Characterization of Residual Conduction Gaps After HotBalloon-Based Antral Ablation of Atrial Fibrillation — Evidence From Ultra-High-Resolution 3-Dimensional Mapping —

Shiro Nakahara, MD; Yuichi Hori, MD; Reiko Fukuda, MD; Naoki Nishiyama, MD; Sayuki Kobayashi, MD; Yoshihiko Sakai, MD; Isao Taguchi, MD

Background: The electrophysiological characteristics of residual conduction gaps between the left atrium (LA) and pulmonary veins (PVs) after HotBalloon-based wide antral ablation (HBWA) of atrial fibrillation (AF) remain incompletely understood. This study aimed to characterize the residual gaps by means of ultra-high-resolution mapping.

Methods and Results: A total of 55 AF patients underwent HBWA by a predetermined protocol (6-shot total-based antral approach). LA-PV maps were created using 64-electrode minibasket catheters. In total, 55 residual gaps were identified among 26 (47%) patients. Residual gaps included 33 left superior (LS: 60%), 10 left inferior (18%), 6 right superior (11%), and 6 right inferior (11%) PVs. Those gaps demonstrated both extremely lower bipolar amplitudes (0.11 [interquartile range: 0.06–0.27] mV) and conduction velocities (0.75±0.27 m/s); however, the length was confined (10.3±4.1 mm) except for the LSPV anterior carina (12.2±2.4 mm) region. Among the carina regions, all gaps had far-field potentials consistently added to the PV potentials. Left atrial appendage pacing to split the far-field activity identified confined gap regions (6.7±1.9 mm). Touch-up ablation eliminated the residual PV potentials in all cases.

Conclusions: HBWA resulted in a certain degree of residual gap conduction in particular antral regions. These gaps exhibited narrow lengths with lower amplitudes, and often had far-field recordings from the left atrial appendage. Combined with pacing maneuvers, ultra-high-resolution activation maps could both visualize all confined gaps and ensure a bare minimum of touch-up ablations in all patients with gap conduction.

Key Words: Atrial fibrillation; Conduction gap; Hot balloon ablation; Rhythmia mapping system

Pulmonary vein isolation (PVI) is currently the mainstream acute procedural endpoint in catheter ablation of paroxysmal atrial fibrillation (AF). Conventional point-by-point ablation is a useful method for achieving PVI, but requires skillful technique and a long procedure time. Radiofrequency HotBalloon catheters have been developed to overcome several of those limitations. The balloon membrane material is elastic and compliant, so it fits variable PV anatomy. Thus, the HotBalloon ablation system has been applied in the clinical setting for paroxysmal and persistent AF ablation. However, a recent multicenter study also demonstrated that the incidence of severe PV stenosis (>70%) has increased to 5.2%. These findings suggest that a more antral side of energy delivery using the HotBalloon (e.g., HotBalloon-based wide antral ablation [HBWA]) is desirable to avoid unpredictable vein stenosis, but this methodology may cause an increase in the creation of residual conduction gaps between the PV and left atrium (LA), because of the loss of balloon flexibility for obliterating the PV ostium as its size becomes larger. To the best of our knowledge, no studies have evaluated the incidence and characteristics of residual conduction gaps after HBWA. Presumably, the difficulty in identifying LA-PV gaps is caused mainly by complex gap pathways within the ablation scar and reduced electrogram signals at the LA-PV junction that cannot be recorded clearly by the ablation or circular catheters with relatively large electrodes.

Recently, a new electroanatomic mapping system using a minibasket array catheter with 64 minielectrodes has been launched to allow rapid ultra-high-resolution electro-anatomic mapping. Several studies have demonstrated the usefulness of this mapping system for AF ablation and confirmation of the existence or absence of PV potentials. We hypothesized that using this mapping system in conjunction with a small basket catheter (IntellaMap Orion catheter) would allow us to easily identify LA-PV conduction gaps after HBWA. Therefore we aimed to characterize the residual conduction gaps after HBWA of AF using the new electroanatomic mapping system.
Reconnection Gaps After HotBalloon Ablation

Methods

Patients
This prospective single-center study included 55 patients with either paroxysmal (n=17) or persistent (n=38) AF undergoing an index PVI using HBWA. This study complied with the Declaration of Helsinki. Written informed consent for the ablation and participation in the study was given by all patients, and the protocol was approved by the institutional review board.

Settings Before Ablation
All antiarrhythmic drugs (AADs) were discontinued for at least 5 half-lives prior to the procedure. Preprocedural cardiac-enhanced computed tomography (CT) was performed to evaluate cardiac anatomy. The procedure was performed under dexmedetomidine-induced moderate sedation. After vascular access was obtained, a single transseptal puncture was performed, and intravenous heparin was administered to maintain an activated clotting time >300 s. Subsequently, the 4 PVs were delineated by LA angiography through the sheath, using contrast medium. If the baseline rhythm was AF, external cardioversion was performed.

HBWA
The SATAKE HotBalloon ablation system (Toray Industries, Inc., Tokyo, Japan) was used for PVI in this study as described previously. In brief, a balloon with an inner lumen and J-tip guidewire (Toray Medical Co., Ltd.) was inflated in each PV ostium through a 13F deflectable guiding sheath (Treswaltz, Toray Industries, Inc.). For PV occlusion, the balloon was inflated to 26–33 mm in diameter with 10–20 mL of contrast medium diluted 1:2 with saline. Once optimal PV occlusion, as assessed by contrast injection, was achieved, a radiofrequency current of 1.8 MHz was applied between the coil electrode inside the balloon and the 4 cutaneous electrode patches on the patient’s back to induce capacitive-type heating of the balloon. The target internal balloon temperature of 70°C was maintained by delivery of vibratory waves through the lumen into the balloon to agitate the fluid inside.

After PV-graphy as described, the operator placed the balloon in the target PV ostium by advancing the guide-wire through the catheter lumen into the PV. Because of the relatively higher incidence of PV stenosis as previously published, we used an antral approach to avoid any intra-PV balloon ablation and thus prevent complications in the chronic phase. In particular, balloon positioning at the PV ostium, and not in the PV, was adjusted by the injection volume, such that the balloon would completely appose the PV antrum and occlude the PV. Furthermore, all patients underwent a predetermined protocol; namely, a single-shot for each of both upper PVs, the carinas, and lower PVs (Figure 1). The first HBWA for the upper PVs was based on full coverage of the upper PV antral region. After the first HBWA, the balloon was deflated slightly, and then pulled and rotated towards the carina region to create an effective lesion around that area. Next, a single-shot HBWA was performed for both lower PVs. The energy application settings were as follows: left superior PV (LSPV: 70°C, 3.5–4.5 min), left inferior PV (LIPV: 70°C, 3.4 min), left anterior PV (70°C, 3.5–4.5 min), right superior PV (RSPV: 70°C, 3.5–4.5 min), right inferior PV (70°C, 3.4 min), and right inferior PV (70°C, 3.5–4.5 min). The duration of the energy-delivering time depended on the operator’s consideration in each case. Despite the presence or absence of residual conduction, no more HBWA was performed in any patients.

To prevent injury to the phrenic nerve, pacing of the diaphragm from an electrode in the superior vena cava was performed during right PV ablation. The ablation energy delivery was terminated if diaphragmatic capture was lost. Furthermore, to avoid damage to the esophagus, the esophageal temperature was monitored (especially during left PV ablation) by applying an esophageal temperature probe (Esophastar, Japan Lifeline). If the temperature exceeded 39°C, cooling water was injected into the esophagus.
**Table 1. Clinical Characteristics of Study Patients (n=55)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>66±11</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>43/12</td>
</tr>
<tr>
<td>Type of AF</td>
<td></td>
</tr>
<tr>
<td>Paroxysmal</td>
<td>18 (33%)</td>
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<tr>
<td>Persistent</td>
<td>37 (67%)</td>
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<tr>
<td>Hypertension</td>
<td>32 (58%)</td>
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<tr>
<td>Diabetes mellitus</td>
<td>9 (16%)</td>
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<tr>
<td>LA diameter (mm)</td>
<td>43.0±5.8</td>
</tr>
<tr>
<td>LVEF</td>
<td>0.59±0.08</td>
</tr>
<tr>
<td>CHADS2 score</td>
<td>1.2±0.8</td>
</tr>
<tr>
<td>CT data</td>
<td></td>
</tr>
<tr>
<td>LAVI (mL/m²)</td>
<td>98.0±21.3</td>
</tr>
</tbody>
</table>

All data expressed as mean±SD, median (quartiles), or n (%).

AF, atrial fibrillation; CT, computed tomography; LA, left atrial volume index; LVEF, left ventricular ejection fraction.

**High-Density Electroanatomic Maps**

After HBWA, if AF persisted external cardioversion was performed. 3D-electroanatomic maps were created by the Rhythmia system including its Orion minibasket catheter (Boston Scientific, Natick, MA, USA). The minibasket catheter consisted of 8 splines, each containing 8 small electrodes. The minibasket catheter was used to create an electroanatomic shell of the LA including the LA-PV junction and proximal PVs. We also assessed the conduction gaps between the LA and PVs using the same minibasket catheter. The minibasket catheter was positioned at each LA-PV junction in a stable position and 20s of continuous recording was performed during sinus rhythm followed by 20s of continuous recording during any atrial site pacing in order to separate and differentiate the extra-PV and PV potentials. After the identification of the best atrial pacing site for the distinction of PV potentials, an ultra-high-density bipolar map was created, and both voltage map and activation maps were generated from the residual gap conduction. The criteria used for the beat acceptance were a stable cycle length, stable timing deviation between 2 reference electrodes placed in the coronary sinus, respiratory gating, stable catheter location, and stable catheter signal compared with the adjacent points. The projection distance and confidence mask were set at 2 mm and 0.03 mV, respectively. The mapping window was automatically set by the system. The system annotated the largest bipolar electrogram within the mapping window, taking into account the activation consistency with the surrounding points.

**Gap Definition and Analysis**

For identification of LA-PV gaps, we tried to localize any residual gap conduction by using activation maps. A gap in propagation was defined as an activation breakthrough inside the PV localized in the antral region with a clear activation-sequence from the LA to inside the PV. The propagation bar was adjusted to 10ms to see a clearer spreading through the gaps. When a gap was detected, a virtual roving probe was used to show the electrogram of the gap as well as the propagation across the spline of the Orion catheter, from the proximal to distal electrodes, to avoid any far-field signals. In addition, when analyzing the left upper PV, an activation map was obtained during pacing at any atrial site (distal side of the coronary sinus [CS]) or left atrial appendage [LAA]) in order to separate and differentiate the extra-PV and PV potentials.

After the activation map analysis, the map was switched to a voltage map. The voltage thresholds were defined as follows: electrograms >0.5 mV were defined as healthy tissue, electrograms <0.2 mV were defined as dense scar, and electrograms with a voltage between 0.5 and 0.2 mV were defined as damaged but viable tissue. A gap in the voltage map was defined as a segment around the antrum of the PV, in the area of the ablated scar, with supposed healthy or viable tissue (i.e., with a voltage of the local electrograms >0.5 mV).

For an electrophysiological analysis of the gaps, the entry (LA side) and exit (PV side) of the gap were defined as the points crossing the gap pathway and lines that extended from the border of the ablated region by HBWA. The distance between the entrance and exit was measured (gap length) by the voltage map. The gap voltage was also calculated at the mid-portion of the gap pathway. The narrowest width of the propagation wave through the gap pathway on the PV antral region was defined as the gap width. The conduction velocity of the gap was calculated as the gap length divided by the activation time difference between the exit and entry of the gap.

**Confirmation of Isolated PVs and Gap-Targeted Ablation**

For all electrically isolated PVs, which were achieved independently by HBWA, an exit block was confirmed by sequential pacing maneuvers from the bipolar electrodes along the equatorial plane of the minibasket catheter. Ablation was performed within the gap estimated by the activation map. The appropriateness of LA-PV gap location was confirmed by the change or disappearance of the PV potentials in response to the radiofrequency application at the estimated gap site.

**Post-Ablation Management and Follow-up**

AADs prescribed previously to the patients were resumed after the procedure, at the operators’ discretion. The patients were followed up every 4 weeks at the dedicated arrhythmia clinic. Routine ECGs were obtained at each outpatient visit, and 24-h ambulatory Holter monitoring was performed every 3 months post-ablation. When patients experienced symptoms suggestive of arrhythmias, a surface ECG, ambulatory ECG, and/or cardiac event recording were also obtained. Any of the following events after the initial 3 months post-ablation (blanking period) were considered to indicate recurrent atrial tachyarrhythmias: (1) atrial tachyarrhythmias recorded on routine or symptom-triggered ECG during outpatient visits, or (2) atrial tachyarrhythmias of at least a 30s duration on ambulatory ECG monitoring.

A 3-dimensional CT (3D-CT) scan was performed at baseline, and at 6 months post-procedure. Stenosis was defined as a reduction in the diameter ≥70%.

**Statistical Analysis**

Continuous data are expressed as the mean±SD for normally distributed variables or median (25th, 75th percentiles) for non-normally distributed variables, and were compared using a Student t test or Mann-Whitney U test, respectively. Categorical variables were compared using the χ² test. P<0.05 was considered significant.
Results

Patients’ Characteristics and Procedural Results of the HBWA

The patients’ characteristics are summarized in Table 1. The procedural characteristics, including the ablation time, balloon volume, and estimated balloon diameter, which was measured by electric calipers ex vivo, are demonstrated in Table 2. In the 55 patients, 220 PVs were identified, and there were no patients who could not undergo an appropriate ablation because of the anatomy of their PVs.

At baseline, 45 patients had AF, so external cardioversion was performed just before HBWA. Because 12 patients had immediate recurrence of AF, a total of 43 patients underwent HBWA during SR. All patients successfully underwent the predetermined HBWA protocol. Concerning the inclusion of persistent AF patients in this study, the average volume of the balloon for each upper and lower PV was larger than that in a recent clinical trial study of paroxysmal AF.5

Mapping and Gap Identification After HBWA Approach

We performed LA-PV mapping using the new mapping system in conjunction with a small basket catheter. After HBWA, 10 patients still had AF, and external DC was successfully performed in all cases. Eventually, all mapping

Table 2. Procedural Characteristics

<table>
<thead>
<tr>
<th>PV</th>
<th>Ablation time per PV (min)</th>
<th>Volume in the balloon per PV (mL)</th>
<th>Estimated balloon diameter* (mm)</th>
<th>No. of ablations per PV</th>
<th>Temperature of the balloon (°C)</th>
<th>Median touch-up ablations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right superior</td>
<td>4.1±0.8</td>
<td>12.8±1.8</td>
<td>28.3</td>
<td>1</td>
<td>70</td>
<td>1.0 (1.0–1.0)</td>
</tr>
<tr>
<td>Right carina</td>
<td>3.5±0.6</td>
<td>10.2±0.8</td>
<td>26.2</td>
<td>1</td>
<td>70</td>
<td>1.0 (1.0–1.0)</td>
</tr>
<tr>
<td>Right inferior</td>
<td>4.0±1.6</td>
<td>11.1±1.8</td>
<td>26.7</td>
<td>1</td>
<td>70</td>
<td>1.0 (1.0–2.0)</td>
</tr>
<tr>
<td>Left superior</td>
<td>4.6±1.2</td>
<td>13.8±1.7</td>
<td>29.1</td>
<td>1</td>
<td>70</td>
<td>1.0 (1.0–2.0)</td>
</tr>
<tr>
<td>Left carina</td>
<td>3.3±0.6</td>
<td>11.2±1.7</td>
<td>26.8</td>
<td>1</td>
<td>70</td>
<td>1.0 (1.0–2.0)</td>
</tr>
<tr>
<td>Left inferior</td>
<td>3.4±1.0</td>
<td>11.3±1.6</td>
<td>26.9</td>
<td>1</td>
<td>70</td>
<td>1.0 (1.0–2.0)</td>
</tr>
</tbody>
</table>

*Ex vivo measurement by electric venier caliper. PV, pulmonary vein.
Among all residual gap conductions, 22 gap pathways (22/55: 40%) were clearly visualized to be <10 mm (width: 7.4 ± 2.5 mm, length: 8.3 ± 0.5 mm) on the activation map using the automatic electrogram annotation system (Figure 3A). Those confined gap regions exhibited a lower bipolar amplitude (0.09 [0.05–0.22] mV) and lower conduction velocity (0.77 ± 0.25 m/s). In contrast, 33 gaps (60%) were roughly (>10 mm) visualized on the activation map. Of those wide gaps, 61% (20/33) were documented in the left anterior carinal region, and all those gaps had far-field LAA potentials that added to the PV myocardial electrograms under CS pacing (Figure 4A). The rest of the wide gaps were located on the roof of the LSPV (9 gaps [27%]), right anterior carina region (2 gaps [6%]), and both left (1 gap [3%]) and right (1 gap [3%]) inferior PV bottom regions (Figure 2, blue line).

Confined Gap Detection by Changing the Pacing Site
To reduce the influence of the far-field LAA recording during the detection of gaps in the anterior left PV carinal region (n=20), LA-PV re-mapping was performed during LAA pacing for detecting the accurate gap location in those regions. LAA pacing to split the far-field activity was initially performed during CS pacing. The mean and standard deviation number of mapping points was 9,045±3,863, and the mean and standard deviation mapping time was 786±212 s.

Overall, 176 of 220 PVs (80%) were isolated exclusively using the HBWA technique. Further, HBWA resulted in isolation of all 4 PVs in 53% (29 of 55) of the patients. The minibasket catheter identified all 55 gaps from 44 PVs in 47% (26 of 55) of the patients. The regional distribution of the gaps is presented in Figure 2. The most common residual gap location was the anterior side of the LSPV (anterior wall: 7 gaps and antero-carina regions: 16 gaps) including the carinal regions (total 42% [23 of 55 gaps]). Combined with the pacing maneuvers, all gaps were successfully confirmed by activation maps (Figures 3A, 4). However, the exact identification and visualization of the gap location was possible only at 20 gaps (36%) by voltage mapping. Figure 3B is an example of a voltage map showing the low-voltage areas created by HBWA and the voltage of the preserved pathway indicating a conduction gap.

Regarding the local electrograms at the gaps, the maps demonstrated both extremely lower bipolar amplitudes (0.11 [IQ: 0.06–0.27] mV) and conduction velocities (0.75±0.27 m/s). Among all residual gap conductions, 22 gap pathways (22/55: 40%) were clearly visualized to be <10 mm (width: 7.4±2.5 mm, length: 8.3±0.5 mm) on the activation map using the automatic electrogram annotation system (Figure 3A). Those confined gap regions exhibited a lower bipolar amplitude (0.09 [0.05–0.22] mV) and lower conduction velocity (0.77±0.25 m/s). In contrast, 33 gaps (60%) were roughly (>10 mm) visualized on the activation map. Of those wide gaps, 61% (20/33) were documented in the left anterior carinal region, and all those gaps had far-field LAA potentials that added to the PV myocardial electrograms under CS pacing (Figure 4A). The rest of the wide gaps were located on the roof of the LSPV (9 gaps [27%]), right anterior carina region (2 gaps [6%]), and both left (1 gap [3%]) and right (1 gap [3%]) inferior PV bottom regions (Figure 2, blue line).
During follow-up, there were no severe complications such as cerebral embolisms or LA-esophageal fistulae. In total 87 (48/55) % of the patients underwent enhanced 3D-CT 6 months later. PV stenosis (>70%) was observed in 1 case (2.1%; 1 of 48; 1 right superior). The stenosis ratio was 75% and the energy delivery time was 3.5 min. During follow-up, no clinical symptoms associated with PV stenosis were reported, and no invasive treatments were required.

**Discussion**

This prospective observational study included 55 patients who underwent a predetermined HBWA protocol. We thoroughly investigated the incidence, distribution, and characteristics of residual PV-LA conduction after HBWA using an ultra-high-resolution 3-D mapping system. The main findings were: (1) HBWA resulted in a certain degree of residual gap conduction, particularly in the PV antral region; (2) the gaps exhibited both extremely lower bipolar amplitudes and conduction velocities; (3) the most common location of the residual gaps was the anterior and carinal regions of the left PVs, and most of those gaps had far-field activity from the LAA, which hindered accurate identification of the gap; (4) LAA pacing to split the far-field activity was effective in identifying narrower confined gap regions in those regions; and (5) additional radiofrequency energy deliveries by a standard RF catheter in the
areas of the identified gaps resulted in a wide-area antral ablation in all cases.

**Creation of Gaps After HBWA**

HotBalloon ablation is being used as an alternative ablation therapy. A recent multicenter randomized study demonstrated superiority of HotBalloon ablation compared with AAD therapy for treatment of patients with paroxysmal AF, and a favorable safety profile. That multicenter study achieved complete isolation between the PVs and LA in almost 93% of the patients by the HotBalloon ablation alone, whereas in the present study PV-LA gaps after only performing HBWA were confirmed in 47% of the patients. One plausible explanation is that there was a relatively higher prevalence of persistent AF in the present patients. A more enlarged PV antrum may lead to insufficient contact of the balloon with the atrial tissue and contribute to the creation of PV-LA conduction gaps. Thus, a greater contrast saline volume in the balloon was also needed to shield the PV-LA junction when compared with the previous multicenter study. Another possible explanation is that the number of HBWA deliveries was much less in our study than in the multicenter study. There were almost twice (11.2 vs. 6.0) the number of shots performed in the previous multicenter study as compared with our study. Such repetitive shots with a relatively smaller sized balloon may cause the energy delivery to be more distal in the PV and yield a relatively higher incidence of PV stenosis. Additionally, balloon positioning during energy delivery also differed in our study. To avoid severe PV stenosis in the future, we located the balloon more proximally at the PV-LA junction, which may create a space between the balloon and PV-LA orifice with an imprecise circular shape. Further, creating a larger HotBalloon by injecting more contrast saline could also be associated with a certain drop in the balloon’s surface temperature, and this may have contributed to the creation of a non-transmural ablated lesion at the PV antrum. However, touch-up energy delivery with a standard radiofrequency catheter achieved PV-LA isolation in all cases, and eventually a wide antral ablation region was created in all subjects. A relatively wide debulking of the LA by the HotBalloon catheter may have a beneficial outcome with regard to longer-term efficacy, and further studies are warranted.

**Identification of Gaps After HBWA**

The electrical isolation of the PVs is the cornerstone of AF ablation procedures, and some studies have demonstrated easy identification of LA-PV reconnection gaps after standard initial PVI by using a new mapping system in the remote phase. However, there are limited data regarding the identification of LA-PV conduction gaps just after balloon-based ablation and balloon technologies have become a mainstream treatment modality for AF ablation in recent clinical practice. We decided to primarily use information from the activation map instead of the voltage map for the rationale described below. First, the activation map shows not only how the activation wavefront is moving around the mapped chamber, but also where the lines of block are on the activation wavefront. Second, the amplitude of the bipolar electrogram is influenced by the direction of the wavefront propagation. Third, as a distended HotBalloon can cover most of the surface area of the PV antral region, widespread damage to the tissue may disturb the accurate identification of PV-LA gaps. In our data, the PV-LA gaps that were identified exhibited extremely lower bipolar amplitudes, suggesting that voltage maps are particularly unhelpful for wide scar areas and require careful attention to identify the real conduction gaps between the PVs and LA.

With respect to the contact of the mapping catheter, a basket-type catheter allows for simultaneous positioning of the electrode wires in longitudinal and radial directions, which provides information about the activation in several transverse planes at different levels of the ablated PV antral region. Additionally, when expanded, the Orion catheter has a more-or-less identical spherical shape to the HotBalloon catheter, which allows more thorough, visualization of residual conduction gaps after HBWA. The high rate of successful ablation based on easy visualization of residual conduction pathways confirms the high degree of reliability of the automated and ultra-high-resolution mapping with this system.

In our study, most residual gaps after HBWA were in the anterior carina region, and that region has been recognized as the most frequent site of far-field signals derived from activation of the LAA during CS pacing. Because of the influence of the far-field recordings from the LAA, the identified gaps at the antero-carina region demonstrated a wide region (>10mm) despite the use of the ultra-high-density mapping system in conjunction with a minibasket catheter. However, as previously reported, we used pacing from the LAA to induce fusion of the far-field component with the pacing artifact and to create a greater separation of the recorded electrograms as compared with CS pacing, which resulted in accurate identification of the real, narrow residual gap pathways in the carina region. These findings provided the following clinically useful information: the actual length of the residual gaps after HBWA was relatively narrower even after the use of an antral approach, and the gaps could be eliminated by a minimal number of point ablation applications at the gaps with a low voltage. Operators must take care to minimize the number of touch-up ablation applications after HBWA because most of the acutely ablated regions within the antral region may have tissue vulnerability, and excessive RF applications to that tissue may lead to an unexpected cardiac perforation.

**Study Limitations**

Several limitations warrant mention. First, the results represent the experience of a single center and might be dependent on the skill of specific operators. Second, in Japan, the HBWA system was approved in April 2016, so a relatively high incidence of reconnection gaps might reflect operator experience. Second, despite the use of a more antral approach for HotBalloon ablation, 1 case of severe RSPV stenosis was documented. Because of a lack of adequate experience when we started this study, our protocol for the energy delivery time might have been too long. Further investigations are needed regarding the duration of ablation time for each PV. Lastly, the demonstrated data might have been influenced by the small size of the study population. Multicenter studies including larger populations are needed to arrive at conclusions about the general usefulness of this ablation technique.

**Conclusions**

HBWA resulted in a certain degree of residual gap conduc-
Reconnection Gaps After HotBalloon Ablation

These gaps exhibited narrow lengths with lower bipolar amplitudes, but often exhibited far-field recordings from the LAA. Combined with pacing maneuvers, the new ultra-high-resolution mapping system could both visualize all LA-PV confined gaps and ensure a bare minimum of touch-up ablations in the patients undergoing HBWA.

Conflict of Interest

None.

References