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# The predictive value of monocyte count to high-density lipoprotein cholesterol ratio combined with left atrial diameter for post-radiofrequency ablation recurrence of paroxysmal atrial fibrillation in patients

Yu Lei[1*†] and Lijun Hu[1†]

## Abstract

**Background** Paroxysmal atrial fibrillation (PAF) usually recurs after radiofrequency ablation (RFA). This study probed the predictive value of monocyte count to high-density lipoprotein cholesterol (HDL-C) ratio (MHR) with left atrial diameter (LAD) for post-RFA recurrence in PFA patients.

**Methods** Totally 210 RFA-treated PAF patients were selected and assigned into Recurrence and Non-Recurrence groups, with clinical baseline data recorded. Preoperative HDL-C, hypersensitive C-reactive protein, interleukin-6, tumor necrosis factor alpha, brain natriuretic peptide, low-density lipoprotein cholesterol, total cholesterol, and total cholesterol were determined. Monocyte count and MHR were examined. The effects of preoperative MHR and LAD on post-RFA PAF recurrence was analyzed by COX regression analysis. Patients were arranged into high and low MHR and high and low LAD groups. The recurrence of PAF patients with different preoperative MHR and LAD within 12 month was analyzed by Kaplan-Meier (KM) analysis. The predictive value of preoperative MHR, LAD, and their combination for post-RFA recurrence in PAF patients was analyzed.

**Results** MHR and LAD were independent risk factors for post-RFA recurrence in PAF patients. KM curve shift left in the high MHR and LAD groups versus the low MHR and LAD groups. MHR and LAD could help predict post-RFA recurrence in PAF patients, and the combined predictive value of MHR and LAD was greater than that of either factor alone.

**Conclusion** MHR and LAD are independent risk factors for post-RFA PAF recurrence, and can help predict post-RFA recurrence in PAF patients, with their combined predictive value higher than that of each factor individually.

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**Keywords** Paroxysmal atrial fibrillation, Radiofrequency ablation, Monocyte count, High-density lipoprotein cholesterol, Monocyte count to high-density lipoprotein cholesterol ratio, Left atrial diameter

## Background

Atrial fibrillation (AF) stands as the most prevalent human arrhythmia [1]. It impacts more than 33 million adults globally, and its prevalence is growing as the populations of many countries continue to age [2]. Paroxysmal AF (PAF) is conventionally characterized by the recurrence of AF with each episode lasting more than 30 s and terminating within 7 days spontaneously [3]. The prevalence of PAF is 15% among individuals aged 80 years and older [4]. The data indicate that PAF elevates the risk of stroke by 1.6–3.5 times and raises its mortality rate by 50–90% [5]. Radiofrequency ablation (RFA) is an effective therapeutic approach for managing AF [6]. Nevertheless, clinical observations have demonstrated a notable recurrence rate of PAF after RFA, with rates ranging from 20 to 45%, which diminishes the efficacy of the RFA and significantly affects the physical and psychological health of PAF patients [7, 8]. Consequently, the current focus of treatment options for PAF patients is on effectively stratifying the recurrence risk, identifying PAF patients suitable for RFA surgery, enhancing the success rate of RFA treatment, and alleviating the physical and psychological burden on patients.

Presently, there is considerable research interest in the association between AF and inflammation, with a previous study indicating that inflammation comes into play in the pathological progression of PAF development [9]. Monocytes, constituting 8% of leukocytes in the peripheral blood, play a regulatory role in inflammatory processes by producing both pro- and anti-inflammatory cytokines, form macrophages, and are implicated in AF [10]. Notably, high-density lipoprotein cholesterol (HDL-C) exhibits potent anti-inflammatory and antioxidant properties, and research have demonstrated a correlation between lower level of HDL-C and an elevated risk of AF [11]. Besides, there has been significant clinical interest in the monocyte count to HDL-C ratio (MHR) as an emerging biomarker that involves in various cardiovascular disease processes, effectively reflecting information about inflammation and oxidative stress, and pitches in the AF maintenance, development, and recurrence [12]. Moreover, AF exhibits strong relevance with remodeling of the left atrium's structure, function, and electrical properties, and the augmentation of atrial fibrosis is responsible for the onset and development of AF [13]. The significance of left atrial enlargement in predicting the recurrence of PAF has been demonstrated [14]. Nevertheless, in patients with insignificant or absent left atrial enlargement after RFA, predicting the recurrence of PAF based solely on left atrium diameter (LAD) is challenging, and additional tests are necessary to supplement the assessment for an effective evaluation of PAF recurrence [15]. Currently, there is limited literature available on the clinical investigation of the combination of MHR and LAD in relation to the PAF recurrence after RFA. This study aimed to explore the predictive value of preoperative serum MHR and LAD in PAF patients for post-RFA recurrence, with the goal of offering effective strategies for the clinical prevention and treatment of PAF.

## Methods

### Ethics statement

This study followed the ethical guidelines of Helsinki Declaration and the relevant norms and regulations of clinical research, and in line with the Enhancing the Quality and Transparency Of health Research network guidelines. The study received approval and consent from the Academic Ethics Committee of Deyang People's Hospital (Approval No. 2023-04-127-K01). All participants in this study were thoroughly briefed on the study's objectives and provided their informed consent prior to sample collection.

### Study subjects

Totally 300 PAF patients who underwent RFA in Deyang People's Hospital from June 2020 to October 2022 were selected, of which 268 met the inclusion criteria, 18 conformed to the exclusion criteria, 10 refused to participate in the study, and 30 withdrew, and finally 210 PAF patients were included as study subjects. Among them, 78 patients recurred within 12 months after RFA were set as the Recurrence group, and the remaining 132 patients did not recur within 12 months after RFA were set as the Non-Recurrence group.

### Inclusion and exclusion criteria

Inclusion criteria were shown below: (1) met the diagnostic criteria for PFA: the onset time of AF not exceeding 24 h or it could be self-reversed to sinus rhythm within 7 days, with a clear diagnosis as PFA; (2) initial onset; (3) underwent RFA for the first time; (4) with complete clinical data; (5) >30 years old and <70 years old; (6) without electrolyte disorders.

Exclusion criteria included thrombus in the left atrium examined by transesophageal echocardiography, valvular disease history, severe hepatic and renal insufficiency, neurologic disorders and hyperthyroidism, and history of major surgical treatment or trauma within the last 6 months.

### Data and sample collection

Clinical baseline data such as age, sex, underlying diseases (diabetes, hypertension, hyperlipidemia, peripheral vascular disease, stroke), AF onset time, preoperative body mass index (BMI), heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), HDL-C, hypersensitive C-reactive protein (hs-CRP), tumor necrosis factor (TNF)-α, interleukin (IL)-6, low-density lipoprotein cholesterol (LDL-C), brain natriuretic peptide (BNP), total cholesterol (TC), triglyceride (TG), and MHR were documented for all study subjects.

### Ultrasound detection

All enrolled patients underwent ultrasonic cardiac examination within 48 h before surgery. The patients stayed in the conventional left lateral position, and were instructed to breathe calmly during the examination, which was performed using a Color Doppler Ultrasonic Diagnostic Device (VIVID 5, GE, MA, USA) (frequency: 1.7–3.3 Hz). LAD was measured at end-systole in parasternal left ventricular long-axis views and the aortic root level after application of a coupling agent by the tester. Left ventricular ejection fraction (LVEF) was evaluated in apical four chamber view and apical two chamber view, respectively.

### Follow-up

PFA patients underwent regular review every 1 month after RFA, including interrogation, outpatient physical examination, electrocardiogram, and echocardiography. A 24-h dynamic electrocardiogram examination was performed to clarify AF when necessary. Patients were followed up for 12 months by consulting the hospital electronic medical record system and pathology. Recurrence of AF after radiofrequency catheter ablation was defined as AF duration > 30 s recorded by routine electrocardiogram or dynamic electrocardiogram at 3 months after operation.

### Statistical analysis

SPSS 21.0 (IBM, Armonk, NY, USA), MedCalc 19.0 (MedCalc software, Ostend, Belgium), and GraphPad Prism 8.0.1 software (GraphPad, San Diego, CA, USA) were applied for statistical analysis and graphing of data. The Shapiro-Wilk test was used to test for normal distribution, and measurement data that conformed to normal distribution were expressed as mean ± standard deviation, and comparisons between groups were conducted using the independent sample *t* test. Measurement data conforming to non-normal distribution were presented in quartiles, with Mann-Whitney U test utilized for comparisons between groups. Counting data were depicted as the number of cases, with the Chi-square test applied for comparisons between groups. COX regression analysis was implemented to analyze the effects of preoperative MHR and LAD on post-RFA recurrence of PAF patients. Chi-square test and Kaplan-Meier (KM) method were utilized to analyze the post-RFA cumulative recurrence of PAF patients with different MHR and LAD. The disparities among groups in the KM curve were assessed using the Log rank method. The receiver operating characteristic (ROC) curve was plotted to assess the predictive value of MHR, LAD, and the combination of the two for the recurrence of PAF patients after RFA. The significance level of the test was set at a = 0.05. *P* was obtained from a two-sided test, with a value of $P<0.05$ deemed to be statistically significant.

## Results

### Characteristics of the baseline data of the enrolled populations

No dramatic differences were observed between patients in the Recurrence and Non-Recurrence groups with regard to age, sex, underlying diseases (hyperlipidemia, peripheral vascular disease, stroke), preoperative BMI, HR, SBP, DBP, IL-6, TNF-α, LDL-C, TC, TG, BNP, and LVEF (all $P>0.05$). The proportions of patients complicated with diabetes and hypertension, the onset time of AF, preoperative LAD and hs-CRP, and monocyte count in the Recurrence group were distinctly elevated compared to the Non-Recurrence group, while HDL-C expression was remarkably abated (all $P<0.05$) (Table 1).

### Comparison of preoperative monocyte count to high-density lipoprotein cholesterol ratio in paroxysmal atrial fibrillation patients preoperatively

The preoperative MHR was calculated by the ratio of preoperative monocyte count to serum HDL-C, with results showing that the preoperative MHR in the Recurrence and Non-Recurrence groups were [41.92 (25.85,87.39)] and [27.30 (7.95,75.07)], respectively, and the MHR in the Recurrence group was observably elevated versus the Non-Recurrence group ($P<0.05$) (Fig. 1).

### Risk factors for post-radiofrequency ablation recurrence in paroxysmal atrial fibrillation patients

To further investigate the factors influencing post-RFA recurrence in PAF patients, we incorporated comorbid diabetes, comorbid hypertension, onset time of AF, hs-CRP, MHR, and LAD with $P<0.05$ from the COX regression analysis as independent variables in the COX regression analysis. As reflected by the results, onset time of AF, hs-CRP, MHR and LAD were found to be independently linked to the recurrence of PAF patients after RFA (Table 2). Overall, the findings manifested that MHR and LAD were risk factors for postoperative recurrence in PAF patients.

**Table 1** General information of the enrolled subjects

| | Recurrence (*n* = 78) | Non-Recurrence (*n* = 132) | *P* value |
|---|---|---|---|
| Age (years) | 54.93 ± 9.39 | 54.16 ± 8.34 | 0.552 |
| Sex (male/female) | 54/24 | 87/45 | 0.62 |
| BMI (kg/m$^2$) | 25.66 ± 3.47 | 25.58 ± 3.39 | 0.874 |
| Underlying diseases | | | |
| Diabetes | 52 (66.67) | 61 (46.21) | 0.004 |
| Hypertension | 65 (83.33) | 89 (67.42) | 0.013 |
| Hyperlipidemia | 27 (34.62) | 48 (36.36) | 0.798 |
| Peripheral vascular disease | 36 (46.15) | 67 (50.76) | 0.519 |
| Stroke | 32 (41.03) | 60 (45.45) | 0.532 |
| Systolic blood pressure (mmHg) | 129.13 ± 5.19 | 128.70 ± 4.62 | 0.54 |
| Diastolic blood pressure (mmHg) | 80.65 ± 3.77 | 80.35 ± 3.35 | 0.541 |
| The onset time of atrial fibrillation (months) | 18.67 ± 2.53 | 16.13 ± 2.16 | < 0.001 |
| hs-CRP (mg/L) | 1.96 ± 0.82 | 1.39 ± 0.56 | < 0.001 |
| IL-6 (ng/L) | 12.55 ± 2.35 | 12.54 ± 2.02 | 0.986 |
| TNF-α (ng/L) | 31.31 ± 5.32 | 29.91 ± 5.34 | 0.068 |
| LDL-C (mmol/L) | 2.45 ± 0.52 | 2.32 ± 0.47 | 0.068 |
| TC (mmol/L) | 4.74 ± 1.17 | 4.68 ± 1.36 | 0.743 |
| TG (mmol/L) | 1.28 ± 0.30 | 1.25 ± 0.22 | 0.393 |
| BNP (pg/mL) | 75.71 ± 12.01 | 74.86 ± 14.04 | 0.656 |
| LVEF (%) | 62.54 ± 3.20 | 63.15 ± 3.11 | 0.152 |
| LAD (mm) | 39.02 (25.26,49.35) | 34.33 (22.91,45.80) | < 0.001 |
| HDL-C (mmol/L) | 0.88 (0.41,1.29) | 1.21 (0.43,2.85) | < 0.001 |
| Monocyte count (× 10$^7$/L) | 36.98 (29.14,46.76) | 31.36 (20.02,41.49) | < 0.001 |

Note: BMI, body mass index; hs-CRP, hypersensitive c-reactive protein; IL-6, interleukin-6; TNF-α, tumor necrosis factor-α; LDL-C, low density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; BNP, brain natriuretic peptide; LVEF, left ventricular ejection fraction; LAD, left atrium diameter; HDL-C, high density lipoprotein cholesterol. The measurement data, which followed a normal distribution, were presented as mean ± standard deviation. The comparisons between groups were conducted using independent sample *t* test. The measurement data exhibiting a non-normal distribution were depicted using quartiles, and compared between groups using the Mann-Whitney U test. The counting data were analyzed utilizing the Chi-square test

### Influence of monocyte count to high-density lipoprotein cholesterol ratio and left atrial diameter on the risk of recurrence after radiofrequency ablation in paroxysmal atrial fibrillation patients

MHR pitches in the development, maintenance and recurrence of AF [12]. Left atrial enlargement serves as a significant parameter for predicting the recurrence of PAF [14]. The post-RFA recurrence of PAF patients with different preoperative MHR and LAD values within 12 months was analyzed. With the median preoperative MHR value (33.58) acting as the cut-off value, PAF patients with MHR > cut-off value were seen as the high MHR group, and PAF patients with MHR ≤ cut-off value were treated as the low MHR group (Table 3). The KM analysis revealed a leftward shift in the curve of high MHR ($P < 0.001$, Fig. 2A). With the median preoperative LAD (36.05) serving as the cut-off value, PAF patients with LAD > cut-off value were assigned into the high LAD group, and PAF patients with LAD ≤ cut-off value were classified as the low LAD group (Table 3). The KM results indicated that the curve of high LAD exhibited a leftward shift ($P < 0.001$, Fig. 2B). The aforementioned findings suggested that PAF patients with high preoperative MHR or LAD at the same follow-up time were more likely to experience recurrence within 12 months after RFA.

### The predictive value of monocyte count to high-density lipoprotein cholesterol ratio combined with left atrial diameter for post-radiofrequency ablation recurrence of paroxysmal atrial fibrillation patients

ROC curve analysis results unveiled that both MHR and LAD demonstrated certain predictive value for postoperative recurrence in PAF patients, with the area under the curve (AUC) of their combination for predicting postoperative recurrence in PAF patients as 0.894 (Fig. 3). As manifested by MedCalc analysis results, there were conspicuous differences in the predictive value between MHR, LAD and the combination of them for postoperative recurrence of patients with PAF, where the predictive value of MHR combined with LAD was markedly boosted relative to MHR and LAD alone (all $P < 0.05$) (Table 4).

## Discussion

AF stands as the most prevalent arrhythmia observed in clinical settings and is bound up with an elevated risk of stroke, mortality, and peripheral embolism [16]. Inflammation and fibrosis pitch in AF pathophysiology [17]. Atrial remodeling encompasses alterations in structural changes, ion channel function and expression, and neural remodeling, collectively contributing to the onset of an arrhythmogenic environment that facilitates the initiation and perpetuation of AF [18]. Despite the considerable advancements in comprehending the pathophysiological substrates, treatments for AF have not undergone substantial changes, as a noteworthy number of patients encountering symptom recurrence after ablation or experiencing proarrhythmic side effects from specific medications [19]. As a result, the prevalence of AF is continuously increasing, creating an urgent demand for innovative treatments. Consequently, our study underscored that MHR and LAD were the independent risk factors for post-RFA recurrence in PAF patients and could aid in the prediction of post-RFA recurrence in PAF patients, with their combined predictive capacity surpassing that of each factor when considered individually.

The topic of the association between MHR and AF ablation success has already been evaluated in previous

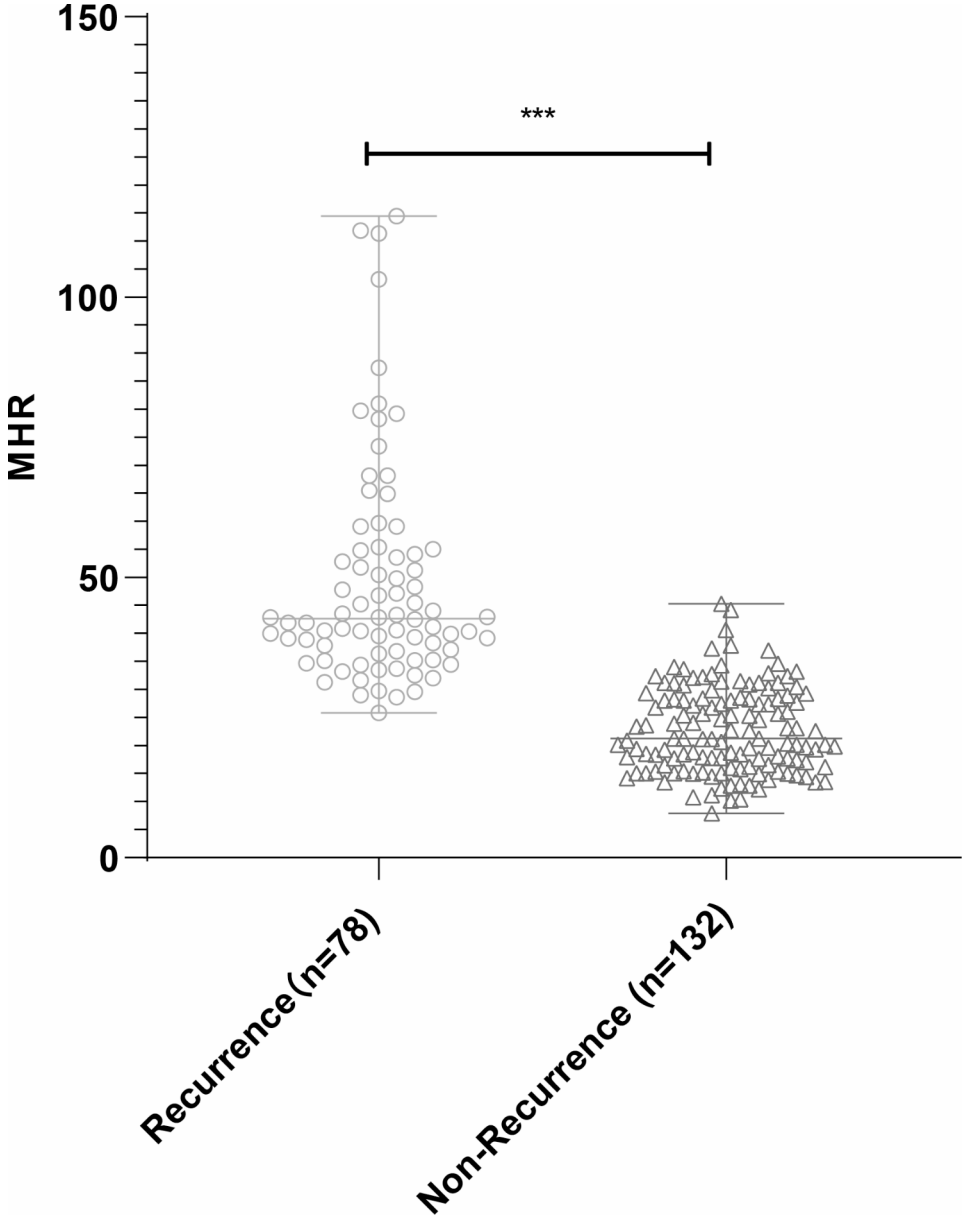


**Fig. 1** Preoperative MHR was higher in post-RFA recurrent of PAF patients than in patients without recurrence. Differences in preoperative expression of MHR among patients in the Recurrence and Non-Recurrence groups. The measurement data were presented in quartiles, and group comparisons were conducted using the Mann-Whitney U test. *** $P < 0.001$

**Table 2** MHR and LAD were risk factors for post-RFA recurrence in PAF patients

| | COX regresion analysis | | |
|---|---|---|---|
| | *P* | OR | 95%CI |
| Diabetes | 0.325 | 1.286 | 0.779–2.124 |
| Hypertension | 0.417 | 1.292 | 0.696–2.399 |
| AF onset time | 0.001 | 1.174 | 1.066–1.293 |
| hs-CRP | 0.003 | 1.564 | 1.164–2.102 |
| MHR | < 0.001 | 1.104 | 1.055–1.155 |
| LAD | < 0.001 | 1.028 | 1.014–1.042 |

**Table 3** Recurrence within 12 months after RFA in PAF patients with different MHR and LAD

| | MHR | | Total |
|---|---|---|---|
| | Recurrence | Non-Recurrence | |
| High MHR Group | 67 | 38 | 105 |
| Low MHR group | 11 | 94 | 105 |
| Total | 78 | 132 | 210 |
| | LAD | | Total |
| | Recurrence | Non-Recurrence | |
| High LAD Group | 63 | 42 | 105 |
| Low LAD group | 15 | 90 | 105 |
| Total | 78 | 132 | 210 |

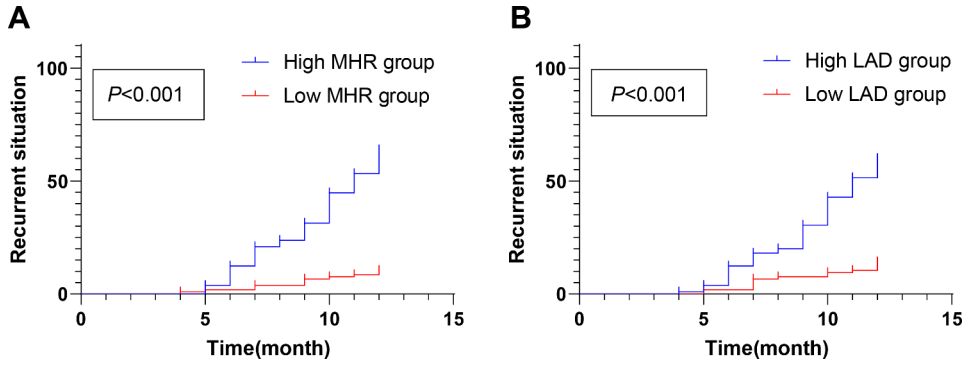


**Fig. 2** The influence of MHR and LAD on post-RFA recurrence within 12 months in PAF patients. Kaplan-Meier method was used to analyze the effects of MHR and LAD expression levels on post-RFA recurrence within 12 months in PAF patients. The curve for high MHR exhibited a leftward shift in comparison to the curve for low MHR (**A**), and the curve for high LAD also shifted left versus the curve for low LAD (**B**)

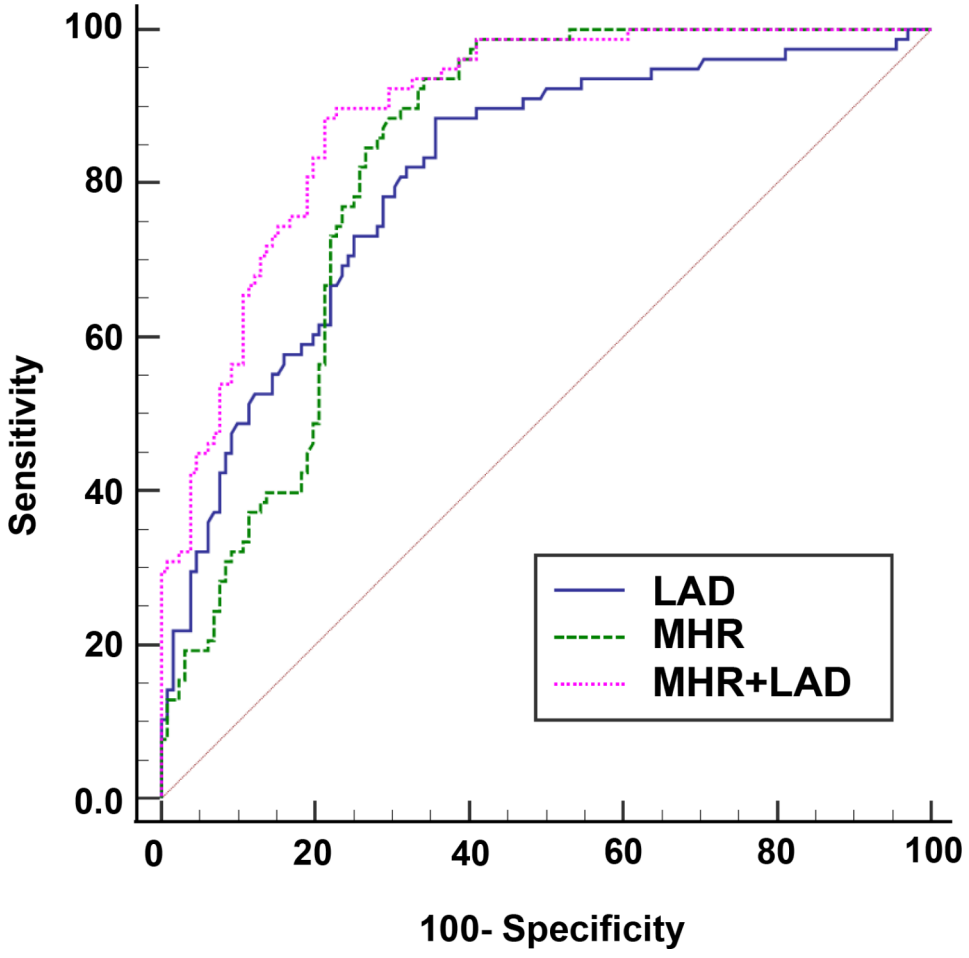


**Fig. 3** Predictive value of MHR combined with LAD for post-RFA recurrence of PAF patients. ROC curve analysis of predictive value of MHR/LAD and their combination for recurrence of PAF patients after RFA

literature, which has suggested that elevated preablation MHR is linked to an increased risk of postoperative AF recurrence [20]. The comprehensive analysis on MHR and postoperative recurrence of AF is a major innovation of this paper. By comparing preoperative MHR levels between PAF patients with and without postoperative recurrence, it was demonstrated that preoperative MHR significantly varied among PAF patients with different prognoses. Subsequently, COX regression analysis and Kaplan-Meier curve analysis results clarified that high preoperative MHR level elevated the risk of recurrence in PAF patients. Additionally, as reported, LAD is a

**Table 4** Predictive value of MHR combined with LAD for postoperative recurrence of PAF patients

| Items | Sensitivity | Specificity | AUC | *P* | 95%CI |
|---|---|---|---|---|---|
| MHR | 93.59 | 65.91 | 0.827 | < 0.001 | 0.750–0.860 |
| LAD | 88.46 | 64.39 | 0.809 | < 0.001 | 0.749–0.870 |
| MHR + LAD | 88.50 | 78.79 | 0.894 | < 0.001 | 0.844–0.932 |
| MHR ~ MHR + LAD | *P* = 0.0006 | | | | |
| LAD ~ MHR + LAD | *P* = 0.0021 | | | | |

predictor of AF recurrence post-ablation. Therefore, this study further innovatively combined LAD with preablation MHR indicator detection for predicting post-ablation recurrence, in order to enhance the assessment and prediction strategies for post-RFA recurrence in PAF patients. The combination of LAD and MHR, as demonstrated by ROC analysis, enhanced the diagnostic efficacy of the prediction model, thereby yielding a more accurate predictive value for post-RFA recurrence in PAF patients.

Left atrium enlargement serves as an echocardiographic indicator of atrial remodeling and is firmly linked to AF occurrence [14, 21]. LAD is a commonly utilized parameter for indicating the size of the left atrium [22]. LAD is considered one of the most reliable predictors of AF recurrence following RFA [23, 24]. Elevated monocyte count or activity, as well as reduced HDL-C levels, were found to be tied up with a higher prevalence of AF, and LAD, early AF recurrence, and AF history duration were identified as independent predictors for AF recurrence following cryoballoon-based catheter ablation [25]. The findings of a prior investigation have indicated that MHR is an independent risk factor for the delayed recurrence of nonvalvular AF following ablation [12]. It has been documented that post-ablation hs-CRP level is elevated in AF recurrent patients, and that hs-CRP level may serve a role as a predictor of recurrence [26]. Consistent with these prior studies, our study also found that onset time of AF episodes, hs-CRP, MHR, and LAD were independently correlated with postoperative recurrence of PAF, and MHR and LAD were risk factors for post-RFA recurrence of PAF. An elevated preablation MHR was found to be correlated with a higher risk of postoperative AF recurrence [20]. An increased LAD has been documented to be relevant to the AF recurrence following catheter ablation [27]. Our study revealed that the preoperative MHR was boosted in patients who experienced recurrent PAF after RFA compared to patients who did not experience recurrence. Interestingly, our study also unveiled that PAF patients with high preoperative expression of MHR or high LAD were at higher risk to experience recurrence within 12 months after RFA at the same follow-up time.

We subsequently plotted the ROC curve to further analyze the predictive value of MHR, LAD and their combination for recurrence of PAF after RFA. The study identified that MHR could predict early recurrence following the radiofrequency maze procedure for valvular AF [28]. A prior study has also unveiled that LAD serves as a predictor of AF recurrence following RFA [29]. The combined assessment of preoperative NLR, hs-CRP, and LAD has been shown to have predictive value for late nonvalvular AF recurrence [30]. Our study innovatively emphasized the predictive value of both MHR and LAD for recurrence following RFA in PAF patients, and higher predictive value of their combination for post-RFA recurrence in PAF patients compared to each factor alone.

## Conclusions

Collectively, our study highlighted that both MHR and LAD were independent risk factors for recurrence following RFA in PAF patients, and could assist in predicting post-RFA recurrence in PAF patients, with their combined predictive value higher than that of each factor individually. Nevertheless, there are also limitations in the study. The duration of the follow-up period was 12 months only, and there was a lack of comprehensive investigation into long-term recurrence, leading to constrained outcomes. In the future, the follow-up period will be extended to conduct a more comprehensive analysis of long-term recurrence after RFA in PFA patients. Additionally, we will investigate the correlation between preoperative MHR and LAD in patients experiencing long-term recurrence after RFA in PFA patients.

### Abbreviations

| | |
|---|---|
| PAF | Paroxysmal atrial fibrillation |
| AF | Atrial fibrillation |
| RFA | Radiofrequency ablation |
| LAD | Left atrial diameter |
| KM | Kaplan-Meier |
| MHR | Monocyte count to high-density lipoprotein cholesterol ratio |
| HDL-C | High-density lipoprotein cholesterol |
| BMI | Body mass index |
| HR | Heart rate |
| SBP | Systolic blood pressure |
| DBP | Diastolic blood pressure |
| hs-CRP | Hypersensitive C-reactive protein |
| TNF | Tumor necrosis factor |
| IL | Interleukin |
| BNP | Brain natriuretic peptide |
| TC | Total cholesterol |
| TG | Triglyceride |
| LVEF | Left ventricular ejection fraction |
| ROC | Receiver operating characteristic |

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### Author contributions

guarantor of integrity of the entire study: Yu Lei; study concepts: Yu Lei; study design: Yu Lei; definition of intellectual content: Yu Lei; literature research: Yu Lei; clinical studies: Lijun Hu; experimental studies: Lijun Hu; data acquisition: Lijun Hu; data analysis: Yu Lei and Lijun Hu; statistical analysis: Yu Lei and Lijun

Hu; manuscript preparation: Yu Lei and Lijun Hu; manuscript editing: Yu Lei and Lijun Hu; manuscript review: Yu Lei and Lijun Hu.

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**Data availability**
The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

**Ethics approval and consent to participate**
This study followed the ethical guidelines of Helsinki Declaration and the relevant norms and regulations of clinical research, and in line with the Enhancing the Quality and Transparency Of health Research network guidelines. The study received approval and consent from the Academic Ethics Committee of Deyang People's Hospital (Approval No. 2023-04-127-K01). All participants in this study were thoroughly briefed on the study's objectives and provided their informed consent prior to sample collection.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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