



Association between postoperative obesity and recurrence after radiofrequency catheter ablation in patients with atrial fibrillation

Wenqing Yang^{1,2}, Daoyang Zhang^{1,2}, Yulai Yan³, Yunhao Li¹, Qi Zhang¹, Ping Zhang¹, Yujie Zhang¹, Jie Zhang¹, Zulu Wang^{1,4}, Yaling Han^{1,4}, Ming Liang^{1,4}

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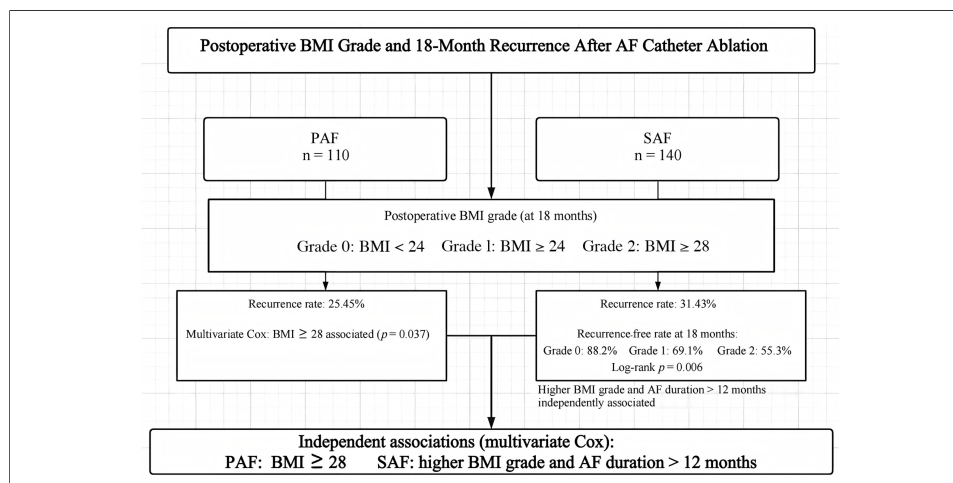
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Abstract

Aim: This study evaluated the association between postoperative body mass index (BMI) category at the 18 months postoperative follow-up and atrial fibrillation (AF) recurrence after radiofrequency catheter ablation (RCA).

Methods: From January to December 2023, 250 patients with AF who underwent single-operator RCA at the General Hospital of Northern Theater Command were enrolled. Baseline characteristics, BMI category at the 18 months postoperative follow-up (normal weight, overweight, obesity), and recurrence were collected. Kaplan-Meier survival analysis and multivariate Cox proportional hazards analysis were performed. The primary endpoint was AF recurrence confirmed by electrocardiogram (ECG) or Holter monitoring within 18 months.

Results: Among 110 patients with paroxysmal atrial fibrillation (PAF) and 140 patients with

¹Department of Cardiology, General Hospital of Northern Theater Command, Shenyang 110016, Liaoning, China.

²Graduate School, Dalian Medical University, Dalian 116044, Liaoning, China.

³Department of Congenital Cardiology, General Hospital of Northern Theater Command, Shenyang 110016, Liaoning, China.

⁴Key Laboratory of Frigid Zone Cardiovascular Disease, General Hospital of Northern Theater Command, Shenyang 110016, Liaoning, China.

Correspondence to: Prof. Ming Liang, Department of Cardiology, General Hospital of Northern Theater Command, Shenyang 110016, Liaoning, China. E-mail: lming000919@sina.com

persistent atrial fibrillation (SAF). Multivariate Cox analysis showed that, among patients with PAF, postoperative obesity was associated with recurrence risk ($P = 0.037$). Among patients with SAF, postoperative overweight ($P = 0.033$), postoperative obesity ($P = 0.003$), and AF duration > 12 months ($P = 0.002$) were independently associated with recurrence. Kaplan-Meier analysis in patients with SAF showed 18 months recurrence-free rates of 88.2% for postoperative normal weight, 69.1% for postoperative overweight, and 55.3% for obesity (log-rank $P = 0.006$).

Conclusion: In this retrospective analysis, postoperative obesity was associated with a higher risk of recurrence after RCA for AF. Specifically, postoperative obesity was associated with recurrence in patients with PAF, whereas higher postoperative BMI grades and AF duration > 12 months were associated with recurrence in patients with SAF.

INTRODUCTION

Atrial fibrillation (AF) is one of the most common clinical arrhythmias worldwide, and its prevalence continues to increase. AF substantially impairs patients' quality of life and increases the risk of adverse cardiovascular events, including stroke and heart failure^[1]. Obesity is a major global public health concern and has been identified in numerous studies as a substantial modifiable risk factor for the development and progression of AF. The underlying mechanisms encompass epicardial adipose tissue-mediated inflammation, atrial structural remodeling, and hemodynamic alterations^[2,3]. Furthermore, obesity-related comorbidities, such as hypertension and obstructive sleep apnea, contribute to the initiation and maintenance of AF^[4]. Radiofrequency catheter ablation (RCA) has become a cornerstone therapy for AF, with demonstrated benefits in improving quality of life, reducing hospitalization, and potentially improving cardiovascular outcomes^[5]. Given the increasing number of patients with obesity undergoing this procedure^[6], evaluating the impact of obesity on procedural safety, efficacy, and post-ablation recurrence is important. However, current evidence regarding the influence of obesity on AF recurrence after RCA remains inconsistent. Some studies have reported that obesity does not affect RCA success rates^[7,8], whereas others have reported a higher recurrence risk in patients with obesity^[9,10].

Previous research has predominantly focused on the prognostic impact of baseline body mass index (BMI), whereas the effect of postoperative BMI on AF recurrence remains unclear. Therefore, this study investigated the association between postoperative BMI and recurrence after RCA in patients with AF, to inform comprehensive postoperative management and individualized treatment strategies.

METHODS

Study design and participants

A retrospective analysis of 276 patients with AF who underwent single-operator RCA at the General Hospital of Northern Theater Command between January and December 2023 was conducted. The study population consisted of consecutive patients treated by the same operator in 2023. The inclusion criteria were as follows: (1) RCA was performed by a single operator, Ming Liang; (2) AF was confirmed by electrocardiogram (ECG) or Holter monitoring; and (3) patients met the indications for RCA and successfully underwent the procedure. Twenty-six patients were excluded for the following reasons: incomplete postoperative ECG or Holter monitoring ($n = 0$), missing baseline data ($n = 20$), missing 18 months postoperative BMI or recurrence data ($n = 4$), and severe valvular heart disease ($n = 2$). Paroxysmal atrial fibrillation (PAF) was defined as AF episodes lasting < 7 days with spontaneous conversion to sinus rhythm; persistent atrial fibrillation (SAF) was defined as episodes lasting ≥ 7 days or requiring medical intervention for conversion^[11]. Patients were categorized by AF type into the SAF group ($n = 140$) and the PAF group ($n = 110$). The duration of persistent AF was assessed using ECG or 24 h Holter monitoring records. Pulmonary vein isolation was performed by a single operator in all patients. Clinical data were extracted from the hospital's electronic medical record system.

Ethical approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Ethics Committee of the General Hospital of Northern Theater Command [Approval No. Y (2025) 529]. The requirement for informed consent was waived by the institutional review board given the retrospective design and complete anonymization of all patient data.

Surgical procedure

Preoperative transesophageal echocardiography was routinely performed to assess for thrombus. Antiarrhythmic medications were discontinued for at least five half-lives before the procedure. Electrophysiological studies and ablation procedures were performed under fentanyl-assisted conscious sedation. In brief, two right femoral venous accesses with 8.5-F sheaths were used for transseptal puncture. After transseptal puncture, intraoperative heparinization was used to maintain an activated clotting time of 300–350 s. A 10-pole catheter was inserted into the coronary sinus via the left femoral or right jugular venous access. The left atrium was mapped using a 20 mm 10-pole circular or adjustable curved mapping catheter to establish a three-dimensional model of the left atrium. A 3.5 mm open-tip irrigated ablation catheter was used to ablate the right pulmonary vein antrum first, followed by the left pulmonary vein antrum. Radiofrequency energy was delivered in a wide-area circular pattern within 0.5–1.5 cm of the corresponding pulmonary vein ostium. Ablation parameters included radiofrequency energy of 35–40 W, contact force of 5–15 g, and impedance of 120–140 ohms. The target ablation index was 360–380 for the posterior wall and 400–420 for the anterior wall. A circular or PentaRay catheter was then placed in each of the four pulmonary veins to confirm isolation. If isolation was incomplete, additional ablation was performed as needed. Intravenous isoproterenol was administered to induce non-pulmonary vein triggers. The durability of pulmonary vein isolation was confirmed 30 min after initial documentation of isolation. If AF persisted after circumferential pulmonary vein ablation, direct current cardioversion was performed to restore sinus rhythm.

Follow-up and clinical outcomes

All patients were followed at 3, 6, 9, 12, and 18 months after the procedure by telephone or outpatient visits. An ECG was recorded at each follow-up visit, and 24 h Holter monitoring was performed at the 3 and 18 months visits. If symptoms suggested a possible arrhythmia recurrence, additional ECG or 24 h Holter monitoring was performed. All patients received antiarrhythmic and anticoagulant therapy for at least three months to prevent early recurrence and reduce thromboembolic risk. Proton pump inhibitors were administered for at least six weeks. The primary outcome was freedom from clinical AF recurrence at 18 months after the procedure. AF recurrence was defined as any documented episode of AF lasting at least 30 s. AF episodes occurring during the initial 3 months blanking period after the procedure were classified as early recurrence. Only recurrences after the blanking period were classified as clinical recurrence. After the blanking period, antiarrhythmic therapy was prescribed if ECG or 24 h Holter monitoring showed recurrent AF/atrial tachycardia or frequent atrial premature beats. Additional outcomes included procedure-related complications, such as groin hematoma and left atrial appendage electrical isolation, as well as other safety endpoints.

Data collection

The initial dataset included demographic and clinical characteristics, including age, sex, preoperative BMI, left atrial diameter, serum creatinine, N-terminal pro-B-type natriuretic peptide (NT-proBNP), AF duration, left ventricular ejection fraction, hypertension, diabetes, heart failure, obstructive sleep apnea, coronary artery disease, and history of stroke. Postoperative BMI was assessed only at the 18 months follow-up (a single time point); only 18 months BMI data were complete, and interim BMI data were not analyzed because of partial missingness. Postoperative BMI was categorized using predefined cutoffs as follows:

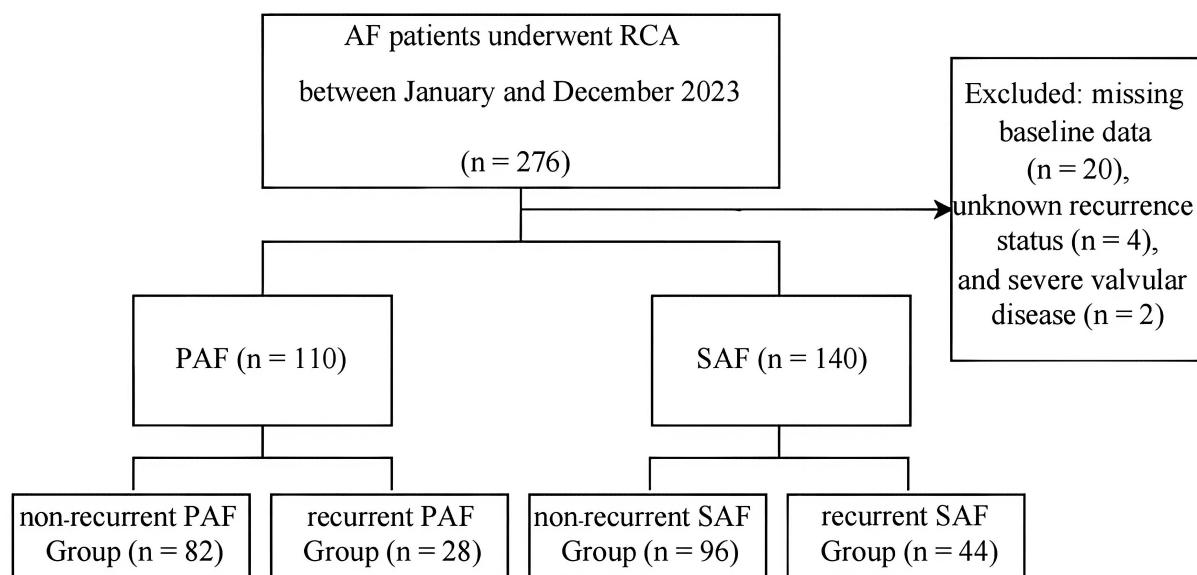


Figure 1. Flowchart of patient enrollment and inclusion in the analysis. PAF: Paroxysmal atrial fibrillation; AF: atrial fibrillation; SAF: persistent atrial fibrillation; RCA: radiofrequency catheter ablation.

normal weight, $< 24 \text{ kg/m}^2$; overweight, $24 \leq \text{BMI} < 28 \text{ kg/m}^2$; and obesity, $\geq 28 \text{ kg/m}^2$. BMI was measured in the morning after an overnight fast.

Statistical analysis

Before formal analysis, data accuracy and outliers were verified through double-entry cross-checking and review of the original medical records to ensure data integrity. The normality of continuous variables was assessed using the Shapiro-Wilk test and Q-Q plots.

Data analysis was performed using SPSS version 29.0. Continuous variables are expressed as the mean \pm standard deviation or median (interquartile range). Normally distributed variables were compared using Student's *t*-test, and non-normally distributed variables were compared using the Mann-Whitney *U* test. Categorical variables are presented as frequencies (n) and percentages (%) and were analyzed using the chi-squared test or Fisher's exact test, as appropriate. The Kaplan-Meier method was used to estimate recurrence-free survival during follow-up, and survival distributions were compared using the log-rank test. Multivariate Cox regression was performed to examine the association between postoperative BMI category and recurrence, with adjustment for potential confounders including age, sex, left atrial diameter, left ventricular ejection fraction (LVEF), AF duration > 12 months, and comorbidities (hypertension, diabetes, heart failure, obstructive sleep apnea, coronary artery disease, and stroke). Variables were selected for the multivariate model based on univariate analysis ($P < 0.10$) and clinical relevance. A two-sided $P < 0.05$ was considered statistically significant.

RESULTS

As shown in the flowchart [Figure 1], 250 patients diagnosed with AF between January and December 2023 were included in the final analysis; 110 were classified as PAF and 140 as SAF. Baseline characteristics are shown in Table 1 for patients with PAF and Table 2 for those with SAF. No significant differences in baseline characteristics were observed between the recurrence and non-recurrence groups among patients with either PAF or SAF.

Table 1. Baseline characteristics of the PAF group

Variables	Total (n = 110)	No recurrence (n = 82)	Recurrence (n = 28)	Statistic	P
Age, years	62.50 (55.00, 67.75)	63.00 (55.00, 67.75)	60.00 (56.00, 67.25)	Z = -0.35	0.726
Male	71 (64.55)	52 (63.41)	19 (67.86)	$\chi^2 = 0.18$	0.671
Preoperative BMI, kg/m ²	25.70 ± 3.19	25.43 ± 3.08	26.50 ± 3.40	t = -1.54	0.126
Left atrial diameter, mm	41.74 ± 5.57	41.91 ± 5.97	41.25 ± 4.29	t = 0.54	0.592
Serum creatinine, mg/dL	69.30 ± 15.73	70.67 ± 15.83	65.31 ± 15.02	t = 1.57	0.120
NT-proBNP, pg/mL	441.45 (170.47, 843.55)	415.55 (170.47, 779.45)	700.80 (206.60, 947.10)	Z = -1.10	0.271
Duration of AF, months	24.00 (10.25, 72.00)	24.00 (10.50, 60.00)	30.00 (10.50, 72.00)	Z = -0.55	0.584
LVEF, %	0.58 (0.51, 0.63)	0.57 (0.50, 0.61)	0.59 (0.53, 0.67)	Z = -1.72	0.085
Hypertension	50 (45.45)	38 (46.34)	12 (42.86)	$\chi^2 = 0.10$	0.749
Diabetes	13 (11.82)	8 (9.76)	5 (17.86)	$\chi^2 = 0.65$	0.419
Heart failure	27 (24.55)	20 (24.39)	7 (25.00)	$\chi^2 = 0.00$	0.948
Obstructive sleep apnea	24 (21.82)	17 (20.73)	7 (25.00)	$\chi^2 = 0.22$	0.637
Coronary artery disease	15 (13.64)	12 (14.63)	3 (10.71)	$\chi^2 = 0.04$	0.839
History of stroke	11 (10.00)	8 (9.76)	3 (10.71)	$\chi^2 = 0.00$	1.000

t: Student's t-test; Z: Mann-Whitney U test; χ^2 : chi-squared test; SD: standard deviation; M: median; Q1: first quartile; Q3: third quartile. $P < 0.05$ was considered statistically significant. PAF: Paroxysmal atrial fibrillation; BMI: body mass index; AF: atrial fibrillation; LVEF: left ventricular ejection fraction.

Table 2. Baseline characteristics of the SAF group

Variables	Total (n = 140)	No recurrence (n = 96)	Recurrence (n = 44)	Statistic	P
Age, years	60.00 (55.00, 67.00)	61.50 (54.00, 68.25)	59.00 (55.75, 65.25)	Z = -1.24	0.214
Male	109 (77.86)	76 (79.17)	33 (75.00)	$\chi^2 = 0.30$	0.581
Preoperative BMI, kg/m ²	26.52 ± 3.21	26.41 ± 3.28	26.76 ± 3.06	t = -0.60	0.548
Left atrial diameter, mm	40.45 ± 5.61	40.11 ± 5.55	41.18 ± 5.74	t = -1.04	0.298
Serum creatinine, mg/dL	71.66 ± 17.14	71.50 ± 17.45	72.01 ± 16.63	t = -0.16	0.871
NT-proBNP, pg/mL	341.85 (103.75, 733.05)	337.65 (99.86, 672.05)	352.50 (128.20, 780.75)	Z = -0.02	0.987
Duration of AF, months	24.00 (8.75, 60.00)	12.00 (6.00, 48.00)	48.00 (24.00, 87.00)	Z = -2.81	0.005
LVEF, %	0.57 (0.49, 0.61)	0.57 (0.49, 0.61)	0.57 (0.50, 0.60)	Z = -0.02	0.987
Hypertension	67 (47.86)	45 (46.88)	22 (50.00)	$\chi^2 = 0.12$	0.731
Diabetes	31 (22.14)	25 (26.04)	6 (13.64)	$\chi^2 = 2.69$	0.101
Heart failure	28 (20.00)	21 (21.88)	7 (15.91)	$\chi^2 = 0.67$	0.413
Obstructive sleep apnea	25 (17.86)	16 (16.67)	9 (20.45)	$\chi^2 = 0.30$	0.587
Coronary artery disease	27 (19.29)	17 (17.71)	10 (22.73)	$\chi^2 = 0.49$	0.485
History of stroke	20 (14.29)	15 (15.62)	5 (11.36)	$\chi^2 = 0.45$	0.504

t: Student's t-test; Z: Mann-Whitney U test; χ^2 : chi-squared test; SD: standard deviation; M: median; Q1: first quartile; Q3: third quartile. $P < 0.05$ was considered statistically significant. PAF: Paroxysmal atrial fibrillation; BMI: body mass index; AF: atrial fibrillation; LVEF: left ventricular ejection fraction.

The recurrence rate in the PAF group was 25.45%. Multivariate Cox analysis showed that BMI ≥ 28 kg/m² was associated with an increased risk of AF recurrence in this group ($P = 0.037$; [Figure 2](#)).

The recurrence rate in the SAF group was 31.43%. Multivariate Cox analysis showed that postoperative overweight [hazard ratio (HR) = 3.19, 95% confidence interval (CI): 1.10-9.27, $P = 0.033$], postoperative obesity (HR = 5.20, 95%CI: 1.76-15.40, $P = 0.003$), and AF duration > 12 months (HR = 3.04, 95%CI:

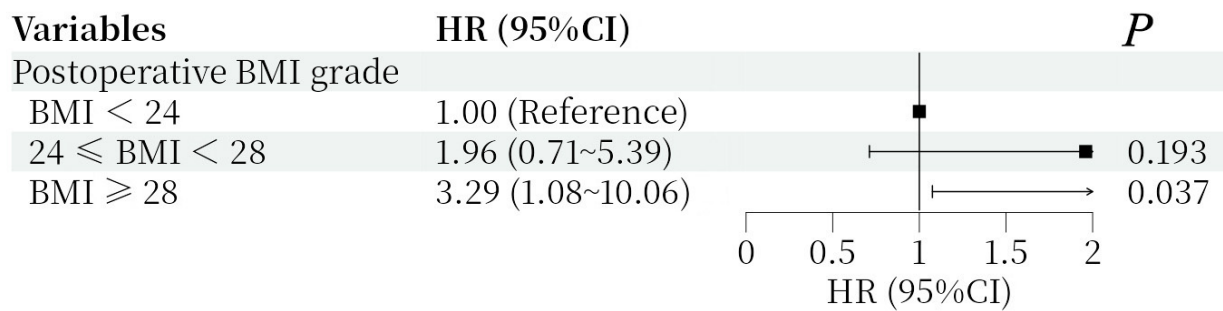


Figure 2. Forest plot of the multivariate Cox analysis for the PAF group. Hazard ratio (HR) with 95% confidence interval (CI) and *P* values are shown for postoperative BMI grade and AF duration. The reference group was BMI < 24 kg/m². PAF: Paroxysmal atrial fibrillation; BMI: body mass index; AF: atrial fibrillation.

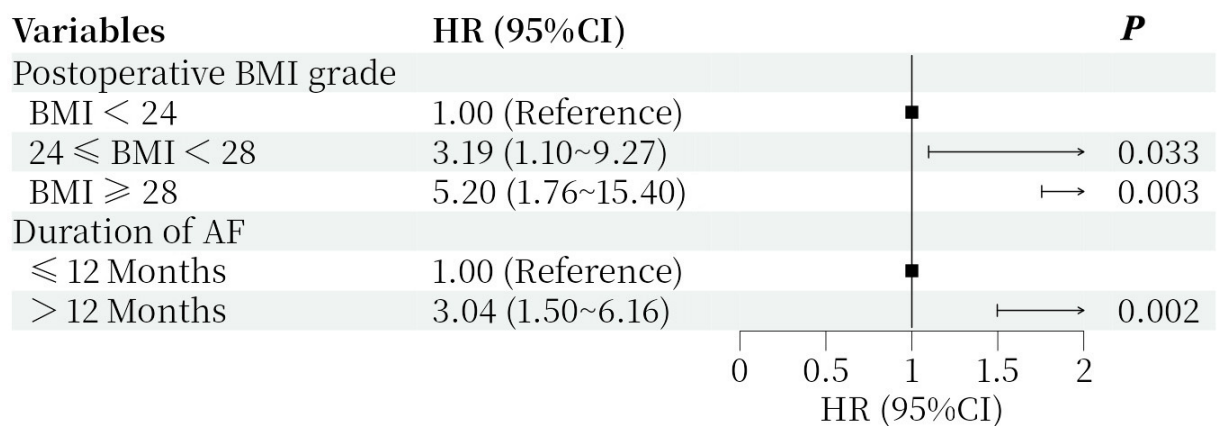


Figure 3. Forest plot of the multivariate Cox analysis for the SAF group. Hazard ratio (HR) with 95% confidence interval (CI) and *P* values are shown for postoperative BMI grade and AF duration. The reference groups were BMI < 24 kg/m² and AF duration ≤ 12 months, respectively. SAF: Persistent atrial fibrillation; BMI: body mass index; AF: atrial fibrillation

1.50-6.16, *P* = 0.002) were independently associated with SAF recurrence [Figure 3]. Kaplan-Meier estimates showed that, among patients with SAF, the 18 months AF recurrence-free rate was 69.1% in postoperative overweight and 55.3% in postoperative obesity, compared with 88.2% in postoperative normal weight (log-rank *P* = 0.006; Figure 4).

No procedure-related complications, including left atrial appendage electrical isolation, pericardial effusion, cardiac tamponade, or left phrenic nerve injury, were observed. No stroke, transient ischemic attack, or death occurred during the 18 months follow-up period in the overall cohort.

DISCUSSION

This single-center retrospective analysis investigated factors independently associated with recurrence after ablation in different AF subtypes. The key findings were as follows: in patients with PAF, postoperative BMI ≥ 28 kg/m² was associated with a higher recurrence risk; in patients with SAF, postoperative BMI category and longer AF duration (> 12 months) showed stronger independent associations with recurrence. Among patients with SAF, postoperative BMI showed a dose-response association with recurrence risk, and freedom from AF recurrence decreased with increasing postoperative BMI grade.

In this study, postoperative BMI was associated with different recurrence patterns after RCA among patients with PAF and SAF, suggesting pathophysiological heterogeneity between these two AF subtypes. In PAF, the

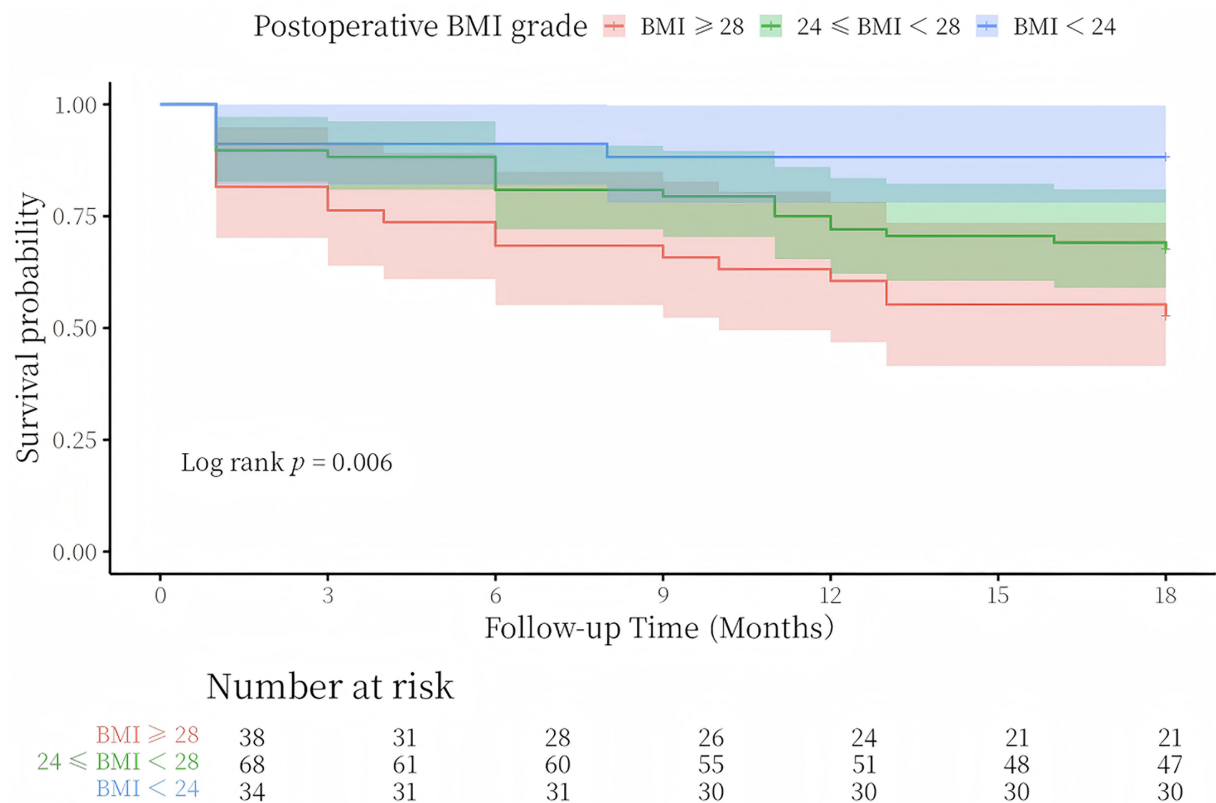


Figure 4. Kaplan-Meier analysis of freedom from AF recurrence in the SAF group. The plot shows recurrence-free survival over follow-up time (months) according to postoperative BMI grade (BMI ≥ 28 kg/m², 24 ≤ BMI < 28 kg/m², and BMI < 24 kg/m²). The log-rank test yielded $P = 0.006$. The number of patients at risk in each BMI category is displayed below the plot. SAF: Persistent atrial fibrillation; BMI: body mass index; AF: atrial fibrillation

main arrhythmogenic mechanism is typically pulmonary vein ectopy, with relatively mild atrial electrical remodeling and limited atrial substrate alteration. Thus, when postoperative BMI was ≥ 28 kg/m², obesity-related systemic pathophysiological changes may have been sufficient to exceed the atrial compensatory capacity, thereby increasing the risk of PAF recurrence. This finding may be related to obesity-mediated systemic inflammation and increased sympathetic tone^[12,13]. In obesity, epicardial adipose tissue accumulates and releases pro-inflammatory cytokines such as interleukin-1 beta (IL-1β), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α). These cytokines may enter the circulation and affect the pulmonary vein myocardial sleeves, enhancing electrical excitability and increasing ectopic activity. Meanwhile, sympathetic activation, accelerated heart rate, and increased myocardial oxygen consumption may further reduce atrial electrical stability, ultimately contributing to recurrence in patients with PAF. In patients with PAF and postoperative BMI < 28 kg/m², obesity-related pathophysiological effects may have been less pronounced and may not have reached a threshold sufficient to disrupt atrial electrophysiological stability; accordingly, this BMI category was not independently associated with recurrence.

In contrast, patients with SAF have a more complex pathophysiological substrate. Their atria may have undergone more advanced electrical and structural remodeling, characterized by more extensive atrial fibrosis, reduced conduction velocity, and greater conduction heterogeneity. These changes may promote the formation of multiple potential reentrant circuits, making the atrial substrate more susceptible to obesity-related effects. At this stage, obesity may exert a more sensitive and profound influence on the atrial substrate. Therefore, both postoperative overweight and postoperative obesity in patients with SAF emerged as factors independently associated with recurrence and were significantly correlated with recurrence-free

survival. In patients with SAF and poor postoperative weight control, persistent obesity may maintain and exacerbate the proarrhythmic milieu through multiple mechanisms. First, epicardial adipose tissue may continue to exert paracrine effects by releasing pro-inflammatory cytokines and fibrotic mediators such as adipocytokines and transforming growth factor-beta 1 (TGF- β 1), thereby promoting atrial fibrosis and stabilizing the reentrant substrate^[14]. Second, obesity-related electrophysiological changes, including increased voltage heterogeneity and more fractionated potentials, may reduce cardiomyocyte electrical stability and provide a substrate for arrhythmogenesis^[15]. Finally, increased circulating blood volume and cardiac load in obesity may contribute to passive atrial dilation and further atrial remodeling^[16], potentially creating a self-reinforcing cycle of obesity-associated atrial remodeling and AF recurrence. Although RCA can isolate pulmonary vein triggers and modify the local atrial substrate, it may not fully reverse the systemic and epicardial proarrhythmic milieu associated with obesity, which may explain why postoperative BMI status was independently associated with recurrence.

Furthermore, AF duration exceeding 12 months was independently associated with SAF recurrence. This finding is consistent with the report by Calvert *et al.*^[17] and supports the concept that atrial fibrosis may progress with longer AF duration. In patients with SAF and AF duration exceeding 12 months, atrial remodeling may have advanced substantially. Although RCA eliminated dominant triggers, the established fibrotic substrate may still facilitate the formation of new reentrant circuits. These findings suggest that, for patients with SAF, clinicians should emphasize not only postoperative weight management but also timely intervention.

Several earlier studies did not identify a significant association between BMI and AF recurrence^[7,8]. However, many investigations have confirmed that obesity is associated with both AF onset and recurrence after ablation^[9,10,18,19]. This study extends previous work in two main respects. First, it identified postoperative BMI, rather than baseline BMI alone, as a factor associated with SAF recurrence, providing direct evidence for dynamic postoperative management. Second, stratified analysis quantified the risk gradient across BMI categories, with recurrence-free survival decreasing from 88.2% in postoperative normal weight to 55.3% in postoperative obesity. This gradient may facilitate more precise risk communication.

The mechanisms outlined above highlight the important role of postoperative BMI management in the comprehensive treatment framework for AF ablation. RCA primarily eliminates localized pulmonary vein triggers and modifies the atrial electrophysiological substrate, whereas persistent obesity is associated with a sustained systemic proarrhythmic milieu. If this systemic proarrhythmic environment is not addressed after the procedure, it may continue to contribute to atrial structural and electrical remodeling and potentially reduce the therapeutic benefit of RCA. Therefore, postoperative BMI may function not only as a risk indicator but also as a modifiable therapeutic target. Systematic postoperative weight management should be considered an important component of ablation therapy because it targets systemic proarrhythmic factors that ablation alone cannot eliminate. This approach may be an important strategy for long-term AF management.

Strengths and limitations

The main strengths of this study are as follows. First, all procedures were performed by the same experienced operator, minimizing the potential impact of procedural variability and enhancing the reliability of the findings. Second, strict exclusion criteria, such as patients with missing baseline data, incomplete postoperative follow-up data, or severe valvular heart disease, improved the homogeneity of the study cohort.

This study has several limitations. First, because this was a single-center retrospective study with a relatively limited sample size ($n = 250$), selection bias may have been introduced, and generalizability may be limited. No a priori sample size calculation was performed, which may have affected the statistical power of subgroup analyses. The retrospective design also precludes causal inference. Second, postoperative BMI was assessed only at the 18 months follow-up; repeated BMI measurements during follow-up were not available. Therefore, potential weight fluctuations or trajectories could not be captured. Third, the limited sample size may have reduced the statistical power of subgroup analyses; for example, it was not possible to further analyze the association between postoperative BMI and AF recurrence in subgroups defined by AF duration, age, or comorbidities. Fourth, this study relied mainly on BMI to assess postoperative obesity. BMI reflects the ratio of weight to height but does not distinguish body fat distribution, whereas measures of abdominal obesity may better reflect visceral adiposity. Finally, although the multivariate Cox model adjusted for several clinically relevant confounders, residual confounding from unmeasured factors may remain, including changes in antihypertensive or antidiabetic medications after the blanking period and adherence to weight management.

Future studies should address these limitations by conducting multicenter prospective cohort studies with larger sample sizes and patients from different regions and hospitals to further evaluate the generalizability of these findings. Randomized controlled trials are also needed to compare conventional management plus intensive weight intervention with conventional management alone for reducing recurrence after AF RCA, with dynamic recording of weight changes to directly assess the clinical efficacy of weight intervention. Future studies should also incorporate more refined measures of obesity, such as waist circumference and body fat percentage, together with inflammatory and metabolic biomarkers, to establish multidimensional recurrence prediction models that integrate clinical and biomarker data. Finally, follow-up should be extended to 3-5 years to dynamically assess postoperative BMI and evaluate the impact of postoperative BMI changes on long-term recurrence and adverse cardiovascular events, thereby providing more comprehensive evidence for long-term management strategies.

Conclusion

In this retrospective analysis, postoperative obesity assessed at a single time point (18 months) was associated with a higher risk of recurrence after RCA for AF. Specifically, among patients with PAF, a BMI ≥ 28 kg/m² at 18 months was associated with an increased recurrence risk. Among patients with SAF, higher postoperative BMI grades at 18 months and AF duration exceeding 12 months were also associated with recurrence.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study and performed data analysis and interpretation: Yang W, Zhang D, Li Y

Performed data acquisition: Yang W, Yan Y

Critical revision and supervision: Zhang Q, Zhang P, Zhang Y, Zhang J

Provided administrative, technical, and material support: Han Y, Wang Z, Liang M

Availability of data and materials

The datasets generated and analyzed during this retrospective study are not publicly available due to privacy protection requirements stipulated by the institutional ethical approval and the waiver of written informed consent for participants, aiming to strictly safeguard patient privacy and confidential medical information. Anonymized data that support the findings of this study may be made available from the corresponding author, Liang M, or from the Ethics Committee of the General Hospital of Northern Theater Command upon reasonable request. Any data sharing will be subject to a formal data use agreement in compliance with institutional regulations and applicable laws.

AI and AI-assisted tools statement

During the preparation of this manuscript, the AI tool ChatGPT (version 5.0, released 2025-08-07) was used solely for English language editing. The tool did not influence the study design, data collection, analysis, interpretation, or the scientific content of the work. All authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Ethics Committee of the General Hospital of Northern Theater Command [Approval No. Y (2025) 529]. The requirement for informed consent was waived by the institutional review board given the retrospective design and complete anonymization of all patient data.

Consent for publication

Not applicable.

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