the high possibility of recurrence following surgery is still concerning. We aimed to evaluate the ability of the left atrioventricular coupling index (LACI), which is the ratio of the left atrium end-diastolic volume to the left ventricle end-diastolic volume, to predict PAF recurrence after CA.

Methods Patients with PAF undergoing CA for the first time between January 2018 and June 2021 were admitted and grouped by recurrence within a year. LACI was measured before CA using ultrasonography. Risk factors identified by multivariable logistic regression analysis, and the area under the receiver operating characteristic (ROC) curve was used to assess the ability of LACI to predict PAF recurrence after CAP.

Results Among the 204 patients treated at our hospital, 164 patients were included in the research after eliminating those who were lost to follow-up. Among them, 56 individuals had recurrence following a 90-day blanking period. Recurrence is more likely in elderly patients with high blood pressure. Patients who suffered recurrence exhibited lower left atrial ejection fraction and increased LACI, left atrial volume minimum, and left atrium volume index maximum. LACI was an independent risk factor for postoperative recurrence (OR: 1.526, 95% CI: 1.325–1.757, $P < 0.001$), and ROC displayed remarkable predictive value [area under the curve (AUC) = 0.868].

Conclusions High LACI is significantly associated with postoperative recurrence in PAF patients, and LACI has incremental prognostic value to predict recurrence.

Keywords Atrial fibrillation, Catheter ablation, Left atrioventricular coupling index, Atrial tachyarrhythmia recurrence, Echocardiography

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Background

Atrial fibrillation (AF) is the most prevalent supraventricular tachyarrhythmia; it affects roughly 46.3 million people globally, the majority of whom are elderly. AF is a major risk factor for ischemic stroke, causing increased morbidity and mortality and incurring a significant economic burden [1, 2]. Owing to the associated disease burden, numerous efforts have been undertaken to enhance the prognosis of patients. Catheter ablation (CA) is now considered an established treatment for AF and has become an important operation for restoring and maintaining sinus rhythm [3–6]. However, with the widespread use of CA in the treatment of AF, the increasing recurrence rate of AF is of concern to clinicians. Although there are numerous risk scores for the first onset or recurrence of AF [7] with varying discriminatory powers, to our knowledge, none of the currently well-recognized models quantitatively predict AF recurrence in patients after CA [8].

The left atrioventricular coupling index (LACI) is defined as the ratio between the left atrium (LA) end-diastolic volume and the left ventricle (LV) end-diastolic volume. In a large cohort study of people with no prior cardiovascular history, this score was found to be a strong predictor of future AF [9]. The occurrence of AF is likely influenced by factors beyond structural or functional impairments of the LA or LV. It may also be associated with the decoupling of these cardiac structures, indicating early signs of LV diastolic dysfunction or LA myopathy [10–12]. In addition, LACI is a measure of early LV diastolic dysfunction and early LA myopathy and more accurately depicts diastolic LV pressure–volume relationships from a pathophysiological standpoint [13]. Therefore, compared with individual parameters of the LA or LV, LACI can provide a more comprehensive reflection of changes in left heart structure and function, thus enabling better prediction of AF occurrence [14].

This study aimed to determine the LACI prognostic value for paroxysmal atrial fibrillation (PAF) recurrence following CA and to offer guidance for the clinical management of individuals at risk for recurrence [15]. In addition, this study collected left atrial volume parameters through three-dimensional speckle tracking echocardiography, which the current research considers advantageous for the measurement of the left atrial volume.

Methods

Study population and data collection

The data of patients admitted to the inpatient Department of Cardiology at the Fuyang People Hospital of the Anhui Medical University sourced from the electronic medical record system served as the foundation for this perspective analysis. The research included PAF patients who underwent CA for the first time between January 2018 and June 2021. According to the ACC/AHA 2020 guidelines on AF, PAF was defined as having AF that terminates spontaneously or with intervention within seven days of onset. The most recent guidelines were closely followed for the criteria for CA of PAF [16]. Baseline characteristics, including medication history, echocardiographic data, underlying diseases, and demographic data, were retrieved from patients' electronic medical records. The Medical Ethics Committee of the Fuyang People Hospital of the Anhui Medical University approved this study, and the study was performed in accordance with the Declaration of Helsinki. The study participants and their families received clear statement and signed a consent form.

Catheter ablation procedure method

Transesophageal echocardiography (TEE) was performed on the day of or one day before CA to check for the presence of LA thrombus. Under the guidance of the CARTO3 system (Biosense Webster) and using standard methodology, 3-dimensional fast anatomic mapping was performed using a LASSO circular mapping catheter (Biosense Webster) [17]. All PAF patients were ablated with a cold saline-infused pressure catheter (Smart Touch, Biosense Webster). The treatment was performed using a flow rate of 17 mL/min, CA radiofrequency energy of 35 W for 30 s on the posterior wall and 30 W for 20 s on the anterior wall, and an upper temperature limit of 43 °C.

Echocardiographic analysis

Two experienced sonographers used the VIVID 7, E9, and E95 ultrasound systems (GE-Vingmed, Horten, Norway) equipped with MS5 and 4Vc-D 4D matrix cardiac probes for comprehensive echocardiography. Two-dimensional, color, spectral continuous-wave, and pulsed-wave Doppler pictures were recorded from parasternal, apical, and subcostal perspectives. According to the guidelines of the American Society of Echocardiography, we assessed left ventricular end-diastolic volume (LVEDV), left atrial diameter, left atrial volume index maximum (LAVImax), left atrial volume minimum (LAVmin), left atrial volume maximum (LAVmax), left atrial volume presystolic, and left atrial ejection fraction (LAEF). The LAVmin refers to the left atrial end-diastolic volume at the first frame after mitral valve closure. All patients underwent echocardiographic examination under sinus rhythm.

Left atrioventricular coupling index

LACI was defined as LAVmin to LVEDV. The LA and LV volumes were measured in the same end-diastolic phase defined by mitral valve closure. LACI values were expressed as percentages, with a higher LACI value

Table 1 The baseline characteristics of the study population

Variables	Recurrence group (*N* = 56)	Non-recurrence group (*N* = 108)	*P* value
Demographic data			
Age, years	61.0 (53.0–71.0)	65.0 (61.3–67.0)	0.445
Male sex, (%)	29 (51.8%)	66 (61.5%)	0.872
BMI, kg/ml^2	26.4 (23.9–28.0)	25.4(23.9–27.7)	0.746
CHADS2 score	2.0 (1.0–3.0)	3.0 (1.0–4.0)	0.240
Past medical history			
Hypertension, n (%)	37 (66.1%)	52 (54.6%)	0.009
Diabetes mellitus, n (%)	13 (23.2%)	30 (27.8%)	0.529
CHD, n (%)	20 (35.7%)	33 (30.6%)	0.503
Stroke, n (%)	6 (10.7%)	12 (11.1%)	0.939
Medication			
Beta-blocker, n (%)	6 (10.7%)	11 (10.2%)	0.916
Amiodarone, n (%)	20 (35.7%)	37 (34.3%)	0.634
Propafenone, n (%)	1 (1.8%)	1 (0.9%)	0.853

CHD, coronary heart disease, BMI, body mass index

Table 2 Echocardiographic analysis of LA or LV parameters

Variables	Recurrence group (*N* = 56)	Non-recurrence group (*N* = 108)	*P* value
LAD (mm)	40.0 (35.0–44.0)	40.5 (36.0–45.8)	0.121
LAVmax (mL)	60.5 (56.0–65.5)	61.8 (55.1–68.5)	0.395
LAVp (mL)	60.0 (44.0–74.8)	66.0 (49.0–81.0)	0.134
LAVmin (mL)	40.0 (39.0–42.0)	43.0 (41.0–45.8)	< 0.001
LAVImax (mL/m^2)	39.0 (29.0–44.8)	42.5 (31.5–49.5)	0.011
LAEF (%)	32.0 (25.0–39.8)	29.0 (22.0–36.8)	0.009
LVEDV (mL)	88.8 (84.8–91.4)	85.9 (82.7–95.1)	0.054
LACI (%)	44.0 (43.0–45.0)	49.5 (47.0–53.0)	< 0.001

LAD, left atrial diameter; LAVmax, left atrial volume maximum; LAVp, left atrial volume presystolic; LAVmin, left atrial volume minimum; LAVImax, left atrium volume index maximum; LAEF, left atrial ejection fraction; LVEDV, left ventricular end-diastolic volume; LACI, left atrial coupling index

indicating greater disproportion between the LA and LV volumes at ventricular end-diastole, consequently reflecting greater impairment of left atrioventricular coupling.

Clinical outcomes and follow-up

The endpoint was recurrence of atrial arrhythmia during the 12-month follow-up period, the last date for which was June 30, 2022. Recurrence was defined as atrial arrhythmia lasting > 30 s again after a 90-day blanking period, indicating AF, atrial tachycardia, or atrial flutter. Atrial arrhythmia was not regarded as an outcome during the blanking period. After a 3-month blanking period, patients underwent a Holter test twice a month to check for atrial arrhythmia recurrence.

Statistical analysis

Statistical data in this study were processed using SPSS17.0 (IBM Corp, Armonk, NY, USA). Counts and percentages (%) were used to express categorical variables. Quantitative data were presented as median (interquartile range). For between-group comparisons, an independent-samples t-test was used if the data were normally distributed and had equal variances; otherwise, the non-parametric rank-sum test was used. Categorical variables were compared using chi-square tests or Fisher's exact tests. The risk factors affecting recurrence were analyzed using a multivariable logistics regression model. All tests were two-tailed, and a *P* value of < 0.05 indicated significant difference.

Results

Baseline patient characteristics

At our institution, a total of 204 patients underwent CA for PAF for the first time between January 2018 and June 2021. Forty patients were lost to follow-up, and the remaining 164 patients were included in the research; among them, 56 patients developed AF recurrence after CA (the recurrence group). The other 108 patients were assigned to the non-recurrence group. Table 1 displays the baseline patient characteristics for both groups. The proportion of patients who experienced AF recurrence after CA was 34.15% (56/164). The age of patients was slightly higher in the recurrence group than in the non-recurrence group ($P \geq 0.05$). However, the incidence of hypertension was significantly higher in the recurrence group than in the non-recurrence group ($P = 0.009$, Table 1). Other baseline characteristics did not significantly differ between the groups ($P \geq 0.05$, Table 1). In addition, the analyses were also performed between individuals who were and were not lost to follow-up, and we observed only a weak difference in LVEDV between them (Supplementary Table 1).

Echocardiographic analysis

As shown in Table 2, we collected preoperative echocardiographic results related to AF recurrence and compared the data between recurrence and non-recurrence groups. There were no significant between-group differences in any parameter, except for LAVImax, LAEF, LAVmin, and LACI, which significantly differed between the two groups. Although LAEF was significantly lower in the recurrence group than in the non-recurrence group, LAVImax, LAVmin, and LACI were significantly higher in the former than in the latter.

Multivariable logistic regression analysis

To test the prognostic value of LACI for postoperative recurrence, we developed a multivariable logistic regression model, and the abovementioned significant indicators, including hypertension, LAVImax, LAEF, LAVmin, and LACI, were selected and included in multivariable logistic regression analysis. A receiver operating characteristic curve was produced, as shown in Fig. 1. We found

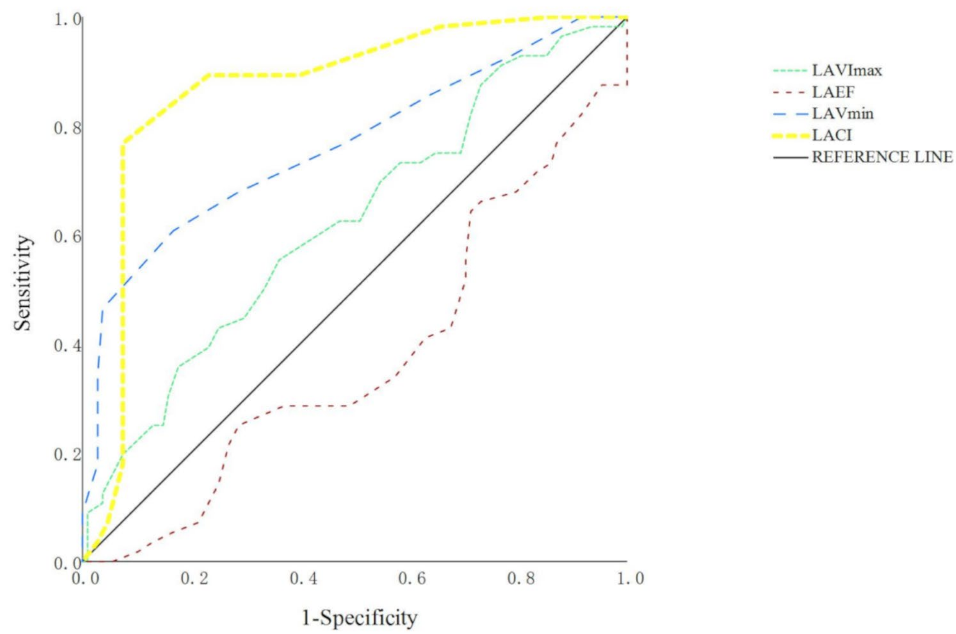

Fig. 1 ROC curve. The area under the ROC curve (AUC) was used to evaluate the performance of the logistic model

Table 3 Multivariable logistic regression analysis of recurrence events according to patient characteristics and LA or LV parameters

Variables	Recurrence group ($N=56$)	Non-recurrence group ($N=108$)	Adjusted OR (95% CI)	*P* value
Hypertension	37 (66.1%)	52 (54.6%)	0.564 (0.213–1.493)	0.249
LAVImax (mL/m^2)	39.0 (29.0–44.8)	42.5 (31.5–49.5)	1.050 (0.989–1.114)	0.109
LAEF (%)	32.0 (25.0–39.8)	29.0 (22.0–36.8)	0.963 (0.895–1.037)	0.318
LAVmin (mL)	40.0 (39.0–42.0)	43.0 (41.0–45.8)	1.351 (1.148–1.590)	< 0.001
LACI (%)	44.0 (43.0–45.0)	49.5 (47.0–53.0)	1.526 (1.325–1.757)	< 0.001

LAVImax, left atrium volume index maximum; LAEF, left atrial ejection fraction; LACI, left atrial coupling index

that a high LACI value (OR: 1.526, 95% CI: 1.325–1.757, Table 3) was associated with higher risk of AF recurrence and had the predictive power [area under the curve (AUC)=0.868, $P<0.05$] to identify patients at risk of AF recurrence within a year after CA was performed to correct hypertension, LAVImax, and LAEF. The calculation of the Youden index identified the optimal cutoff value for the LACI as 34.5, with a sensitivity of 75.9% and specificity of 69.6%.

Discussion

In this study, we identified LACI to be a significant predictor of AF recurrence in individuals having undergone CA. Notably, LACI had a satisfactory ability to stratify the risk of AF recurrence after CA within a year.

Given its appreciable efficacy and safety, CA is a frequently used method for the treatment of AF. The high recurrence rate following CA, however, is still concerning and has restricted the use of CA in the clinic [18]. The current standard procedure for CA of PAF involves pulmonary vein isolation, and intraoperative circumferential pulmonary vein ablation is the most predominant cause of postoperative recurrence [19]. Therefore, it is crucial to identify the risk factors for postoperative recurrence in AF patients by analyzing preoperative data to appropriately stratify patients on the basis of recurrence risk and inform subsequent treatment plans and decisions. In this study, we found that PAF patients with higher LACI were more likely to experience recurrence and that the LACI could be a predictor of PAF recurrence after CA. For practitioners, a comprehensive preoperative assessment of AF patients, including LACI, is suggested. If the patient has a high risk of recurrence after radiofrequency ablation, radiofrequency ablation should not be recommended as the first choice.

Notably, AF is the most prevalent supraventricular arrhythmia among cardiac arrhythmias. Presently, electrophysiological abnormalities in atrial myocytes and structural changes in the atria, including fibrosis, are suggested to be the electrical substrate leading to AF. The extent and severity of the abnormalities increase with age and vary with the type of AF [20]. The primary mechanism of AF is still unknown and varies among individuals. AF development is widely believed to be closely related to structural and functional remodeling of the LA. Atrial arrhythmias may persist owing to the structural and electrical remodeling of the LA brought on by LA enlargement [21–24]. Upon comparing the clinical data of recurrence and non-recurrence groups, we discovered that patients with recurrent AF were characterized by advanced age and a history of hypertension. These findings are in agreement with those of Steinberg et al. and MacGregor et al. [25, 26] and suggest that age and a history of hypertension influence the recurrence of postoperative AF.

Studies evaluating left heart function using magnetic resonance have acknowledged LACI as a powerful predictor of heart failure, untreatable cardiovascular disease, and mortality from coronary artery disease. Left atrial fibrosis is an independent risk factor for AF recurrence after catheter radiofrequency ablation. The emergence of speckle tracking echocardiography enables further assessment of the condition of the left atrial matrix by measuring left atrial strain capabilities. Research indicates that low levels of atrial reservoir phase strain and the strain rate are highly sensitive and reliable indicators of the recurrence of AF [27]. However, many studies emphasize that the development and progression of AF are not solely due to adverse left atrial remodeling; left ventricular diastolic dysfunction has also been identified as a prognostic marker for AF [14]. It can impair left heart function by disrupting the functional interplay between the two chambers. Atrioventricular coupling is complex, given the asynchrony in filling, emptying, as well as active contraction between the LA and LV. Although the parameters of the LA and LV have independent prognostic values for predicting post-ablation recurrence in AF patients, the intrinsic physiological link between LA and LV indicates that assessing changes in left atrioventricular coupling can more accurately reflect left heart dysfunction and better predict the prognosis of AF [14, 27]. Herein, we defined LACI as the proportion of LAVmin to LVEDV assessed during the mitral valve closure-specified diastolic phase. The variable LACI signifies a pronounced mismatch in the volumes of LA and LV at the end of ventricular diastole, which is indicative of a more substantial deterioration in left atrioventricular coupling. LACI provides a higher predictive value than individual LA or LV characteristics in predicting cardiovascular events with high specificity [9]. It also detects the early stages of LA remodeling which are linked with decreased LV compliance. It accurately reflects and predicts anatomical and functional changes in the left heart in AF [14]. LACI is a measure of early LV diastolic dysfunction and early LA myopathy, and it accurately depicts diastolic LV pressure–volume relationships from a pathophysiological standpoint [13]. During the ideal cardiac cycle for measuring LACI, which is LV diastole, significant hemodynamic interactions occur between the LA and LV. Early in the diastole, the blood passively enters the LV from the LA, generating a vortex there. Blood flow rotation in the LA is outmatched by this early diastolic vortex, causing the LV to enlarge more quickly. A large amount of blood is taken straight into the LV from the pulmonary venous circulation because the LV's expansion substantially outweighs the LA's decompression. It is believed that the late diastole blood flow vortex helps initiate the LV before cardiac ejection by rerouting LA blood flow to the LV outflow zone [28]. This may elucidate the unique prognostic significance of LACI.

This study has several limitations. First, 40/204 patients were excluded from this study because they could not complete the follow-up on time to provide echocardiographic data (Supplementary Table 2). The primary limitation of using Holter monitoring for PAF recurrence is its inability to detect AF outside of the monitoring periods. In our study, we instructed patients to immediately undergo ECG examination at the nearest community hospital if they experienced symptoms like palpitations or chest tightness, which are similar to those of preoperative AF episodes; they were asked to then bring us the reports for further evaluation, thus partially mitigating this limitation. Furthermore, only individuals with PAF were included in our research. It is difficult to obtain a long enough sinus rhythm cycle in cases of persistent AF to provide an accurate picture for echocardiographic imaging for a significant number of patients. Besides, although the follow-up period of this study was only one year, which may affect the quality of evidence for the predictive value of LACI in terms of the recurrence of AF after surgery, we still found a significant association of higher LACI with higher recurrence risk of AF. These findings emphasize the need for a longer follow-up period in a larger study in the future. This was a single-center study with a limited number of cases, and thus, a multicenter study with a larger sample size is warranted to evaluate the clinical predictive value of these instances.

Conclusions

In this study, LACI was found to be an independent risk factor for recurrence after CA of PAF and was a better predictor of AF recurrence than LA and LV volume parameters alone.

Abbreviations

PAF	Paroxysmal atrial fibrillation
CA	Catheter ablation
LACI	Left atrioventricular coupling index
ROC	Receiver operating characteristic
AUC	Area under the curve
AF	Atrial fibrillation
LA	Left atrium

LV	Left ventricle
LVEDV	Left ventricular end-diastolic volume
LAEF	Left atrial ejection fraction
LAVmax	Left atrial volume maximum
LAVmin	Left atrial volume minimum
LAVp	Left atrial volume presystolic
LAVImax	Left atrial volume index maximum
LVEF	Left ventricular ejection fraction

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13019-024-03070-6.

Supplementary Material 1

Supplementary Material 2

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None.

Author contributions
BN designed the study. AL and MZ contributed to data collection, study management, and data analysis. AL and BN wrote the manuscript, critically reviewed and commented on the manuscript, and approved the final submitted version. All authors have read and agreed to the published version of the manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The Medical Ethics Committee of the Fuyang People Hospital of the Anhui Medical University approved this study, and the study was carried out in accordance with the Declaration of Helsinki. The study participants and their families received clear statement and signed a consent form.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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