Epicardial Connections After a Conventional Pulmonary Vein Antrum Isolation in Patients With Atrial Fibrillation

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Background: The existence of epicardial connection(s) (ECs) between the pulmonary veins (PVs) and atrium may hinder establishing a complete PV antrum isolation (AI) (PVAI) in patients with atrial fibrillation (AF). Thus, the purpose of this study was to determine the prevalence and location of ECs inside the conventional PVAI lines.

Methods and Results: Three-hundred consecutive patients with non-valvular AF were evaluated. This study revealed that: (1) the prevalence of patients with ECs and the number of ECs per patient between the PVs and atrium became significantly greater, respectively, in accordance with the progression of paroxysmal to long-lasting AF and left atrial enlargement; (2) some ECs were located at sites far distal to the PVAI lines; (3) 25% of ECs could be detected only by high-density mapping catheters, but not by conventional circular mapping catheters; (4) a B-type natriuretic peptide (BNP) level of 176.6 pg/mL and left atrial volume (LAV) of 129.0 mL may be important predictors of the presence of ECs; and (5) the rate of conduction of ECs from the right PVs was dominantly to the atrium and His-bundle, and that from the left PVs to the coronary sinus was most dominant.

Conclusions: The PVAI may not be completed by using only a conventional PVAI method, and additional EC ablation inside the PVAI lines detected using high-density mapping may be able to achieve a more complete PVAI.

Key Words: 3-dimentional mapping; Atrial fibrillation; Epicardial connection; High-density mapping; Pulmonary vein antrum isolation
randomized clinical trials in Japan (UMIN000040363). From August 2019 to May 2021, 300 consecutive patients with non-valvular AF who were admitted to our hospitals to undergo RFCA of AF using an EnSite™ Cardiac Mapping System (Abbott) were evaluated. The type of AF was determined according to the 2020 JCS/JHRS guidelines on Pharmacotherapy of Cardiac Arrhythmias.4 The patients with a history of RFCA of AF and RFCA of AF by a balloon ablation were excluded. All patients had their history recorded, and underwent a physical examination, laboratory analysis, chest radiogram, 12-lead electrocardiogram, and echocardiography within at least 1 month before admission. The CHADS2: score, diameter of the LA (LAD) and left ventricular ejection fraction (LVEF) by echocardiography, and anatomy, size, and volume of the PVs and LA (LAV) by cardiac computed tomography (CT) were also evaluated before the RFCA.

Procedure of the RFCA to Treatment AF
All patients were effectively anticoagulated with non-vitamin K oral anticoagulants (NOACs) or vitamin K antagonists (VKAs) for at least 1 month before the procedure. The procedures were performed after tranesophageal echocardiography to rule out any LA thrombi. All patients gave their informed consent. RFCA was performed as described previously.5 In brief, patients were put under deep sedation and a supraglottic airway was inserted under an intravenous administration of propofol and dexmedetomidin. A temperature probe for monitoring the esophageal temperature was inserted. Femoral arterial access was routinely acquired for continuous blood pressure and heart rate monitoring. A 60 unit per kilogram administration of heparin was administered following the transseptal puncture guided by intracardiac echocardiography (ViewFlex Xtra ICE catheter; Abbott). Then, heparinized saline was additionally infused to maintain the activated clotting time at 300–400 s. A 6-French deflectable catheter, BeeAT™ (Japan Lifeline, Tokyo, Japan), was inserted and positioned into the coronary sinus (CS) and high right atrium (RA). Then, 6-French deflectable catheters were inserted and positioned at the His-bundle (His) and in the right ventricle. An HDM catheter, Advisor™ HD Grid catheter, through a steerable introducer (Agilis™ NxT; Abbott, or Guidee Left™, Japan Lifeline) and a circular mapping catheter (CMC) (Optima™, Abbott) were positioned in the LA after a double transseptal puncture. If AF continued, intracardiac electrical conversion using 30 J with the BeeAT™ catheter was performed in order to recover sinus rhythm. The LA was reconstructed by an EnSite™ system using the HDM catheter. Then, a conventional circumferential PVAI and LA posterior wall (LAPW) isolation (LAPWI) was performed using an open irrigated ablation TactiCath SETM irrigation catheter (Abbott) through a steerable introducer with electroanatomic guidance using a 3D mapping system under the administration of isoproterenol (10–20 μg/h). The generator was set to a maximal temperature of 45°C, maximum power of 35 W, with at least 10 g via contact force assessment, and an irrigation rate of 13 ml/min. When ablating the posterior wall in front of the esophagus, a maximum power of 50 W for short duration of a maximum 5 s was used to avoid any esophageal damage, and when the temperature exceeded 40°C, the energy supply was discontinued. Each application of radiofrequency energy was delivered for about 30–180 s while dragging, with a goal of a ≥70% decrease in the electrogram amplitude at the local site. When AF persisted after the PVAI and LAPW, intracardiac electrical conversion with the BeeAT™ catheter was performed in order to recover sinus rhythm.

Definition of the Establishment of Complete Conventional PVAI Lines
Entrance block was defined as the abrupt loss of all near-field PV activity during encirclement or the absence of any luminal PV activity elicited during sinus rhythm or by LA pacing. Exit block was determined by PV capture with the absence of any LA conduction when the ablation catheter was placed on and just inside (<5 mm) the conventional PVAI lines, and pacing from the tip of ablation catheter was performed along the conventional PVAI lines with an output of 5–10 V. If conduction to the LA was noted, the pacing output was decreased until there was local PV capture without any conduction to the LA or no PV capture was noted to assess the far-field capture in both upper PVs.7 In addition, during the assessment of the PV to LA conduction (exit block), local capture was assessed by an ablation catheter placed in the atrium or left atrial appendage.8 If no PV capture or conduction to the LA was noted, the pacing output was increased to 10–20 V. If the LA was excitable at this output, conduction gaps were suspected and additional radiofrequency energy was delivered until the loss of pacing capture was obtained, the so-called pace and ablate technique.9 Moreover, the PVAI and LAPW lines were reevaluated in detail with the EnSite™ system using the HDM catheter to detect concealed low-voltage signals (CLVs)2 and propagation within the antral scar. If there were any RPs (±0.1 mV) and/or CLVs, additional radiofrequency energy was delivered until abolishment of those potentials.

Definition of ECs
The ECs were defined as the existence of RPs during sinus rhythm or atrial pacing (earliest activation sites), and AF within the encircled PV regions, which were located at a distance exceeding at least 5 mm from complete conventional PVAI lines (Figure 1A,B,F,H).8,11

Evaluation of ECs Inside the Conventional PVAI Lines
After completion of the conventional PVAI, during sinus rhythm or CS pacing, the conduction from the atrium to the RPs inside the conventional PVAI lines (entrance conduction) was detected in detail using the HDM catheter with the EnSite™ system. If any RPs were detected (Figure 1A,B,F,H), 5–10 V pacing from the ablation catheter on the RPs was performed in order to confirm where the RPs connected to the atrium (ECs) (exit conduction), such as the coronary sinus (CS) (Figure 1C,J), high right atrium (HRA) (Figure 1G,K), and His-bundle (His) (Figure 11L). When AF continued even after cardioversion was performed and the sites where the ECs originated from could not be confirmed, it was defined as unknown. When there were RPs in the PVs, but pacing could not capture them and they could not be conducted to the atrium (unidirectional conduction from the atrium to the PV),11 it was defined as none. Then, radiofrequency energy was delivered until non-capture by pacing at 5–10 V from the ablation catheter occurred (Figure 1D). To avoid any PV stenosis, the radiofrequency energy delivery was with a low power (20–25 W) and at a short duration (5–10 s). Further, to avoid any phrenic nerve palsy, non-capture of
Figure 1. Left lateral view of an EnSite™ activation map (A). The green area in the left superior (LS) pulmonary vein (PV) is the remaining potentials (RPs) (white arrow) during sinus rhythm after archiving the completion of the PV antrum isolation (PVAI) lines. The intra-cardiac electrocardiograms (B–E) for case A. The Advisor™ HD Grid catheter could detect the RPs when it was positioned on those RPs (white arrows in B). Pacing with the ablation catheter could capture them, and the earliest activation site in the atrium was a distal site in the coronary sinus (CS) (white arrows in C). A radiofrequency energy delivery steadily caused a loss of capture during pacing by the ablation catheter (white arrows in D) and abolished the RPs in the LSPV (yellow arrows in E). The frontal view of the EnSite™ voltage map is shown in parts (F) and (H). The colored areas in the LSPV and right superior (RS) PV are the RPs during sinus rhythm after archiving the completion of the PVAI lines. The intra-cardiac electrocardiograms (parts (G) and (I)) are for cases (F) and (H), respectively. Pacing with the ablation catheter could capture RPs, and the earliest activation sites in the atrium were in the high right atrium (HRA) and at the His-bundle (His), respectively (white arrows in G, I). The EnSite™ activation maps (J–L) during LSPV (J), RSPV (K), and RIPV (L) pacing. The earliest activation site was near the coronary sinus (white arrows in J), HRA (white arrows in K), and His (white arrows in L). ABL, ablation catheter; IVC, inferior vena cava; LA, left atrium; LCPV, left common pulmonary vein; LIPV, left inferior pulmonary vein; MA, mitral annulus; RIPV, right inferior pulmonary vein; SVC, superior vena cava.
Complications and Adverse Events Associated With the Procedures

The complications associated with the procedures, including any new PV stenosis, phrenic nerve palsy, cerebrovascular accidents, death, cardiac tamponade, pericardial effusions, vascular complications, or any bleeding, during or after the procedures were evaluated.

Patient Care and Follow up

After the procedure, anticoagulation therapy was continued for at least 3 months after the RFCA. All patients received monthly follow up for at least 12 months after the RFCA. The anti-arrhythmic agents were withdrawn in all patients 3 months after the RFCA. The proportion of the AF-free rates was evaluated during a mean follow-up period of $14.0 \pm 7.3$-months. Documented episodes of AF, atrial flutter, and atrial tachycardia, of >30 s by 12-lead electrocardiography, 24-h Holter monitoring, and/or ambulatory portable electrocardiography after the 3-month blanking period were identified as recurrences. If AF recurred after the 3-month blanking period, the anti-arrhythmic agent(s) was re-started and a repeat RFCA to treat the AF was considered.

Statistical Analysis

The numerical results are expressed as the mean±standard deviation. Paired data were compared by using a Fisher’s exact test and a Student’s t-test or the Wilcoxon signed-rank test. The trend in the proportions and correlation between the prevalence of ECs and types of AF or LAV was determined by using Cochran–Armitage analysis.
Comparisons among the 3 different types of AF were performed using the chi-squared test for categorical variables and a one-way analysis of variance for continuous variables. A multivariate logistic regression analysis was carried out to evaluate the association between the prevalence of ECs and those factors. The sensitivity and specificity of the presence of ECs associated with the B-type natriuretic peptide (BNP) level and LA volume (LAV) were evaluated by using receiver-operating characteristic (ROC) curve analysis. The proportion of AF-free patients was determined using Kaplan-Meier analysis with a log-rank test. All analyses were performed with SAS version 9.2 software (SAS Institute, Cary, NC, USA). A P value of <0.05 was considered to indicate statistical significance.

### Results

#### Patient Characteristics

The baseline characteristics of all 300 patients (178 males and 122 females with a mean age of 73.5±9.6 years, body mass index [BMI] of 22.9±3.4 kg/m², and body surface area [BSA] of 1.69±0.21 m²) are shown in Table 1. There were statistically significant differences in the male sex, BNP level, LVEF, LAD, LAV, and prevalence of the internal use of amiodarone, mineralocorticoid-receptor antagonists, and diuretics, among the types of AF.

#### ECs Between the PV or LAPW and the Atrium

When a conventional PVAI was performed, the rate of a first pass isolation was ~90% in this study. After the conventional PVAI, the validated HDM of the PVs and LA consisted of ~1,000 points on average. There was a total of 61 ECs in the PVs of 34 (11%) patients (Figure 2B). Fifteen (25%) out of 61 ECs in PVs with RPs (ECs) could be detected only by the HDM catheter, but not by the conventional CMC. Because all 61 RPs were at least 5 mm away from the antral PVAI line, gap conduction was unlikely. Interestingly, in 3 (5%) out of the 61 ECs in the PVs, there were RPs in the PVs, but pacing could not capture them, and they could not conduct to the atrium. Spontaneous PV activity with exit block was documented in 89 (30%) patients. More interestingly, spontaneous activity originating from EC was confirmed in 1 patient. There were statistically significant differences in the prevalence of patients with ECs (8% vs. 13% vs. 19%; P<0.001) (Figure 3A) and the number of ECs per patient (1.11±0.33 vs. 2.08±0.51 vs. 2.33±1.03; P<0.001) (Figure 3B) between the PVs and

### Table 1. Baseline Patient Characteristics

<table>
<thead>
<tr>
<th>Type of atrial fibrillation</th>
<th>Paroxysmal (n=150)</th>
<th>Persistent (n=113)</th>
<th>Long-lasting (n=37)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>81 (54)</td>
<td>69 (61)</td>
<td>28 (76)</td>
<td>0.031</td>
</tr>
<tr>
<td>Age (years)</td>
<td>73.4±9.8</td>
<td>73.7±10.0</td>
<td>71.9±8.6</td>
<td>0.571</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.2±3.5</td>
<td>22.8±3.3</td>
<td>23.1±3.8</td>
<td>0.940</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.66±0.22</td>
<td>1.70±0.20</td>
<td>1.76±0.21</td>
<td>0.070</td>
</tr>
<tr>
<td>CHADS2 score</td>
<td>2.61±1.04</td>
<td>2.75±1.30</td>
<td>3.03±1.24</td>
<td>0.195</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>7 (5)</td>
<td>2 (2)</td>
<td>0 (0)</td>
<td>0.571</td>
</tr>
</tbody>
</table>

Data are presented as mean±standard deviation or n (%). ACE, angiotensin-converting enzyme; VKA, vitamin K antagonist; NOAC, non-vitamin K antagonist oral anticoagulant.
The patients were divided into 4 groups (<100 mL [n=120], 100 ≤ <150 mL [n=119], 150 ≤ <200 mL [n=49], and 200 mL ≤ [n=12]) according to the LAV. The prevalence of patients with ECs between the PVs and atrium (7% vs. 10% vs. 33%; P<0.001) (Figure 3C) and number of ECs per patient between the PVs and atrium (1.40 ± 0.55 vs. 1.50 ± 0.53 vs. 2.00 ± 0.71 vs. 3.00 ± 1.00; P<0.001) (Figure 3D), became significantly greater, respectively, in accordance with the progression of the LAV enlargement from <100 mL to 200 mL ≤.

**Characteristics of Patients With ECs**
The baseline characteristics of the patients with (EC group) or without (Control group) ECs are shown in Table 2. There were statistically significant differences in the prevalence of pAF (29% vs. 53%; P=0.011) and LLAF (24% vs. 11%; P=0.035) and the BNP level (327±672 vs. 141±156 pg/mL; P<0.001), serum creatinine level (1.54±1.64 vs. 1.07±1.04 mg/dL; P=0.002), LAD (46.4±6.7 vs. 42.5±6.6 mm; P=0.002), and LAV (144.1±46.0 vs. 115.3±37.5 mL; P<0.001), among the 2 groups. There were no statistical differences in the prevalence of the internal use of medications on admission (data not shown).
ECs in Patients With AF

were 0.754 and 0.556, and 0.681 and 0.704, respectively, for a BNP level of 176.6 pg/mL and a LAV of 129.0 mL.

Complications and Adverse Events Associated With the Procedures
There were 3, 2, and 2 patients with a cardiac tamponade (1.0%), esophagogastric functional disorder (0.7%), and bleeding needing a transfusion (0.7%), respectively, after the procedure. There were no adverse events during the follow-up period.

Proportion of an AF-Free Rate
The Kaplan-Meier analysis with a log-rank test revealed that the proportion of an AF-free rate was 87%, 79%, and 68%, for pAF, persAF, and LLAF (Figure 4A), and 76%

RFCA of ECs
All ECs were completely ablated by RFCA inside the PVs. The mean frequency and duration of the RFCA of the ECs were 3.0±0.8 and 49±24s, respectively.

Independent Risk Factors for the Presence of ECs in Patients With AF
Using a logistic regression analysis, the independent predictors of ECs were determined. A multivariate analysis of all the significant single variable factors of ECs was performed (Table 3). As a result, the BNP level (OR=1.13, P=0.045) and LAV (OR=1.22, P=0.029) were found to be independent risk factors of ECs.

An ROC curve analysis of the BNP level (Figure 3E) and LAV (Figure 3F) revealed that the specificity and sensitivity of the presence of ECs were 0.754 and 0.556, and 0.681 and 0.704, respectively, for a BNP level of 176.6 pg/mL and a LAV of 129.0 mL.

Complications and Adverse Events Associated With the Procedures
There were 3, 2, and 2 patients with a cardiac tamponade (1.0%), esophagogastric functional disorder (0.7%), and bleeding needing a transfusion (0.7%), respectively, after the procedure. There were no adverse events during the follow-up period.

Proportion of an AF-Free Rate
The Kaplan-Meier analysis with a log-rank test revealed that the proportion of an AF-free rate was 87%, 79%, and 68%, for pAF, persAF, and LLAF (Figure 4A), and 76%
and 82% in patients with or without ECs (Figure 4B), respectively, during the 12-month follow-up period, as the initial 3-month blanking period was excluded. There were no statistical differences among the groups (P=0.119 and P=0.221), respectively.

The Redo Procedures
The number of recurrences of AF in the patients was 19, 24, and 12 in those with pAF, persAF, and LLAF, and 8 or 47 in those with or without ECs, respectively. A second session of RFCA for AF was performed in 19, 24, and 9 patients with pAF, persAF, and LLAF, and 8 or 44 patients with or without ECs, respectively. The PV reconnections were more likely to occur in patients with ECs (88%) than in those without (70%), but this was not significant (P=0.319). Three patients with LLAF did not want to undergo a redo procedure and continued on anti-coagulation and heart rate control therapy. PV stenosis was not observed in any patients who underwent redo procedures.

Discussion
Patient Characteristics
Kitakyushu city, where our hospital exists, is the city that has aged the most among the ordinance-designated cities of Japan. Thus, the mean age, BMI, and BSA of all patients in this study were comparably older, lower, and smaller, respectively. The BNP value, LAD by echocardiography, LAV by CT, and prevalence of the internal use of amiodarone, mineralocorticoid-receptor antagonists, and diuretics, or the LVEF value by echocardiography and internal use of bepridil, became significantly greater or smaller in accordance with the progression of AF from paroxysmal to long-lasting. These findings indicated that heart failure progressed in accordance with the progression of AF from paroxysmal to long-lasting.

Completion of the Conventional PVAI
In order to achieve a high procedural success rate, we tried to pay attention to the 4 points described below. (1) To gain strong support, a steerable introducer was routinely used. (2) To obtain a stable lesion creation and abolish the CLVSs and ECs, an open irrigated ablation TactiCath SETM irrigation catheter with at least 10 g via contact force assessment was routinely used. (3) To detect more precise CLVSs and to identify the breakthrough region of the LA and PV conduction, electro-anatomical mapping was performed in detail using a HDM catheter on the PVAI lines.
and inside the PVs. (4) To complete the conventional PVAI lines, the conduction gaps, including CLVSs, were suspected and additional radiofrequency energy was delivered until the loss of pacing capture was obtained using the pace and ablate technique, because previous reports have demonstrated that ablation of CLVSs and ablation using the pace and ablate technique on the ablation lines could improve the freedom from AF. Spontaneous PV activity with exit block, which is a criterion for exit block from the PV to the atrium, was documented in 89 (30%) patients. However, unfortunately, unidirectional PV to LA conduction during spontaneous activity was not observed in our study, because our observation time after the completion of the conventional PVAI was comparably shorter than that of a previous report.

**Association Among the ECs, Type of AF, and LAV**

In this study, 34 (11%) out of 300 patients had ECs in the PVs. Thus, ablation using only the conventional PVAI lines may not complete the PVAI, and additional ablation of the ECs inside the PVAI lines may be able to complete the PVAI. The prevalence of patients with ECs (Figure 3A,C) and the number of ECs per patient between the PVs and the atrium (Figure 3B,D) correlated with the progression of AF from paroxysmal to long-lasting (Figure 3A,B) or the progression of an LAV enlargement from <100 mL to 200 mL ≤ (Figure 3C,D), respectively. Further, in accordance with the progression of AF from paroxysmal to long-lasting, the LAV increased (Table 1). Moreover, it has been reported that an LAV enlargement is strongly associated with the initiation, maintenance, and recurrence of AF. Thus, despite their shared common risk factors, AF progression from paroxysmal to persistent/long-lasting AF, the presence of ECs, and an enlargement of the LAV subtypes may exacerbate each other and create a vicious triangle of those 3 factors.

**RFCA of ECs**

In this study, all ECs were completely ablated by RFCA inside the PVs with a low power (20–25 W) and short duration (5–10 s). In contrast, we could not completely ablate ECs at the breakout sites of the ECs. These findings indicated that RFCA of ECs inside the PVs might be more effective than at the breakout sites of ECs. However, a recent report demonstrated that RFCA of ECs at the breakout site in the RA could successfully complete the isolation of the right-sided PVs. Thus, if a PVAI by RFCA of ECs inside PVs is not effective, RFCA of ECs at the breakout site in the atrium should be considered.

**Mechanism(s) of the Expression of the ECs**

This study could not reveal the mechanism(s) of the expression of the ECs or whether the ECs increased in accordance with the progression of AF from paroxysmal to long-lasting and an LAV enlargement, or whether the patients who had ECs inherently had an easy progression from paroxysmal to LLAF and an enlargement of the LAV. A previous report demonstrated that there were gaps located on the PV antra by mapping the atrial side of the conventional PVAI lines during pacing from inside the PVs; this is the pace and map maneuver. This finding allowed the localization of the atrial breakthrough sites on the ablation line, indicating an epicardial structure jumping from the PVs into the atrium. Further, our study demonstrated that the ECs were located in the distal PVs and were located distal to the first branching (Figures 1A,F,H,2B). These findings indicated that HDM inside the PV, including sites far distal to the PVAI lines, may be an important strategy to find ECs and complete the PVAI. Moreover, the ECs were mainly located on the carina of the left and right PVs. A previous study also demonstrated that the non-isolation of the PV carinas after a successful PVAI may be an independent predictor of a recurrence of AF. These findings indicated that the ECs may play an important role in the recurrence of AF because the ECs were mainly located on the carina (Figure 2B). Because balloon ablation can easily perform a carina ablation, a balloon ablation may be a more effective strategy for the PVAI than RFCA in patients with ECs. Further, a previous report revealed that connections located on the LAPW might be associated with the septopulmonary bundle, supporting our finding of the location of ECs on the LAPW. Finally, a recent comprehensive study and case report demonstrated that ECs involving the left-sided PVs were associated with not only the LA, but also the CS or Marshall bundle. The findings in those reports may support our findings that the rate of conduction of ECs from the left PV was also dominant in the CS. Those ECs were assumed to travel along the epicardium; however, this study could not reveal where the ECs traveled along.

**Proportion of an AF-Free Rate and the Clinical Implications of ECs**

The proportion of an AF-free rate for LLAF seemed to be high (Figure 4A). RFCA of ECs in addition to the conventional PVAI might improve the proportion of an AF-free rate for LLAF (Figure 4A) because the patients with LLAF had a higher prevalence of ECs (Table 2, Figure 3A,B). Moreover, 25% of the ECs could be detected only by a HDM catheter, but not by a conventional CMC. Thus, the detection and treatment of ECs using a HDM catheter may be one of the most effective strategies to successfully complete the PVAI in patients with AF. However, as the number of patients in the EC group was very low (n=34), further randomized clinical trials including a larger number of patients with ECs to make a comparison between the treated and untreated patients with ECs will be needed to clarify the clinical implications of the ECs in the future.

**Study Limitations**

This study had a prospective design and was a single-center trial, but not a randomized clinical trial. Further, it was limited by its relatively low number of patients. Because of the short follow-up period, our study still could not demonstrate the long-term clinical benefits of the ablation of ECs, and adverse effects including PV stenosis. The mean patient age in this study of 73.5±9.6 years was comparably older to other studies. Whether our results can safely be extrapolated to include a larger number of younger patients and a longer follow-up period for those patients by a randomized clinical trial should be determined in further studies. Additionally, whole LA and/or RA mapping with an HDM catheter during PV pacing should be performed in all patients who have ECs in the PVs to determine the exact breakout sites of the ECs.

**Conclusions**

About 11% of all patients with AF in this study had ECs inside the conventional PVAI lines including those sites far
distal to the PVAI lines. Thus, ablation with only a conventional PVAI may not complete the PVAI, and additional ablation of the ECs detected by HDM may be able to achieve the completion of the PVAI as compared to a traditional CMC-guided PVAI, especially in patients with advanced AF such as persAF and LLAF and/or those with LAV enlargement. Finally, a BNP level of ≥17.6 pg/mL and a LAV of ≥129.0 mL may be one of the important predictors of the presence of ECs in patients with AF who underwent RFCA of AF.

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Disclosures
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IRB Information
The present study was approved by the institutional review committee and ethics review board of our hospital, the Ethical Review Board of Steel Memorial Yawata Hospital (reference number: 20-54).

Data Availability
The deidentified participant data will not be shared.

References