Indian Pacing and Electrophysiology Journal 22 (2022) 200–206

Contents lists available at ScienceDirect

Indian Pacing and Electrophysiology Journal

journal homepage: www.elsevier.com/locate/IPEJ

Ablation index-guided 50W radiofrequency ablation for left atrial posterior wall isolation in atrial fibrillation

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ARTICLE INFO

Article history:
Received 26 February 2022
Received in revised form
11 April 2022
Accepted 23 May 2022
Available online 26 May 2022

Keywords:
High-power
Short-duration
50W
Ablation
Posterior wall
Box
Isolation
Atrial fibrillation

ABSTRACT

Background: Ablation index (AI)-guided ablation for posterior wall isolation (PWI) using high-power, short-duration remains untested. We sought to evaluate the acute outcomes of AI-guided 50 W ablation *vs.* conventional ablation, and investigate the differences in relationship between contact force (CF), time and AI in both groups.

Methods: Consecutive patients undergoing first-time AI-guided ablation with PWI using either 50 W or 35–40 W ablation were enrolled. Acute procedural metrics and individual lesion level ablation data were compared between groups.

Results: 40 patients (50 W: n = 20, 35–40 W: n = 20) with atrial fibrillation were included. Total procedure time was significantly reduced with 50 W (120 *vs.* 143 mins, $p = 0.004$) and there was a trend toward decreased ablation time (22 *vs.* 28 mins, $p = 0.052$). First pass and acute success of PWI were comparable between the 50 W and 35–40 W groups (10 vs. 8 patients, $p = 0.525$ and 20 vs. 19 patients, $p = 1.000$, respectively). Individual lesion analysis of all 959 RF applications (50 W: n = 458, 35–40 W: n = 501) demonstrated that 50 W ablation led to lower ablation time per lesion (10.4 *vs.* 13.0s, $p < 0.001$), and increased AI (471 *vs.* 461, $p < 0.001$) and impedance drop (7.4 *vs.* 6.9ohms, $p = 0.007$). Excessive ablations (AI>600 for roof line; AI>500 elsewhere) were more frequently observed in the 50 W group (9.0% *vs.* 4.6%, $p = 0.007$). CF had very good discriminative capability for excessive ablation in both groups. At 50 W, limiting the CF to <10 g reduced the number of excessive ablations on the floor line and within the posterior box to 12% and 4%,respectively. Recurrence of atrial arrhythmias at 12 months were comparable between the groups.

Conclusion: AI-guided 50 W RF ablation reduces the ablation time of individual lesions and total procedure time without compromising first pass and acute success rates of PWI or 12-month outcomes compared to conventional powers.

1. Introduction

Catheter ablation is increasingly used in the treatment of patients with atrial fibrillation (AF). While pulmonary vein isolation (PVI) is the cornerstone of this approach, the long-term success rates with PVI alone remains suboptimal, especially in persistent and long-standing persistent AF. Hence, alongside technological improvements such as the irrigated-tip radiofrequency (RF) ablation catheters, introduction of contact force (CF) measurements and determining lesion formation with ablation index (AI) [1], there has been a quest for further ablation strategies. In this regard, the addition of posterior wall isolation (PWI) over PVI has been reported to improve outcomes in some studies [2–6]. Nonetheless, this strategy involves the delivery of more ablation lesions and prolongs procedure times, besides potentially increasing the risk of oesophageal injury.

More recently, the use of high-power, short-duration (HPSD) RF ablation has been described [7,8]. Despite safety concerns regarding the use of high powers (50 W), initial studies have been reassuring [9,10], though the incidence of endoscopically detected

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Peer review under responsibility of Indian Heart Rhythm Society.
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https://doi.org/10.1016/j.ipej.2022.05.002

oesophageal lesion was 16% in 1 study [11]. A meta-analysis of 15 studies involving 3718 patients demonstrated that HPSD RF ablation in patients with AF was associated with better procedural effectiveness for PVI with no difference in total complications compared to conventional powers [12]. However, the use of AI-guided 50 W ablation for PWI, and the interplay between ablation parameters at this power as compared to lower powers has not been described. In this study, we sought to evaluate the acute outcomes of AI-guided RF 50 W ablation *vs.* conventional ablation, and investigate the differences in relationship between CF, time and AI in both groups.

2. Methods

2.1. Patient population

Consecutive patients undergoing first-time AI-guided RF ablation with PWI over a 2-year period from October 2017 to September 2019 at our institution were enrolled. No specific exclusion criteria were imposed. Patients were categorised according to the RF ablation power (50 W *vs.* 35–40 W) applied during their procedure. Baseline demographics and procedural data were extracted from an institutional board-approved registry and an anonymised database. All patients provided written informed consent prior to enrolment, and the study was conducted in alignment with ethical standards described in the Declaration of Helsinki.

2.2. Catheter ablation workflow

Details of our procedural workflow have previously been described [13]. In brief, all procedures were performed under general anaesthesia using 3-dimensional electro-anatomical mapping (CARTO 3, Biosense Webster Inc, Diamond Bar, CA) and continuous oesophageal temperature monitoring. A CF-sensing ablation catheter (Thermocool SmartTouch, Biosense Webster, Inc, Diamond Bar, CA) was used to first create a fast anatomical map of the left atrium (LA), and then to deliver point-by-point ablation using a steerable sheath. After PVI, left atrial roof line and left atrial floor lines were created (Fig. 1). Automated lesion tagging (VisiTag™, Biosense Webster Inc, Diamond Bar, CA) was used with a VisiTag™ diameter of 3 mm, and settings as follows: 3 mm stability for 3s, minimum 3 g contact force for >30% time. The generator impedance graph was monitored in real-time to allow prompt cessation of RF application in case of a sudden rise of impedance, or if impedance drop exceeded 40 Ω. RF application was terminated if the oesophageal temperature rose by more than 1 °C or it reached 38 °C, and no further RF applications were delivered till it returned to baseline. Lesion contiguity was maintained by ensuring a maximum inter-tag distance (ITD) of 5 mm on the roof line and 6 mm on the floor line. The following AI values were targeted: 550–600 on the roof line, and 400–450 on the floor line and within the posterior box. Isolation of the posterior wall was confirmed by documenting both entrance and exit block through placement of the ablation catheter at all four corners of the box lesion. Ablation inside the box was delivered in case of failure of first pass isolation. Any gap(s) were localised by mapping local conduction times during coronary sinus pacing, and any residual signals on the posterior wall were targeted directly with ablation. If recurrent or rapid oesophageal temperature rise was observed, then attempts at PWI were abandoned. No additional linear ablation or complex fractionated electrogram ablation was attempted in any patient. Patients were discharged on a proton pump inhibitor for 1 month.

2.3. Individual lesion analysis

Every patient in this study underwent detailed offline retrospective analyses of each of their posterior wall lesion set. The data retrieved for each VisiTag™ included ablation duration, CF, impedance drop and AI. Ablation duration was quantified as the time of RF delivery during each application. CF was defined as the mean CF during ablation, and impedance drop as the difference between the pre-ablation and the lowest recorded impedance values during ablation. Calculation of AI was an automated process on the CARTO 3 system, and it was determined using a complex exponential formula allocating different weighting to CF, time, and power [1]. Excessive ablation was defined as AI above 600 on the roof line, and over 500 on the floor line and within the posterior box.

2.4. Follow-up and arrhythmia recurrence

Follow-up clinic visits were undertaken at 3, 6 and 12 months with a full review and 12-lead electrocardiography (ECG) performed at each visit. Where appropriate, patients also underwent supplementary ambulatory ECG monitoring. Ongoing medical therapy was left to the discretion of clinicians, but wherever possible, class I and class III anti-arrhythmic drugs were ceased after 3 months. Arrhythmia recurrence was any atrial arrhythmia (AF, atrial tachycardia, atrial flutter) lasting longer than 30s after the 3-month blanking period. Patients were censored at 1 year for arrhythmia-free survival analysis if there was no documented arrhythmia at last follow-up.

2.5. Statistical analyses

Continuous variables were described with mean and standard deviation, or median and interquartile range (IQR), and tested for differences with *t*-test or Mann-Whitney *U* test. Categorical

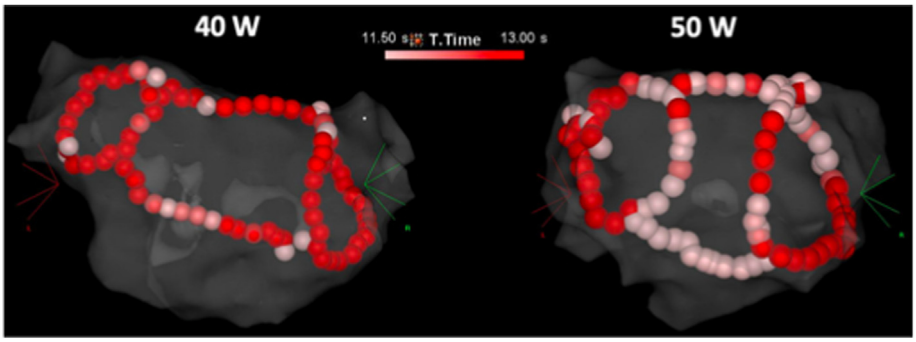

Fig. 1. Example of CARTO maps for ablation index-guided 50 W (right) and 40 W (left) radiofrequency ablation for left atrial posterior wall isolation in atrial fibrillation.

variables were described with count and percentage, and tested for differences with chi-squared or Fisher's exact test. Spearman's rho was used to analyse the correlation between contact force and ablation time. Scatter plot diagrams displaying the relationship between these variables were created. The predictive capability of contact force and ablation time for excessive ablation was investigated in each group using receiver-operating characteristic (ROC) curves. Area under the curve (AUC) was used to represent the ability of these parameters to predict events of excessive ablation. The performance of contact force and ablation time in the 50 W group was tested against the 35–40 W group using DeLong's test [14]. Freedom from atrial arrhythmia recurrence during follow-up of up to 360 days was analysed using plots of Kaplan-Meier curves and survival distributions were compared using log-rank test. A two-sided p value of less than 0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 24 (IBM Corp, Armonk, NY) and R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Baseline demographics

We included a total of 40 patients (50 W: n = 20, 35–40 W: n = 20) who underwent AF ablation with PWI at our institution. Overall, the median age was 65.4 (IQR 56.8–73.2) years with 35% females. Baseline characteristics and medication use are shown in Table 1. Patients in the 50 W group had a significantly larger LA size (45 *vs.* 40 mm) and a greater burden of AF compared to those in the 35–40 W group. There was no statistical difference between the groups in terms of age, gender distribution, comorbidities, CHA_2DS_2-VASc score and medication use.

3.2. Procedural details

Procedural details and acute outcomes of PWI are presented in Table 2. The total procedure time was significantly reduced in the 50 W group (120 *vs.* 143 mins in the 35–40 W group, $p = 0.004$). There was a trend toward a decreased ablation time with 50 W compared to 35–40 W but this did not reach statistical significance (22 *vs.* 28 mins, $p = 0.052$). First pass PWI was achieved in 10 (50%) patients with 50 W ablation and 8 (40%) patients with 35–40 W ablation, $p = 0.525$ for difference. Acute success of PWI was accomplished in 20 (100%) patients with 50 W ablation and 19 (95%) patients with 35–40 W ablation, $p = 1.000$ for difference.

3.3. Relationship between ablation parameters

Individual lesion analysis was performed for all 959 RF applications (50 W: n = 458, 35–40 W: n = 501) aimed at PWI. Overall, the median number of RF lesions required for PWI and CF utilised were 23 (IQR 20–28) and 21 (15–29)g, respectively. There were no significant differences in these parameters between the groups (number of RF lesions, $p = 0.322$ and CF, $p = 0.559$) (Table 3). Compared to 35–40 W ablation, the use of 50 W led to reduced ablation time per lesion (10.4 *vs.* 13.0s, $p < 0.001$), and increased AI (471 *vs.* 461, $p < 0.001$) and impedance drop (7.4 *vs.* 6.9 Ω, $p = 0.007$). There was no steam pop during any of the RF applications.

Overall, there was moderate but significant correlation between the variables CF and ablation time in both groups (50 W group: r −0.449, $p < 0.001$; 35–40 W group: r −0.570, $p < 0.001$). Scatter plots showing the relationships between CF and ablation time for the floor and roof lines, and within posterior box for both groups are shown in Fig. 2. For the floor line, the slope of the regression line for the 50 W and 35–40 W groups were −2.48 and −1.35, respectively. For the roof line, the slope of the regression line for the 50 W and 35–40 W groups were −1.38 and −0.88, respectively. For the posterior box segment, the slope of the regression line for the 50 W and 35–40 W groups were −3.89 and −2.38, respectively.

3.4. Excessive ablations

Excessive RF ablations were more frequently observed in the 50 W group (41 [9.0%] *vs.* 23 [4.6%] in 35–40 W group, $p = 0.007$) (Table 4). The number of excessive ablations on the floor line were 31 (6.8%) with 50 W and 13 (2.6%) with 35–40 W, $p = 0.006$ for difference. No excessive ablations were observed while ablating on the roof line in either group. There was no statistical difference between the groups in the number of excessive ablations within the posterior box (50 W, 10 [2.2%] *vs.* 35–40 W, 10 [2.0%], $p = 0.413$).

Table 1
Baseline characteristics and medication use.

Baseline data and medication use	50 W (n = 20)	35–40 W (n = 20)	p value
Age (years), median (IQR)	66.0 (56.5–73.0)	65.0 (56.9–74.0)	0.914
Female sex, n (%)	7 (35%)	7 (35%)	1.000
LA size (mm), median (IQR)	45 (42–48)	40 (36–44)	0.047
AF classification, n (%)			0.022
Paroxysmal	2 (10%)	10 (50%)	
Persistent	11 (55%)	6 (30%)	
Long-standing persistent	7 (35%)	4 (20%)	
Comorbidities, n (%)			
Coronary artery disease	1 (5%)	6 (30%)	0.091
Diabetes mellitus	2 (10%)	3 (15%)	1.000
Heart failure	8 (40%)	3 (15%)	0.077
Hypercholesterolaemia	6 (30%)	9 (45%)	0.327
Hypertension	12 (60%)	10 (50%)	0.525
Obstructive sleep apnoea	4 (20%)	0 (0%)	0.106
Previous stroke	3 (15%)	0 (0%)	0.231
CHA_2DS_2-VASc score, median (IQR)	2 (1–4)	2 (1–3)	0.934
Medication use, n (%)			
Beta-blocker	18 (90%)	17 (85%)	1.000
Calcium channel blocker	3 (15%)	1 (5%)	0.605
Class I AAD	2 (10%)	2 (10%)	1.000
Class III AAD	1 (5%)	2 (10%)	1.000

AAD, anti-arrhythmic drug; AF, atrial fibrillation; IQR, interquartile range; LA, left atrial.

Table 2
Procedural details and outcomes of posterior wall isolation.

Procedural details and outcomes	50 W (n = 20)	35–40 W (n = 20)	*p* value
Total procedure time (min), median (IQR)	120 (106–136)	143 (135–156)	0.004
Ablation duration (min), median (IQR)	22 (20–25)	28 (22–32)	0.052
First pass PWI, n (%)	10 (50%)	8 (40%)	0.525
Acute success of PWI, n (%)	20 (100%)	19 (95%)	1.000

IQR, interquartile range; PWI, posterior wall isolation.

Table 3
Individual lesion analysis for posterior wall isolation.

Posterior wall isolation	50 W (n = 458)	35–40 W (n = 501)	*p* value
Number of lesions, median (IQR)	22 (19–27)	24 (21–30)	0.322
Floor line	13 (11–15)	13 (11–14)	0.838
Roof line	7 (6–9)	8 (6–10)	0.173
Within posterior box	6 (6–7)	6 (3–11)	0.568
Ablation time per lesion (s), median (IQR)	10.4 (8.8–12.5)	13.0 (11.6–16.2)	<0.001
Floor line	9.9 (8.7–11.4)	12.7 (11.4–15.9)	<0.001
Roof line	13.0 (10.9–16.0)	14.5 (12.4–19.0)	<0.001
Within posterior box	8.1 (6.9–9.5)	11.8 (10.6–14.2)	<0.001
Contact force (g), median (IQR)	21.1 (14.4–30.3)	21.2 (14.9–28.1)	0.559
Floor line	19.2 (13.2–25.3)	19.0 (14.0–25.2)	0.864
Roof line	23.9 (17.8–32.7)	24.3 (17.1–30.5)	0.447
Within posterior box	25.5 (18.4–37.0)	23.1 (16.8–31.9)	0.209
Ablation index, median (IQR)	471 (441–519)	461 (434–493)	<0.001
Floor line	453 (436–475)	446 (426–464)	0.003
Roof line	560 (509–571)	502 (466–543)	<0.001
Within posterior box	461 (430–489)	455 (433–479)	0.592
Impedance drop (ohm), median (IQR)	7.4 (5.2–10.3)	6.9 (4.8–9.7)	0.007
Floor line	6.9 (5.0–10.1)	6.0 (4.2–8.3)	0.001
Roof line	8.7 (6.0–11.4)	7.5 (5.1–10.0)	0.040
Within posterior box	7.1 (5.4–9.8)	8.3 (5.8–10.9)	0.164

IQR, interquartile range.

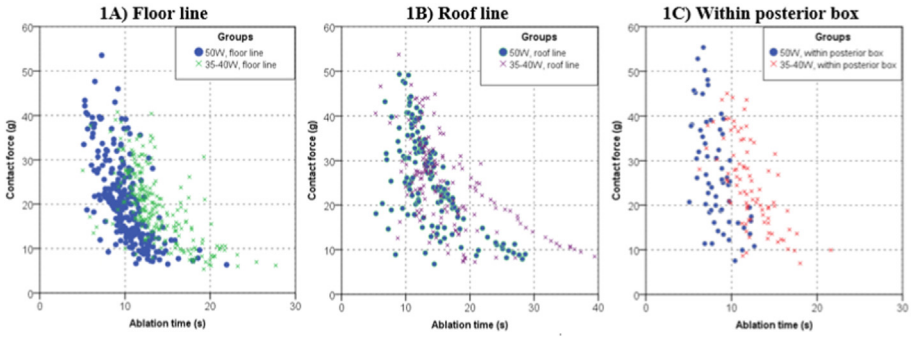

Fig. 2. Scatter plots of contact force and ablation time by power and ablation site.

Table 4
Excessive ablations with 50 W *vs.* 35–40 W ablation.

Excessive ablations	50 W (n = 458)	35–40 W (n = 501)	*p* value
Number of excessive ablations, n (%)	41 (9.0%)	23 (4.6%)	0.007
Floor line (AI >600)	31 (6.8%)	13 (2.6%)	0.006
Roof line (AI >500)	0	0	NA
Within posterior box (AI >500)	10 (2.2%)	10 (2.0%)	0.413

AI, ablation index; IQR, interquartile range; RF, radiofrequency ablation.

ROC curves for 50 W *vs.* 35–40 W ablation power are displayed in Fig. 3. CF had very good discriminative capability for excessive ablation with no significant difference between both groups (50 W: 81.2% [95% CI, 74.8–87.6%] *vs.* 35–40 W: 81.1% [95% CI, 72.6–89.5%], $p = 0.979$). Ablation time had moderate discriminative capability for excessive ablation and this was comparable between both groups (50 W: 58.8% [95% CI, 51.0–66.6%] *vs.* 35–40 W: 54.2% [95% CI, 43.8–64.6%], $p = 0.471$). Similar results were obtained when these parameters were analysed separately according to the location of RF delivery (floor line or within the posterior box). At 50 W,

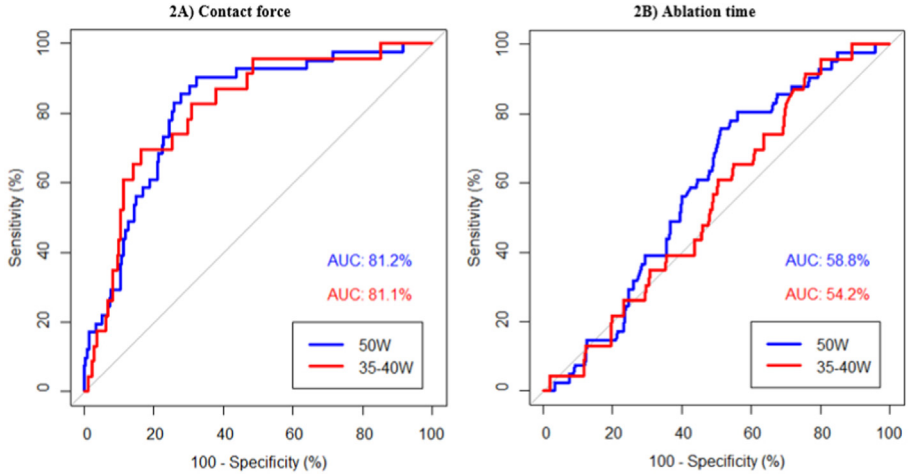

Fig. 3. Receiver-operating characteristic curves of 50 W *vs.* 35–40 W ablation power with respective area under the curves for excessive ablation in relation to A) contact force, and B) ablation time.

limiting the CF to 10 g would reduce the number of excessive ablations on the floor line and within the posterior box to 12% and 4%, respectively.

3.5. Recurrence of atrial arrhythmias

All patients completed 12 months follow-up. During this period, there were a total of 7 (17.5%) recurrences of atrial arrhythmias. 6 occurred in the 50 W group and 1 in the 35–40 W group ($p = 0.091$). There was no significant difference in the mean time to arrhythmia recurrence between the 50 W and 35–40 W groups (308 [±89] vs. 327 [±73], $p = 0.476$). Kaplan-Meier curves are shown in Fig. 4, with log-rank $p = 0.07$.

4. Discussion

Although PWI in addition to PVI has been suggested as a strategy to improve ablation outcomes, this results in increased ablation and procedure times, besides concerns about oesophageal injury. A potential approach to compensate for this is to use HPSD RF ablation. However, despite initial reports on the safety of 50 W RF ablation [9–12], it has not been widely adopted because of real-world concerns that this may lead to delivery of excessive RF energy, especially when employed for PWI. In this regard, AI may have a role to prevent excessive RF delivery by incorporating three ablation metrics (time, power and CF) in a weighted formula. Nevertheless, ex-vivo and in-vivo studies investigating AI targets are limited to powers of 45 W and 35 W, respectively [1,15]. Here, we demonstrated that the application of AI-guided 50 W RF ablation (compared to conventional 35–40 W) for PWI results in a significantly reduced procedure time and a trend toward lower ablation time, without compromising first pass and acute success rates. Using lesion-level analysis, we found that 50 W ablation was associated with greater AI values and impedance drop, specifically when creating roof and floor lines, while reducing the ablation time per lesion. However, the use of 50 W over 35–40 W ablation led to a greater number of excessive RF delivery in the floor line. The number of excessive RF delivery may be kept to a minimum by limiting CF to 10 g on the floor line and within the posterior box. We found no significant difference in the recurrence of atrial arrhythmias at 1-year.

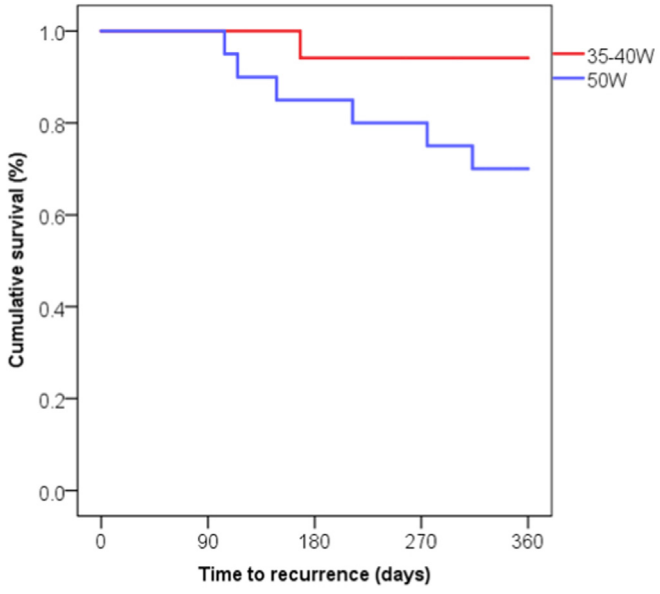

Fig. 4. Kaplan-Meier curves of recurrence of atrial arrhythmias at 12 months (log-rank $p = 0.07$).

Similar to our findings, Kumagai et al. previously demonstrated that HPSD resulted in faster PWI (by 21 min) and reduced overall procedure time (by 22 min) compared to conventional ablation [16]. Furthermore, there was no compromise in the rate of arrhythmia recurrence at 12 months. Nonetheless, the authors utilised lesion size index (LSI) and did not report on the relationship between ablation parameters for PWI at the individual lesion-level. In this aspect, our study may be regarded as novel.

Research has shown that RF ablation time is a major determinant of conductive heating to deeper tissue, and that HPSD applications changes the balance towards superficial resistive heating [17]. Therefore, the advantage of HPSD lies in the fact that the majority of tissue death occurs by resistive heating with potential benefits in terms of optimising lesion geometry, reducing collateral damage and increasing lesion durability [18]. Clinical studies have found that for PWI, there was no increase in oesophageal lesions detected on oesophagogastroduodenoscopy with HPSD and this may be linked to the fact that thermal injury with HPSD is restricted mainly to the shallow layer of the peri-oesophageal wall, avoiding deeper thermal injuries that reach the oesophageal mucosal layer [19]. The implementation of AI, as demonstrated in our study,

provides additional safety for operators new to this technique. Using our approach, we did not observe a single steam pop event. This aligns with the experience of Chen et al. [20,21]. Notably, we discontinued RF application if the luminal oesophageal temperature reached 38 °C, and we did not recommence until it had dropped to baseline. Furthermore, we strived to keep CF below 30 g on the posterior wall.

Interestingly, we did not observe any excessive RF ablation during creation of the roof line. In contrast, ablation on the floor line appeared vulnerable toward excessive RF delivery, especially with 50 W ablation. Overall, we showed that the inverse relationship between CF and RF time in the AI formula becomes more pronounced at higher powers, leaving operators less room for error in timings if high CF is applied for PWI using 50 W. Therefore, limiting the CF to below 10 g seems prudent based on our results.

4.1. Limitations

Our study has several limitations that are worth considering. Though consecutive patients were recruited prospectively, there may have been inherent bias due to the observational nature of the study design. In fact, there was a degree of heterogeneity between the groups, albeit such that the 50 W group had more unfavourable baseline characteristics. Nonetheless, the similarities in terms of number of RF lesions and CF applied suggest that operator technique did not vary between 50 W and 35–40 W RF application. As we did not perform routine endoscopy, we were not able to assess subclinical effects of excessive RF ablation on oesophageal injury. The AI-thresholds use to define 'excessive ablation' were applied retrospectively, and are by nature, arbitrary. However, it is unlikely that the use of different threshold values would materially alter the conclusions of our work, namely to limit the CF while ablating on the posterior wall. Additionally, the findings should be interpreted with caution given the relatively small sample size. There was borderline non-significance for the recurrence of atrial arrhythmias between the groups which may have been significant with a larger cohort or longer follow-up duration.

5. Conclusions

AI-guided 50 W RF ablation reduces the ablation time of individual lesions and total procedure time without compromising first pass and acute success rates of PWI or 12-month outcomes compared to conventional powers. However, there was greater risk of excessive RF delivery with 50 W which may be kept to a minimum by restricting CF to below 10 g when ablating on the floor line and within the posterior box.

Availability of data and material

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

WYD, LT, CB and RLS: None declared.

NK: Grants from the Swiss National Science Foundation (P400PM-194477), Gottfried und Julia Bangerter-Rhyner-Stiftung. The author acknowledges funding received from the European Society of Cardiology in form of an ESC Training Grant.

DG: Speaker for Bayer, BMS/Pfizer, Boehringer Ingelheim, Daiichi-Sankyo, Medtronic, Biosense Webster and Boston Scientific. Proctor for Abbott. Research Grants from Medtronic, Biosense Webster and Boston Scientific.

Ethics approval

Data were extracted from an institutional board-approved registry.

Consent to participate

All patients provided written informed consent prior to enrolment.

Consent for publication

See above.

Clinical trial registration

Not applicable.

Acknowledgements

None.

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