Higher Pulmonary Arterial Pressure Was Related to Non-Pulmonary Vein Atrial Tachyarrhythmia

Wei-Chieh Lee, MD, Masaya Watanabe, MD, Hisashi Yokoshiki, MD, Taro Temma, MD, Rui Kamada, MD, Hikaru Hagiwara, MD, Yumi Takahashi, MD, Taro Koya, MD, Motoki Nakao, MD and Toshihisa Anzai, MD

Summary

Recurrence of atrial tachyarrhythmias (ATA) following catheter ablation for atrial fibrillation (AF) is often associated with the recovery of conduction into previously isolated pulmonary veins (PVs). Little evidence concerning repeat PV isolation (PVI) and non-PV ATA ablation has been reported. This study aimed to explore the clinical outcome of recurrent ATA ablation after PVI and the difference between patients with and without non-PV ATA.

A total of 49 patients without structural heart diseases who received catheter ablation for recurrent AF between January 2014 and December 2018 were recruited (prior ablation with PVI only 71.4% and PVI with cavo-tricuspid isthmus line ablation 28.6%). Patients were divided into two groups according to the presence or absence of non-PV ATA.

Most patients (53.1%) experienced very late recurrence with a median duration of 15 months. A total of 15 patients had non-PV ATA and received non-PV ATA ablation whereas 34 patients received only repeat PVI for reconnected PVs. A higher pulmonary arterial systolic pressure (PASP) was associated with non-PV ATA (odds ratio: 1.161; 95% confidence interval: 1.021-1.321; \( P = 0.023 \)). During 4.7 ± 1 months, 4/15 (26.7%) and 1/34 (2.9%) patients with and without non-PV ATA, respectively, had ATA recurrence (\( P = 0.011 \)). The cumulative incidence of ATA recurrence after repeat ablation was significantly lower in patients without non-PV ATA (\( P = 0.013 \)).

In our study, a high PASP was associated with non-PV ATA in patients with recurrent AF. Repeat PVI had a high rate of maintenance of sinus rhythm in patients without non-PV ATA.

Key words: Atrial fibrillation, Recurrence, Atrial tachycardia, Pulmonary vein isolation, Catheter ablation

Atrial fibrillation (AF) is the most common arrhythmia and radiofrequency catheter ablation (RFCA) has become widely used for symptomatic AF patients. The current Heart Rhythm Society/European Heart Rhythm Society Expert Consensus statement prescribes pulmonary vein isolation (PVI) as the primary strategy of RFCA for AF.1 In patients with paroxysmal AF, single procedure success rates of 60-80% for PVI by RFCA have been reported.2 However, AF recurrence after RFCA is a common clinical problem regardless of the type of AF.2 According to several studies, AF recurrence rates after initial ablation procedures range from 40% to 70% and most patients require a repeat ablation procedure to achieve sinus rhythm during long-term follow-up.1-3 In addition, many studies also reported that PV reconnection is still the biggest problem of recurrent atrial tachyarrhythmia (ATA) after the first PVI.4,5 However, with the development of the irrigated-tip catheter and contact-force catheter, PV reconnection may decrease during repeat ablation procedures. In fact, it is well known that the incidence of PV reconnection in redo procedures after a first PVI has decreased, and recently, AF recurrence with 4 PVs isolated has raised as a new problem.6 Currently, no standard strategies have been reported for AF from non-PV origins after the first PVI.7,8 In recent studies, ablation for non-PV targets improved the outcome of paroxysmal AF ablation when non-PV foci are detected and...
eliminated, especially in patients with a low left ventricular ejection fraction (LVEF). Therefore, it is necessary to focus on the importance of recurrent ATA from non-PV origins.

The aim of this study was to explore the difference between patients with and without non-PV ATA after initial PVI ablation and their associated outcomes after repeat ablation.

**Methods**

**Patient population:** A total of 49 patients who received RFCA for recurrent AF after their first PVI ablation at Hokkaido University Hospital between January 2014 and December 2018 were recruited for this study. None of the study patients received extensive ablation procedures and prior non-PV ATA ablation except for cavotricuspid isthmus (CTI) line ablation. We excluded patients with severe lung disease and structural heart disease, including prior valvular surgery, prior percutaneous transvenous mitral commissurotomy or hypertrophic cardiomyopathy. Patients were divided into two groups according to the presence or absence of non-PV ATA (Figure 1). Fifteen patients with non-PV ATA were classified into group A and 34 patients without non-PV ATA were classified into group B.

General demographics, duration and the rhythm of the recurrent AF, the rhythm of the first AF ablation, associated comorbidities, CHA2DS2-VASc score, left atrial (LA) volume, LVEF, estimated pulmonary arterial systolic pressure (PASP), and incidence of early-onset and late-onset ATA recurrence were compared between the two groups. This study conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved for human research by the Institutional Review Board of Hokkaido University Hospital.

**Echocardiography:** Echocardiography was performed within one month before RFCA in all the study patients. Echocardiographic parameters, including LVEF and LA volume, LV mass, and estimated PASP were measured using a GE Vivid 9 or Philips IE33. LA volume and LA index were quantified using the biplane area-length method. LV mass and LV mass indexed to body surface area were estimated by LV cavity dimension and wall thickness at end-diastole. LVEF and LV volume were quantified by the M-mode and corrected by the 2-dimensional guided biplane Simpson’s method of disc measurements by echocardiography. PASP was estimated from the tricuspid regurgitant jet velocity using the modified Bernoulli equation and adding the estimated right atrial pressure based on the diameter and collapsibility of the inferior vena cava.

**Electrophysiologic study and procedural management:** Anti-arrhythmic drugs (AADs) were usually discontinued at least 5 half-lives before RFCA except for amiodarone, which was continued during the procedures. Transesophageal echocardiography was performed to exclude the presence of LA thrombi. Exclusion of LA thrombi using multislice computed tomography (CT) with sufficient image quality was accepted only in the cases with paroxysmal AF who were admitted in sinus rhythm. Each patient provided written informed consent to undergo electrophysiologic study and ablation procedures. The procedure was performed under deep sedation using a continuous infusion of propofol and non-invasive ventilation support. Venous accesses were obtained from the bilateral femoral veins and the left subclavian vein. A bolus injecc-
Ablation procedure: The ablation strategy for all patients was to first confirm PV isolation with the guidance of an electroanatomic mapping system (CARTO 3, Biosensor Webster, Diamond Bar, CA, USA). For PVs reconnected with LA, RFCA was performed targeting the earliest activation of PV potentials. RF current applications were delivered with a 3.5-mm tip irrigated catheter Navistar ThermoCool SmartTouch or STSF catheter, Biosensor Webster at 20-25 W for the posterior and at 25-30 W for the anterior aspects of the PV antrum. Proof of an electrical PV entrance block at any of the 4 PVs was confirmed using circumferential mapping catheters. The endpoint of PVI was a bidirectional conduction block between the LA and the PVs.

After confirmation of PVI (Figure 1), we mapped non-PV ATA. In cases where stable atrial tachycardia was sustained, an activation map was constructed to define the nature of AT using the electroanatomic mapping system. For targeting the ectopic initiating AF, mapping was performed typically by positioning 2 circular mapping catheters in both sides of the superior PVs, the ablation catheter in the LA posterior wall, and the decapolar catheter in CS. Electroanatomic mapping was also used for the further mapping of the earliest site of the triggers. Finally, if no spontaneous triggers were observed, isoproterenol was administered as a continuous infusion beginning with a dose of 1 μg/minute, which was increased at a rate of 1 μg/minute every 5 minutes until reaching an increase in baseline sinus rhythm higher than 30%, or a maximum dose of 4 μg/min, or the induction of ectopia, or the appearance of side effects. Any solitary ectopic beat that did not initiate AF was not targeted.

Additional linear ablation at the LA was performed for a macroreentrant flutter, or bow-shaped linear ablation by creating roof and floor lines for ectopic beats from the LA, whereas superior vena cava (SVC) isolation was performed for ectopic beats from the SVC. Ablation of the cavo-tricuspid isthmus (CTI) block was performed for induced CTI-dependent atrial flutter and complete bidirectional conduction block with double potentials divided by more than 120 msec across the CTI was confirmed.

Follow-up: After the procedure, patients were followed up in the clinic at 1 month and every 3 months thereafter. Patients underwent an electrocardiographic examination at each follow-up. A 24-hour Holter monitor examination was performed when a patient displayed recurrent symptoms. At 3 months of follow-up, we withdrew the AADs if the patient was free of symptoms.

Definition: ATA included AF, atrial flutter (typical and atypical) and atrial tachycardia. Non-PV ATA typically arises from discrete anatomical structures including the mitral and tricuspid periannular regions, the crista terminals and Eustachian ridge, the interatrial septum, the LA (posterior wall or anterior wall), the LA appendage, and other thoracic veins such as the superior vena cava, the coronary sinus, and the ligament of Marshall. Early-onset recurrence of ATA was defined as recurrence occurring during the first 3 months after the AF ablation procedure, and late-onset recurrence of ATA was defined as recurrence occurring from 4-12 months after the AF ablation procedure.

Study endpoints: The study endpoints were early-onset or late-onset ATA recurrence.

Statistical analysis: Data are presented as percentages and the median with the interquartile range. Clinical characteristics between the study groups were compared by the t-test or Mann-Whitney U test for continuous variables, and the chi-squared test or Fisher’s exact test for categorical variables. Univariate logistic regression analyses were performed to identify associations with non-PV ATA and were expressed as odds ratios (ORs) and 95% confidence intervals (CIs). A Kaplan-Meier curve was performed with log-rank test for late-onset ATA recurrence in non-PV ATA and without non-PV ATA groups during the 1-year follow-up period. Receiver operating characteristic (ROC) curves were used to determine the optimal values for associations between PASP and non-PV triggers in terms of sensitivity and specificity. Statistical analysis was performed using statistical software (SPSS for Windows, version 22). A two-sided p value of 0.05 was considered to indicate statistical significance.

Results

Baseline characteristics of the study patients: The baseline characteristics of the study participants are listed in Table I. The median age was 68 years old and 32.7% of the patients were female. Most patients experienced very late recurrence (53.1%) and the mean recurrent duration was 15 months. The most prevalent recurrent rhythm was paroxysmal AF (85.7%).

In group A, there was a higher prevalence of females (group A versus group B; 53.3% versus 23.5%; P = 0.040). A higher prevalence of paroxysmal AF was noted in group B (group A versus group B; 53.3% versus 82.4%; P = 0.034). The duration of recurrence, the prevalence of comorbidities, and the CHA2DS2-V AS score showed no significant differences between the two groups.

When echocardiographic parameters were compared, a higher PASP was noted in group A (group A versus group B; 33.0 (29.0-38.7) mmHg versus 26.5 (24.4-28.6) mmHg; P = 0.001). The level of brain natriuretic peptide (BNP) (normal range: 0-18.4 pg/mL) was higher in group A (group A versus group B; 80.9 (54.1-276.9) pg/mL versus 44.6 (31.0-60.3) pg/mL; P = 0.009). Prior and present CTI ablation and the incidence of early-onset ATA recurrences showed no statistical differences between the two groups. The incidence of late-onset ATA recurrence was higher in group A (group A versus group B; 26.7% versus 2.9%; P = 0.011), the majority of which were AF (3/4 in group A and 1/1 in group B).

Associated data of reconnected PV and non-PV ATA: The number of reconnected PV and the sites of non-PV ATA are listed in Table II. There was a significant differ-
ence in the number of reconnected PV between the two groups (group A versus group B; 0 (0-1) versus 3 (2-4); P < 0.001). The percentage of CTI ablation was similar between the two groups. In group A, non-PV foci were the mitral isthmus (1), LA septum (2), LA anterior wall (2), LA posterior wall (4), LA roof (3), superior vena cava (2), tricuspid perianular region (1), crista terminalis of the right atrium (2), and cavotricuspid isthmus (1). Three patients had multiple non-PV ATAs.

**Predictors of non-PV ATA:** In univariate logistic regression analysis, female sex (OR: 3.714; CI: 1.025-13.456; P = 0.046), prior persistent or long-standing AF (OR: 4.083; CI: 1.065-15.657; P = 0.040), and PASP (OR: 1.180; CI: 1.049-1.328; P = 0.006) showed significant associations.

### Table I. Baseline Characteristics and Clinical Outcomes of Study Patients

| Parameter                                      | All (n = 49) | Group A (n = 15) | Group B (n = 34) | P value  |
|------------------------------------------------|-------------|-----------------|-----------------|----------|
| **General demographics**                        |             |                 |                 |          |
| Age (years)                                    | 68 (66-71)  | 71 (65-75)      | 68 (65-71)      | 0.411    |
| Female sex (%)                                 | 16 (32.7)   | 8 (53.3)        | 8 (23.5)        | 0.040    |
| BMI (kg/m²)                                    | 25.3 (24.0-26.9) | 26.5 (23.6-27.6) | 25.2 (23.7-27.0) | 0.917    |
| **Comorbidities**                              |             |                 |                 |          |
| Hypertension (%)                               | 34 (69.4)   | 13 (86.7)       | 21 (61.8)       | 0.081    |
| Diabetes mellitus (%)                          | 12 (24.5)   | 6 (40.0)        | 6 (17.6)        | 0.148    |
| Heart failure (%)                              | 8 (16.3)    | 2 (13.3)        | 6 (17.6)        | 0.707    |
| Prior stroke (%)                               | 10 (20.4)   | 3 (20.0)        | 7 (20.6)        | 0.962    |
| Vascular disease (%)                           | 6 (12.2)    | 2 (13.3)        | 4 (11.8)        | 0.877    |
| Thyroid disease (%)                            | 3 (6.1)     | 2 (5.9)         | 1 (6.7)         | 0.916    |
| Sick sinus syndrome (%)                        | 13 (26.5)   | 5 (33.3)        | 8 (23.5)        | 0.474    |
| Chronic obstructive lung disease and fibrotic lung disease (%) | 2 (4.1) | 0 (0)          | 2 (5.9)         | 0.338    |
| **Atrial fibrillation type at the time of first procedure** |             |                 |                 |          |
| Paroxysmal atrial fibrillation (%)             | 36 (73.5)   | 8 (53.3)        | 28 (82.4)       | 0.304    |
| Persistent atrial fibrillation (%)             | 13 (26.5)   | 7 (46.7)        | 6 (16.7)        | 0.015    |
| Prior ablation procedure                       |             |                 |                 |          |
| PVI (%)                                        | 49 (100)    | 15 (100)        | 34 (100)        | -        |
| CTI (%)                                        | 14 (28.6)   | 5 (33.3)        | 9 (26.5)        | 0.735    |
| Duration of recurrence (months)                | 15 (10-18)  | 14 (5-22)       | 15 (10-20)      | 0.716    |
| **Type of recurrence**                         |             |                 |                 |          |
| Late recurrence (%)                            | 23 (46.9)   | 7 (46.7)        | 16 (47.1)       | 0.980    |
| Very later recurrence (%)                      | 26 (53.1)   | 8 (53.3)        | 18 (52.9)       | 0.980    |
| **Recurrent rhythm**                           |             |                 |                 |          |
| Paroxysmal atrial fibrillation (%)             | 42 (85.7)   | 12 (80.0)       | 30 (88.2)       | 0.448    |
| Persistent atrial fibrillation (%)             | 7 (14.3)    | 3 (20.0)        | 4 (11.8)        | 0.448    |
| **Other atrial tachyarrhythmias**              |             |                 |                 |          |
| Atrial tachycardia (%)                         | 12 (24.5)   | 6 (40.0)        | 6 (17.6)        | 0.094    |
| Atrial flutter (%)                             | 8 (16.3)    | 5 (14.7)        | 3 (20.0)        | 0.644    |
| Prior or present complete CTI ablation (%)     | 19 (38.8)   | 7 (46.7)        | 12 (35.3)       | 0.451    |
| CHADS2-VASc score                              | 3 (2-3)     | 3 (3-5)         | 2 (2-3)         | 0.194    |
| **Parameters of echocardiography**             |             |                 |                 |          |
| LA volume (mL)                                 | 80.0 (66.9-91.0) | 83.0 (65.3-100.7) | 80.0 (63.6-92.4) | 0.554    |
| LA volume index (mL/m²)                        | 46.9 (41.6-53.1) | 54.2 (40.4-60.0) | 43.0 (35.7-48.8) | 0.229    |
| LV mass (g)                                    | 150.0 (141.9-163.8) | 148.1 (117.2-183.8) | 151.8 (136.5-164.0) | 0.907    |
| LV mass index (g/m²)                           | 83.8 (80.1-91.6) | 88.2 (79.1-105.5) | 83.6 (79.9-91.9) | 0.569    |
| LVEDV (mL)                                     | 121.3 (99.8-140.2) | 123.2 (101.2-144.3) | 120.4 (99.5-138.6) | 0.761    |
| LVESV (mL)                                     | 48.0 (38.5-57.5) | 48.6 (41.5-59.8) | 47.5 (38.5-56.7) | 0.781    |
| LVEF (%)                                       | 61.0 (60.0-63.5) | 60.0 (56.3-67.0) | 61.5 (60.0-63.3) | 0.798    |
| PASP (mmHg)                                    | 29.0 (27.0-31.4) | 33.0 (29.0-38.7) | 26.5 (24.4-28.6) | 0.001    |
| PASP > 35 mmHg (%)                              | 11 (22.4)   | 6 (40.0)        | 5 (14.7)        | 0.050    |
| BNP (pg/mL)                                    | 51.8 (34.5-68.1) | 80.9 (54.1-276.9) | 44.6 (31.0-60.3) | 0.009    |

Data are expressed as the median (interquartile range) or as number (percentage). BMI indicates body mass index; PVI, pulmonary vein isolation; CTI, cavotricuspid isthmus; LA, left atrium; LVEDV, left ventricular end-diastolic volume; LVESV, left ventricular end-systolic volume; LV, left ventricle; LVEF, left ventricular ejection fraction; PASP, pulmonary arterial systolic pressure; BNP, brain natriuretic peptide; and AF, atrial fibrillation.
with non-PV ATA (Table III). Because of the limited number of the study patients, multivariate analysis was not performed.

**Receiver operating characteristic curves of PASP and non-PV ATA:** ROC curves of PASP and non-PV ATA were constructed, and they revealed that the cut-off point for PASP was 28.5 mmHg. This resulted in the best sensitivity (76.6%) and specificity (69.7%) for AF from non-PV ATA in the whole group. The area under this curve was 0.807 ($P < 0.001$).

**Event-free survival of late-onset ATA recurrence after repeat procedure:** There was a significant difference between the two groups (log-rank test $P = 0.013$) (Figure 2).

### Discussion

Three important findings of our study should be noted. First, non-PV ATA was found in 30.6% (15/49) of the patients who received repeat AF ablation after initial PVI ablation. Second, repeat PVI had a high rate of freedom from ATA recurrence (97.1%) at one-year follow-up concerning freedom of late-onset ATA recurrence in the without non-PV trigger group. Third, a high PASP was associated with non-PV ATA.

**Importance of non-PV ATA:** PVI is widely accepted as the cornerstone of the first AF ablation procedure regardless of AF type. However, even with the improvement of treatment expertise and technical equipment, approximately 30% of patients still need to undergo a repeat ablation procedure because of the recurrence of symptomatic ATA. PV reconnection is suggested to be the main cause of recurrent ATA after the first PVI. A non-PV ATA is defined as macroreentrant flutter or ectopic foci which derive from non-PV regions and has a confirmed pattern of spontaneous AF onset. A non-PV ATA was also related to AF recurrences. The non-PV regions may be related to the SVC, LA free wall, crista terminalis, CS ostium, ligament of Marshall, LA ap-

| Table II. Associated Data of Reconnected PV and Non-PV ATA |
|----------------------------------------------------------|
| **Group A** | **Group B** | **P value** |
| **Number of reconnected PV** | 0 (0-1) | 3 (2-4) | < 0.001 |
| **Site of reconnected PV** | | | |
| LSPV (%) | 2 (13.3) | 24 (70.6) | 0.008 |
| LIPP (%) | 1 (6.7) | 26 (76.5) | < 0.001 |
| RSPV (%) | 5 (33.3) | 27 (79.4) | 0.201 |
| RIPV (%) | 3 (20.0) | 24 (70.6) | 0.030 |
| CTI block ablation (%) | 2 (13.3) | 4 (11.8) | 1.000 |
| **Sites of Non-PV ATA** | | |
| LA | | |
| Mitral isthmus (%) | 1 (5.6) | 2 (1.1) | - |
| Septum (%) | 2 (11.1) | 2 (11.1) | - |
| Anterior wall (%) | 2 (22.2) | 3 (16.7) | - |
| Posterior wall (%) | | | |
| Roof (%) | 0 (0) | 1 (6.7) | - |
| CTI | | |
| Crista terminalis (%) | 2 (11.1) | 2 (11.1) | - |
| Tricuspid perianular region (%) | 1 (5.6) | 1 (0.6) | - |
| Cavo-tricuspid isthmus (%) | 1 (5.6) | | |
| SVC (%) | 2 (11.1) | | |

Data are expressed as the median (interquartile range) or as number (percentage). PV indicates pulmonary vein; ATA, atrial tachyarrhythmia; LSPV, left superior pulmonary vein; LIPP, left inferior pulmonary vein; RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein; CTI, cavo-tricuspid isthmus; LA, left atrium; RA, right atrium; and SVC, superior vena cava.

| Table III. Univariate Analyses of Predictors of Ectopic Beats from Non-PV Atrial Tachyarrhythmia |
|----------------------------------------------------------|
| **Variables** | **Odds ratio** | **95% CI** | **P value** |
| Age (years) | 1.036 | 0.953-1.127 | 0.403 |
| Female sex | 3.714 | 1.025-13.456 | 0.046 |
| Duration of recurrence | 0.997 | 0.991-1.002 | 0.251 |
| Prior persistent or long-standing AF | 4.083 | 1.065-15.657 | 0.040 |
| Hypertension | 4.024 | 0.779-20.775 | 0.096 |
| Diabetes mellitus | 3.111 | 0.800-12.099 | 0.101 |
| Heart failure with NYHA Class ≥ II | 0.718 | 0.127-4.051 | 0.707 |
| Prior stroke | 0.964 | 0.212-4.382 | 0.962 |
| Vascular disease | 1.154 | 0.187-7.106 | 0.877 |
| Sick sinus syndrome | 1.625 | 0.428-6.171 | 0.476 |
| CHADS2-VASc score | 1.272 | 0.885-1.829 | 0.193 |
| LA volume | 1.007 | 0.985-1.028 | 0.546 |
| LA volume index | 1.022 | 0.986-1.060 | 0.234 |
| LVEF (%) | 0.988 | 0.902-1.082 | 0.791 |
| PASP (per 1 mmHg) | 1.180 | 1.049-1.328 | 0.006 |
| BNP (per 10 pg/mL) | 1.009 | 0.998-1.021 | 0.118 |
| Prior or present complete CTI ablation | 1.604 | 0.467-5.512 | 0.453 |

PV indicates pulmonary vein; CI, confidence interval; AF, atrial fibrillation; NYHA, New York Heart Association; LA, left atrium; LVEF, left ventricular ejection fraction; PASP, pulmonary arterial systolic pressure; BNP, brain natriuretic peptide; and CTI, cavo-tricuspid isthmus.
pendage, interatrial septum, and right atrium.19,20) Another study also stated that very late recurrence ATA is mainly due to non-PV ATA, even when using an extensive PVI strategy.21) Therefore, non-PV ATA was related to an ongoing pathological process of atrial remodeling and non-paroxysmal AF.16,21,22) However, routine additional linear ablation has not been found to provide better outcomes for recurrent AF after PVI.23) On the other hand, not all patients with recurrent ATA need additional ablation other than PVI if no non-PV ATA were induced. Therefore, it is important to identify who has non-PV ATA and need non-PV ATA ablation.

Relation between high PASP and non-PV ATA: High PASP is a condition that is characterized by high pulmonary vascular pressure and is related to several disease processes. Prior studies reported that a cumulative incidence of 15.8 % of ATA over 6 years was found in patients with idiopathic pulmonary hypertension and the incidence was higher than the general population.24,25) In patients with mitral valve disease, LA dysfunction and enlargement are common, especially in association with AF.26) Indeed, AF plays a key role in reducing LA compliance and contributes to pulmonary vascular pressure because there is no active atrial emptying and thus the chamber is full when blood enters from the PVs.27) Elevated pulmonary vascular pressure that occurred after PVI ablation was reported to be related to developing LA diastolic dysfunction, high LA pressure, and severe LA scar.28,29) In our study, high PASP was related to the existence of non-PV ATA. The presence of non-PV ATAs and high PASP may be related to chronic disease processes including left heart disease, and LV diastolic dysfunction, and diseased substrate of LA, as well as continuous duration of AF. In our study, a higher BNP level and a higher prevalence of recurrent persistent AF were noted in the non-PV ATA group. Therefore, it is reasonable to suspect a relationship between non-PV ATA induced LA remodeling and high PASP after PVI. In our study, the average LVEF and LV volume and the duration of recurrence did not differ between the two groups. There was no significant difference concerning the median of PASP between the patients with non-PV ATA from LA or RA (LA versus RA; 34.6 ± 7.3 mmHg versus 35.4 ± 7.7 mmHg; \( P = 0.814 \)). Therefore, a further randomized study is needed for elevated PASP and recurrent ATA after PVI.

Outcome of repeat PVI in patients without non-PV ATA: In our study, all patients with recurrent AF received isoproterenol infusion to examine the possibilities of non-PV ATA after ablation for PV reconnection or repeat PVI. A poor outcome of recurrent AF was noted in patients with non-PV ATA. However, there was a high success rate (97.1 %) with repeat PVI if the patients did not have non-PV ATA. Currently, few randomized studies have been performed for mapped non-PV ATA ablation and recurrent AF ablation. Even though this is a retrospective study including data and a relatively small number of patients, the simple method of estimated PASP was provided to identify the possibility of recurrent AF from non-PV foci. In addition, we also provided a valuable finding regarding the high success rate of repeat PVI in patients without non-PV ATA.

Limitations: The first limitation was selection bias and we only included patients who received repeat RFCA due to AF recurrent, and did not include those for whom re-
peat ablation was not performed despite recurrence. The second limitation was this was a retrospective study with a relatively small number of patients from only a single center, which prevented us from performing multivariate analysis. The third limitation was not all patients received high-density voltage mapping of the LA and right atrium to define low-voltage areas of the atrium. The fourth limitation was that we used an indirect method to measure PASP by echocardiography.

Conclusions

In this retrospective observational study, a high PASP was slightly associated with non-PV ATA in patients with recurrent AF after ablation. Repeat PVI had a higher success rate in patients without non-PV ATA.

Disclosure

Conflicts of interest: All authors declare that they have no conflicts of interest.

Human rights statements and informed consent: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later revisions.

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