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ORIGINAL ARTICLE

Clinical efficacy of radiofrequency ablation guided by high-density mapping on persistent atrial fibrillation

Eficacia clínica de la ablación por radiofrecuencia guiada por mapeo de alta densidad en el tratamiento de la fibrilación auricular persistente

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Abstract

Objective: *The study aimed to explore the clinical efficacy of radiofrequency ablation (RFA) guided by high-density mapping on persistent atrial fibrillation (PsAF).* **Method:** *A total of 190 patients with PsAF undergoing RFA were divided into a routine group (n = 105) and a high-density mapping group (n = 85). The indicators of therapeutic efficacy were collected and compared.* **Results:** *A statistically significant difference was found in the overall rate of post-operative recurrence between the two groups (11.58% vs. 23.81%, χ^2 = 5.055, p = 0.025). The effects of different treatment methods on SF-36 score varied (FSF-36 treatment = 43.142, p < 0.05), and SF-36 scores at 3, 6, and 12 months of both groups were in the same order: the high-density mapping group > the routine group. While surgery guided by high-density substrate mapping (odds ratio = 0.453, 95% confidence interval: [0.232-0.784], p < 0.001) was a protective factor for recurrence.* **Conclusion:** *For patients with PsAF, more accurate mapping is conducted on the atrial substrate using a PentaRay electrode, which further verifies that the success rate of individualized ablation strategy is like mainstream procedures, and it significantly improves the subsequent health status of patients and reduces their incidence of adverse reactions.*

Keywords: *High-density mapping. Voltage mapping. Persistent atrial fibrillation. Catheter ablation.*

Resumen

Objetivo: *Explorar la eficacia clínica de la ablación por radiofrecuencia guiada por mapeo de alta densidad en el tratamiento de la fibrilación auricular persistente.* **Método:** *Ciento noventa pacientes con fibrilación auricular persistente que recibieron ablación por radiofrecuencia se dividieron en dos grupos: convencional (n = 105) y mapeo de alta densidad (n = 85). Se recopilaron y compararon los indicadores de eficacia.* **Resultados:** *La diferencia en la tasa total de recurrencia posoperatoria entre los dos grupos fue estadísticamente significativa (11,58% vs. 23,81%; χ^2 = 5055; p = 0.025). Los efectos de los diferentes métodos de tratamiento en el puntaje SF-36 variaron (FSF-36 tratamiento = 43.142, p < 0.05), y los puntajes SF-36 a los 3, 6 y 12 meses de ambos grupos siguieron el mismo orden: grupo de mapeo de alta densidad > grupo convencional. Por su parte, la cirugía guiada por mapeo de matriz de alta densidad (OR: 0.453; IC95%: 0.232-0.784; p < 0.001) es un factor protector contra la recurrencia.* **Conclusión:** *Para los pacientes con fibrilación auricular persistente, el uso de electrodos Pentaray para mapear con mayor precisión en la matriz auricular verificó aún más que la tasa de éxito de la estrategia de ablación individualizada es similar a la de la cirugía convencional, mejorando significativamente el estado de salud posterior del paciente y reduciendo la incidencia de reacciones adversas.*

Palabras clave: *Cartografía de alta densidad. Mapeo de voltaje. Fibrilación auricular persistente. Ablación por catéter.*

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Introduction

Atrial fibrillation (AF) is a complex arrhythmia characterized by rapid and uncoordinated atrial activation, with high disability and mortality[1,2]. The latest research shows that the standardized incidence of AF in Chinese adults is about 1.6%, with an estimated number of patients reaching 20 million[3]. As the aging deepens and continues to increase over the next 30 years, it will become one of the biggest epidemics and public health challenges[4].

AF is a chronic progressive disease. At present, a comprehensive management strategy for AF treatment is currently being implemented[5]. Catheter ablation (CA), as the initial treatment, benefits patients more than drug therapy, and may alter the pathogenic mechanism of AF and its progression to persistent AF (PsAF)[6]. At present, it has been demonstrated that further addition of other ablation lines based on PVI, such as mitral isthmus line, cavotricuspid isthmus (CTI) line, left atrial roof, bottom and posterior wall ablation, can achieve modification of additional AF substrates[7]. Although various ablation technologies have been developed in addition to PVI, there is still uncertainty about whether AF patients can benefit from additional ablation strategies[8]. Therefore, the current surgery is still based on PVI.

The key to the success of radiofrequency ablation (RFA) lies in the ability to clarify its electrophysiological mechanisms and accordingly select appropriate ablation plans. Morillo et al.[9] have reported that AF can cause ultrastructural changes in the atrium, which can lead to atrial enlargement and an increase in extracellular matrix, resulting in asynchronous conduction. Heterogeneous intra-atrial conduction can cause voltage reduction. In addition, the presence of widespread low-voltage and complex fractionated atrial electrograms (CFAEs) in the atrium under a pathological condition has also been proven[10]. As a result, an abnormally slow conduction zone, as well as conduction blocks and reentries appear, all of which can facilitate AF maintenance. Moreover, the alteration of atrial substrates is currently considered an important factor in the recurrence and maintenance of AF following a CA procedure. According to the study of Verma et al.[11], low-voltage area (LVA) and scar can predict long-term recurrence of AF after PVI. Therefore, atrial substrate mapping is particularly important.

Routine single-ablation electrode mapping has a limited sampling range and consumes a long time. Without detailed information on cardiac surgery procedures, it is difficult to achieve accurate high-density mapping, which is also an important reason for the low success rate and high recurrence rate of RFA in such patients[12,13]. With the advancement of catheter mapping technology in AF, three-dimensional (3D) electroanatomic mapping (EAM) systems can more accurately, realistically and intuitively reflect the voltage changes and potential activity of atrial substrates, contributing to a deeper understanding of atrial electrical remodeling. They have gradually become a hot topic in the research on AF substrates. Compared with PxAF patients, PsAF patients have more stubborn and irreversible lesions, and a higher recurrence rate after routine RFA; However, there are only a few studies on the clinical efficacy of RFA based on high-density substrate mapping guided by 3D EAM in PsAF patients, and the most are case reports. On this basis, the present study focuses on patients with PsAF and explores the clinical efficacy and safety of RFA based on high-density substrate mapping guided by 3D EAM, is expected to improve clinical efficacy and reduce recurrence rate in patients with PsAF.

Materials and methods

Subjects

A total of 190 patients with PsAF undergoing RFA in our hospital from January 1, 2019, to June 30, 2021, were retrospectively collected using a convenient sampling method. According to different surgical methods, they were divided into a routine group (n = 105) and a high-density mapping group (n = 85).

Inclusion criteria

(1) Patients met the diagnostic criteria for PsAF and were confirmed by 12-lead electrocardiogram (ECG) or dynamic ECG, and PsAF lasted for more than 7 days without self-termination (5); (2) transesophageal ultrasound was performed preoperatively, without surgical contraindications such as left atrial appendage thrombus (LAAT); (3) surgical procedure was based on PVI and successful. Surgical success was defined as antiarrhythmic drug use within 3 months after surgery, without an episode of AF, atrial flutter or atrial tachycardia lasting $\geq$ 30 s, and (4) patients received RFA for AF for the 1st time, with 18 years $\leq$ age $\leq$ 80 years.

Exclusion criteria

(1) Patients had a previous history of ablation for AF; (2) patients had valvular AF and secondary AF caused by other factors, such as hyperthyroidism leading to AF and thyroid dysfunction; (3) patients had AF during the acute phase of myocardial infarction (MI); (4) patients had pre-operative contraindications due to various causes, such as allergy to iodine contrast agent and femoral artery occlusion in both lower limbs; and (5) Patients were unable to accept regular anticoagulation therapy after surgery, had incomplete clinical data, or were lost to follow-up.

This study was approved by the Ethics Committee of our hospital, and all participants signed the informed consent.

Research methods

The routine group received routine single-ablation electrode mapping but no high-density substrate mapping guided by 3D EAM, while the remaining treatments were the same as the high-density mapping group.

– Pre-operative preparation: Within 3 days before surgery, all subjects underwent transesophageal echocardiography to exclude LAAT and left atrial thrombus, as well as pulmonary vein computed tomography angiography (CTA) to determine the presence of mural thrombus, and further understand the anatomical position and structure of the left atrial appendage and bilateral pulmonary veins. Relevant antiarrhythmic drugs were discontinuated preoperatively (not < 5 half-life periods). In the case of oral anticoagulation with warfarin before admission, the INR value was adjusted and maintained at 1.8-2.5. In patients with novel oral anticoagulants (NOACs) before surgery, the drugs were stopped once in the morning on the day of surgery.

– High-density substrate mapping guided by 3D EAM: After pre-operative routine disinfection and towel laying, the patients were subjected to local infiltration anesthesia with 1% lidocaine hydrochloride injection. Assisted by X-ray digital subtraction angiography, the right internal jugular vein was first punctured and placed with a coronary sinus (CS) electrode, and then, the right femoral vein was punctured for placing a SwartzL1 sheath along the right femoral vein, followed by puncture of the atrial septum for intravenous injection of heparin (70-100 IU/kg). During surgery, 1000 IU/h heparin was added, and the patients' activated coagulation time was closely monitored and maintained at 250-350 s. Subsequently, left and right pulmonary vein CTA was performed to further understand the position of their openings. Supported by the long sheath, the PentaRay mapping electrode was inserted into the left atrium (LA). The right atrial substrate mapping method was consistent with the left atrial mapping method: Guided by the 3D EAM system CARTO3, high-density mapping of left atrial electroanatomic substrates was performed using synchronous mapping electrodes under AF rhythm, and a 3D model of the atrium was constructed to export 3D electroanatomic and voltage substrate maps.

– Radiofrequency CA: After mapping of the left and right atrial substrates in AF patients, RFA was conducted using a Smartouch pressure-monitoring catheter with a 4-mm head, with discharge parameter settings: power 50 W, temperature 43℃, cold saline flow rate 30 mL/min, and discharge time per point 15 s (10-12 s on the left atrial posterior wall). CA procedures: first, PVI was conducted; second, modified left atrial BOX linear ablation was carried out (based on PVI, left atrial roof and bottom ablation was performed, with the bottom line connecting to the ablation loop of the left pulmonary vein along the endometrial surface of the CS); third, individualized substrate modification was conducted in electrically induced lesions based on high-density substrate mapping during AF rhythm. Characteristics of endocardial potential in electrically induced lesions were as follows: (1) Location distribution: LVA of substrate mapping under AF rhythm (especially in the transition zones of different colors within the LVA); (2) Frequency observation: Relative high frequency of local potential (compared with A-wave on the CS); (3) Discrepancy measurement: High discrepancy of local potential (the potential duration in a single beat by PentaRay generally accounted for 80% or more of the average circumference of the CS, and some electrodes had visible or invisible CFAEs); (4) Potential rearrangement and marking: Adjacent mapping electrodes had a tendency to divergent or reversal potentials (electrode arrangement was adjusted to spiral expansion).

– Surgical endpoint: Sinus rhythm was restored by intraoperative individualized substrate modification in electrically induced lesions as much as possible. Electrical cardioversion was adopted for lower and more regular atrial frequency without restored sinus rhythm after ablation.

– Post-operative treatment: After surgery, routine bedside ECG was used to record ECG changes. The patients were monitored by an ECG telemonitoring system. The puncture sites were locally treated with compression bandages to stop bleeding, and the patients were asked for immobilization for 6 h. Post-operative anticoagulation therapy lasted for at least 3 months using warfarin (with a target INR maintained between 2.0-3.0) or NOACs (dabigatran, rivaroxaban, etc.). Three months later, whether anticoagulation therapy continued was based on the CHA2DS2-VASc score. AF recurrence was defined as an episode of atrial tachycardia, atrial flutter, or AF lasting months later, whether anticoagulation therapy continued was based on the CHA2DS2-VASc score. AF recurrence was defined as an episode of atrial tachycardia, atria2 months after surgery). Three months after surgery was the "blanking period" of AF, after which the patients were followed up by outpatient visits, telephone, or WeChat for post-operative recurrence.

Data collection

Clinical data

The following baseline data were collected: age, gender, history of AF, body mass index (BMI), echocardiography (left atrial diameter, right atrial diameter, and ejection fraction), CHA2DS2-VASc score, comorbidities, and pre-operative use of cardiovascular drugs. The indicators of efficacy, including immediate surgical success rate, surgical duration, recurrence 3, 6, and 12 months after surgery, readmission, secondary surgery, and SF-36 score 3, 6, and 12 months after surgery, were collected. The indicators of safety included complications such as pericardial tamponade, pericardial effusion, severe bleeding, stroke, and sychnosphygmia (atrial tachycardia).

As a concise health survey questionnaire, SF-36 comprehensively summarizes the quality of life of respondents from eight aspects: physical function, role physical, bodily pain, general health, vitality, social function, role emotional, and mental health. The higher the score, the better the condition[14].

Endpoints

At present, it is believed that the inflammation and changes in the autonomic nervous system caused by ablation injury to the LA are a reasonable explanation for temporarily triggering atrial tachyarrhythmia[15], and 3 months after ablation is a surgical blanking period[16]. If necessary, antiarrhythmic drugs and reablation can be adopted in a 3-month blanking period[17]. Primary endpoints were as follows: AF, atrial flutter and (or) sychnosphygmia (atrial tachycardia) lasting > 30 s recorded not in the surgical blanking period 3 months after surgery[18], and death from AF-related events. Secondary endpoints included thrombotic events such as stroke, peripheral arterial thrombosis and transient ischemic attack, and death from non-AF-associated diseases.

Follow-up

Telephone follow-up was conducted at 3, 6, and 12 months, respectively, to determine whether there were any episodes of arrhythmia like those before surgery and whether ECG or 24-h dynamic ECG indicated an episode of atrial flutter, AF, or atrial tachycardia. In the case of a recurrence, whether rhythm should be restored, and how it should be restored were considered. Cerebral infarction, systemic embolism, heart failure, etc. were clarified before readmission. The patients with symptoms such as palpitations and shortness of breath during the follow-up were notified to visit a nearby hospital for an ECG or 24-h dynamic ECG examination. The cause of death was explored in dead patients.

Statistical analysis

Statistical processing was carried out using SPSS 26.0. The K-S method was used to test for normality. The measurement data that satisfied normality were expressed as ($x \pm s$), and their inter-group mean comparisons were conducted by the *t*-test. The counting data were expressed as frequency (*n*) or rate (%), and analyzed with the χ^2 test for those satisfying normality and the Fisher's exact probability test for those not satisfying normality. The skewed data were compared using the *Kruskal–Walis H*-rank sum test. Logistic regression analysis was adopted for risk factors of recurrence after RFA in AF patients. The predictive value of various indicators in recurrence after RFA in AF patients was explored using a receiver operating characteristic curve. The significant level was set at $\alpha = 0.05$.

Table 1. Comparison of general data between the two groups

Item	High-density mapping group (n = 95)	Routine group (n = 105)	t/χ^2/Z	p
Age (year, x ± s)	60.36 ± 9.44	62.60 ± 9.34	1.328	1.240
Gender (male/female)	71/24	65/40	3.774	0.052
History of AF (month, M [Q1, Q3])	4 (1, 12)	5 (2, 12)	–1.610	0.107
BMI (kg/m^2, x ± s)				
Echocardiography	25.63 ± 3.53	25.83 ± 3.46	0.798	0.440
Left atrial diameter (mm, x ± s)	40.47 ± 3.58	41.96 ± 4.81	0.788	0.440
Right atrial diameter (mm, x ± s)	38.22 ± 5.19	38.92 ± 5.03	0.007	0.933
Ejection fraction (%, x ± s)	60.09 ± 9.59	56.27 ± 10.75	1.118	1.020
CHA2DS2-VASc score (point, x ± s)	2.00 ± 1.76	2.38 ± 1.74	1.557	0.120
Comorbidity (*n*)				
Hypertension	43	53	0.543	0.461
Coronary heart disease	3	4	0.063	0.802
Diabetes	5	6	0.020	0.889
Chronic obstructive pulmonary disease	1	1	-	1.000[a]
Preoperative use of cardiovascular drugs (n)				
ACEI/ARB	72	80	0.004	0.947
Diuretic	29	42	1.955	0.162
β-blocker	45	46	0.255	0.614
Calcium-channel blocker	15	21	0.599	0.439
Positive inotropic agent	12	14	0.022	0.883

BMI: body mass index; ACEI: angiotensin converting enzyme inhibitor; ARB: angiotensin II receptor blocker; a: Fisher's exact probability test.

Results

General data

In the high-density mapping group, there were 95 patients, including 71 males and 24 females, with an average age of 60.36 ± 9.44 years, a history of AF for $4^{1,12}$ months, and an average BMI of 25.63 ± 3.53 kg/m^2. The routine group included 105 patients, including 65 males and 40 females, with an average age of 62.60 ± 9.34 years, a history of AF for $5^{2,12}$ months, and an average BMI of 25.83 ± 3.46 kg/m^2. The two groups showed no statistically significant differences in age, gender, history of AF, BMI, echocardiography (left atrial diameter, right atrial diameter, ejection fraction), CHA2DS2-VASc score, comorbidities, or pre-operative use of cardiovascular drugs ($p > 0.05$), as seen in table 1.

Indicators of efficacy

As for immediate surgical success rate, surgical duration, recurrence 3, 6, and 12 months after surgery, readmission and secondary surgery, the results revealed a statistically significant difference in the overall rate of postoperative recurrence between the two groups (11.58% vs. 23.81%, $\chi^2 = 5.055$, $p = 0.025$), but no statistically significant difference in immediate surgical success rate, surgical duration, the proportion of readmitted patients, or the proportion of patients with secondary surgery ($p > 0.05$), as seen in table 2.

The effects of different treatment methods on the patients' SF-36 scores within 12 months were explored using one-way repeated measures analysis of variance. The baseline data presented no statistically significant differences between the two groups ($p > 0.05$), indicating high comparability. The Shapiro–Wilk test suggested that the data of each group followed an approximate normal distribution ($p > 0.05$). According to Mauchly's test of sphericity, the variance–covariance matrix of each group was equal ($p > 0.05$) (Table 2). The results are summarized as follows:

The time treatment interaction effect of the SF-36 score was significant between the two groups ($F_{SF\text{-}36\ interaction} = 45.624$, $p < 0.05$), indicating that different treatment methods have different individual effect sizes on SF-36 scores at 3 time points between the two groups. In addition, the SF-36 scores of both groups increased over time ($F_{SF\text{-}36\ time} = 67.581$, $p < 0.05$), suggesting significant changes in SF-36 score over time. Finally, the effects of different treatment methods on SF-36 score varied ($F_{SF\text{-}36\ treatment} = 43.142$, $p < 0.05$). Based on further pairwise comparison of SF-36 scores

Table 2. Comparison of indicators of efficacy between the two groups

Item	High-density mapping group (n = 95)	Routine group (n = 105)	t/χ^2/Z	p
Immediate surgical success rate (%)	100	100	-	1.000[a]
Surgical duration (min, x ± s)	176.83 ± 9.64	168.90 ± 8.20	1.371	0.172
Number of postoperative recurrences (n)	11 (11.58%)	25 (23.81%)	5.055	0.025
3 months	8	13		
6 months	0	6		
12 months	3	6		
Number of readmitted patients (n)	7	15	2.438	0.118
Number of patients with secondary surgery (n)				
SF-36 score (point, x ± s)[b]	4	7	0.579	0.447
Baseline	96.42 ± 4.55	95.62 ± 6.33	1.371	0.252
3 months	106.61 ± 8.53	101.21 ± 6.90	4.532	< 0.001
6 months	118.45 ± 5.67	112.18 ± 6.17	5.443	< 0.001
12 months	124.34 ± 6.54	118.40 ± 6.55	4.695	< 0.001

a: Fisher's exact probability test; b: repeated measures analysis of variance ($F_{interaction}$/$P_{interaction}$: 45.624/0.001; F_{time}/P_{time}: 67.581/0.001; $F_{treatment}$/$P_{treatment}$: 43.142/0.001); SF-36: Concise health survey questionnaire.

Table 3. Comparison of adverse reactions

Group	Atrial tachycardia	Pericardial tamponade	Pericardial effusion	Severe bleeding	Stroke	Incidence (%)
High-density mapping group (n = 95)	2	0	0	1	1	4 (4.21)
Routine group (n = 105)	11	0	1	2	0	14 (13.33)
χ^2 value						5.068
p-value						0.024

at 3, 6 and 12 months between the two groups, it was found that SF-36 scores at the 3 time points of both groups were in the same order: the high-density mapping group > the routine group.

Comparison of adverse reactions

In the high-density mapping group, atrial tachycardia occurred in two patients, severe bleeding in one patient, and stroke in one patient. In the routine group, there were 11 patients with atrial tachycardia, one with pericardial effusion, and two with severe bleeding. The incidence of adverse reactions had a statistically significant difference between the two groups (4.21% vs. 13.33%, χ^2 = 5.068, p = 0.024), as shown in table 3.

Univariate and multivariate analysis of influencing factors for recurrence

An univariate logistic regression analysis was conducted on the correlations between recurrence and various factors, revealing that left atrial diameter (odds ratio [OR] = 1.563, 95% confidence interval [CI]: [1.246-1.785], p < 0.001), course of AF (OR = 1.123, 95% CI: [1.043-1.343], p < 0.001) and surgical method (OR = 0.453, 95% CI: [0.342-0.895], p < 0.001) were the influencing factors for recurrence, with statistical significance. The results showed that large left atrial diameter (OR = 1.565, 95% CI: [1.324-1.884], p < 0.001) and long course of AF (OR = 1.145, 95% CI: [1.078-1.653], p < 0.001) were risk factors for recurrence, while surgery guided by high-density substrate mapping (OR = 0.453, 95% CI: [0.232-0.784], p < 0.001) was a protective factor for recurrence, as displayed in table 4.

Predictive value of various factors in recurrence

The results demonstrated that left atrial diameter, course of AF, and surgical method all had certain predictive values for post-operative recurrence. The area under the curve (AUC) of left atrial diameter, course of

Table 4. Univariate and multivariate analysis of influencing factors for recurrence

Variable	Univariate analysis		Multivariate analysis	
	OR (95%CI)	p-value	OR (95%CI)	p-value
Age	1.022 (0.981~1.065)	0.291	-	-
Gender	1.154 (0.561~1.453)	0.734	-	-
History of hypertension	0.845 (0.635~1.454)	0.532	-	-
History of diabetes	0.561 (0.353~1.586)	0.125	-	-
History of coronary heart disease	0.784 (0.682~1.583)	0.320	-	-
BMI	0.944 (0.876~1.543)	0.452	-	-
Left atrial diameter	1.563 (1.246~1.785)	< 0.001	1.565 (1.324~1.884)	< 0.001
Course of AF	1.123 (1.043~1.343)	< 0.001	1.145 (1.078~1.653)	< 0.001
Surgical method	0.453 (0.342~0.895)	< 0.001	0.453 (0.232~0.784)	< 0.001

BMI: body mass index; AF: atrial fibrillation.

Table 5. Predictive value of various indicators for postoperative corneal edema in cataract patients

Item	AUC	95% CI	Sensitivity (%)	Specificity (%)
Left atrial diameter	0.743	0.656~0.832	76.31	74.54
Course of AF	0.756	0.701~0.824	80.61	81.70
Surgical method	0.689	0.623~0.711	71.44	73.48
Combined prediction	0.865	0.774~0.887	86.24	85.73

BMI: body mass index; AF: atrial fibrillation; AUC: area under the curve.

AF, and surgical method in predicting post-operative recurrence was 0.743 (95% CI: 0.656-0.832), 0.756 (95% CI: 0.701-0.824), and 0.689 (95% CI: 0.623-0.711), respectively. Their combination showed the highest value in predicting post-operative recurrence, with an AUC of 0.865 (95% CI: 0.774-0.887), as exhibited in table 5.

Discussion

AF occurs based on the changes in pathophysiological substrates of the atrium. The alteration of atrial substrates is currently considered an important factor in AF recurrence and maintenance following a CA procedure. Based on the study of Verma et al.[11], LVA and scar can predict long-term recurrence of AF after PVI. The key to the success of RFA lies in the ability to clarify its electrophysiological mechanisms and accordingly select appropriate ablation plans. Current research has demonstrated that atrial tachycardia after surgery for congenital heart diseases is mainly related to electrophysiological abnormalities caused by surgical scars[19], and it can be further divided into recurrent and focal types. Recurrent atrial tachycardia is more common, and caused by intra-atrial reentry. The formation of reentrant circuits is related to the presence of a slow conduction zone in the atrium, which is caused by the primary heart disease and surgical scar[19]. The origin of focal atrial tachycardia is also near the scar. Unlike the typical reentry mechanism based on CTI atrial tachycardia, this type of patients mostly present surgical scar-related reentry, where surgical scars, patches or sutures in certain areas between the superior and inferior vena cava can form complete blocks. If there is viable myocardium between these tissues and scars, it is possible to form a slow conduction zone, thereby producing stable reentries and resulting in atrial tachycardia[20]. Therefore, atrial substrate mapping is particularly important.

For a long time, scholars generally believed that PVI alone is not enough for the ablation of PsAF, and additional linear ablation and/or CFAE ablation are needed[21]. However, additional ablation significantly prolongs surgical duration, as well as increases the incidence of post-operative atrial tachycardia and severe complications. Therefore, for patients with PsAF, current guidelines do not recommend empirical pulmonary vein ablation[22]. In the present study, high-density mapping was conducted using a PentaRay electrode, which further verifies the superiority of individualized ablation strategy with left atrial voltage-guided substrate modification. Its success rate is not lower than that of domestic mainstream procedures, with higher post-operative quality of life in patients.

At present, the multi-electrode mapping catheters used in clinical practice for the atrium mainly include annular electrodes, PentaRay electrodes, basket electrodes, and HDGrid electrodes. Basket electrodes are characterized by high point density, but high costs and difficult operation, and the 3D mapping system is not compatible with pressure monitoring ablation catheters. HDGrid electrodes can simultaneously record 32 bipolar signals, which can more realistically, effectively, and accurately identify voltage zones. However, they have not yet been applied in clinical practice in China. The number of points in circular electrode mapping is relatively small and the density is low, resulting in an inability of automatic mapping. Most of the time, manual calibration is required[23]. PentaRay electrodes can reach the entire cardiac cavity, and when combined with confidence software, they can achieve safe and accurate mapping, with fewer anatomical pseudolumens and less manual calibration. Thus, they are significantly superior to circular electrodes.

In the current ablation strategy with voltage-guided substrate modification, bipolar LVA is mainly used as an alternative electrophysiological indicator of atrial fibrosis to guide ablation. In addition, there is still controversy over whether LVA is equivalent to the need for substrate modification. Rolf et al.[24] have found that AF patients with individualized ablation based on LVA have a significantly higher AF-free recurrence rate compared with those with PVI alone. According to the study of Jadidi et al.[25], for patients with PsAF, PVI combined with left atrial LVA-guided ablation is superior to PVI alone, and PVI is only suitable for patients with left atrial LVA (measured under AF attacks) < 10%. There are also research results demonstrating that the AF-free recurrence rate of PVI combined with modified LVA-guided ablation is higher than PVI alone and PVI combined with empirical ablation, the incidence of postoperative atrial tachycardia is lower, as well as the surgical duration, irradiation time and ablation time are significantly reduced[21].

Of course, this study also has some limitations. First, this study is a single-center study with a small sample size and a follow-up time of 1 year. There was a trend of differences in the recurrence-free survival period, but due to the short duration, no differential results were observed. In future research, the sample size can be enlarged and the follow-up time can be prolonged to obtain more results. In addition, the data collection in this study was mainly based on case review, which may lead to recall bias in the course of the disease. If there is a portable ECG recording device in future research, it will provide more effective and accurate information.

Conclusion

For patients with PsAF, more accurate mapping is conducted on the atrial substrate using a PentaRay electrode, which further verifies that the success rate of individualized ablation strategy is like mainstream procedures, and it significantly improves the subsequent health status of patients and reduces their incidence of adverse reactions.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained approval from the Ethics Committee for analysis and publication of routinely acquired clinical data and informed consent was not required for this retrospective observational study.

Use of artificial intelligence for generating text. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript or for the creation of images, graphics, tables, or their corresponding captions.

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