

Efficacy of the peak frequency map for left atrial posterior wall isolation

Shintaro Yamagami MD¹  | Suguru Nishiuchi MD, PhD¹  | Tomohiro Sato MD¹ | Masaya Akiyama CE² | Yuta Nakano CE² | Kondo Hirokazu MD, PhD¹ | Toshihiro Tamura MD, PhD¹

¹Department of Cardiology, Tenri Hospital, Tenri, Nara, Japan

²Department of Clinical Engineering, Tenri Hospital, Tenri, Nara, Japan

Correspondence

Suguru Nishiuchi, MD, PhD, Department of Cardiology, Tenri Hospital, 200 Mishima-cho, Tenri, Nara 632-8552, Japan.

Email: su9uru@me.com

Disclosures: None.

Abstract

Introduction: Complete isolation of the left atrial posterior wall (LAPW) is challenging owing to overlapping epicardial conduction. Peak frequency (PF) is a novel parameter that focuses on near- and far-field electrogram components. In this study, we aimed to determine whether transmural block completion is related to the ablation site PF.

Methods: We analyzed 44 consecutive patients undergoing initial LAPW isolation (LAPWI) between June 2023 and February 2024. Pre-LAPWI and PF maps were obtained using an HD-Grid catheter. In 17 of the 44 patients (Group-1), LAPWI was performed conventionally. In the remaining 27 patients (Group-2), PF-guided LAPWI was applied based on Group-1 results.

Results: In Group-1, the left atrial (LA) roof and floor line success rates were 58.8% and 76.5%, respectively. The average PF value in the roof lines of patients with a completed block line was significantly higher than that of the remaining patients (286.6 ± 29.3 Hz vs. 236.1 ± 40.9 Hz, $p = .012$), but the floor lines were similar. In Group-2, relatively high PF values were targeted to achieve complete block of the LA roof and floor lines, following the results obtained in Group-1. The LA roof line success rates (92.6% vs. 58.8% , $p = .007$), total number of radiofrequency (RF) applications (22.7 ± 5.6 vs. 27.6 ± 8.5 , $p = .03$), and procedural time (32.6 ± 18.3 vs. 47.9 ± 25.6 min, $p = .03$) differed between Group-1 and Group-2.

Conclusion: Using a PF map for determining the optimal ablation line for LAPWI by RF catheter ablation is feasible.

KEYWORDS

atrial fibrillation, left atrial posterior wall isolation, near field, omnipolar technology, peak frequency map

1 | INTRODUCTION

Atrial fibrillation (AF) is a common arrhythmia, with its incidence increasing with age, and is associated with heart failure and strokes.¹ Catheter ablation (CA) is superior to medical therapy in maintaining

sinus rhythm, and several reports have shown that it reduces the risk of stroke and hospitalization for heart failure, and improves prognosis in patients with AF.^{2–4}

Early in the course of AF, triggers from the pulmonary veins (PVs) are the predominant mechanism of this condition, and the

elimination of these AF triggers via PV isolation (PVI) has been the most important technique for AF ablation to date.⁵ However, improving CA outcomes for persistent AF (PsAF) has been challenging, and the efficacy of PVI for PsAF is inferior to that for paroxysmal AF.⁶

The left atrial posterior wall (LAPW) is a potential source of non-PV triggers and is an atrial substrate that may promote the initiation and maintenance of AF.^{7,8} This suggests that LAPW isolation (LAPWI) may be an additional option for AF ablation; however, evidence that patients who undergo additional LAPWI have improved maintenance of sinus rhythm compared to those undergoing PVI alone is limited. The addition of LAPWI may not lead to improved outcomes due to the difficulty in achieving complete LAPWI because of the complex alignment of myocardial fibers in the LAPW. In particular, epicardial connections through the septo-pulmonary bundle (SPB) represent a particularly common cause of failure to achieve a block of roof lines, even when using contiguous and optimized radiofrequency (RF) lesions with good stability and contact force (CF).^{9,10} Therefore, identifying the areas where transmural block lines are likely to succeed before RF treatment is important.

Peak frequency (PF), associated with bipolar electrograms (EGM), is a novel parameter that can distinguish between near-field EGM and far-field EGM components. The EnSite XTM EP System (Abbott) with the AdvisorTM HD-Grid (HDG) Mapping Catheter Sensor EnabledTM (Abbott) facilitates PF mapping.

We hypothesized that detecting near-field cardiomyocytes and creating a transmural conduction block based on higher PF areas may be easier when using PF map technology. In the present study, we examined whether PF mapping is useful for determining the optimal left atrial (LA) roof and floor lines for LAPWI.

2 | MATERIALS AND METHODS

2.1 | Study population

This single-center prospective study focused on consecutive patients with PsAF who underwent an initial LAPWI with radiofrequency CA (RFCA) after PVI using the EnSite XTM EP System between June 2023 and February 2024 at Tenri Hospital. During that period, the LAPWI in all of the initial cases was performed using the Ensite system. Regarding the redo cases, an LAPWI was routinely performed. Patients were excluded if other 3D mapping systems were selected or HDG mapping data were not available. The study adhered to the Declaration of Helsinki guidelines.

2.2 | Consent

Written informed consent for RFCA and participation in this study was obtained from all patients.

2.3 | General ablation strategy

All ablation procedures were performed by three experienced operators in the same clinical team with the patient under continuous deep sedation with dexmedetomidine (0.7 µg/kg/h after a loading dose of 3 µg/kg/h). In general, antiarrhythmic medications, except amiodarone, were discontinued for approximately five half-lives before the procedure. For the periprocedural management of anticoagulant therapy, warfarin and dabigatran were continuously administered, while direct oral anticoagulants, except dabigatran, 12 h before the procedure, at the operator's discretion. The activated clotting time was maintained at a minimum of 300 s with unfractionated heparin after transseptal puncture. An esophageal temperature probe (Esophastar; Japan Lifeline) was placed in the mid-esophagus for esophageal temperature monitoring. A 6-F duodecapolar catheter with wide-band electrodes (BeeAT[®], Japan Lifeline) that could be used for internal cardioversion with the SHOCK AT atrial cardioversion system (Japan Lifeline) was inserted through the right femoral vein and positioned in the coronary sinus for pacing, recording, and internal cardioversion. A trans-septal puncture was performed under fluoroscopy and intracardiac echocardiography (AcuNav, Biosense Webster) guidance with an RF needle (Baylis Medical). Two long sheaths (SL-0TM 8.5-F, Abbott and AgilisTM S curl, Abbott) were then introduced into the LA. Following internal electrical cardioversion, voltage and PF maps of the LA were created during high right atrium pacing using the EnSite X system (voxel mode) with the HDG mapping catheter. An Agilis sheath was used in all cases during the mapping, and the PF values were evaluated by mapping firmly until no gaps were left at an interpolation setting of 2.

If the sinus rhythm was not restored, only the LA geometry was constructed during AF. In the initial procedure for AF, PVI was performed before LAPWI using a 4.0-mm-tip, open-irrigated ablation catheter (TactiFlexTM CF Ablation Catheter, Sensor EnabledTM, Abbott) with a power of 40 W, CF of 10–20 g, temperature limit of ≤40°C, and irrigation rate of 13 mL/min. Circumferential ablation around the ipsilateral PV was performed using a point-by-point technique with the single-circular catheter method, with one circular catheter placed in the ipsilateral superior PV. Each RF application was sequentially located at intervals of 5 mm and was performed with a 4-mm-diameter point tag on the map. The PVI was confirmed by demonstration of the PV entrance and exit blocks. In the second redo procedure (second session), the PVs were reisolated before LAPWI if a reconnection between the LA and PVs was observed. Additional ablation was performed whenever appropriate in all the patients after LAPWI.

2.4 | LAPWI

If AF persisted after bilateral PVI, internal electrical cardioversion was performed to restore sinus rhythm, and PF and voltage maps of the LAPW were created during LA appendage pacing. The settings for LA

linear ablation were the same as those used for PVI. The RF power was set to 40 watts, and the duration of each RF application was 30–35 s for the LA roof lines and 10–30 s for the LA floor lines. During ablation, the power delivery was interrupted if the esophageal temperature increased to $\geq 40^{\circ}\text{C}$, to minimize the risk of esophageal injury.

In 17 of the 44 patients fulfilling the inclusion criteria (Group-1), LAPWI was performed using a conventional anatomical approach. First, a roof line was placed on the LA posterior roof area between the top of the bilateral PVI lines (Figure 1A). After the first pass of the roof line, a bidirectional conduction block along the roof line was confirmed by creating a high-density activation map using the HDG mapping catheter during LA appendage pacing and differential pacing maneuvers. If a block was not achieved after the first pass, additional RF applications were delivered at the earliest activation site on the designed roof line and at the sites of local LA capture with a pacing output of 20 V/2 ms until the capture was no longer present. Following roof line ablation, the floor line was placed at the inferior margins of the inferior PVs (Figure 1A). During floor line ablation, a 10-pole circular mapping catheter (Advisor™ FL Circular Mapping Catheter Sensor Enabled™, Abbott) was placed on the LAPW to assess its local potential. If LAPWI was not achieved after the first pass of the floor line, an activation map was created again, and additional RF applications were delivered in the same manner as for the roof line. Finally, if LAPWI was not completed after dense ablation of the first designed lines, the earliest activation site within the LAPW was targeted (Figure 1B). LAPWI was confirmed by elimination of LAPW potentials and the loss of LA capture during pacing within the LAPW.

An interim analysis was performed at the end of Group-1 ablation to compare the PF values between patients with and without complete block of LA roof and floor lines, respectively. Figure 2 shows the method used to measure the PF values on the LA roof and floor lines. The PF values on the surface points within the area surrounding the RF application sites in the 17 patients in Group-1 were measured. In the remaining 27 patients (Group-2), the position of LA

linear ablation was determined based on the PF value according to the results from Group-1, targeting relatively high PF values. The position of the ablation line was decided after a discussion among all the EP lab staff and the operator so as not to deviate from the area where the line is usually created in the conventional anatomical approach.

The ablation strategy for LAPWI in Group-2 after determining the position of the block lines was the same as that used in Group-1. After the treatment of all patients was completed, the efficacy of the PF-guided LAPWI in Group-2 was validated by comparison with the clinical outcomes of Group-1 as a historical control.

2.5 | Definitions and outcome measures

The primary outcome was the success rate of achieving complete block of the LA roof and floor lines. The key secondary outcomes were the rate of requiring additional RF applications within the LAPW, total RF application numbers, procedure time for LAPWI after PVI, and major complications related to the procedures. Major complications were defined as a composite of atrio-esophageal fistula, pericardial tamponade, severe gastric hypomotility requiring extended hospitalization or readmission, and stroke.

2.6 | Statistical analysis

Categorical variables are presented as numbers with percentages and were compared using the chi-squared test or Fisher's exact test. Continuous variables are presented as means with standard deviations or medians with interquartile ranges and were compared using Student's *t*-test or the Wilcoxon rank-sum test, based on the normality of data distribution. Statistical analyses were performed using the JMP Pro 14 software (SAS Institute Inc.). All analyses were two-tailed, and a *p* Value of $< .05$ was considered statistically significant.

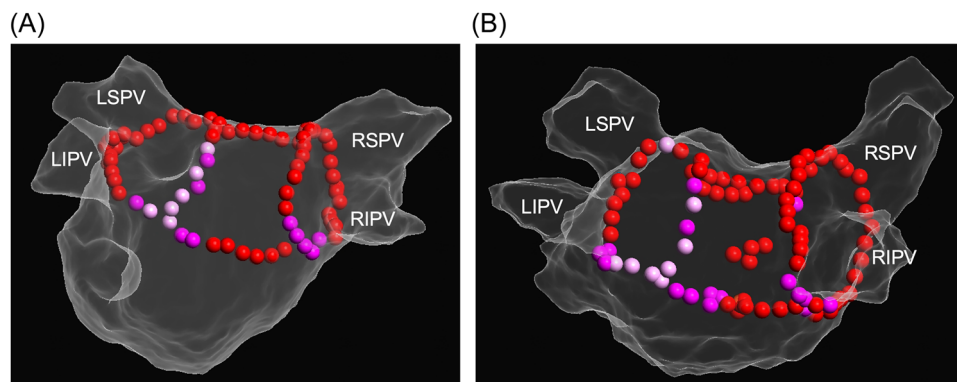


FIGURE 1 Pulmonary vein isolation (PVI) and left atrial posterior wall (LAPW) isolation. (A) PVI with LAPW isolation achieved by adding a left atrial (LA) roof line connecting the superior aspects of the pulmonary veins (PVs) and an LA floor line connecting the inferior aspects of the PVs. (B) LAPW isolation with additional radiofrequency applications within the LAPW to eliminate local electrograms and achieve electrical silence on the LAPW.

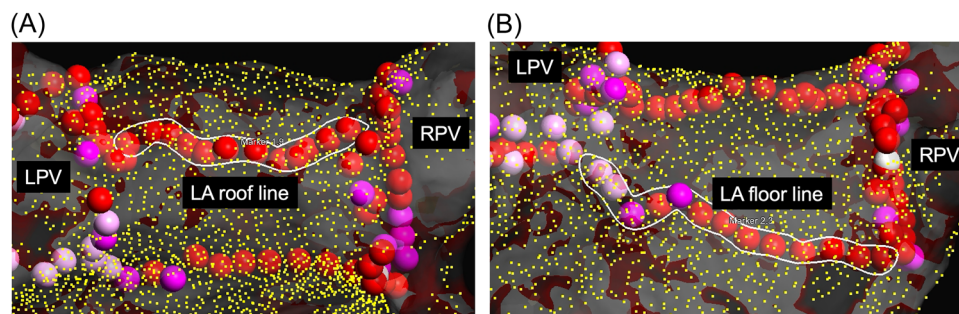


FIGURE 2 An analysis of the peak frequency (PF) values on the left atrial (LA) roof (A) and floor line (B). The PF values on the surface points that existed within the area surrounding the radiofrequency application sites (white lines) in the 17 patients in Group-1 were measured.

3 | RESULTS

3.1 | Baseline characteristics

The characteristics of the 44 included patients are shown in Table 1. The median age was 70.2 ± 10.0 years. Twelve patients (27.2%) were female. Fourteen (31.8%) had long-standing non-PAF. The present procedure was the initial procedure in 32 (72.7%) patients and the second procedure in 12 (27.3%). No significant differences in characteristics were found between Group-1 and Group-2.

3.2 | General ablation data

PVI was successfully achieved in 32 patients. In 1 of the 12 redo cases, reconnections between the LA and PVs were observed. The PVs were then reisolated before LAPWI. No cases of significant low-voltage areas on the LAPW or LA linear ablation lines were observed. Further details of the procedures other than LAPWI are shown in Table 2.

3.3 | PF analysis on the LA linear ablation block lines in Group-1

In an analysis of 4977 points on the LA roof and floor lines of the 17 cases in Group-1, the average PF of the LA roof and floor lines was 267.7 ± 41.3 Hz and 263.3 ± 53.0 Hz, respectively. In 10 of 17 (58.8%) patients, complete block of the LA roof line was achieved on the first designed line, and the average PF of the LA roof line in these 10 patients was significantly higher than that in the remaining 7 (286.6 ± 29.3 Hz vs. 236.1 ± 40.9 Hz, $p = .012$) (Figure 3A). In 13 of the 17 (76.5%) patients, complete block of the LA floor line was achieved, and no significant difference was found between the patients with and without LA floor line completion in terms of the average PF (272.3 ± 51.2 Hz vs. 224.3 ± 49.8 Hz, $p = .16$) (Figure 3B).

Based on these results, the LA roof and floor lines were created in relatively high PF areas in Group-2, by setting the display to

300 Hz or higher around the anatomically optimal area, determined in the same manner as in Group-1 (Figure 4).

3.4 | Comparison of the average PF values for Group-1 and Group-2

We designed linear ablation sites based on the relatively high PF values in the patients of Group-2. The average PF values on the LA roof and floor lines were both significantly higher in Group-2 than in Group-1 (353.7 ± 65.9 vs. 267.7 ± 41.3 ; and 351.9 ± 44.2 vs. 263.3 ± 53.0 , respectively; both $p < .0001$) (Figure 5).

3.5 | Primary and secondary outcomes

Primary and secondary outcomes are summarized in Table 3. The success rate of achieving complete block of the LA roof line on the first designed line was significantly higher in Group-2 than in Group-1 (92.6% vs. 58.8%, $p = .007$), whereas the success rate of the LA floor line was comparable between the two groups (92.6% vs. 76.5%, $p = .13$). The rate of requiring additional RF applications within the LAPW was significantly lower in Group-2 than in Group-1 (7.4% vs. 47.1%, $p = .002$). Group-1 and Group-2 also differed significantly regarding the total number of RF applications and the procedure time for LAPWI (22.7 ± 5.6 vs. 27.6 ± 8.5 points; 32.6 ± 18.3 vs. 47.9 ± 25.6 min, respectively; both $p = .03$). No major complications related to the procedures occurred; however, one patient in Group-1 complained of abdominal discomfort 2 days after CA.

3.6 | LA roof line ablation

The success rate of the LA roof line ablation was significantly higher in Group-2 than in Group-1 (25/27 [92.6%] vs. 10/17 [58.8%], $p = .007$) (Figure 6A). Further details of the results are presented in Table 4. Regarding the success rate of the first-pass block, we found no significant differences between the two groups ([20/27] 74.1% vs.

TABLE 1 Baseline characteristics of the study population comparing Group-1 and Group-2.

	Total population (N = 44)	Group-1 (N = 17)	Group-2 (N = 27)	p Value
Age (years)	70.2 ± 10.0	70.1 ± 10.3	70.3 ± 10.0	.93
Female sex (%)	12 (27.2)	6 (35.3)	6 (22.2)	.35
BMI (kg/m ²)	24.2 ± 4.2	24.3 ± 4.4	24.1 ± 4.2	.87
Long-standing PsAF (%)	14 (31.8)	3 (17.7)	11 (40.7)	.11
CHA2DS2-VASc score	2.9 ± 1.7	2.9 ± 1.8	3.0 ± 1.7	.88
<i>Comorbidities</i>				
Hypertension (%)	26 (59.1)	9 (52.9)	17 (63.0)	.51
IHD	6 (13.6)	1 (5.9)	5 (18.5)	.23
Stroke	8 (18.2)	4 (23.5)	4 (14.8)	.47
Diabetes (%)	4 (9.1)	1 (5.9)	3 (11.1)	.56
OSA (%)	12 (27.3)	6 (35.3)	6 (22.2)	.35
Hemoglobin (g/dL)	13.9 ± 1.8	14.2 ± 2.0	13.6 ± 1.7	.26
eGFR	59.7 ± 15.5	54.5 ± 8.0	62.9 ± 18.2	.08
BNP	149.8 (85.7–320.0)	128.1 (83.9–208.0)	252.5 (87.3–327.1)	.27
<i>Transthoracic echocardiography</i>				
LVEDD (mm)	45.6 ± 5.9	44.5 ± 4.7	46.3 ± 6.5	.35
LVEF (%)	63.3 ± 10.2	65.1 ± 10.5	62.1 ± 10.0	.35
LAD (mm)	41.6 ± 5.8	40.8 ± 5.9	42.2 ± 5.7	.44
LAVI (mL/m ²)	49.5 ± 15.0	47.8 ± 12.3	50.6 ± 16.7	.56
Antiarrhythmic drugs (%)	30 (63.8)	11 (64.7)	19 (63.3)	.93
Class I antiarrhythmic (%)	1 (2.1)	1 (5.9)	0 (0)	.18
Beta-blocker (%)	29 (61.7)	10 (58.8)	19 (63.3)	.76
Class III antiarrhythmic (%)	0 (0)	0 (0)	0 (0)	-
Non-dihydropyridine calcium channel blocker (%)	2 (4.3)	1 (5.9)	1 (3.3)	.68

Abbreviations: BMI, body mass index; BNP, brain natriuretic peptide; eGFR, estimated glomerular filtration rate; IHD, ischemic heart disease; LAD, left atrial diameter; LAVI, left atrial volume index; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; OSA, obstructive apnea; PsAF, persistent atrial fibrillation.

[9/17] 52.9%, $p = .15$). However, among the 15 patients in whom the first-pass block failed, the success rate of achieving complete block with additional RF applications on the first designed line was significantly higher in Group-2 than in Group-1 (5/7 [71.4%] vs. 1/8 [12.5%], $p = .02$). Furthermore, the average PF values on the conduction gap sites in the six patients in whom the complete block line was achieved with additional RF applications on the first designed line were significantly higher than those in the remaining nine patients with a failed block line (377.3 ± 43.6 Hz vs. 277.7 ± 53.1 Hz, $p = .002$). The average length of the LA roof line was significantly longer in Group-2 than in Group-1 (34.3 ± 8.9 vs. 29.1 ± 6.5 mm, $p = .04$). The total number of RF applications and the number of RF applications for the first-pass block did not differ between Group-2

and Group-1 (10.0 ± 3.5 vs. 11.2 ± 3.4 , $p = .27$ and 9.1 ± 2.8 vs. 9.1 ± 2.2 , $p = .96$, respectively).

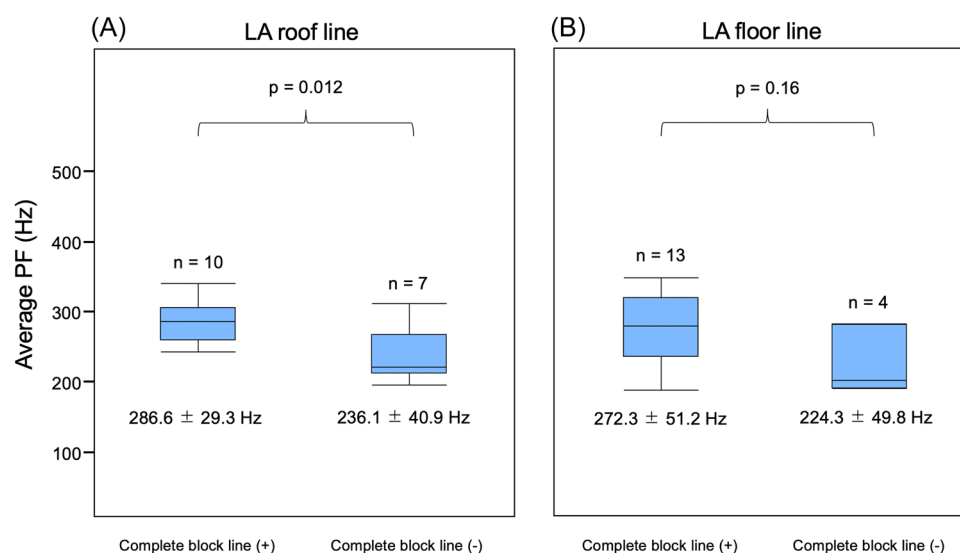
3.7 | LA floor line ablation

The success rate of the LA floor line ablation was comparable between Group-2 and Group-1 (25/27 [92.6%] vs. 13/17 [76.5%], $p = .13$) (Figure 6B). Further results are detailed in Table 4. Similar to the results for the LA roof line, the success rate of the first-pass block of the floor line was comparable between the two groups (19/27 [70.4%] vs. 11/17 [64.7%], $p = .70$). In contrast to the results for the LA roof line, among the 14 patients with a failure of the first-pass block of the floor

TABLE 2 Procedural Outcome Details Other than LAPW Isolation.

	Total population (N = 44)	Group-1 (N = 17)	Group-2 (N = 27)	p Value
Initial ablation (%)	32 (72.3)	11 (64.7)	21 (77.8)	.35
Overall PVI success (%)	44 (100)	17 (100)	27 (100)	-
SVC isolation (%)	10 (22.7)	3 (17.7)	7 (25.9)	.52
Non-PV ablation (%)	3 (6.8)	1 (5.9)	2 (7.4)	.85
LA linear ablation (%)	4 (9.1)	3 (17.7)	1 (3.7)	.12
Lateral mitral isthmus (%)	1 (2.3)	0 (0)	1 (3.7)	.42
Anterior mitral isthmus (%)	3 (6.8)	3 (17.1)	0 (0)	.02
CTI ablation (%)	13 (29.6)	4 (23.5)	9 (33.3)	.49

Abbreviations: CTI, cavo-tricuspid isthmus; LAPW, left atrial posterior wall; PVI, pulmonary vein isolation; SVC, superior vena cava.

**FIGURE 3** Box plots presenting the average peak frequency (PF) values comparing patients with complete block lines versus those without complete block lines on the left atrial roof (A) and floor (B) lines.

line, no significant difference in the success rate of completing the block by additional RF applications on the first designed floor line was noted between the groups (6/8 [75.0%] vs. 2/[33.3%], $p = .12$). Nine of the 14 conduction gaps were in close proximity to the esophagus, and RF delivery was interrupted due to the increased esophageal temperature. The average PF values on the conduction gap sites were also comparable between the eight patients with completion of the block line with additional RF applications on the first designed line and the remaining six patients in whom the block line failed (344.8 ± 58.3 Hz vs. 327.5 ± 55.6 Hz, $p = .71$). The average length of the LA floor line was also comparable between the two groups (47.3 ± 7.5 vs. 44.5 ± 6.4 mm, $p = .21$). The total number of RF applications and the number of RF applications for the first-pass block did not differ between Group-2 and Group-1 (12.7 ± 3.1 vs. 13.2 ± 3.4 , $p = .62$ and 11.4 ± 2.1 vs. 11.4 ± 1.6 , $p = .96$, respectively).

4 | DISCUSSION

4.1 | Main findings

This study on PF-guided LAPWI yielded several notable findings. First, the PF value in the patients with a complete block of the LA roof line on the first designed line was significantly higher than that in patients without a complete block of the LA roof line. Second, the success rate of the LA roof block line targeting the high PF areas was significantly better than that of the conventional anatomical approach. Third, the success rate of LAPWI targeting the high PF areas without additional RF application within the LAPW was also significantly better than that of the conventional anatomical approach. Lastly, the PF-guided LAPWI significantly reduced the total number of RF applications and procedure time.

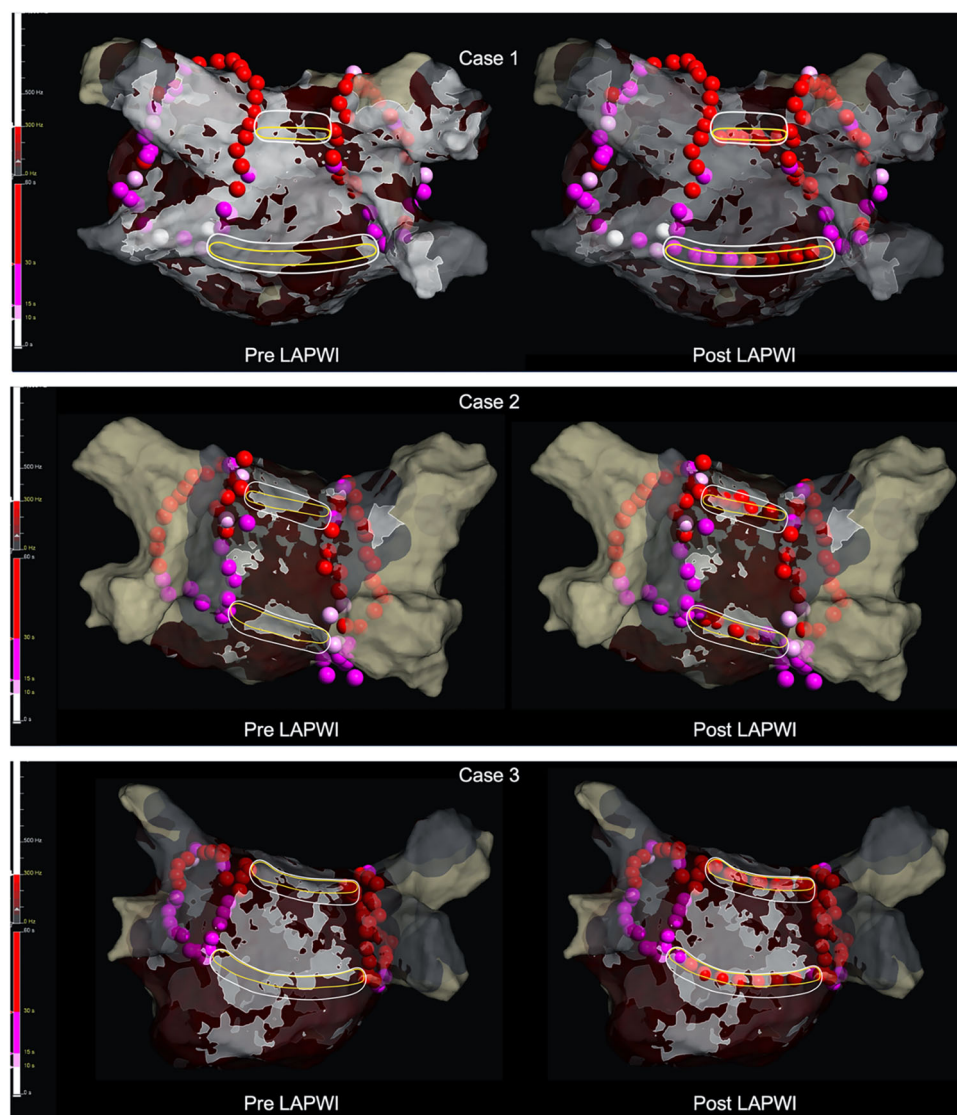


FIGURE 4 Three representative cases of the PF-guided LAPWI. The LA roof and floor lines were created in the relatively high PF areas (enclosed by the yellow line) with PF map setting the display to 300 Hz or higher (highlighted area) around the anatomically optimal area (enclosed by the white line), determined in the same way as in Group-1. LA, left atrium; LAPWI, left atrial posterior wall isolation; PF, peak frequency.

4.2 | LAPWI

LAPWI is advocated as a type of extensive ablation for PsAF to decrease the high recurrence rates associated with the performance of PVI alone.¹¹ However, in some patients, it remains challenging to create a transmural conduction block on the LA roof and floor lines. Generally, LAPWI is performed using an anatomical approach, such as the position of the PVs, to determine the LA roof and floor line position. However, even in the CAPLA study, a large randomized clinical trial, the success rate of the LAPWI with complete block of the LA roof and floor lines using this conventional method was only 42.7%.¹² The anatomy and course of the SPB are particularly common causes of failure to create a block line in the LA roof, which leads to the need for additional applications within the LAPW.^{9,10} In addition, the distance from the endocardial

side to the SPB is particularly large where these two layers are prominently separated by interposed adipose tissue, which may “protect” the SPB from thermal ablation energy from the endocardial side.¹³ Accordingly, if LAPWI is performed, the linear ablation sites should be placed in the optimal sites, avoiding epicardial conduction, where transmural conduction block lines might be easily created.

4.3 | PF-guided LAPWI

To the best of our knowledge, no previous study has validated the feasibility of using PF maps for LAPWI. A PF map can quantitatively distinguish near-field from far-field potentials by characterizing the sharpness of the intraoperative EGM. PF may reflect

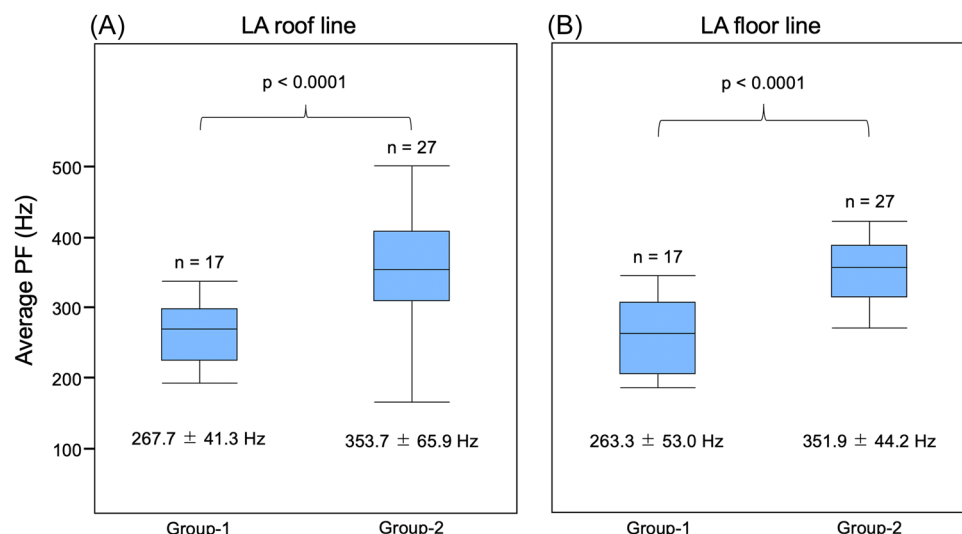


FIGURE 5 Box plots presenting the average peak frequency (PF) values for each group on the left atrial (LA) roof (A) and floor (B) lines.

TABLE 3 Primary and Secondary Outcomes.

	Total population (N = 44)	Group-1 (N = 17)	Group-2 (N = 27)	p Value
<i>Primary outcomes</i>				
Success rate				
LA roof line (%)	35 (79.5)	10 (58.8)	25 (92.6)	.007
LA floor line (%)	38 (86.4)	13 (76.5)	25 (92.6)	.13
<i>Secondary outcomes</i>				
Rate of requiring additional RF applications within the LAPW (%)	10 (22.7)	9 (47.1)	2 (7.4)	.002
Total number of RF applications (%)	24.6 ± 7.2	27.6 ± 8.5	22.7 ± 5.6	.03
Procedure time for LAPW isolation (%)	38.5 ± 22.4	47.9 ± 25.6	32.6 ± 18.3	.03
Major complication (%)	0 (0)	0 (0)	0 (0)	-

Abbreviations: LA, left atrium; LAPW, left atrial posterior wall; RF, radiofrequency.

the existence of endocardial live tissues measured by the omnipolar electrodes and the proximity of the electrodes to them. Specifically, when live tissue is at the endocardial surface, the omnipolar EGMs tend to be sharp which leads to higher PF. On the contrary, if the live tissue is in subendocardial or epicardial layers, the EGMs may be less sharp which leads to lower PF. On the LAPW, the near- and far-field activations are suggested to reflect endocardial activation in the LA and epicardial conduction, such as in the SPB, respectively. Recently, Takamiya et al. reported the distribution of PF across the atrial body and thoracic veins in normal heart.¹⁴ They demonstrated the PF is significantly larger in the superior vena cava and PVs where the muscle volume is scarce compared to the atrial body which has more transmural and multi layered myofibers and suggested that a significant muscle mass farther from the endocardial surface could increase far-field effects and consequently decrease PF. These findings support why

the success rate of targeting high PF areas for LA roof was significantly higher than that of using the conventional anatomical approach in the present study. In the present study, we also found that PF-guided LAPWI improved the success rate of LA roof line and LAPWI without additional RF application within the LAPW, resulting in a reduction in the total number of RF applications and procedure time. Furthermore, as shown in Table 4, the PF-guided LAPWI exhibited no significant difference in the posterior wall isolation area from that with the usual anatomical approach (11.0 ± 1.5 vs. 10.1 ± 1.9 cm², $p = .10$).

Regarding the LA floor line, in contrast to the LA roof line, the success rate of the complete block line was comparable between the PF-guided LAPWI and the conventional anatomical approach. Therefore, in some patients, adequate RF applications to create transmural lesions are difficult at sites close to the esophagus. In the present study, the conduction gap was located in close proximity to

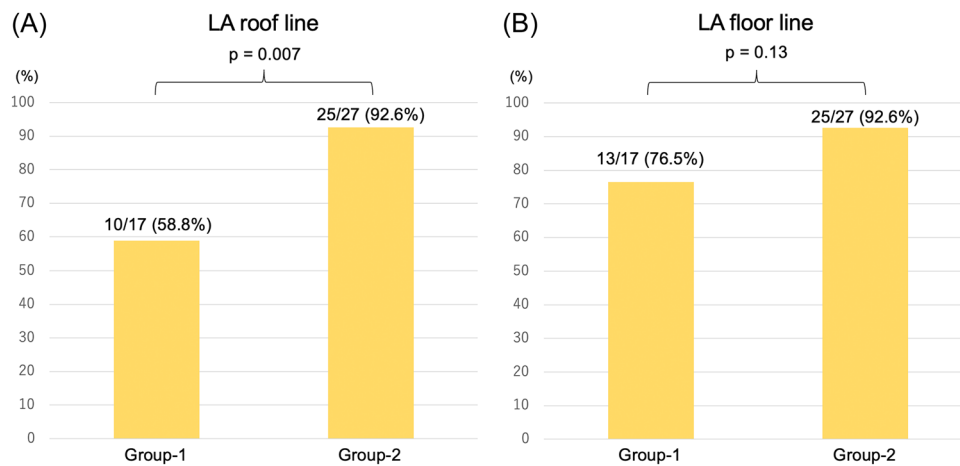


FIGURE 6 Success rate of the complete block lines. (A) Left atrial (LA) roof line, (B) LA floor line.

TABLE 4 Procedural outcome details of LAPW isolation.

	Total population (N = 44)	Group-1 (N = 17)	Group-2 (N = 27)	p Value
<i>LA roof line ablation</i>				
Success rate of 1st-pass block (%)	29 (65.9)	9 (52.9)	20 (74.1)	.15
Number of RF applications for 1st-pass block (n)	9.1 ± 2.6	9.1 ± 2.2	9.1 ± 2.8	.96
Success rate with additional RF applications on the first designed line (%)	6/15 (40.0)	1/8 (12.5)	5/7 (71.4)	.02
Line length (mm)	32.3 ± 8.4	29.1 ± 6.5	34.3 ± 8.9	.04
Total number of RF applications (n)	10.4 ± 3.5	11.2 ± 3.4	10.0 ± 3.5	.27
<i>LA floor line ablation</i>				
Success rate of 1st-pass block (%)	30 (68.2)	11 (64.7)	19 (70.4)	.70
Number of RF applications for 1st-pass block (n)	11.4 ± 1.9	11.4 ± 1.6	11.4 ± 2.1	.96
Success rate with additional RF applications on the first designed line (%)	8/14 (57.1)	2/6 (33.3)	6/8 (75.0)	.12
Line length (mm)	46.2 ± 7.2	44.5 ± 6.4	47.3 ± 7.5	.21
Total number of RF applications (n)	12.9 ± 3.2	13.2 ± 3.4	12.7 ± 3.1	.61
The area of LAPW isolation (cm ²)	10.5 ± 1.8	10.1 ± 1.9	11.0 ± 1.5	.10

Abbreviations: LA, left atrium; LAPW, left atrial posterior wall; RF, radiofrequency.

the esophagus in 9 of 14 patients (64.3%) with a failed first-pass block.

In the present study, we targeted relatively high PF areas by setting the display to 300 Hz or higher based on the results in Group-1, because PF is a novel technology, and the optimal cutoff value has not yet been established. Therefore, further studies are required to validate the useful thresholds to identify the optimal areas for the LA roof and floor lines. Finally, although PF-guided LAPWI is a novel ablation technique, the site of RF applications is almost the same as that used in the conventional anatomical approach; therefore, the possibility of increased risk from the treatment is expected to be extremely low if applied to a larger population.

4.4 | Limitations

The present study has some limitations. First, this was a single-center prospective study with the inherent limitations of such a study design. Second, the sample size was small, although this was the largest series of patients to date in whom a PF map was used to guide LAPWI. The sample size may have limited the statistical power for evaluating the impact of the PF-guided ablation strategy. Third, we did not examine the correlation between the atrial wall thickness and PF values along the roof and floor lines. Most of the patients in this study underwent preoperative CT. However, there were many cases in which plain CT was used, and we considered that it would be difficult

to accurately evaluate the thickness of the LA wall using CT. Furthermore, in addition to the LA wall, the PF value may also be affected by intervening fatty tissue, so we did not examine the relationship between the PF and LA wall thickness in this study. We believe that this is an extremely important point and requires further investigation.

5 | CONCLUSION

In conclusion, using a PF map for determining the optimal ablation line for LAPWI using RFCA is feasible and may increase the probability of completing LAPWI without excess applications within the LAPW.

ACKNOWLEDGMENTS

We are grateful to the Clinical Engineering Technologists at our hospital who provided technical support. The authors thank Mr. John Martin for his linguistic support.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Shintaro Yamagami  <http://orcid.org/0000-0003-3192-4639>

Suguru Nishiuchi  <http://orcid.org/0000-0002-3117-9985>

REFERENCES

- Joglar JA, Chung MK, Armbruster AL, et al. ACC/AHA/ACCP/HRS guideline for the diagnosis and management of atrial fibrillation: a report of the American college of Cardiology/American heart association joint committee on clinical practice guidelines. *Circulation*. 2023;2024(149):e1-e156.
- Packer DL, Mark DB, Robb RA, et al. Effect of catheter ablation vs anti-arrhythmic drug therapy on mortality, stroke, bleeding, and cardiac arrest among patients with atrial fibrillation: the CABANA randomized clinical trial. *JAMA*. 2019;321:1261-1274.
- Saliba W, Schliamser JE, Lavi I, Barnett-Griness O, Gronich N, Rennert G. Catheter ablation of atrial fibrillation is associated with reduced risk of stroke and mortality: a propensity score-matched analysis. *Heart Rhythm*. 2017;14:635-642.
- Marrouche NF, Brachmann J, Andresen D, et al. Catheter ablation for atrial fibrillation with heart failure. *N Engl J Med*. 2018;378:417-427.
- Pappone C, Augello G, Sala S, et al. A randomized trial of circumferential pulmonary vein ablation versus antiarrhythmic drug therapy in paroxysmal atrial fibrillation. *J Am Coll Cardiol*. 2006;48:2340-2347.
- Scherr D, Khairy P, Miyazaki S, et al. Five-year outcome of catheter ablation of persistent atrial fibrillation using termination of atrial fibrillation as a procedural endpoint. *Circ Arrhythm Electrophysiol*. 2015;8:18-24.
- Markides V, Schilling RJ, Yen Ho S, Chow AWC, Davies DW, Peters NS. Characterization of left atrial activation in the intact human heart. *Circulation*. 2003;107:733-739.
- Kalifa J, Tanaka K, Zaitsev AV, et al. Mechanisms of wave fractionation at boundaries of high-frequency excitation in the posterior left atrium of the isolated sheep heart during atrial fibrillation. *Circulation*. 2006;113:626-633.
- Tonko JB, Silberbauer J, Mann I. How to ablate the septo-pulmonary bundle: a case-based review of percutaneous ablation strategies to achieve roof line block. *Europace*. 2023;25:euad283.
- Kobayashi A, Hasebe H, Yoshida K. Uncoupling endocardial bundles coupled by an epicardial bundle in the left atrium and pulmonary veins. *J Arrhythm*. 2024;40:624-628.
- Sharma E, Varley A, Osorio J, et al. Procedural trends in catheter ablation of persistent atrial fibrillation: insights from the Real-AF Registry. *Circ Arrhythm Electrophysiol*. 2023;16:e011828.
- Kistler PM, Chieng D, Sugumar H, et al. Effect of catheter ablation using pulmonary vein isolation with vs without posterior left atrial wall isolation on atrial arrhythmia recurrence in patients with persistent atrial fibrillation: the CAPLA randomized clinical trial. *JAMA*. 2023;329:127-135.
- Pambrun T, Duchateau J, Delgove A, et al. Epicardial course of the septopulmonary bundle: anatomical considerations and clinical implications for roof line completion. *Heart Rhythm*. 2021;18:349-357.
- Takamiya T, Takigawa M, Noda M, et al. Distribution of peak frequency and omnipolar voltage in electrograms across the atrial body and thoracic veins in a normal heart. *J Interv Card Electrophysiol*. Published online June 17, 2024. doi:10.1007/s10840-024-01845-4

How to cite this article: Yamagami S, Nishiuchi S, Sato T, et al. Efficacy of the peak frequency map for left atrial posterior wall isolation. *J Cardiovasc Electrophysiol*. 2024;1-10. doi:10.1111/jce.16477