Am J Transl Res 2022;14(3):1778-1787
www.ajtr.org /ISSN:1943-8141/AJTR0138921

Original Article

Value of echocardiography in evaluating efficacy of radiofrequency catheter ablation in patients with atrial fibrillation

Ying Li[1], Bing Han[2], Jinfang Li[1], Fei Ge[1], Lianwei Yang[3]

[1]Department of Cardiac Ultrasound, Weihai Municipal Hospital, Cheeloo College of Medicine, Shangdong University, Weihai 264200, Shangdong Province, China; [2]Department of Ultrasound, Weihai Municipal Hospital, Cheeloo College of Medicine, Shangdong University, Weihai 264200, Shangdong Province, China; [3]Department of Cardiology Group Two, Weihai Municipal Hospital, Cheeloo College of Medicine, Shangdong University, Weihai 264200, Shangdong Province, China

Received September 6, 2021; Accepted December 10, 2021; Epub March 15, 2022; Published March 30, 2022

Abstract: Objective: To analyze the cardiac structure and function of patients with recurrent atrial fibrillation (AF) after radiofrequency catheter ablation (RFCA) with echocardiography and to predict the factors affecting recurrence. Methods: In this retrospective study, 87 patients who received RFCA for AF in the Weihai Municipal Hospital from June 2018 to December 2019 were enrolled. According to the recovery of postoperative sinus rhythm (SR), patients with recovered SR were assigned to the research group (Res group, n=60), while those with AF recurrence were included in the control group (Con group, n=27). The transthoracic echocardiography was adopted to measure the changes of left atrium-related parameters of patients before RFCA and at 6 months after surgery, and the transesophageal three-dimensional echocardiography was adopted for measuring the changes of left atrial appendage (LAA)-related parameters. In addition, multivariate logistic regression was performed to analyze the factors influencing postoperative recurrence of AF. Results: After 6-month follow up, SR was restored in 60 cases and AF recurred in 27 cases. After surgery, the left atrial anteroposterior diameter (LAAPD), left atrial left and right diameter (LALRD), left atrial up and down diameter (LAUDD), maximum volume of left atrium (LAVmax), minimum volume of left atrium (LAVmin), opening diameter of LAA (LAAOD), maximum volume of LAA (LAAVmax), and minimum volume of LAA (LAAV min) of the Res group decreased, and were lower than those of the Con group. In addition, the left atrial ejection fraction (LAEF), vessel function index and dilatation index of the Res group increased significantly postoperatively, and were higher than those of the Con group. The Res group also showed significantly higher LAA area change percentage [LAAAC (%)] and LAA emptying velocity (LAAEV) than the Con group. Moreover, age, history of hypertension, LAVmax and LAAAC (%) were identified to be the independent risk factors for postoperative recurrence of AF. Conclusion: Patients with increased left atrial diameter and volume, large LAAOD, and small ejection fraction are more susceptible to AF recurrence, and LAAOD is a predictor of postoperative recurrence of AF.

Keywords: Echocardiography, atrial fibrillation, radiofrequency catheter ablation, left atrial appendage, left atrium

Introduction

Atrial fibrillation (AF), a frequent-occurring arrhythmia, is common in cardiology [1]. With a serious threat to human life and health, the disease affects at least 3 million adults in the United States. The risk of AF increases with age, so the elderly are most susceptible to the disease [2]. AF can be clinically manifested as palpitation, chest distress, etc., and can even cause dizziness, syncope and angina pectoris in severe cases [3]. Heart failure, cerebral stroke, pulmonary embolism, and sudden cardiac death are the common complications of patients with AF, which seriously compromise the life quality of patients [4]. According to statistics, the direct cause of death of patients with AF is heart failure [5]. Under the long-term influence of AF on the function of left atrium (LA), AF patients lose effective atrial contraction, which leads to a decrease in left ventricular ejection fraction (LVEF). Meanwhile, during an AF episode, the ventricular rate accelerates, which leads to shortened left ventricular dia-

stolic phase, impaired left ventricular compliance, increased end-diastolic pressure, finally resulting in elevated afterload and increased pressure in LA [6, 7]. Long-term AF will give rise to LA enlargement, atrial fibrosis, myocardial remodeling and tachyarrhythmia cardiomyopathy, and eventually lead to heart failure [8]. Therefore, it is of particular importance to treat AF. At the current stage, anti-arrhythmia drugs are mainly used to restore sinus rhythm (SR) in patients with AF, but for some paroxysmal atrial fibrillation (PAF) patients with ineffective drug therapy or intolerance, radiofrequency catheter ablation (RFCA) is recommended [9, 10].

As an effective treatment for AF, RFCA has been increasingly used in recent years, and has captured extensive attention because of its favorable efficacy as an invasive therapy. A recent study [11] showed that, RFCA was more effective in the treatment of AF, especially in patients with PAF, than traditional antiarrhythmic agents in maintaining SR, relieving symptoms and improving quality of life. At the current stage, SR recovery of patients after surgery is judged only based on the self-reported clinical manifestations of patients and their electrocardiogram (ECG) examination results in clinical practice, but the effects of RFCA on the structure and function of patients' atria are rarely reported [12]. Echocardiography has the advantages of economy, noninvasiveness and simple-operation among various imaging evaluation methods, and has been widely applied in clinical practice [13]. In recent years, non-invasive evaluation of left atrial function by echocardiography has become a research hotspot in the cardiovascular field [14]. Real-time three-dimensional echocardiography is a newly developed technology that can display the three-dimensional anatomical structure of the heart intuitively, dynamically and in real time [15]. The innovation of this study is to use the latest real-time three-dimensional ultrasound technology to quantitatively analyze the effect of treatment on patients with atrial fibrillation, which can provide accurate evaluation indicators for the clinic.

This study determines the effects of RFCA on atrial structure and function of patients with PAF by echocardiography and predicts factors impacting the recurrence, with the aim of providing more useful reference for clinical treatment.

Materials and methods

General data of patients

Totally 87 patients who received RFCA for AF in the Weihai Municipal Hospital from June 2018 to December 2019 were enrolled. According to the postoperative SR recovery, patients with recovered SR were assigned to the research group (Res group, n=60), and those with recurred AF were assigned to the control group (Con group, n=27). In the Res group, there were 36 males and 24 females, with an average age of 55.26±6.35 years. The male to female ratio in the Con group was 13:14, and the average age was 65.19±5.16 years. This is a retrospective study approved by the medical ethics committee of our hospital, and the subjects and their families were informed and signed a fully informed consent.

Inclusion and exclusion criteria

Inclusion criteria: (1) Patients with an age of 18-80 years; (2) Patients who met the diagnostic criteria of PAF [16], and were diagnosed by ECG or 24-hour dynamic ECG examination combined with medical history; (3) Patients with LVEF >50%; (4) Patients who actively cooperated with postoperative follow-up.

Exclusion criteria: (1) Patients with LVEF <50%; (2) Patients with the first attack of AF within 24-48 hours; (3) Patients with rheumatic heart disease or cardiomyopathy; (4) Patients with acute coronary syndrome; (5) Patients with a permanent pacemaker; (6) Patients who could not maintain SR during echocardiography; (7) Patients with severe liver or kidney dysfunction or malignant tumor; (8) Patients with cognitive impairment, central nervous system diseases or severe peripheral nerve diseases. (9) Patients without detailed case data.

Methods

All patients were followed up for 6 months after therapy, and related data were measured before and 6 months after surgery. Siemens SC2000 ultrasonic diagnostic instrument (Siemens, ACUSON SC2000) was used for examination, with a probe frequency of 2-4 MHz. The patient was placed in the left lateral position to record the sinus rhythm at rest. In addition, an ECG was performed, during which the patient was required to hold his/her breath

Table 1. Comparison of general data between the two groups [n (%)] ($\bar{x}$±sd)

Item	Research group (n=60)	Control group (n=27)	t/χ^2 value	*P*-value
Age (Y)	55.26±6.35	65.19±5.16	7.128	<0.001
BMI (kg/m^2)	23.38±2.12	23.10±2.20	0..476	0.636
Gender				
Male	36 (60.00)	13 (48.15)	1.063	0.303
Female	24 (40.00)	14 (51.85)		
Place of residence				
Urban area	31 (51.67)	16 (59.26)	0.432	0.511
Rural area	29 (48.33)	11 (40.74)		
Education background				
≥ senior high school	23 (38.33)	12 (44.44)	0.289	0.591
< senior high school	37 (61.67)	15 (55.56)		
Smoking history				
Yes	13 (21.67)	9 (33.33)	1.342	0.247
No	47 (78.33)	18 (66.67)		
Drinking history				
Yes	38 (63.33)	8 (29.63)	0.967	0.326
No	22 (36.67)	19 (70.37)		
Diabetes history			1.015	0.314
Yes	10 (16.67)	7 (25.93)		
No	50 (83.33)	20 (74.07)		
Hypertension history				
Yes	17 (28.33)	19 (70.37)	13.57	<0.001
No	43 (71.67)	8 (29.63)		

Note: BMI, body mass index.

and the probe position was adjusted to clearly display the left atrial intima. Two-dimensional images of parasternal long-axis view, apical four-chamber view, and two-chamber view were acquired at a frame rate of 60-90 frames/s. The left atrial anteroposterior diameter (LAAPD) was measured under parasternal long-axis view, and the left atrial up and down diameter (LAUDD) and left atrial left and right diameter (LALRD) were measured under apical four-chamber view. In addition, the maximum volume of LA (LAVmax) was measured using the GE EchoPAC Clinical Workstation Software (G.E., USA, EchoPAC), and the minimum volume of LA (LAVmin) was determined at the end of left ventricular diastole. Moreover, the left atrial presystolic volume (LAVps) was measured by ECG localization, on which the left atrial ejection fraction (LAEF) and left atrial active ejection fraction were calculated.

The iE Elite and EPIQ7C color Doppler ultrasound machines produced by Philips were used with the transesophageal probe model numbers of S7-2t and X7-2t (2.0-7.0 MHz) respectively, and QLab 9.5 software was used for analysis. When the existence of thrombosis was ruled out by the transesophageal echocardiography (TEE), the following items were measured: left atrial appendage width (LAAW), LAA length (LAAL), maximum volume of LAA (LAAVmax), minimum volume of LAA (LAAVmin), LAA ejection fraction (LAAEF), LAA emptying velocity (LAAEV), LAA peak filling velocity (LAAFV), LAA peak systolic velocity (LAATSV), and LAA peak diastolic velocity (LAATDV). Based on the measured values, the structure and function of LAA were evaluated.

Outcome measures

Primary outcome measures: (1) LA-related parameters: LAAPD, LALRD, LAUDD, LAVmax, LAVmin, LAEF, vessel function index, and dilation index before and after treatment. (2) LAA-related parameters: opening diameter of LAA (LAAOD), LAAVmax, LAAVmin, LAA area change percentage [LAAAC (%)], and LAAEV.

Figure 1. There are a large number of cloud-like echoes in the LA imaging. Note: LA, atrial fibrillation.

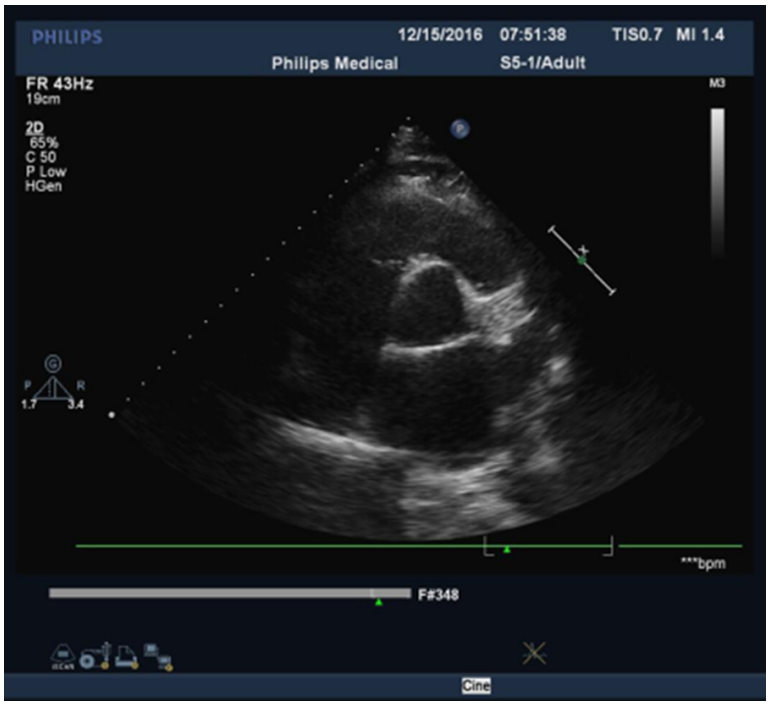

Figure 2. There are a lot of cloud-like echoes in the LAA imaging. Note: LAA, left atrial appendage.

Secondary outcome measures: Independent risk factors of AF recurrence.

Statistical analyses

Data in this study were statistically processed by SPSS24.0 (IBM Corp, Armonk, NY, USA), and visualized into corresponding figures via GraphPad Prism 7. The enumeration data were expressed as [n (%)], and the the Chi-square test was used for comparison between groups. Measurement data were expressed as ($\bar{x}\pm sd$). Independent-samples t test was used for inter-group comparison of measurement data, and paired t test was used for intra-group comparison. The risk factors affecting treatment efficacy were analyzed using a multivariate logistics regression model. $P<0.05$ indicates a significant difference.

Results

General data

The two groups were not significantly different in clinical baseline data such as gender, body mass index (BMI), place of residence, education background, smoking history, drinking history, and diabetes history (all $P>0.05$). Whereas, the patients in the Res group were younger, and there were fewer hypertension cases (all $P<0.001$, **Table 1**).

Image analysis

On the sonogram, the LA and LAA of the patient showed a large number of cloud-like echoes, as shown in **Figures 1** and **2**.

Structural parameters of LA

Before surgery, the two groups were not greatly different in LAAPD, LALRD, LAUDD, LAVmax, and LAVmin ($P>0.05$); while after treatment, LAAPD, LALRD, LAUDD, and LAVmin of the Res group decreased, and were lower than those of the Con group ($P<0.001$). In the Con group, LAAPD, LALRD, LAUDD, and LAVmin slightly but not significantly increased after surgery compared with those

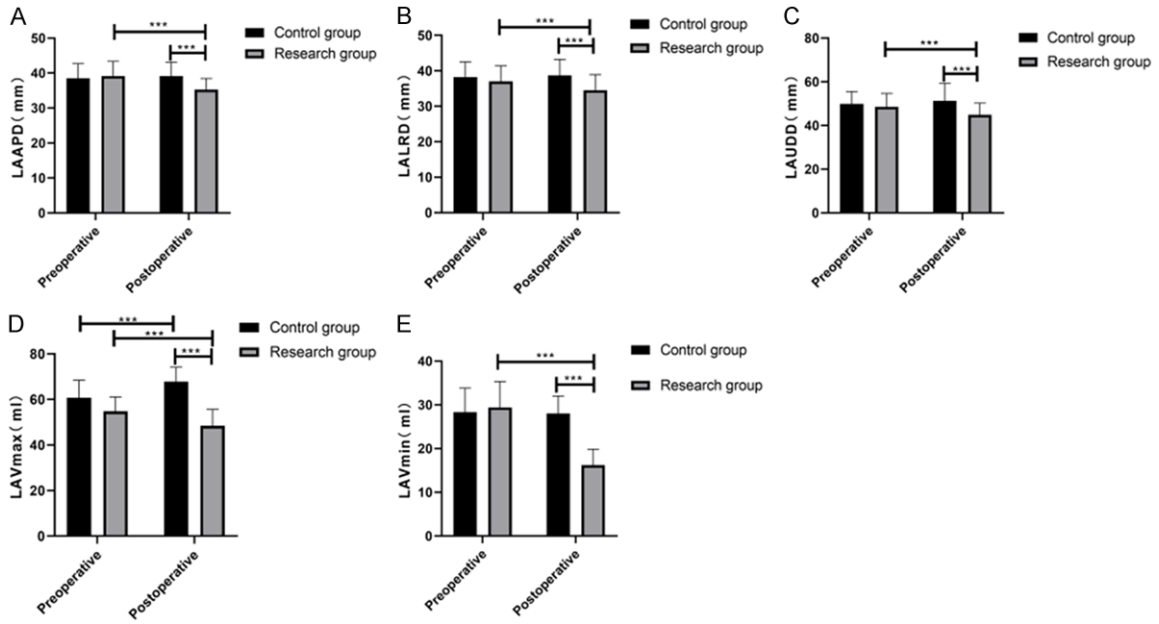

Figure 3. Comparison of indexes of LA structure. After surgery, LAAPD (A), LALRD (B), LAUDD (C), LAVmax (D), and LAVmin (E) of the research group were all significantly smaller than those of the control group. Note: ***P<0.001; LA, atrial fibrillation; LAAPD, left atrial anteroposterior diameter; LALRD, left atrial left and right diameter; LAUDD, left atrial up and down diameter; LAVmax, maximum volume of atrial fibrillation; LAVmin, minimum volume of atrial fibrillation.

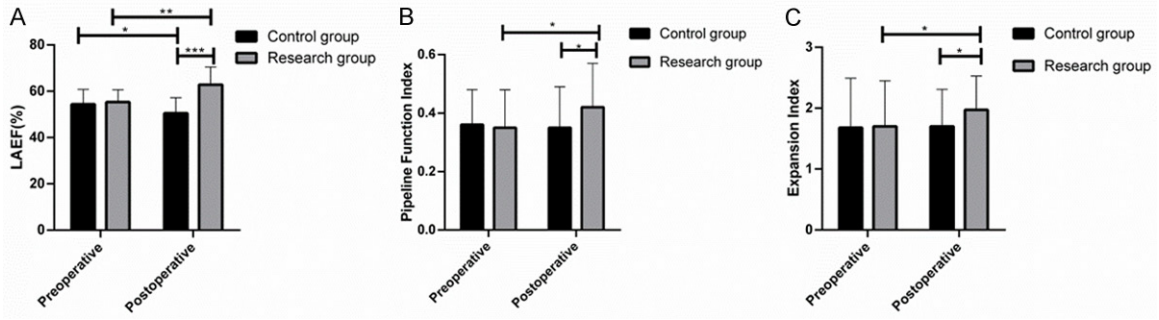

Figure 4. Comparison of functional indexes of LA. The LAEF (A), vessel function index (B) and dilation index (C) of the research group were significantly higher than those of the control group after surgery. Note: ***P<0.001; **P<0.01; *P<0.05; LA, atrial fibrillation; LAEF, left atrial ejection fraction.

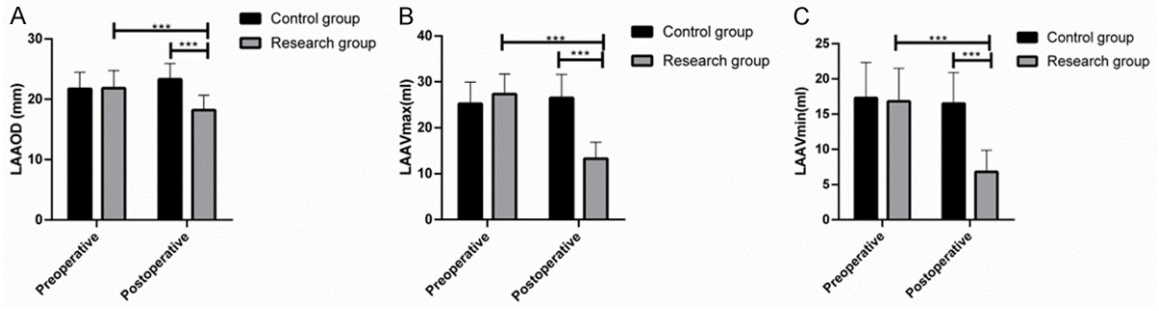

Figure 5. Comparison of structural indexes of LAA. After surgery, LAAOD (A), LAAVmax (B), and LAAVmin (C) of the research group were all smaller than those of the control group. Note: ***P<0.001; LAA, left atrial appendage; LAAOD, opening diameter of left atrial appendage; LAAVmax, maximum volume of left atrial appendage; LAAVmin, minimum volume of left atrial appendage.

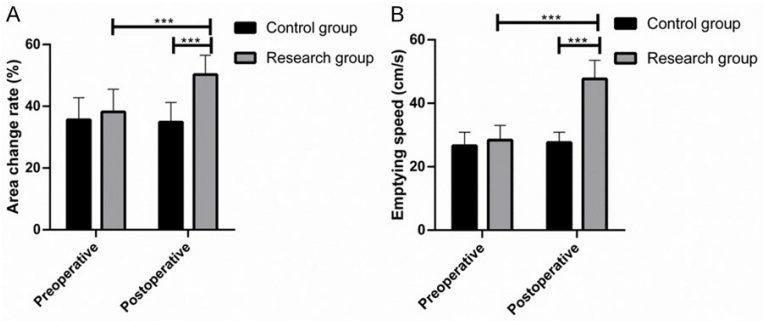

Figure 6. Comparison of functional indexes of LAA. The research group showed higher LAA area change percentage (A) and LAAEV (B) than the control group after surgery. Note: ***P<0.001; LAA, left atrial appendage; LAAEV, left atrial appendage emptying velocity.

before surgery (P>0.05). In addition, after surgery, the LAVmax of the Con group increased obviously and was significantly higher than that of the Res group (P<0.001, **Figure 3**).

Functional parameters of LA

There were no significant differences in LAEF, vessel function index and dilation index between the two groups before surgery (all P>0.05). After surgery, the LAEF increased in the Res group (P<0.01) while it decreased in the Con group (P<0.05), and the LAEF in the Res group was significantly higher than that in the Con group (P<0.001). In the Res group, the vessel function index and dilation index were significantly higher than those before surgery (P<0.05) and were higher than those of the Con group (P<0.05). There was no significant change in the Con group before and after treatment (**Figure 4**).

Structural parameters of LAA

Before surgery, no significant difference was found between the two groups in LAAOD, LAAVmax, and LAAVmin (P>0.05), while after surgery, the Res group showed lower LAAOD, LAAVmax and LAAVmin than the Con group (P<0.05, **Figure 5**).

Functional parameters of LAA

Before surgery, LAAAC (%) and LAAEV of the two groups were not significantly different (P>0.05), while after surgery, the Res group showed notably higher LAAAC (%) and LAAEV than the Con group (P<0.001, **Figure 6**).

Multivariate analysis of factors for postoperative recurrence

With the recurrence of AF after RFCA as the dependent variable, and factors of clinical baseline data, as well as the structural and functional parameters of LA and LAA as independent variables, multivariate logistic regression was carried out to analyze the independent risk factors for postoperative recurrence. The results showed that age, history of hypertension, LAVmax, and LAAAC (%) were independent risk factors of AF recurrence (**Table 2**).

Discussion

The prevalence of AF, which adversely affects cardiac function and increases the risk of stroke, increases with age [17]. AF is often associated with heart failure, so its incidence and mortality are remarkably higher among patients with heart failure [18]. Thanks to its rapid development, RFCA can effectively lower the recurrence of arrhythmia after AF ablation at the current stage [19]. RFCA is a common surgery for the treatment of AF, with obvious effects and high safety. However, the high recurrence rate after RFCA is still a disturbing problem [20, 21]. Therefore, it is of great significance to examine the cardiac function of patients with AF after RFCA.

The high recurrence rate of AF after RFCA may involve non-anomalous pulmonary venous lesions, and other ectopic lesions such as vena cava, coronary sinus, left atrial posterior wall, and LAA are possible origins of AF [22, 23]. Reportedly, LA and LAA associated parameters, which have been confirmed to be closely related to the recurrence of AF, can be used to predict the recurrence risk of AF after RFCA [24, 25]. LAA, a heart cavity with different shapes and sizes, has a strong relationship with atrial arrhythmia and thrombus. Real-time three-dimensional echocardiography can display the three-dimensional anatomical structure of the heart such as LAA directly, dynamically and in real-time [26]. In this study, we

Table 2. Multivariate logistic regression analysis

Factors	β	S.E	χ^2	*P*-value	Exp (B)	95% CI	
						Lower limit	Upper limit
Age	1.078	0.523	4.223	0.042	2.936	1.051	8.201
Hypertension	1.089	0.465	5.537	0.018	2.986	1.201	7.428
LAVmax	0.982	0.397	6.542	0.011	2.741	1.270	5.873
Area change percentage	0.935	0.356	6.127	0.013	2.462	1.194	5.387

Note: LAVmax, maximum volume of atrial fibrillation.

adopted echocardiography to evaluate the cardiac structure and function of patients with AF after RFCA, so as to evaluate the efficacy of RFCA and recurrence factors of AF. Patients with postoperative recurrence were assigned to the Con group, and the rest to the Res group. First, we compared the clinical data of the two groups, and found that patients with AF recurrence were characterized by advanced age and history of hypertension, indicating that age and hypertension may be factors affecting the postoperative recurrence of AF, which was similar to the results obtained by Steinberg et al. [27] and MacGregor et al. [28]. By evaluating parameters associated with LA in the two groups, we found that after surgery, LAAPD, LALRD, LAUDD, LAVmax and LAVmin of the Res group decreased and were lower than those of the Con group. In addition, the LAEF, vessel function index, and dilation index of the Res group increased significantly and were higher than those of the Con group. It suggests that the left atrial structure and function of patients in the Res group returned to normal after RFCA treatment. Moreover, it indicates the favorable efficacy of RFCA and the great value of echocardiography in evaluating the cardiac function of patients after RFCA. Atrial remodeling will be aggravated with age and duration of AF. In addition, the increase of atrial pressure load in patients with hypertension also leads to atrial remodeling, and the atrium itself with reconstruction expansion is likely to induce AF [29].

LAA-related parameters are crucial indexes for AF evaluation, and age and LAAEV are independent risk factors of AF [30]. According to evaluation results of structural and functional indexes of LAA of patients in the two groups, the Res group had lower LAAOD, LAAVmax and LAAVmin and higher LAAAC (%) and LAAEV than the Con group, suggesting that the LAA structure and function in the Res group have been restored. It also indicates that RFCA has a good therapeutic effect, and echocardiography can effectively evaluate LAA-related parameters to understand the postoperative condition of patients with AF. Because of the unique shape, complex lobulation and special internal anatomy, LAA becomes a predilection site of AF. Moreover, the morphology of LAA varies greatly among different individuals, which increases the difficulty to the evaluation of the condition of patients with AF [31]. Real-time three-dimensional echocardiography is considered as the most commonly used imaging method to evaluate the anatomy and internal structure of LAA [32], which is further confirmed by the results of this study. Similar to our results, Cameli et al. [33] have demonstrated that echocardiography is a crucial imaging means for the diagnosis and prognosis of arterial hypertension and AF. At the end of the study, we adopted multivariate logistic regression to analyze the risk factor for AF recurrence, and found that age, history of hypertension, LAVmax and LAAAC (%) were independent risk factors for postoperative recurrence of AF. Moreover, there are reports that left atrial volume, left atrial diameters, age, gender, BMI, and related primary diseases are risk factors for AF recurrence after surgery [34-36], which are basically consistent with our research.

Currently, RFCA is the preferred treatment for AF, and the success rate of this procedure is 77.8%, which means that some patients may still experience recurrence after surgery [37]. This study has confirmed the high efficacy of RFCA in the treatment of AF and the high value of echocardiography in the detection of postoperative recurrence. In addition, age, history of hypertension, LAVmax and LAAAC (%) are independent risk factors for postoperative recurrence of AF. However, there are some limitations in this study. This study was a single-center retrospective study with a small sample

size, and the patients with non-PAF were not further classified and analyzed. Therefore, in future studies, we will expand the sample size and increase the study participants to provide a strong basis for clinical treatment of AF.

Disclosure of conflict of interest

None.

Address correspondence to: Lianwei Yang, Department of Cardiology Group Two, Weihai Municipal Hospital, Cheeloo College of Medicine, Shangdong University, No. 70 Heping Road, Huancui District, Weihai 264200, Shangdong Province, China. Tel: +86-0631-5287660; E-mail: yanglianwei2013@126.com

References

[1] Bosch NA, Cimini J and Walkey AJ. Atrial fibrillation in the ICU. Chest 2018; 154: 1424-1434.

[2] Westerman S and Wenger N. Gender differences in atrial fibrillation: a review of epidemiology, management, and outcomes. Curr Cardiol Rev 2019; 15: 136-144.

[3] Dilaveris PE and Kennedy HL. Silent atrial fibrillation: epidemiology, diagnosis, and clinical impact. Clin Cardiol 2017; 40: 413-418.

[4] January CT, Wann LS, Calkins H, Chen LY, Cigarroa JE, Cleveland JC Jr, Ellinor PT, Ezekowitz MD, Field ME, Furie KL, Heidenreich PA, Murray KT, Shea JB, Tracy CM and Yancy CW. 2019 AHA/ACC/HRS focused update of the 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines and the heart rhythm society. J Am Coll Cardiol 2019; 74: 104-132.

[5] Hohendanner F, Heinzel FR, Blaschke F, Pieske BM, Haverkamp W, Boldt HL and Parwani AS. Pathophysiological and therapeutic implications in patients with atrial fibrillation and heart failure. Heart Fail Rev 2018; 23: 27-36.

[6] Mogensen UM, Jhund PS, Abraham WT, Desai AS, Dickstein K, Packer M, Rouleau JL, Solomon SD, Swedberg K, Zile MR, Køber L and McMurray JJV; PARADIGM-HF and ATMOSPHERE Investigators and Committees. Type of atrial fibrillation and outcomes in patients with heart failure and reduced ejection fraction. J Am Coll Cardiol 2017; 70: 2490-2500.

[7] Shah AM, Cikes M, Prasad N, Li G, Getchevski S, Claggett B, Rizkala A, Lukashevich I, O'Meara E, Ryan JJ, Shah SJ, Mullens W, Zile MR, Lam CSP, McMurray JJV and Solomon SD; PARAGON-HF Investigators. Echocardiographic features of patients with heart failure and preserved left ventricular ejection fraction. J Am Coll Cardiol 2019; 74: 2858-2873.

[8] Wijesurendra RS and Casadei B. Mechanisms of atrial fibrillation. Heart 2019; 105: 1860-1867.

[9] Andrade JG, Wells GA, Deyell MW, Bennett M, Essebag V, Champagne J, Roux JF, Yung D, Skanes A, Khaykin Y, Morillo C, Jolly U, Novak P, Lockwood E, Amit G, Angaran P, Sapp J, Wardell S, Lauck S, Macle L and Verma A; EARLY-AF Investigators. Cryoablation or drug therapy for initial treatment of atrial fibrillation. N Engl J Med 2021; 384: 305-315.

[10] Marrouche NF, Brachmann J, Andresen D, Siebels J, Boersma L, Jordaens L, Merkely B, Pokushalov E, Sanders P, Proff J, Schunkert H, Christ H, Vogt J and Bänsch D; CASTLE-AF Investigators. Catheter ablation for atrial fibrillation with heart failure. N Engl J Med 2018; 378: 417-427.

[11] Gaita F, Scaglione M, Battaglia A, Matta M, Gallo C, Galata M, Caponi D, Di Donna P and Anselmino M. Very long-term outcome following transcatheter ablation of atrial fibrillation. Are results maintained after 10 years of follow up? Europace 2018; 20: 443-450.

[12] Chew DS, Rennert-May E, Spackman E, Mark DB and Exner DV. Cost-effectiveness of extended electrocardiogram monitoring for atrial fibrillation after stroke: a systematic review. Stroke 2020; 51: 2244-2248.

[13] Ptaszynska-Kopczynska K, Krentowska A, Sawicka E, Skoneczny A, Jasiewicz M, Knapp M, Musial WJ, Sobkowicz B and Kaminski KA. The strengths and weaknesses of non-invasive parameters obtained by echocardiography and cardiopulmonary exercise testing in comparison with the hemodynamic assessment by the right heart catheterization in patients with pulmonary hypertension. Adv Med Sci 2017; 62: 39-44.

[14] Hoit BD. Assessment of left atrial function by echocardiography: novel insights. Curr Cardiol Rep 2018; 20: 96.

[15] Berbarie RF, Dib E and Ahmad M. Stress echocardiography using real-time three-dimensional imaging. Echocardiography 2018; 35: 1196-1203.

[16] January CT, Wann LS, Alpert JS, Calkins H, Cigarroa JE, Cleveland JC Jr, Conti JB, Ellinor PT, Ezekowitz MD, Field ME, Murray KT, Sacco RL, Stevenson WG, Tchou PJ, Tracy CM and Yancy CW; American College of Cardiology/American Heart Association Task Force on Practice Guidelines. 2014 AHA/ACC/HRS

guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol 2014; 64: e1-76.

[17] Gutierrez C and Blanchard DG. Diagnosis and treatment of atrial fibrillation. Am Fam Physician 2016; 94: 442-452.

[18] Sugumar H, Nanayakkara S, Prabhu S, Voskoboinik A, Kaye DM, Ling LH and Kistler PM. Pathophysiology of atrial fibrillation and heart failure: dangerous interactions. Cardiol Clin 2019; 37: 131-138.

[19] Andrade JG, Champagne J, Dubuc M, Deyell MW, Verma A, Macle L, Leong-Sit P, Novak P, Badra-Verdu M, Sapp J, Mangat I, Khoo C, Steinberg C, Bennett MT, Tang ASL and Khairy P; CIRCA-DOSE Study Investigators. Cryoballoon or radiofrequency ablation for atrial fibrillation assessed by continuous monitoring: a randomized clinical trial. Circulation 2019; 140: 1779-1788.

[20] Nielsen AB, Skaarup KG, Lassen MCH, Djernaes K, Hansen ML, Svendsen JH, Johannessen A, Hansen J, Sorensen SK, Gislason G and Biering-Sorensen T. Usefulness of left atrial speckle tracking echocardiography in predicting recurrence of atrial fibrillation after radiofrequency ablation: a systematic review and meta-analysis. Int J Cardiovasc Imaging 2020; 36: 1293-1309.

[21] Cherian TS and Callans DJ. Recurrent atrial fibrillation after radiofrequency ablation: what to expect. Card Electrophysiol Clin 2020; 12: 187-197.

[22] Santangeli P and Marchlinski FE. Techniques for the provocation, localization, and ablation of non-pulmonary vein triggers for atrial fibrillation. Heart Rhythm 2017; 14: 1087-1096.

[23] Higa S, Lo LW and Chen SA. Catheter ablation of paroxysmal atrial fibrillation originating from non-pulmonary vein areas. Arrhythm Electrophysiol Rev 2018; 7: 273-281.

[24] He Y, Zhang B, Zhu F, Hu Z, Zhong J and Zhu W. Transesophageal echocardiography measures left atrial appendage volume and function and predicts recurrence of paroxysmal atrial fibrillation after radiofrequency catheter ablation. Echocardiography 2018; 35: 985-990.

[25] Xu M, Liu F, Ge ZX, Li JM, Xie X and Yang JH. Functional studies of left atrium and BNP in patients with paroxysmal atrial fibrillation and the prediction of recurrence after CPVA. Eur Rev Med Pharmacol Sci 2020; 24: 4997-5007.

[26] Nemes A, Havasi K, Ambrus N, Kohari M, Saghy L and Forster T. Echocardiographic assessment of the left atrial appendage - transoesophageal, transthoracic and intracardiac approaches. Orv Hetil 2018; 159: 335-345.

[27] Steinberg JS, Shabanov V, Ponomarev D, Losik D, Ivanickiy E, Kropotkin E, Polyakov K, Ptaszynski P, Keweloh B, Yao CJ, Pokushalov EA and Romanov AB. Effect of renal denervation and catheter ablation vs catheter ablation alone on atrial fibrillation recurrence among patients with paroxysmal atrial fibrillation and hypertension: the ERADICATE-AF randomized clinical trial. JAMA 2020; 323: 248-255.

[28] MacGregor RM, Khiabani AJ, Bakir NH, Manghelli JL, Sinn LA, Carter DI, Maniar HS, Moon MR, Schuessler RB, Melby SJ and Damiano RJ Jr. Impact of age on atrial fibrillation recurrence following surgical ablation. J Thorac Cardiovasc Surg 2021; 162: 1516-1528, e1511.

[29] Parkash R, Green MS, Kerr CR, Connolly SJ, Klein GJ, Sheldon R, Talajic M, Dorian P and Humphries KH; Canadian Registry of Atrial Fibrillation. The association of left atrial size and occurrence of atrial fibrillation: a prospective cohort study from the Canadian Registry of Atrial Fibrillation. Am Heart J 2004; 148: 649-654.

[30] Chen L, Zinda A, Rossi N, Han XJ, Sprankle S, Bullock-Palmer R, Zingrone D, Moshiyakov M, Szawlewicz J, Mogtader A and Hsi DH. A new risk model of assessing left atrial appendage thrombus in patients with atrial fibrillation - using multiple clinical and transesophageal echocardiography parameters. Int J Cardiol 2020; 314: 60-63.

[31] Holmes DR Jr and Alkhouli M. The history of the left atrial appendage occlusion. Card Electrophysiol Clin 2020; 12: 1-11.

[32] Vainrib AF, Harb SC, Jaber W, Benenstein RJ, Aizer A, Chinitz LA and Saric M. Left atrial appendage occlusion/exclusion: procedural image guidance with transesophageal echocardiography. J Am Soc Echocardiogr 2018; 31: 454-474.

[33] Cameli M, Mandoli GE, Ambrosio G, Cerbai E, Coiro S, Emdin M, Marcucci R, Morrone D, Palazzuoli A, Savino K, Padeletti L, Mondillo S, Pedrinelli R; Società Italiana di Cardiologia and Sezione Regionale Tosco-Umbra. Arterial hypertension and atrial fibrillation: standard and advanced echocardiography from diagnosis to prognostication. J Cardiovasc Med (Hagerstown) 2018; 19: 51-61.

[34] Njoku A, Kannabhiran M, Arora R, Reddy P, Gopinathannair R, Lakkireddy D and Dominic P. Left atrial volume predicts atrial fibrillation recurrence after radiofrequency ablation: a meta-analysis. Europace 2018; 20: 33-42.

[35] Wu C, Xu Q, Shi R and Zhang G. Risk factors for atrial fibrillation recurrence after catheter ablation. Zhong Nan Da Xue Xue Bao Yi Xue Ban 2019; 44: 1196-1202.

[36] Kim YG, Choi JI, Boo KY, Kim DY, Oh SK, Park HS, Lee KN, Shim J, Kim JS, Park SW, Park SM, Shim WJ and Kim YH. Clinical and echocardiographic risk factors predict late recurrence after radiofrequency catheter ablation of atrial fibrillation. Sci Rep 2019; 9: 6890.

[37] Tripathi B, Arora S, Kumar V, Abdelrahman M, Lahewala S, Dave M, Shah M, Tan B, Savani S, Badheka A, Gopalan R, Shantha GPS, Viles-Gonzalez J and Deshmukh A. Temporal trends of in-hospital complications associated with catheter ablation of atrial fibrillation in the United States: an update from Nationwide Inpatient Sample database (2011-2014). J Cardiovasc Electrophysiol 2018; 29: 715-724.