Particular Morphology of Inferior Pulmonary Veins and Difficulty of Cryoballoon Ablation in Patients With Paroxysmal Atrial Fibrillation

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Background: The CRYO-Japan PMS study indicated that cryoballoon ablation (Cryo-Abl) has a lower acute success rate of pulmonary vein isolation (PVI) for the right and left inferior PVs (RIPV and LIPV, respectively) than for the superior PVs. This study aimed to determine if the orientation and position of the inferior PVs are related to the difficulty of acute success of PVI.

Methods and Results: We investigated 30 consecutive patients who underwent Cryo-Abl. A “difficult PV” was defined as the requirement for $>2$ cooling applications and/or touch-up ablation to achieve PVI. We measured the ventral angle between the vertical line and the direction of each PV trunk (PV angle) on the transverse plane of enhanced CT images. PV position was defined as the difference in the levels between the bottom of the RIPVs and the non-coronary cusp of the aorta. PV angle $<105^\circ$ and PV position $<1.250\,mm$ were independent factors of difficult RIPV isolation (PV angle: odds ratio (OR)=$23.80$, confidence interval (CI) $−3.15528$ to $−0.53622$, $P=0.002$; PV position: OR=$12.14$, CI $−2.77301$ to $−0.23160$, P=$0.014$). PV position $<16.875\,mm$ was also related to the difficulty of LIPV isolation (OR=$5.78$, CI $−1.77095$ to $−0.09474$, P=$0.027$).

Conclusions: RIPV with ventral orientation may require difficult maneuvers to advance an ablation system towards it. Low take-off of the inferior PVs may cause non-coaxial configuration of balloon catheters towards the direction of these veins.

Key Words: Anatomy; Atrial fibrillation; Cryoballoon ablation; Pulmonary veins

Cryoballoon ablation (Cryo-Abl) is a useful treatment for curing paroxysmal atrial fibrillation (PAF) by creating complete circular lesions around each pulmonary vein (PV). In many cases, a “one shot” application successfully isolates the PV from the left atrium (LA). However, incomplete circumferential balloon contact to the PVs may result in residual connecting gaps, especially for the inferior PVs. When the first attempt fails, multiple freezing procedures and/or focal (“touch-up”) ablation are required to accomplish isolation of the PVs. Therefore, careful selection of patients for Cryo-Abl before the procedure may shorten the procedural time and contribute to reducing the cost by avoiding use of an additional ablation catheter.

The inferior PVs (right and left: RIPV and LIPV, respectively) are difficult targets for creating complete isolation with current cryoballoon technology. Previous reports have proposed that several anatomical characteristics of the IPVs (oval shape of the ostium and early branching of the RIPV) inhibit the efficacy of Cryo-Abl. However, the exact orientation (angulation) and position of the IPVs have not been investigated to determine if, and how, they affect Cryo-Abl outcomes.

We hypothesized that the angle of the IPVs from the LA (PV angle) and their take-off position (PV position) are related to the difficulty of cryoballoon wedging into the PVs.

Methods

Patients

We retrospectively investigated 30 consecutive patients with PAF who underwent enhanced computed tomography (CT) to evaluate the anatomy of their LA and PVs before Cryo-Abl was performed between October 2015 and July 2016. Patients with a common PV canal were not included because a large diameter of the ostium of the PV can be an independent factor related to difficulty with Cryo-Abl.

Cryo-Abl Procedure

All Cryo-Abl procedures were performed under a local...
and general anesthetic (lidocaine and dexmedetomidine). A 20-polar catheter was inserted into the coronary sinus and a 10-polar catheter was inserted into the right ventricle. After transseptal puncture, a deflectable circumferential catheter (Lasso catheter; Biosense Webster or Optima; St. Jude Medical [SJM]) was delivered to the PV or LA through an 8.5F sheath. A 28-mm cryoballoon (Arctic Front Advance; Medtronic, CA, USA) was also inserted in the LA guided by an 11F FlexCath sheath (CryoCath; Medtronic). PV/LA angiography was performed to identify the anatomy of the PV using standard angulations (right anterior oblique view 0° and left anterior oblique view 55°). Pre-ablation voltage mapping was performed by a circumferential catheter on a 3D mapping system (Ensite System Velocity; SJM).

The cryoballoon was inflated within the LA and advanced into the ostium of each PV guided by a particular ring wire (Achieve; Medtronic). Retrograde PV angiography was performed to verify complete PV occlusion by the cryoballoon. We performed Cryo-Abl in sequential order from the left superior PV (LSPV), LIPV, right superior PV (RSPV), and RIPV. In all cases, freezing was continued for 180 or 200 s, except in cases of achieving local excessive cooling (<−60°C), delayed cooling (>−40°C until 60 s), or a decline in temperature of the esophagus (<25°C).

We defined successful isolation of the PVs as follows: (1) disappearance of PV potentials that were recorded by a guiding electrode (Achieve) during freezing, (2) absence of PV potentials confirmed by a circumferential catheter after freezing, and (3) no conduction from the PV to LA during high-output pacing from a circumferential catheter placed in each PV. In cases of failure of PV isolation, freezing was repeated by changing the position of the guiding catheter (Achieve) to another PV branch, and/or using the pull-down technique. During ablation of the right-sided PVs, stimulation of the phrenic nerve by high-output pacing from a catheter in the superior vena cava was continued to avoid injury to the nerve. If PV isolation was still not achieved with several freezing procedures, point lesions in the connecting gap (touch-up ablation) were added using an irrigated ablation catheter (Flexability; SJM) until achievement of PV isolation.

Five operators (operators A–E) participated in the present study. Every procedure was performed by a team of 2 or 3 operators. All operators’ agreement was required for switching to a touch-up radiofrequency ablation when the first cooling application failed.

**Definition of a “Difficult PV”**

Requirement for multiple freezing procedures and/or the touch-up ablation procedure to create complete PV isolation was defined as a difficult PV. Other PVs were classified as easy. Early termination of freezing because of a decline in esophageal temperature and local excessive cooling were not included as difficult PVs.

**Enhanced CT Imaging**

A standard method for imaging and enhancement of CT was used in the present study. An ECG-gated 64-slice multidetector CT system (GE Health Care) was used to perform CT with the bolus tracking method. Administration of propranolol or landiolol intravenously was performed prior to CT scanning to reduce heart rate. To estimate scan timing, a test bolus of contrast agent (10 mL of Iopamiron370®) was administered. The main bolus of contrast agent (0.8 mL/kg of Iopamiron370®) was then injected. The scan was started at the time of maximum enhancement of the ascending aorta. The scan parameters were as follows: 120 kV, 500–700 mA, 0.16 helical pitches, 350 ms gantry rotation time, and 0.625×0.625-mm slice thickness by interval.

We constructed a CT image at 75% of the R-R interval to reduce the influence of geometrical movement. We measured the ostial dimensions, PV angle, and PV position on CT images using a general medical recording system.

![Figure 1. Orientation of the inferior pulmonary veins (definitions of PV angle and PV position). The PV angle was defined as the ventral angle between the vertical line and the direction of each PV trunk (A, D). Case 1 shows ventral orientation of the RIPV in which the angle is 95° (A). Case 2 shows dorsal orientation of the RIPV in which the angle is 125° (D). In case 1, the level of the RIPV (B) was 21 slices lower than the non-coronary cusp (C), and the position of the RIPV was calculated as −13 mm. In case 2, the level of the RIPV (E) was 8 slices higher than the non-coronary cusp (F), and the RIPV position was calculated as 5 mm. LIPV, left inferior PV; RIPV, right inferior PV.](Image)
Table 1. Baseline Characteristics of Patients Undergoing Cryo-Abl

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
<th>LIPV</th>
<th>RIPV</th>
<th>Easy PV</th>
<th>Difficult PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>59±14</td>
<td>56±15</td>
<td>57±10</td>
<td>57±14</td>
<td>60±15</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>23/7</td>
<td>23/7</td>
<td>23/7</td>
<td>26/6</td>
<td>20/7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166±8</td>
<td>166±8</td>
<td>167±7</td>
<td>166±7</td>
<td>166±8</td>
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<tr>
<td>Weight (kg)</td>
<td>66±11</td>
<td>64±11</td>
<td>68±11</td>
<td>65±12</td>
<td>65±12</td>
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<tr>
<td>CHA₂DS₂-VASc</td>
<td>1.5±1.2</td>
<td>1.4±1.2</td>
<td>1.6±1.2</td>
<td>1.6±1.2</td>
<td>1.3±1.2</td>
</tr>
<tr>
<td>CHF</td>
<td>1 (3.3%)</td>
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<td>1 (3.3%)</td>
<td>1 (3.3%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>13 (43.3%)</td>
<td>13 (43.3%)</td>
<td>13 (43.3%)</td>
<td>13 (43.3%)</td>
<td>13 (43.3%)</td>
</tr>
<tr>
<td>Age ≥75 years</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>2 (6.7%)</td>
<td>2 (6.7%)</td>
<td>2 (6.7%)</td>
<td>2 (6.7%)</td>
<td>2 (6.7%)</td>
</tr>
<tr>
<td>Vascular disease</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
<td>3 (10.0%)</td>
</tr>
<tr>
<td>LA dimensions</td>
<td>40±5</td>
<td>41±6</td>
<td>39±5</td>
<td>39±6</td>
<td>40±5</td>
</tr>
<tr>
<td>LVEF</td>
<td>67±7</td>
<td>67±7</td>
<td>67±7</td>
<td>67±7</td>
<td>67±7</td>
</tr>
</tbody>
</table>

Cryo-Abl, cryoballoon ablation; LA, left atrial; LVEF, left ventricular ejection fraction.

Table 2. Results of Cryo-Abl in Patients With Paroxysmal Atrial Fibrillation

<table>
<thead>
<tr>
<th>PV</th>
<th>n</th>
<th>Freezing Time (min)</th>
<th>Touch-up Frequency</th>
<th>Touch-up Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td>265±167</td>
<td>2.0±1.2</td>
<td>2 (6.6%)</td>
</tr>
<tr>
<td>LIPV</td>
<td>30</td>
<td>229±148</td>
<td>1.6±1.2</td>
<td>7 (23.3%)</td>
</tr>
<tr>
<td>RIPV</td>
<td>30</td>
<td>180±37</td>
<td>1.4±0.6</td>
<td>0</td>
</tr>
<tr>
<td>Easy PV</td>
<td></td>
<td>174±41</td>
<td>1.1±0.3</td>
<td>0</td>
</tr>
<tr>
<td>Difficult PV</td>
<td></td>
<td>412±199</td>
<td>3.0±1.2</td>
<td>2 (20.0%)</td>
</tr>
<tr>
<td>RIPV</td>
<td>12</td>
<td>339±187</td>
<td>2.4±1.5</td>
<td>7 (58.3%)</td>
</tr>
</tbody>
</table>

Cryo-Abl, cryoballoon ablation; LIPV, left inferior pulmonary vein; RIPV, right inferior pulmonary vein.

Table 3. Geographic Parameters of Inferior Pulmonary Veins

<table>
<thead>
<tr>
<th>PV</th>
<th>Dimension (mm)</th>
<th>Angle (°)</th>
<th>Position (mm)</th>
<th>Early Branching</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIPV</td>
<td>12±2</td>
<td>110±12</td>
<td>17±10</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>RIPV</td>
<td>14±3</td>
<td>109±16</td>
<td>2±10</td>
<td>17 (56.7%)</td>
</tr>
</tbody>
</table>

(Lipus; Fujifilm, Tokyo, Japan).

Orientation of IPVs (Definitions of PV Angle and Position)
The PV angle was measured on enhanced CT images in the 2 IPVs. The ostium of the IPVs was defined as the intersection between the PV trunk and the posterior LA wall on a traverse plane. On the transverse plane at the level where the ostial diameter of the RIPV or LIPV was maximal, we measured the ventral angle between the vertical line and the direction (longitudinal line) of each PV trunk (Figure 1). The vertical line was perpendicular to both the transverse and sagittal plane on CT images, so it did not depend on the anatomy of the PVs or LA. The longitudinal line of the PV trunk was drawn between the 2 distinct middle points of proximal and distal traverse (intersection) lines on a PV trunk. The proximal traverse line was placed on the PV ostium as previously defined, and the distal traverse line was placed approximately 1 cm distal to the ostium. If a branch bifurcated within 1 cm distal to the ostium (defined as early branching), the distal traverse line was placed just proximal to the bifurcation.

Figure 1 shows a representative case (patient 1) of ventral orientation of the RIPV in which the angle was measured as 95° (Figure 1A). Figure 1 also shows dorsal orientation of the RIPV in which the angle was measured as 125° (patient 2, Figure 1D). The ostial diameters of the 2 PVs were also measured at the same level on the image.

The cranio-caudal position of IPVs was also investigated on transverse CT images. We selected a non-coronary cusp of the aorta as a reference for the position of the PV, and defined the take-off level of the IPVs by measuring the difference in vertical level between the bottom of the IPVs (Figure 1B,E) and the bottom of the non-coronary cusp (Figure 1C,F) by manually moving the transverse images. In case 1, the level of the RIPV (Figure 1B) was 21 slices caudal to the non-coronary cusp (Figure 1C). The RIPV position could then be calculated as −13 mm. In case 2, the level of the RIPV (Figure 1E) was 8 slices cranial to the non-coronary cusp (RIPV position was calculated as −5 mm, Figure 1F).

Statistical Analysis
All data were repeatedly measured and analyzed without knowledge of the patients’ clinical backgrounds. Univariate and multivariate logistic regression analyses were performed to evaluate the relationships between the anatomical characteristics of the IPVs (PV angle, PV position, early branching, and PV ostial dimensions) and the results of Cryo-Abl. Analysis using a receiver-operating characteristic (ROC) curve was performed to identify an appropriate cutoff value of the CT parameters with which to discriminate patients with a difficult PV for Cryo-Abl. Statistical analysis was performed with JMP software (SAS Institute Inc., Cary, NC, USA). To evaluate the intra- and interobserver reliability, the PV angle was measured twice by 2 independent cardiologists who were blinded to the results of Cryo-Abl. In 15 randomly selected cases, intraclass correlation coefficients (ICC) were calculated using IBM SPSS Statistics 21.0. Continuous variables are presented as mean ± standard deviation. Categorical variables are presented as number and percentage. P<0.05 was considered statistically significant.

Results
Clinical and Echocardiographic Variables
Clinical and echocardiographic variables of the 30 patients are shown in Table 1. No patients had concomitant heart disease, such as valvular heart disease, congenital heart disease, or cardiomyopathy.

Results of Cryo-Abl
The overall number of applications of Cryo-Abl was 2.0±1.2 in the LIPV and 1.6±1.2 in the RIPV. The overall duration of applications of Cryo-Abl was 229±148 s in the RIPV and 265±167 s in the LIPV (Table 2). A difficult PV was observed in 12/30 (40.0%) patients for the RIPV and...
IPVs and Cryoballoon Ablation

The ostial dimension of the LIPV was 12±2 mm (range: 8–15; median: 11 mm) and that of the RIPV was 14±3 mm (range: 10–21; median: 14 mm). The PV angle of the LIPV was 110°±12° (range: 77°–130°; median: 111°) and that of the RIPV was 109°±16° (range: 74°–136°; median: 72°). The position of the LIPV was 17±10 mm (range: −6 to 36; median: 17 mm) and that of the RIPV was 2±10 mm (range: −14 to 24; median: 2 mm) (Table 3).

Early branching was observed in 17 of 30 (56.7%) RIPV, but none of the patients had early branching of the LIPV (Table 3).

Intra- and Interobserver Reliability for the RIPV Angle
For the RIPV angle, intraobserver reliability (ICC: 1,1) and interobserver reliability (ICC: 2,1) showed almost perfect agreement (r=0.927 and r=0.912, respectively).

Geographic Parameters of IPVs on CT Images
Patients with a common ostium of the superior and inferior PVs were not included in this study. The middle branch of the right PV was observed in 2 patients. The ostial dimension of the LIPV was 12±2 mm (range: 8–15; median: 11 mm) and that of the RIPV was 14±3 mm (range: 10–21; median: 14 mm). The PV angle of the LIPV was 110°±12° (range: 77°–130°; median: 111°) and that of the RIPV was 109°±16° (range: 74°–136°; median: 72°). The position of the LIPV was 17±10 mm (range: −6 to 36; median: 17 mm) and that of the RIPV was 2±10 mm (range: −14 to 24; median: 2 mm) (Table 3).

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Relationships Between CT Parameters and Difficulty of Cryo-Abl for the RIPV
Figure 2A–C shows the relationships between CT parameters and difficulty of Cryo-Abl for the RIPV. The dimension of the RIPV was not significantly different between a difficult and an easy PV (13±2 vs. 15±3 mm, P=0.08). The PV angle of difficult RIPVs was significantly narrower than that of easy RIPVs (98°±14° vs. 116°±14°, P=0.002).
The position of difficult RIPVs was significantly more caudal (lower) than that of easy RIPVs (−3±6 vs. 5±10 mm, P=0.034). ROC analysis (area under the curve [AUC], 0.83) showed that a PV angle cutoff of 105° discriminated a difficult PV with a sensitivity of 75% and specificity of 89% (Figure 3A). ROC analysis (AUC, 0.76) showed that a RIPV position cutoff of 1.250mm discriminated a difficult RIPV with a sensitivity of 83.3% and specificity of 72.2% (Figure 3B). In patients with both of these factors predicting difficulty of Cryo-Abl (PV angle <105° and a low take-off position <1.250mm), multiple applications of the freezing procedure were required in 5/6 (83%) patients and the touch-up procedure was required in 2/6 (33%) patients. Univariate logistic analysis showed that the low take-off position (cutoff value <1.250mm) and ventral PV angle (cutoff value <105°) were significant parameters for indicating difficulty of RIPV isolation (low take-off RIPV position: odds ratio (OR)=7.80, 95% confidence interval (CI) −1.93640 to −0.23963, P=0.010; ventral PV angle: OR=16.00, 95% CI −2.47058 to −0.51350, P=0.001). Early branching was not associated with difficulty of RIPV isolation (RIPV: OR=2.00, 95% CI −1.14276 to 0.39676, P=0.364, Table 4). When PV angle and position were analyzed as categorical variables, multivariate logistic analysis showed low take-off position (cutoff value <16.875mm) and ventral PV angle (cutoff value <105°) were significant parameters for identifying difficulty of RIPV isolation (low take-off RIPV: OR=12.14, 95% CI −2.77301 to 0.23160, Table 4).
P=0.014; ventral PV angle: OR=23.80, 95% CI −3.15528 to −0.536, P=0.281; LVEF: 67%±6% vs. 67%±7%, P=0.941). In multivariate logistic analysis of these parameters as continuous variables, only PV angle was a significant parameter for identifying difficulty of RIPV isolation (RIPV position: OR=1.07, 95% CI −0.04187 to 0.20443, P=0.222; RIPV angle: OR=1.08, 95% CI 0.01535 to 0.15762, P=0.012). We also analyzed the echocardiographic data, but left atrial dimensions (LAD) and left ventricular ejection fraction (LVEF) were not significantly different between difficult and easy RIPVs (LAD: 38±4 vs. 40±6 mm, P=0.333; LVEF: 68%±6% vs. 66%±8%, P=0.505).

**Relationships Between CT Parameters and Difficulty of Cryo-Abl for the LIPV**

Figure 4A-C shows the relationships between CT parameters and difficulty of Cryo-Abl for the LIPV. The dimension and PV angle of difficult LIPVs were not significantly different compared with easy LIPVs (12±2 vs. 12±2 mm, P=0.804; 115°±7° vs. 108°±13°, respectively, P=0.106). The take-off position of difficult LIPVs was significantly lower than for easy LIPVs (1±8 vs. 2±2±10 mm, P=0.032). ROC analysis (AUC: 0.739) showed that an LIPV position cutoff of 16.875 mm discriminated a difficult LIPV with a sensitivity of 81.8% and specificity of 68.4% (Figure 3C). In the univariate analysis, a low take-off level of the LIPV (<1.250 mm) was also related to difficulty of LIPV isolation (OR=5.78, 95% CI −1.77095 to −0.09474, P=0.027, Table 4). In the univariate analysis, LIPV position was related to difficulty of LIPV isolation (OR=1.10, 95% CI 0.01535 to −0.04187 to 0.20443, P=0.222; RIPV angle: OR=1.08, 95% CI 0.01535 to 0.15762, P=0.012). We also analyzed the echocardiographic data, but left atrial dimensions (LAD) and left ventricular ejection fraction (LVEF) were not significantly different between difficult and easy RIPVs (LAD: 38±4 vs. 40±6 mm, P=0.333; LVEF: 68%±6% vs. 66%±8%, P=0.505).

**Discussion**

The major finding of this study was that the PV angle and take-off level of inferior PVS were significantly associated with difficulty in PV isolation using Cryo-Abl. In the case of an RIPV angle <105°, the requirement of multiple freezing procedures and/or touch-up catheter ablation (defined as a difficult PV) was approximately 6-fold higher than in cases of an angle ≥105°. In the case of an RIPV position <1.250 mm, the rate of a difficult PV was approximately 12-fold higher than in the case of an RIPV position ≥1.250 mm. In the case of an LIPV position <16.875 mm, the rate of a difficult PV was approximately 6-fold higher than in the case of an LIPV position ≥16.875 mm.

**PV Angle and Difficulty of Cryo-Abl**

Previous reports have demonstrated that several anatomical characteristics of the PVS (oval shape, early branching, and dull-edged shape) result in difficult maneuvers using cryo-ablative techniques. Only one study has proposed a relationship between the angle of the RIPV and acute success of RIPV isolation. In this study, the non-perpendicular angle between the axis of the PV and the ostial plane was a parameter that suggested difficulty of RIPV isolation. However, on some CT images, determination of the PV ostial plane is not easy because of obtuse (gradual) transition of the RIPV from the LA. In the present study, we drew a vertical line as an axial reference to the PV angle, which provided a distinct and easy method for evaluating the orientation of the PV.

The CRYO-Japan PMS study demonstrated that IPVs are harder targets for achieving PV isolation using the Cryo-Abl technique compared with SPVs. In the present study, we found that narrow angulation (ventral orientation) of the RIPV and low take-off positions were anatomical characteristics that resulted in incomplete PV isolation using Cryo-Abl.

**Study Limitations**

First, the design of our study was retrospective in a single institution with a small number of patients. Particularly, the number of patients is the ultimate limitation. Our results must be interpreted as limited data from an initial 30 patients. Our data should be reconfirmed by a multicenter study including a large number of patients. Second, we did not evaluate the long-term results of Cryo-Abl because official use of this novel technique in Japan was only approved in February 2014. In the future, we should address the relationship of PV anatomy and results of long-term follow-up by showing the exact site with re-
connection of the PV to the LA. Third, because we enrolled patients from the beginning of our experience with this procedure, our data should be interpreted with caution because there would have been a learning curve. The relatively high percentage of touch-up RF ablation might be caused to inexperience with the technique in the initial phase of our study. Because tips and techniques based on experience may improve achievement of PV isolation by Cryo-Abl, our results will change with further training and learning. However, our data may be useful especially for beginners who have not yet become highly skilled for Cryo-Abl to assist with predicting difficulty and to prepare back-up procedures (e.g., touch-up methods).

Fourth, the position of the IPVs should be defined using the septal punctured site as a reference, not a non-coronary cusp. However, precise identification of the puncture site on pre-procedural CT images was impossible in our study. Finally, definition of a difficult PV is the limitation of the present study because some operators may consider that PVs requiring 2 cooling procedures were not difficult. In the CRYO-Japan PMS study, additional (touch-up) ablation was allowed if PVI was not achieved by >1 Cryo-Abl application. When the first cooling procedure is insufficient, one operator may continue the balloon procedure further, but another may select touch-up ablation. Accordingly, if we defined a difficult PV as requirement for >3 applications, we may produce a selection bias that depends on the operator’s personal choice.

Conclusions
Anatomical characteristics (ventral orientation of the RIPV and low take-off of IPVs) may require difficult maneuvers to achieve complete PV isolation using Cryo-Abl. A tailored ablation strategy based on the anatomical features of the PVs may allow a reduction in procedural time and medical costs by avoiding additional use of touch-up ablation catheters.

Disclosures
The authors did not receive any grants concerning this study.

References