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Research article

Safety and efficacy of ablation index-guided high-power ablation for the treatment of atrial fibrillation

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ABSTRACT

Objective: To study the safety and efficacy of high-power ablation for atrial fibrillation (AF) guided by lesion size index (LSI) and impedance cutoff.
Method: A total of 223 patients who underwent radiofrequency catheter ablation of atrial fibrillation (including paroxyparal atrial fibrillation and persistent atrial fibrillation) in the Department of Cardiology of Anhui Provincial Hospital from February 2019 to July 2020 were enrolled, and were divided into 123 patients in the high-power ablation group (HPAI) and 100 patients in the conventional power ablation group (CPAI). The HPAI group adopted high-power (40–50 W) ablation by impedance cutoff, and the CPAI group adopted conventional-power (30–35 W) ablation. Patients in both groups were ablated guided by the same LSI. For both groups, we analyzed the pulmonary vein single-circle isolation rate, ablation time, X-ray exposure, impedance drop value, incidence of complications, and recurrence rate within one year after operation.
Results: There was no significant difference in the success rate of pulmonary vein single-circle isolation, X-ray perspective time, and X-ray exposure quantity between the HPAI group and the CPAI group (88.60% vs 82.00%, $P = 0.161$; 8.7 ± 3.74 min vs 7.82 ± 3.86 min, $P = 0.067$; 54.74 ± 28 min vs 52.78 ± 39.58 min, $P = 0.139$); the annular pulmonary vein ablation time and total ablation time were less in the HPAI group (35.74 ± 7.25 min vs 65.49 ± 7.34 min, $P < 0.01$; 55.42 ± 11.61 min vs 76.9 ± 6.79 min, $P < 0.01$); the impedance drop values at 10–15Ω and 15–20Ω were higher in the HPAI group (25.3% vs 19.1%, $P < 0.05$; 24.1% vs 19.1%, $P < 0.05$); there was no significant difference in the recurrence rate within one year after operation between the two groups; and no serious complications occurred in the two groups.
Conclusion: High-power ablation guided by LSI and impedance cutoff could significantly shorten the AF ablation time and reduce complications.

1. Introduction

Catheter ablation for atrial fibrillation (AF) to achieve pulmonary vein isolation (PVI) is an effective therapy for heart rhythm management. In recent years, much progress has been made in catheter ablation in AF, ensuring more effective and safer PVI [1]. Ablation lesion size index (LSI) refers to the quantification of the depth and width of the ablation lesion based on parameters such as pressure, time, and current (power and impedance). Studies have shown that using the LSI value as a reference, can increase the

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efficacy and safety of AF ablation and it has been used as a clinical ablation observation index [2]. In recent years, the safety and efficacy of high-power radiofrequency catheter ablation (RFCA) have been more significant in clinical application [3,4].

To further promote standardized treatment of AF, we compared the efficacy of high-power and conventional-power radiofrequency ablation.

2. Participants and methods

1.1 Participants: A total of 223 patients who underwent radiofrequency catheter ablation of atrial fibrillation (including paroxysmal atrial fibrillation and persistent atrial fibrillation) in the Department of Cardiology of Anhui Provincial Hospital from February 2019 to July 2020 were included; the group, comprised 117 males and 106 females, aged 60.5 ± 10.48 years. Inclusion criteria: (1) Age >18 years; (2) RFCA for AF was performed for the first time. Exclusion criteria: (1) Left atrial diameter >55 mm; (2) Uncontrolled heart failure or NYHA function was at grade III or IV; (3) Life expectancy was shorter than 12 months.

All patients voluntarily participated in the study—the patients and their family members agreed and signed the letter of authorization and informed consent. Patients were divided into the Conventional-Power Ablation Index (CPAI) group (100 patients) and the Higher-Power Ablation Index (HPAI) group (123 patients), according to operation methods.

2.1. Operation methods and follow-up

2.1.1. Ablation devices and drugs used during operation

We used the Ensite 5.0 3D mapping system. The pressure sensing saline-irrigated catheter (St. Jude Medical Inc.) and pulmonary vein mapping catheter (St. Jude Medical Inc.) were used as the ablation catheter and mapping catheter, and the Agilis long sheath (St. Jude Medical Inc.) was used as the adjustable bent sheath catheter. We used five bottles of fentanyl (0.1 mg/bottle), which could be continuously pumped for analgesia during the operation.

2.1.2. Operation process

Patients regularly took warfarin orally before the operation, but the international normalized ratio (INR) remained below 2.5. If the patients who took the novel oral anticoagulant did not do so on the day of the operation, all ablations were performed under local anesthesia. After successful intraoperative inter-atrial septal puncture, heparin 100 U/kg was given, and then added every hour, with the intraoperative activated clotting time (ACT) remaining at 250–300 s. In all patients, the grade 10 coronary sinus (CS) and right ventricular catheters (St. Jude Medical Inc.) were placed via the left femoral vein, wherein the CS catheter was used as the reference electrode and the atrial septum was inserted twice. The Ensite 5.0 (St. Jude Medical Inc.) 3D mapping system and annular pulmonary vein mapping catheter were used to establish the left atrium model, and the adjustable bent outer sheath catheter Agilis (St. Jude Medical Inc.) and pressure sensing ablation catheter were used for point by point ablation.

In the CPAI group, the power was set as 35 W for the anterior wall and 30 W for the posterior wall, the maximum temperature was 43 °C, the cold saline irrigation rate was 17 ml/min, the catheter pressure remained at 5–15 g, and the ablation was performed point by point.

In the HPAI group, the power was set as 50 W for the anterior wall and 40 W for the posterior wall, the maximum temperature was 43 °C, the cold saline irrigation rate was 20 ml/min, the catheter pressure remained at 5–15 g, and the ablation was performed by automatic cutoff with the impedance drop of over 15% within 3 s. The LSI value was used as the reference for ablation lesion degree, where the LSI values of the anterior wall and the top were within 5.0–5.5, those of the posterior wall and the bottom were within 4.0–4.5, the distance between two ablation points was 4 mm, and the ablation targets reached bilateral pulmonary vein antrum isolation; linear ablation was performed according to the condition of the left atrial stroma, and patients who failed to recover sinus rhythm after the operation were given drugs or electrical cardioversion to recover sinus rhythm.

2.1.3. Postoperative drugs and follow-up

Postoperative drugs: (1) anticoagulant drugs: warfarin (PT-INR remained at 2–3) or novel oral anticoagulants for three months; (2) antiarrhythmic drugs: patients with persistent AF were routinely administered with oral amiodarone and/or metoprolol sustained-release tablets for three months after operation. We monitored the recurrence of AF using seven days of dynamic electrocardiogram (DCG) at 3, 6, and 12 months after operation.

Criteria for successful ablation: No antiarrhythmic drugs were used, and no AF, atrial flutter, and atrial tachycardia occurred three months after operation. Recurrence was defined as patients developing AF, atrial flutter, and atrial tachycardia for 30 s after three months.

2.1.4. Study indicators

The pulmonary vein single-circle isolation rate, ablation time, X-ray exposure, and incidence of complications were compared between the two groups, including pericardial tamponade, arterial embolism, atrial-esophageal fistulas, and blood vessel complications (such as pseudoaneurysm, arterio-venous fistula, pneumothorax, or hemothorax) requiring emergency treatment, as well as recurrence rate within one year after operation.

2.2. Statistical methods

SPSS 26.0 was used for statistical analysis. Measurement data conforming to normal distribution were expressed as Mean ± SD, and comparison between groups was performed by *t*-test. The count data were expressed as cases or percentage, and $\chi 2$ test was used for comparison. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Comparison of baseline data between the two groups

Among the 223 patients, 100 patients were in the CPAI group and 123 patients in the HPAI group. The baseline data of the two groups were compared, and the results showed that the gender, age, left atrial diameter, and course of disease were in normal distribution; the difference was compared by *t*-test, and $P > 0.05$ was considered as not statistically significant; enumeration data were compared by chi-square test, and $P > 0.05$ was considered as not statistically significant (Table 1).

3.2. Comparison of parameters during ablation between the two groups

There were statistical differences in the annular pulmonary vein ablation time (65.49 ± 7.34 min vs 35.74 ± 7.25 min, $P < 0.01$) and the total ablation time (76.9 ± 6.79 min vs 55.42 ± 11.61 min, $P < 0.01$) between the CPAI group and the HPAI group; there was no difference in the X-ray perspective time (8.7 ± 3.74 min vs 7.82 ± 3.86 min, $P = 0.067$) and the X-ray exposure quantity (54.74 ± 28 mGy vs 52.78 ± 39.58 mGy, $P = 0.139$) (Table 2). There was no statistical difference in the success rate of pulmonary vein single-circle isolation (82.00% vs 88.60%, $P = 0.161$, $\chi 2 = 1.965$) between the CPAI group and the HPAI group; ablation was set to be performed by automatic cutoff with the impedance drop of 15% within 3 s; the comparison of impedance drop values showed that compared with the CPAI group, the proportion of ablation points at the impedance drop of 10–15Ω (25.3% vs 19.1%, $P < 0.05$) and 15–20Ω (24.1% vs 19.1%, $P < 0.05$) was significantly higher in the HPAI group, suggesting that more points were effectively ablated and excessive ablation was prevented in the HPAI group (Fig. 1).

3.3. Comparison of recurrence rate within one year after operation between the two groups

The comparison of recurrence rates 3, 6, and 12 months after operation between the HPAI group and the CPAI group showed 13.00% vs 11.38%, 23.00% vs 21.95%, and 25.00% vs 22.76%, respectively; the recurrence rates were compared by the chi-square test between the two groups, and the results showed $P > 0.05$, suggesting that there was no statistical difference (Table 3).

3.4. Complication

There were no serious complications such as atrial esophageal fistula, cardiac tamponade and stroke in the two groups. One patient in CPAI group developed 1 mm arteriovenous fistula after surgery, which closed by ultrasound after outpatient review 1 month later. Two patients in the HPAI group developed pseudoaneurysm after surgery, one was closed by mechanical compression, and the other was closed by ultrasound guided thrombin injection. Reexamination of echocardiography on the second day after surgery showed that 2 cases in the HPAI group were asymptomatic and the vital signs were stable and untreated, and the pericardial effusion disappeared after reexamination of echocardiography 1 month later.

Table 1
Comparison of baseline data between the two groups.

Group	CPAI (n = 100)	HPAI (n = 123)	P
Gender (male/female)	53/47	64/59	0.886
Age (y)	61.61 ± 9.25	60.5 ± 10.48	0.410
Duration of atrial fibrillation (m)	10.45 ± 4.95	9.72 ± 4.56	0.257
Left atrial diameter (mm)	41.74 ± 6.60	42.70 ± 7.00	0.297
Left ventricular ejection fraction (%)	58.46 ± 8.34	57.65 ± 10.90	0.531
CHA2DS2-VASc score	2.74 ± 1.72	2.84 ± 1.74	0.677
HAS-BLED score	1.44 ± 0.95	1.67 ± 0.90	0.060
Anti-arrhythmia (n)	48	54	0.541
Anti-coagulation (n)	38	48	0.876
Hypertension (n)	37	51	0.498
Diabetes mellitus (n)	21	18	0.213
Cerebral infarction (n)	3	5	0.980
Paroxysmal atrial fibrillation (n)	72	86	0.311
Persistent atrial fibrillation (n)	28	37	0.389

Table 2
Comparison of intraoperative time, and X-ray exposure quantity and time between the two groups.

Group	Number of cases (n)	RPV (min)	LPV (min)	PVI (min)	Total ablation time (min)	X-ray exposure quantity (mGy)	X-ray exposure time (min)
CPAI	100	30.54 ± 4.65	34.95 ± 6.09	65.49 ± 7.34	76.9 ± 6.79	54.74 ± 28	8.7 ± 3.74
HPAI	123	17.28 ± 4.42	18.46 ± 4.47	35.74 ± 7.25	55.4 ± 11.61	52.78 ± 39.58	7.82 ± 3.86
P		0.000	0.000	0.000	0.000	0.139	0.067

Notes: RPV: right pulmonary vein, LPV: left pulmonary vein, PVI: pulmonary vein isolation.

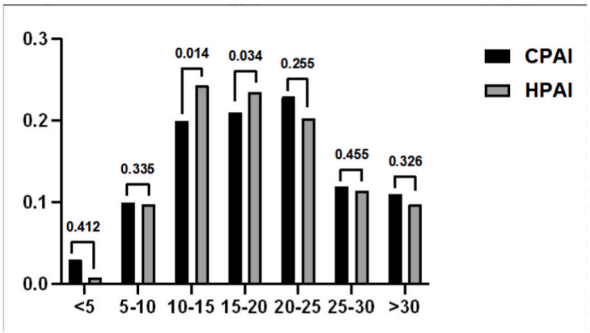

Fig. 1. Proportion of impedance value decrease during ablation in the two groups (%).

Table 3
Comparison of parameters between the two groups after 3 months, 6 months, and 12 months of follow-up after operation.

Time	Group	Number of cases (n)	Number of recurrent cases	Recurrence rate (%)	P
3 months after operation	CPAI	100	13	13.00	0.713
	HPAI	123	14	11.38	
6 months after operation	CPAI	100	23	23.00	0.852
	HPAI	123	27	21.95	
12 months after operation	CPAI	100	25	25.00	0.696
	HPAI	123	28	22.76	

4. Discussion

Radiofrequency catheter ablation has been recommended as a first-line treatment for symptomatic AF that fails to respond to drug therapy [5]. How to achieve a more efficient and safer ablation has been the pursuit of researchers. With the development of ablation tools, the emergence of pressure sensing catheters has improved the effectiveness and safety of AF ablation, but quantified ablation still cannot be achieved. LSI as a new AF ablation observation index provides real-time quantified information on ablation lesions, making the quantified ablation of AF possible. In the past, most centers adopted AF ablation with low power and long term, and performed AF ablation with LSI as the target value, which was more scientific, effective, and safer compared to the traditional mode with time as the reference. [6] Animal studies have shown that with the LSI value as the reference, when compared with the high-power short-term ablation, low-power long-term ablation, with the same LSI value, is more likely to damage adjacent atrial tissues [7]. High-power short-term AF ablation has been applied gradually in clinical practice, and study results have shown that it has greatly reduced the ablation and operation time, without significantly increasing the incidence of complications [8,9].

In the present study, we compared the efficacy and safety of high-power ablation and conventional-power ablation in AF radiofrequency ablation, and the results showed that compared with the CPAI group, the operation time and ablation time were significantly reduced with no significant increase in complications in the HPAI group, and the AF recurrence rates within one year were close in the two groups, which were consistent with the results reported in previous studies.

High-power ablation increases the incidence of steam pop (POP). First, local impedance drop (LID) $\geq$ 10Ω during ablation is considered a key marker of lesion formation [10]. However, another study indicated that when POP occurred, the percentage drop in LID was significantly larger than that without POP (35.2% ± 8.1% vs 27.0% ± 8.2%, $P < 0.01$) [11]. Since the power level seriously affects the local myocardial impedance drop [12], the impedance changes rapidly at high-power ablation, and we can avoid serious complications caused by POP by performing ablation based on timely impedance cutoff before the occurrence of POP. In the early stage, there were serious complications caused by POP when high-power AF ablation was performed in our center. Retrospective analysis showed that instantaneous change of impedance also occurred before POP. To this end, we conducted relevant basic

experiments, and the results confirmed that performing ablation based on timely impedance cutoff with an impedance drop of over 15% within 3 s during ablation could reduce the occurrence of POP and improve operation safety [13]. In this study, 123 patients who underwent high-power ablation were included and the above setting was adopted, and the results showed that there were no serious complications caused by POP. Of course, the impedance cutoff mainly occurred in the anterosuperior part of right pulmonary vein, the bottom of right pulmonary vein, and the ridge of left pulmonary vein. This may be partly caused by the relatively poor stability of catheter attachment in these parts, or the large local impedance changes due to high transient attachment pressure; stable attachment and proper pressure (5–20 g) during high-power ablation are ways to avoid frequent impedance cutoff.

5. Conclusion

There are mainly two types of radiofrequency ablation lesions: impedance heat and conductive heat. The high-power short-term ablation increases the contribution of impedance heat and reduces the role of heat conduction. Recently, Nakagawa et al. compared the lesion size (depth, diameter, and volume) and tissue temperature in the ablation at 90 W/4 s, 50 W/10 s and 30 W/30 s [14]. The results suggested that 90 W/4 s $<$ 50 W/10 s $<$ 30 W/30 s; that is, the lesion caused by the high-power short-term was shallower and narrower than that caused by the low-power long-term ablation. The reasons for this phenomenon remain unclear. However, the results suggested that in the AF ablation, especially in the left atrial posterior wall, high-power short-term ablation may have more value in reducing cardiac tamponade and is similar to the low-power long-term ablation in terms of safety. There was no significant difference in the recurrence rate during one year of follow-up observation between the high-power ablation and the conventional-power ablation; the two groups were equal in the short-term efficacy, and longer follow-up may be required for the long-term efficacy.

Patients in the high-power ablation group were all from a single center, the sample size was limited, and the follow-up time was short. Therefore, there are certain limitations to our study, and the outcome of postoperative long-term efficacy needs to be further evaluated.

Author contribution statement

Jing Zhu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper. Xian-he Lin: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Data availability statement

No data was used for the research described in the article.

Declaration of interest's statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval and consent to participate

This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of The First Affiliated Hospital of Anhui Medical University. A written informed consent was obtained from all participants.

Additional information

No additional information is available for this paper.

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