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Safety and efficacy of lesion size index guided 50 W radiofrequency ablation in patients with paroxysmal atrial fibrillation

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Abstract

Background Pulmonary vein isolation (PVI) using conventional power (30–35 W) radiofrequency ablation (RFA) has been an effective treatment strategy for paroxysmal atrial fibrillation (PAF), but its longer duration may cause collateral damage to peripheral tissue including esophageal and phrenic nerve. High-power (HP) RFA, due to better transmural performance and shorter duration, may reduce the damage to adjacent tissue and is expected to be a safe and efficient ablation strategy.

Methods In this retrospective cohort study, we included 259 patients with PAF who underwent lesion size index (LSI)-guided radiofrequency ablation. All patients underwent PVI-based ablation, and some underwent additional ablation, including superior vena cava isolation, tricuspid isthmus block, or left anterior atrial matrix modification. A total of 119 PAF patients underwent 50 W ablation. Complications and twelve-month arrhythmia-free outcomes of the procedure were compared with those of 140 patients who underwent 30–35 W ablation.

Results PVI was successfully achieved in all patients. The procedural duration (140.3 ± 34.4 vs. 151.3 ± 40.6 min, $P = 0.022$) and overall radiation (112.0 ± 67.2 vs. 188.2 ± 119.2 mGy·cm^2, $P < 0.001$) were significantly lower in the 50 W group. No major complications occurred in the high-power short-duration (HPSD) group, whereas in the conventional power group, five participants developed complications. Among them, three cases were related to venipuncture, one had pericardial tamponade, and one had slight pericardial effusion. The recurrence of arrhythmia at the twelve-month follow-up was not significantly different between the two groups [11 (9.2%) vs. 19 (13.6%), $P = 0.278$].

Conclusion LSI-guided HPSD-RFA was demonstrated to be comparably safe and efficacious compared to conventional ablation and resulted in reduced procedure time and radiation exposure.

Keywords Paroxysmal atrial fibrillation, High-power short-duration ablation, Pulmonary vein isolation, Radiofrequency ablation

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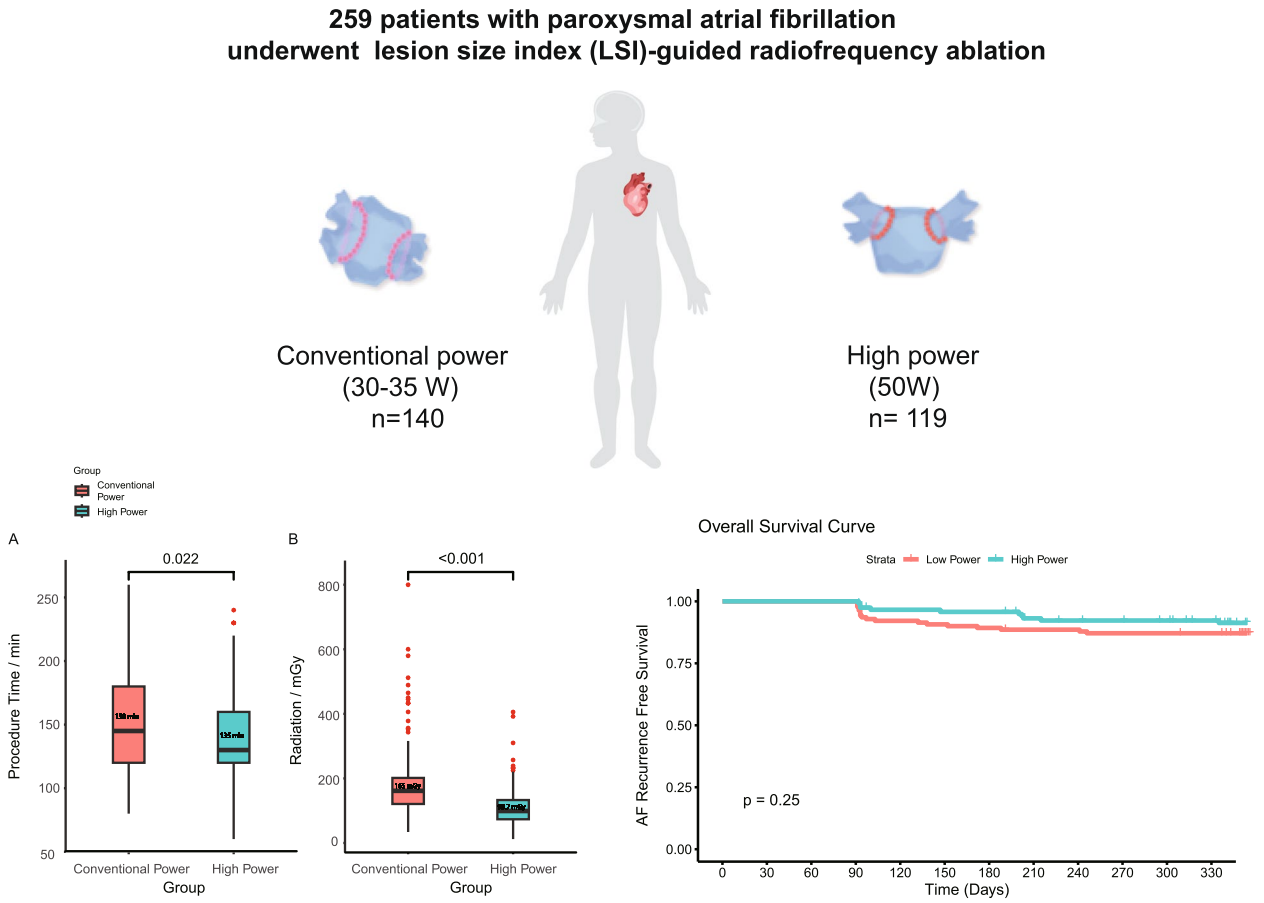
Graphical Abstract

Central Illustration. Safety and Efficacy of Lesion Size Index Guided 50 W Radiofrequency ablation in Patients with Paroxysmal Atrial Fibrillation. A total of 259 patients with paroxysmal atrial fibrillation underwent lesion size index (LSI)-guided radiofrequency ablation were enrolled. High-Power Short-Duration ablation reduced total procedure time, significantly decreased radiation exposure, and had similar recurrence rate of atrial fibrillation.



Introduction

Pulmonary vein isolation (PVI) is the core strategy of catheter ablation for the treatment of paroxysmal atrial fibrillation (PAF), which has been proven effective in clinical practice and can improve the quality of life in patients with PAF [1]. Quantitative ablation guided by lesion size index (LSI), an integrated radiofrequency (RF) parameter that combines time, power and contact force (CF) into a weighted formula, could significantly improve the isolation rate of pulmonary veins (PVs) [2–4]. Conventional power (30 W-35 W) has been widely used in RF ablation of PAF. However, the long duration required for lesion creation may increase conductive heating and radiation exposure, both for electrophysiologists and patients.

Mainly based on transient thermal impedance and wider damage diameter, the proportion of the irreversible component of a lesion from high-power short-duration radiofrequency (HPSD) ablation could be higher [5]. The HPSD group (45–50 W/8–15 s) had a lower acute pulmonary vein conduction recovery rate than the low power (LP) group (20–40 W/20–30 s), and the long-term PV conduction recovery rate also decreased [6]. Moreover, the significantly shortened conductive heating phase may prevent injury to adjacent tissues by reducing passive conductive heating and thermal latent effects. A recent study also reported that HPSD reduced AF recurrence in PAF patients after one year and had a low risk of esophageal injury [7]. However, there is still debate regarding the application of

HPSD methods. According to a recent study, adenosine stimulation after HPSD (50 W/6 ~ 10 s) still resulted in a high pulmonary vein conduction rate of 18%, lower than the expected response rate [8]. A meta-analysis of low-power long-duration (LPLD) and HPSD ablation showed that the risks of recurrent atrial tachycardia and perioperative complications were not improved in the HPSD group [9]. These findings suggest that whether HPSD is significantly better than LPLD in PAF remains controversial. Therefore, the utilization of LSI with powers of 50 W or greater still needs to be validated in clinical settings.

In the present study, LSI-guided HPSD (50 W) was used for bilateral PVI in patients with PAF, and we compared these patients with a cohort using a conventional power (30–35 W). The recurrence of AF was investigated at the 12-month follow-up, as well as the differences in the relationships between procedure time and complications in the two groups to help verify the intraprocedural safety and effectiveness of HPSD in PAF.

Methods

Study population

A total of 259 participants with PAF, who were admitted to Nanfang Hospital of Southern Medical University between January 2017 and December 2021 and underwent radiofrequency ablation, were included in the study (Supplemental Fig. 1). The enrollment period of HP group (50 W) was from January 2018 to December 2021, and that of LP group (30–35 W) was from January 2017 to December 2020. PAF was defined according to the most recent guidelines [10]. RFA was performed by the same surgical team using the same 3D mapping system for all participants, and the selection of high and low power was sequential. The power of HP group was 50 W in all sites, while the power of LP group was 35 W in anterior wall, roof, and bottom, and 30 W in the posterior wall. Participants were enrolled consecutively, and the follow-up was performed at 3-month intervals for all participants. The study excluded participants who had previously undergone unsuccessful ablation for PAF, participants who had accompanying cardiac thrombosis or complications with active hemorrhagic disease, participants who had vascular disease requiring surgical treatment and participants who had taken amiodarone within the 3 months preceding their admission. This study was conducted in accordance with the principles of the Helsinki Declaration and was approved by the Medical Ethics Committee of Nanfang Hospital of Southern Medical University. Written informed consent was obtained from all participants before the ablation procedures.

Catheter ablation procedure

Participants received anticoagulant therapy for 3 weeks before the ablation procedure and underwent preoperative transesophageal echocardiography. The catheter ablation procedures were performed by three experienced surgeons who had completed 500 AF ablation cases. All procedures were performed under conscious sedation with fentanyl. The study design is shown in Supplemental Fig. 1. Through the left or right femoral vein path, an 8F or 8.5F SL1 Swartz sheath and/or steerable sheath was placed in the left atrium (LA) following double transseptal punctures, and the pulmonary vein vestibule was determined by venography and/or three-dimensional mapping system (EnSite-Velocity 3000, Abbott Medical, USA) modeling. Pulmonary vein mapping was performed using a multipole catheter (A-Focus, Abbott Medical). Radiofrequency ablation with contact force (Tacticath Quartz, Abbott Medical) was enforced to achieve pulmonary vein isolation through large, wide-area circumferential ablation on the left and right sides. After isolation, 10 min of observation were required to confirm PVI by using a multipole catheter. Additional ablation was recommended to induce isolation in case of conduction recovery. A saline irrigation rate of 15–30 mL/min was set in both groups and adjusted according to temperature and other feedback. In the HP group, automated lesion tagging (Automark algorithm, Abbott Medical, St Paul, MN) was used to guide point-by-point ablation in real time and settings as follows: 2.5 mm stability for 8 s, minimum 5 g contact force for > 80% time. The diameter of the ablation site was 4 mm, and the distance between adjacent ablation sites was required to be ≤ 4 mm. The LSI targets were ≥ 5.0 for the anterior wall, roof and inferior wall and ≥ 4.3 for the posterior wall. In the conventional group, the size and direction of the contact force were visible in the ablation process. Automark software was also used to guide real-time ablation. The catheter setting and related parameters were the same as those in the HP group. The end point of the procedure was to achieve bilateral pulmonary vein block. Intraoperative ablation intervention was recommended for persistent non-pulmonary vein atrial fibrillation, typical atrial flutter and supraventricular tachycardia. In the HP group, ninety-five patients underwent PVI only. Of the other twenty-four patients, in addition to PVI, seven patients completed isthmic block of the tricuspid valve, fourteen patients completed electrical isolation of the superior vena cava, three patients underwent local modification of the left anterior atrial wall, and two patients had episodes of supraventricular tachycardia, including one AVNRT and one AVRT. In the LP group, one hundred

and ten patients underwent PVI only, and among the other thirty patients, in addition to PVI, ten patients completed tricuspid isthmic block, sixteen patients completed superior vena cava electrical isolation, four patients underwent left anterior atrial wall local modification, and three patients experienced superior ventricular tachycardia, including two cases of AVNRT and one case of atrial tachycardia.

Participants follow-up and recurrence of AF

The enrolled patients were followed up at 3, 6, 9, and 12 months after ablation to analyze the recurrence of AF. The procedural safety, characteristics and 1-year outcomes of the two groups were compared. Antiarrhythmic drugs were not routinely used after the initial ablation in either group, but patients with electrocardioversion or a large left atrial low-voltage area were given amiodarone or propafenone orally. Recurrence of arrhythmia was considered to be any atrial arrhythmia (atrial fibrillation, atrial tachycardia and atrial flutter) lasting more than 30 s after a 3-month blank period. Patients were analyzed for 1-year arrhythmia-free survival if no arrhythmias were recorded at the last follow-up.

Statistics

Continuous variables were presented as the median with interquartile range (IQR) or mean with standard deviation. Categorical variables were expressed as frequencies and percentages. The normality of the variable distribution was assessed using the Kolmogorov–Smirnov test. T-tests (continuous variables) and χ^2 tests were performed for univariate comparisons. Cumulative event incidence was shown by using the Kaplan–Meier curve. The event distribution between the two groups was compared by using the log-rank test. Cox proportional hazards regression models were used to assess the association between groups and recurrence of arrhythmias, reporting hazard ratios (HR) and 95% confidence intervals (CI). The multivariable Cox model was adjusted for baseline demographics (age and gender), left atrium size, and anti-coagulation drugs. All analyses were performed using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA) and R version 4 (R Foundation for Statistical Computing, Vienna, Austria). A two-sided P value of <0.05 was considered statistically significant.

Results

Baseline characteristics

A total of 259 participants were included in the final analysis (119 patients in the HPSD group and 140 participants in the conventional power group), with a mean age of 60.9 ± 10.7 years, 166 (64.1%) participants were male at baseline. The baseline characteristics of the population are shown in Table 1. The two groups were well matched in age, gender, body mass index (BMI), CHA2DS2-VASc score, left ventricular ejection fraction, cardiac structures (left atrial diameter and left ventricular end-diastolic diameter) ($p>0.05$). There was also no significant difference in baseline clinical characteristics, including hypertension, coronary heart disease and diabetes, between the two groups ($p>0.05$). However, compared with the conventional power group, the HPSD group had a higher bleeding risk score (1.06 ± 1.28 vs. 0.86 ± 0.88, $p=0.022$) and more inconsistent use of anticoagulant drugs ($p<0.001$). The HPSD group had a lower proportion of warfarin use [3 (2.5%) vs. 16 (11.4%)]. Baseline characteristics of participants in the arrhythmia-free and arrhythmia groups at 12-month follow-up are shown in Supplemental Table 1.

Procedural characteristics

PVI was successfully achieved in all patients in both groups. Procedural data are shown in Table 2. The procedural duration was significantly lower in the HPSD group than in the conventional power group (140.3 ± 34.4 min vs. 151.3 ± 40.6 min, $p=0.022$). Overall radiation was also significantly lower in the HPSD group than in the conventional power group (112.0 ± 67.2 mGy·cm^2 vs. 188.2 ± 119.2 mGy·cm^2, $p<0.001$) (Table 2 and Fig. 1).

Complications and outcomes

The complications observed in this study are shown in Table 2. No major complications occurred in the HPSD group. In the conventional power group, 5 participants developed complications, including hematoma, pseudoaneurysm, pericardial tamponade, slight pericardial effusion, and aneurysm, all of which were managed conservatively. The main arrhythmia observed in recurrent patients was atrial fibrillation, which was 11 (9.2%) in the HPSD group and 19 (13.6%) in the conventional power group at the 1-year follow-up. The incidence of arrhythmia was lower in the HPSD group than in the conventional power group, but the results were not statistically significant ($p=0.278$). Kaplan–Meier curves showed higher arrhythmia-free survival at the end of 12 months in the HPSD group than in the conventional power group, but the difference between the two groups was not statistically significant (Fig. 2, $p=0.25$). Due to previous studies suggesting sex differences in almost all aspects of AF, we stratified by gender and found that the arrhythmia-free survival rate in the high-power group appeared to be higher in females, but without statistical significance (Fig. 3). The results were also similar after stratification by BMI, mitral valve status, tricuspid valve status and anti-coagulation strategy (Supplemental Figs. 2, 3, 4 and 5). Compared with the conventional

Table 1 Baseline participants characteristics

Baseline variables	Overall (*n* = 259)	Conventional power (*n* = 140)	High power (*n* = 119)	*P* Value
Age, yrs	60.9 ± 10.7	61.2 ± 9. 9	60.6 ± 11.6	0.685
Male, n (%)	166 (64.1)	91 (65.0)	75 (63.0)	0.841
BMI, kg/m^2	24.1 ± 3.34	24.2 ± 3.33	24.1 ± 3.37	0.828
Medical history				
Hypertension, n (%)	117 (45.2)	70 (50.0)	47 (39.5)	0.117
Diabetes, n (%)	31 (12.0)	15 (10.7)	16 (13.4)	0.629
CHD, n (%)	43 (16.6)	23 (16.4)	20 (16.8)	1.000
Renal Insufficiency, n (%)	9 (3.5)	5 (3.6)	4 (3.4)	1.000
DCM, n (%)	1 (0.4)	1 (0.7)	0 (0)	1.000
SSS, n (%)	3 (1.2)	2 (1.4)	1 (0.8)	1.000
Thromboembolism, n (%)	23 (8.9)	13 (9.3)	10 (8.4)	0.976
Atrioventricular Block, n (%)	6 (2.3)	5 (3.6)	1 (0.8)	0.223
LVEF, %	62.9 ± 6.17	62.7 ± 6.52	63.1 ± 5.75	0.550
LV size, mm	44.1 ± 4.09	44.1 ± 4.19	44.1 ± 3.99	0.974
LA size, mm	41.2 ± 5.23	41.4 ± 5.33	41.0 ± 5.12	0.545
RV size, mm	29.8 ± 4.16	30.1 ± 4.04	29.4 ± 4.29	0.176
RA size, mm	37.1 ± 5.20	37.4 ± 5.54	36.8 ± 4.79	0.371
HAS-BLED	0.95 ± 1.09	0.86 ± 0.88	1.06 ± 1.28	0.022
CHA2DS2-VASc	1.79 ± 1.54	1.86 ± 1.51	1.71 ± 1.58	0.458
Anticoagulant, n (%)				< 0.001
Dabigatran	76 (29.3)	41 (29.3)	35 (29.4)	
Warfarin	19 (7.3)	16 (11.4)	3 (2.5)	
Rivaroxaban	151 (58.3)	83 (59.3)	68 (57.1)	
Non	5 (1.9)	0 (0)	5 (4.2)	
Mitral Valve, n (%)				0.206
Normal	34 (13.1)	22 (15.7)	12 (10.1)	
Mild	205 (79.2)	110 (78.6)	95 (79.8)	
Moderate to severe	20 (7.7)	8 (5.7)	12 (10.1)	
Tricuspid Valve, n (%)				0.297
Normal	32 (12.4)	21 (15.0)	11 (9.2)	
Mild	197 (76.1)	105 (75.0)	92 (77.3)	
Moderate to severe	30 (11.6)	14 (10.0)	16 (13.4)	

Abbreviation: BMI Body mass index, *CHD* Coronary heart disease, *DCM* Dilated cardiomyopathy, *SSS* Sick sinus syndrome, *LVEF* Left ventricular ejection fraction, *LV* Left ventricular, *LA* Left atrium, *RV* Right ventricle, *RA* Right atrium

Table 2 Procedural characteristics

Variables	Overall (*n* = 259)	Conventional power (*n* = 140)	High power (*n* = 119)	*P* Value
Complication, n(%)	5 (1.9)	5 (3.6)	0 (0)	0.064
Procedure Time, min	146.2 ± 38.2	151.3 ± 40.6	140.3 ± 34.4	0.022
Radiation, mGy	153.2 ± 105.7	188.2 ± 119.2	112.0 ± 67.2	< 0.001
Recurrent arrhythmia, n(%)	30 (11.6)	19 (13.6)	11 (9.2)	0.278
Survival time, day	334.9 ± 81.9	331.1 ± 82.4	339.3 ± 81.5	0.427

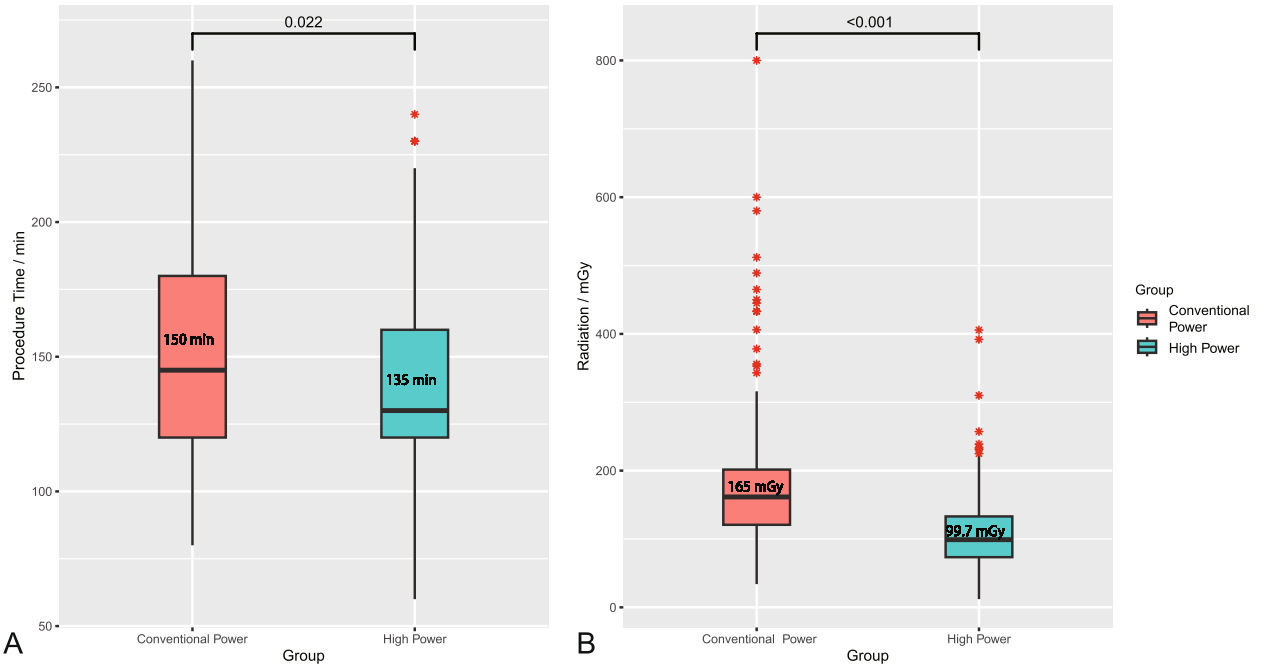


Fig. 1 Comparison of the procedure time and radiation change between The HP and CP settings. **A** procedure time between high and conventional power; (**B**) radiation between high and conventional power. The procedural duration and overall radiation were significantly lower in the HP group than in the CP group. HP, high power; CP, conventional power

power group, participants in the HPSD group had a lower risk of arrhythmia recurrence, with an HR of 0.63 (95% CI, 0.30–1.34) in the multivariable model, although there was no statistically significant difference (Table 3, $p=0.23$).

Discussion

Our present study compared the safety and efficacy of HPSD ablation (50 W) to conventional power (30–35 W) in patients with PAF. In terms of contact force (CF)–sensing catheters and PAF, this retrospective cohort study included the relatively large population in this field, and suggested that HPSD ablation saved total procedure time, significantly reduced the radiation exposure for both the operator and patient, and could be performed safely with no additional complications compared to the conventional power group. In terms of the recurrence rate of atrial fibrillation, the results were consistent in both groups.

Radiofrequency catheter ablation has become one of the important measures for the treatment of PAF in recent years. Over the past decade, ablation success rates have increased with advancements in ablation techniques, especially after the introduction of contact force–sensing catheters [11]. The mechanism of RF ablation is intricate, involving two stages of RF energy heating: the early resistive heating stage and the later conductive heating stage. Conductive heating is generally considered to cause deeper collateral damage. Compared to conventional power catheter ablation, HPSD is believed to damage tissues by resistive heating and can minimize the endocardial retention that may occur in an irrigated tip catheter heated at lower power [5].

The high-power RF energy from the small electrodes heats the tissue immediately and rapidly by producing a high current [12]. Based on the above situation, previous studies have consistently shown a shorter procedure time for HPSD [13]. Quantitative 50 W AF ablation has been suggested to be as safe as lower power and can result in reduced ablation and procedure time [14]. Our study also demonstrated that the total operative time was significantly reduced in the HPSD group. A clear advantage of HPSD was revealed in our current study in reducing the time of intravenous fluid infusion and anesthesia by shortening the procedure time. Some studies have reported a statistically significant reduction in fluoroscopy time for HPSD, while others have shown no difference [9]. Although the effect on fluoroscopy time was inconsistent in previous studies, our results suggested that HPSD could significantly reduce the radiation exposure, which was partly due to the improved ablation efficiency of HP and reduced catheter operation time, thus producing a direct beneficial effect on the patient, operator and supporting personnel.

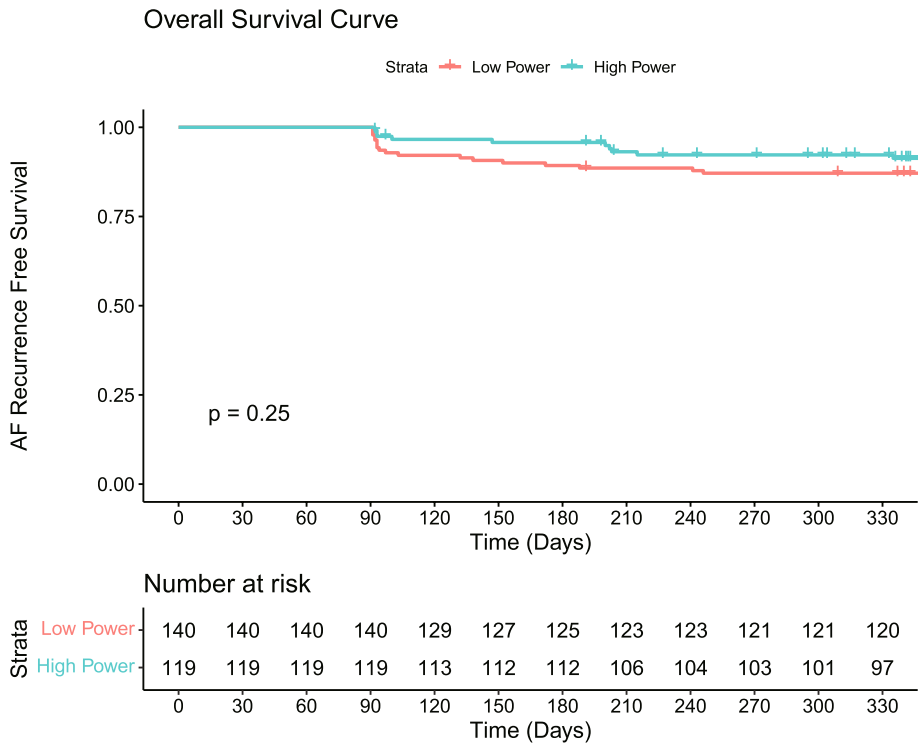


Fig. 2 Kaplan–Meier curves for RF power settings and arrhythmia-free survival. Higher arrhythmia-free survival at the end of 12 months in the HP group than in the CP group, but the difference was not statistically significant. HP, high power; CP, conventional power

A prospective randomized controlled trial showed that HPSD ablation reduced procedure time and also decreased the number of ablation lesions for PVI without increasing the incidence of complications [15]. The main challenge with RF is to achieve transmurality, which was assessed in previous studies using epicardial maps after ablation on the PW with HPSD, vHPSD and SPLD [16]. Moreover, this seems more feasible with the new PFA system [17]. Due to good transmural ablation and safety, HPSD had also been shown to reduce the incidence of gaps between ablation sites and reduced the risk of atrial perforation [18]. Studies on HPSD that had been carried out in AF patients indicated that a catheter radiofrequency ablation power of 45 ~ 50 W was safe and effective [14, 19]. Our data also showed that HPSD had a relatively low incidence of complications, including no thromboembolic complications, pericardial tamponade and atrio-esophageal fistula, which was consistent with previous research. However, pulmonary vein reconnection following PVI remains a major clinical challenge. Using in vitro and in vivo models, Bhaskaran et al. demonstrated that, compared to the LPLD ablations, the lesion widths were similar and the lesion depths were shallower for the HPSD 50 W and 60 W ablations [20]. There was concern that the shallower lesions associated with HPSD might cause a higher recurrence rate of late arrhythmia compared to conventional power [12]. We therefore observed the clinical outcomes of LSI-guided HPSD ablation at twelve months of follow-up and suggested that the 50 W group had a similar rate of arrhythmia-free survival at twelve months compared to the conventional power group. It was worth mentioning that, we found that HPSD had a better prognosis for women with PAF, with a lower recurrence rate after ablation at one year follow-up, although there was no statistical difference compared to LPSD. Therefore, our existing data suggests that HPSD ablation is suitable for treating PAF in both males and females.

In general, our present study showed that HPSD was a safe and effective strategy for patients with PAF. However, it was still necessary to include more patients with PAF and longer follow-up to determine the full advantages of HPSD.

Study limitations

First, this study was a retrospective cohort, and patients were not prospectively recruited, but were sequentially selected, which may lead systematic bias for the procedural and follow-up differences between the study groups. Second, Secondary PV mapping was not performed in enrolled patients to assess the recovery of PV potential. Third, ablation parameters, including contact force, force–time

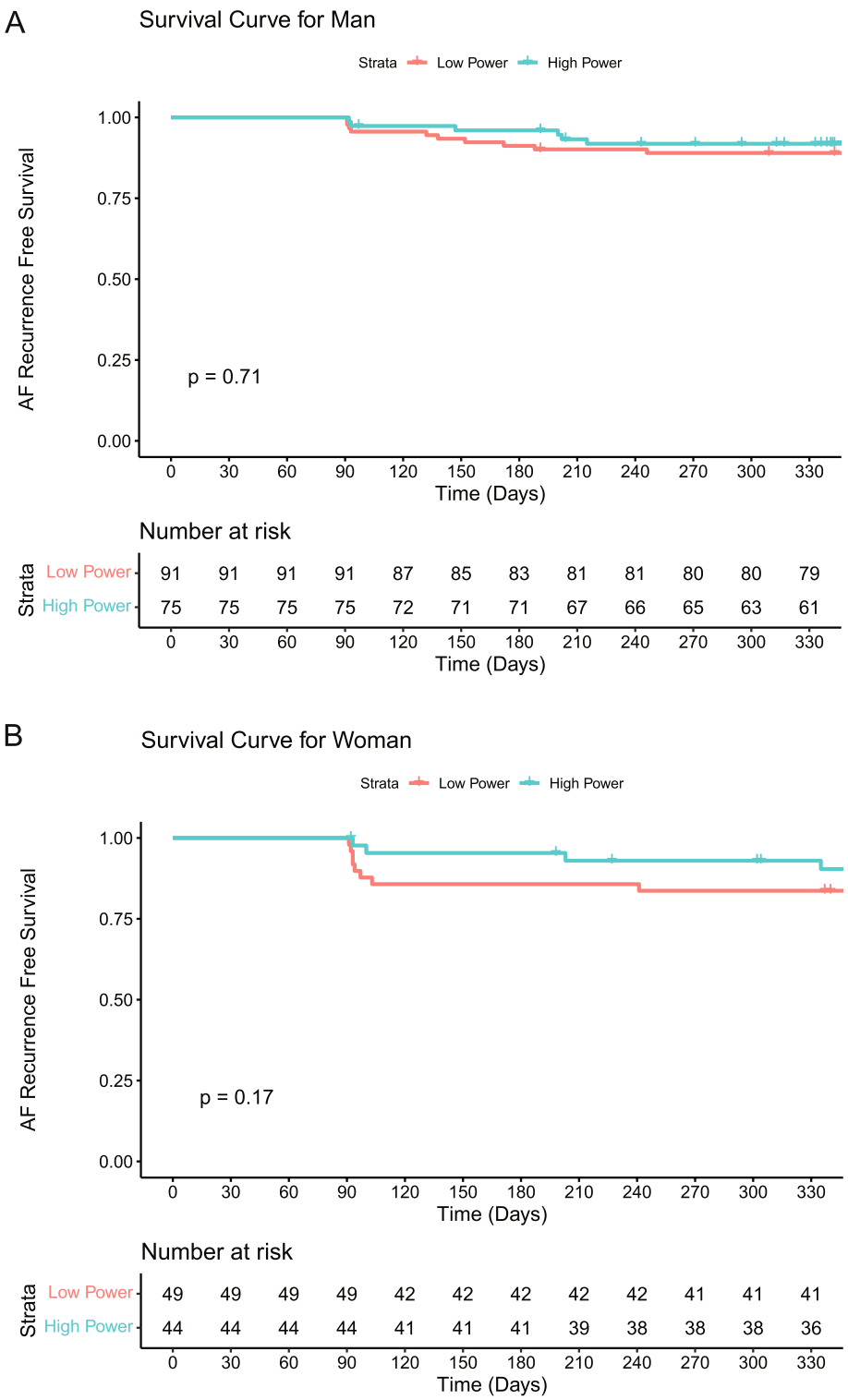


Fig. 3 Kaplan–Meier curves for RF power settings and arrhythmia-free survival stratified by gender. **A** Kaplan–Meier survival curve for men; (**B**) Kaplan–Meier survival curve for women. In women, the HP group appears to have a higher arrhythmia-free survival rate compared to the CP group, but without statistical significance. HP, high power; CP, conventional power

Table 3 Cox regression analysis: the association between the HPSD group and recurrence of arrhythmias

Group	Events No. (%)	Unadjusted HR (95% CI)	Adjusted HR (95% CI)
Conventional power	19 (13.6)	1(ref.)	1(ref.)
High power	11 (9.2)	0.65(0.31–1.36)	0.63(0.30–1.34)
P value		0.25	0.23

Adjusted for baseline demographics (age and gender), left atrium and anti-coagulation drugs

integral, and continuity (distance between adjacent ablation sites), were not compared between the two groups. We were unable to assess subclinical esophageal injury because routine esophageal endoscopy monitoring was not implemented in our study. Finally, systematic monitoring for recurrences after ablation is also required in future studies.

Conclusion

A population of patients with PAF was recruited for LSI-guided radiofrequency ablation, and the use of 50 W power was associated with a significant reduction in procedure time and radiation exposure without increasing the risk of postoperative complications or AF recurrence. HPSD-RFA was a safe and effective treatment for PAF, multi-center studies and longer follow-up are needed to be further performed.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12872-025-04597-9.

Supplementary Material 1

Clinical trial number

Not applicable.

Authors' contributions

Concept/design (Xinzhong Li, Jianyong Li, Jianping Bin, Yuegang Wang), data collection (Xinzhong Li, Xiaobo Huang, Hairuo Lin, Senlin Huang), data analysis/interpretation (Zhiwen Xiao, Jiachen Zhang), drafting article (Xinzhong Li,Zhiwen Xiao, Yuegang Wang), critical revision of article (Jiachen Zhang, Xiaobo Huang, Hairuo Lin, Senlin Huang, Yulin Liao, Juefei Wu, Jiancheng Xiu, Jianyong L, Jianping Bin), approval of article (all of the authors).

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

The protocol of the study was approved by Medical Ethics Committee at Nanfang Hospital of Southern Medical University. All patients gave written informed consents.

Competing interests

The authors declare no competing interests.

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