Prevalence, Morphological and Electrophysiological Characteristics of Confluent Inferior Pulmonary Veins in Patients With Atrial Fibrillation

Teiichi Yamane, MD; Taro Date, MD; Michifumi Tokuda, MD; Yasuko Aramaki, MD; Keiichi Inada, MD; Seiichiro Matsu, MD; Kenri Shibayama, MD; Satoru Miyanaga, MD; Hidekazu Miyazaki, MD; Ken-ichi Sugimoto, MD; Tohru Sakuma, MD*; Kunihiko Fukuda, MD*; Seibu Mochizuki, MD**; Michihiro Yoshimura, MD

Background Although the common trunk of left pulmonary veins (PVs) has been reported as a relatively popular anatomical variation of PVs, little is known about the coalescence of contralateral PVs. The present study was conducted to reveal the prevalence and electrophysiologic characteristics of the confluent inferior common PVs.

Methods and Results Anatomical variation in the PV drainage to the left atrium (LA) was assessed using the multidetector computed tomography scan in 326 patients with atrial fibrillation (AF) who underwent the PV isolation procedure. Coalescence of inferior PVs was observed in 5 cases (1.5%). Both inferior PVs conjoined prior to the junction with the LA in 3 cases, while they coalesced at the LA junction in the other 2 cases. The arrhythmogenic activities of the confluent inferior PVs were generally low in all cases without any ectopic firings triggering the observed AF. All inferior PVs, as well as the superior PVs, were successfully isolated either en bloc at the common trunk or individually at the orifice of each PV.

Conclusions Confluent inferior PVs were present in 1.5% of cases in patients with AF who underwent the PV isolation procedure. Preoperative recognition of this venous anomaly by 3-dimensional imaging is important for smooth and safe ablation. (Circ J 2008; 72: 1285–1290)

Key Words: Atrial fibrillation; Catheter ablation; Common ostium; Pulmonary vein

The electrophysiological and anatomical properties of the pulmonary veins (PVs) have been focused on since their crucial role in triggering or generating atrial fibrillation (AF) was first revealed. Several different mapping and ablation techniques have so far been proposed, including segmental PV isolation (PVI) with electrophysiological guidance, wide area circumferential ablation, 2-by-2 ipsilateral-PVs isolation, and balloon ablation techniques, most of which are based on the presence of normal PV anatomies.

Anatomical variations in PV drainage to the left atrium (LA) have been reported using a multidetector computed tomography (MDCT) scan or magnetic resonance imaging (MRI); thus demonstrating that the common left PV was the most popular anatomical abnormalities of PVs (3–29%). Recently, sporadic cases with confluent inferior PVs have been reported; however, the true prevalence of this anomaly remains to be determined. We herein describe the prevalence, anatomical and electrophysiological characteristics of confluent inferior PVs in patients with AF.

Methods

Patient Population

This study focused on 5 cases whose inferior PVs conjoined together, out of 326 consecutive patients who underwent PV mapping and ablation for multidrug-resistant AF (paroxysmal AF: 196 patients, persistent or chronic AF: 130 patients). They included 262 men and 64 women with a mean age of 55±8 years old. One hundred and four patients had evidence of cardiovascular disease: 76 had hypertension, 43 had coronary artery disease, 8 had dilated cardiomyopathy, 6 had hypertrophic cardiomyopathy, and 15 had mitral valve regurgitation. All patients underwent the PVI procedure and subsequent observations at a single institution (Jikei University Hospital). Informed consent was obtained from each patient before they underwent the procedure according to the protocol approved by the Hospital Human Research Committee.

Imagings

Computed Tomography (CT) All patients underwent a contrast-enhanced CT scan of the chest a few or several weeks prior to the PVI procedure, with a 16-row MDCT scanner (Sensation 16, Siemens Medical Solutions, Erlangen, Germany). Non-ionic intravenous contrast material (100 ml of Iopamiron 370, Nihon Schering, Osaka, Japan) was administered through an antecubital vein with a power injection at a rate of 4 ml/s, followed by flushing with 50 ml...
The PV ostium was defined by the intersection of tangents extending from the outer surface of the PV and the wall of the adjacent LA on 3-D imagings, as has been previously demonstrated. The distance between the contralateral wall of the adjacent LA on 3-D imagings, as has been previously demonstrated.10 The distance between the contralateral PVs and the LA or if contralateral PVs open to the LA just adjacently (defined as the LS-RS or LI-RI distance of less than 10 mm).

### Definition of Confluent PVs

The PV ostium was defined by the intersection of tangents extending from the outer surface of the PV and the wall of the adjacent LA on 3-D imagings, as has been previously demonstrated. The distance between the contralateral PVs (left superior to right superior distance: LS-RS distance) and the contralateral inferior PVs (LI-RI distance) were measured as the length between the centers of the contralateral PV ostia on the 3-D reconstructed models (example of measurement is shown in Figs 2,3). We defined the confluence of contralateral PVs as the conjunction of contralateral PVs either prior to the junction with the LA or just at the LA junction. Accordingly, cases were regarded as having the confluence of contralateral PVs if the common trunk (>5 mm) exists between the conjunction of contralateral PVs and the LA or if contralateral PVs open to the LA just adjacently (defined as the LS-RS or LI-RI distance of less than 10 mm).

### Table 1 Characteristics and Ablation Results of 5 Patients With Inferior Common PVs

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Sex</th>
<th>Age</th>
<th>Type of AF</th>
<th>LA dimension (mm)</th>
<th>Type of conjunction</th>
<th>Isolation method</th>
<th>ABL results</th>
<th>No. of ABL sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>58</td>
<td>Persistent</td>
<td>42</td>
<td>Common trunk</td>
<td>Individual</td>
<td>Success</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>58</td>
<td>Paroxysmal</td>
<td>36</td>
<td>Common trunk</td>
<td>En bloc</td>
<td>Success</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>46</td>
<td>Paroxysmal</td>
<td>35</td>
<td>Common trunk</td>
<td>En bloc</td>
<td>Success</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>57</td>
<td>Paroxysmal</td>
<td>39</td>
<td>Neighboring ostium</td>
<td>Individual</td>
<td>Success</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>57</td>
<td>Persistent</td>
<td>49</td>
<td>Neighboring ostium</td>
<td>Individual</td>
<td>Success</td>
<td>2</td>
</tr>
</tbody>
</table>

PV, pulmonary vein; AF, atrial fibrillation; LA, left atrium; ABL, catheter ablation.

Type of conjunction indicates whether both inferior PVs coalesced prior to or just at the junction to the LA.

LA dimension was echocardiographically measured on the parasternal view.

**Mapping and Catheter Ablation**

PVI was performed as described previously. Prior to endocardial mapping, a direct visualization of all 4 PVs was performed using selective venography through a long sheath (8F, SR-0, St. Jude Medical, Minnetonka, USA for superior PVs, and 8F, percutaneous transseptal introducer sheath, Medtronic, USA for inferior PVs) by the hand injection of contrast medium. Prior to the ablation of PV, provocative maneuvers (isoproterenol infusion: 2–4 μg/min, and burst pacing) were performed to reveal ectopic firings. Presence of arrhythmogenic activity in each PV was defined as the appearance of ectopic firings from the vein, recorded by the Lasso or mapping catheters.

All superior PVs were individually, electrically disconnected from the LA. In cases with confluent inferior PVs, they were disconnected from the LA either en bloc at the common trunk or individually at the ostium of each inferior PV. PV mapping was performed with a steerable circular catheter measuring either 20, 25 or 30 mm in diameter (Lasso, Biosense Webster, Diamond Bar, CA, USA; the choice was based on the PV diameter as determined by angiography) and equipped with 20 electrodes. The segments of the PV perimeter demonstrating the earliest activation with electrogram polarity reversal were preferentially targeted. The RF energy was delivered at the distal electrode (8-mm tip) of the thermocouple-equipped ablation catheter (target: 50°C) with a power limit of 30–35 W for 30–60 s at each site. The end-point of ablation was the establishment of a bidirectional conduction block between the LA and PV. No continuous ablation lines were produced in any case presented in this study.

**Patient Follow up After Ablation**

After discharge, the patients underwent careful observations (2 weeks after discharge, then every month thereafter) at our cardiology clinic, without taking any antiarrhythmic agents. The outcome of PVI was evaluated based on the patient symptoms, ECG at the periodical follow up, and also

---

**Fig 1.** Demonstration of the correlation between the LS-RS distance and the LI-RI distance measured on the 3-dimensional (D)-multidetector computed tomography views. The mean LS-RS distance and the LI-RI distance was 36.3±5.0 mm and 37.5±5.0 mm, respectively (p=NS) among all cases except for the 5 patients with inferior common PVs (white circles, n=321). In contrast, in the 5 cases presented in this study (black circles), the LI-RI distance was much shorter than the LS-RS distance (34.7±6.2 mm vs 7.4±1.3 mm, p<0.001). RS, right superior pulmonary vein; LS, left superior pulmonary vein; RI, right inferior pulmonary vein; LI, left inferior pulmonary vein.

---

**Table 1 Characteristics and Ablation Results of 5 Patients With Inferior Common PVs**

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Sex</th>
<th>Age</th>
<th>Type of AF</th>
<th>LA dimension (mm)</th>
<th>Type of conjunction</th>
<th>Isolation method</th>
<th>ABL results</th>
<th>No. of ABL sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>58</td>
<td>Persistent</td>
<td>42</td>
<td>Common trunk</td>
<td>Individual</td>
<td>Success</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>58</td>
<td>Paroxysmal</td>
<td>36</td>
<td>Common trunk</td>
<td>En bloc</td>
<td>Success</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>46</td>
<td>Paroxysmal</td>
<td>35</td>
<td>Common trunk</td>
<td>En bloc</td>
<td>Success</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>57</td>
<td>Paroxysmal</td>
<td>39</td>
<td>Neighboring ostium</td>
<td>Individual</td>
<td>Success</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>57</td>
<td>Persistent</td>
<td>49</td>
<td>Neighboring ostium</td>
<td>Individual</td>
<td>Success</td>
<td>2</td>
</tr>
</tbody>
</table>

PV, pulmonary vein; AF, atrial fibrillation; LA, left atrium; ABL, catheter ablation.

Type of conjunction indicates whether both inferior PVs coalesced prior to or just at the junction to the LA.

LA dimension was echocardiographically measured on the parasternal view.
Confluent Inferior PVs in AF Patients

by periodically conducting 24-h ambulatory monitoring. The patients were discharged on warfarin anticoagulation but without any antiarrhythmic drugs. All patients underwent a repeat CT angiogram 3 months after the procedure to exclude the possibility of PV stenosis progression.

**Statistical Analysis**

All values are expressed as the mean ±SD. A statistical analysis was conducted using the Student’s t-test (paired or unpaired). Statistical analysis was performed with the use of a statistical software program (SPSS for Windows, version 11.5, SPSS Inc, Chicago, IL, USA). Differences showing a value of p<0.05 were considered to be statistically significant.

**Results**

**Patient Characteristics**

Among all 326 cases included in this study, conjunction of 2 PVs was observed in 71 cases (21.8%); 65 cases with left common PVs (16 cases with long common trunks (≥15 mm) and 49 cases with short common trunks (<15 mm)), 1 case with right common PVs, and 5 cases with confluent inferior PVs, which we focused on in the present study. The clinical characteristics of these 5 cases with confluent inferior PVs are shown in the Table 1. All patients were male in their mid-fifties, except for 1 female in her mid-thirties. AF was paroxysmal in 3 cases, and persistent in the other 2 cases. An echocardiographic image revealed a dilated LA dimension (>40 mm) in 2 cases with persistent AF. No patients with confluent inferior PVs had cardiovascular diseases. Other types of PV variant, such as the isolated right middle branch and the right top PV, were also observed in 15% (49 of 326) and 1.5% (5 of 326), respectively.

**Distance Between Contralateral PVs**

Fig 1 demonstrated the correlation between the LS-RS distance and the LI-RI distance among all patients in this study. The mean LS-RS distance (36.3±5.0 mm) and the LI-RI distance (37.5±5.0 mm) were generally equivalent (p=NS), except for 5 cases with confluent inferior PVs, whose LI-RI distances were much shorter than the LS-RS distances (34.7±6.2 vs 7.4±1.3 mm, p<0.001). It is clear that these 5 cases represent absolutely distinct entities from a majority of cases, without any intermediate types between them.

**Morphological Character of Inferior Common PV Ostium**

In all 5 cases presented herein, the confluent inferior PV was formed by the displacement of the LIPV ostium to the right. In 3 cases (#1, 2, 3), contralateral inferior PVs conjoined together before they flowed into the LA, and a common trunk interposed between the conjunction and the LA (Fig 2). In the other 2 cases (#4, 5), both inferior PVs coalesced at the junction to the LA (Fig 3). In all 5 cases, the junction of both inferior PVs was never located in the middle of the LA posterior wall, but was rightwardly shifted. Consequently, the LIPV trunk traversed a longer
distance than usual, running behind the LA posterior wall and in front of the esophagus (shown in Fig. 3, case #4). The ostial diameter of inferior PV branches was always larger in the right side than the left side, with a significant difference (19.0±2.5 mm vs 14.2±1.6 mm, p<0.05). Catheter insertion into the LIPV involved some difficulties in all cases, which were aided by the use of a pre-formed long-sheath (SR-2, DAIG Company, USA) in 2 cases (cases #1,5).

**Arrhythmogenicity**

Ectopic firings were rarely seen to originate from the confluent inferior PVs in the 5 cases, even with isoproterenol...
infusion and/or burst atrial pacings. Only a few ectopic firings without inducing AF could be observed inside the RIPV in 1 case (case #4). There were no dissociated firings in any case inside the isolated inferior PVs after ablation.

**Mapping and Ablation**

In all cases of this study, all 4 PVs were targeted to be disconnected from the LA, regardless of the presence/absence of documented arrhythmogenicity. In 5 cases with confluent inferior PVs, the activation of the PV myocardium could be recorded at the individual ostium of the LI, RI, and also at the common trunk of the inferior PVs (cases #1–3); almost circumferentially in all cases. The electrical isolation of all 4 PVs was successfully performed in all 326 cases with the guide of circular mapping catheter. Among 5 cases with confluent inferior PVs, isolation of both inferior PVs en bloc at the common trunk was achieved in 2 cases (cases #2,3), whereas they were individually isolated in the remaining 3 cases (Figs 4A,B). No serious complications occurred in any of the 5 cases, except for the occurrence of arterio-venous fistula of the femoral vessels in case #1.

**Follow up**

During a mean observation period of 18±12 months, all 5 cases remained in sinus rhythm without any antiarrhythmic drugs after a mean of 1.6±0.5 ablation procedures. A second procedure was performed in 3 cases for the recurrent arrhythmia because of the re-conduction of previously isolated PVs (including the re-conduction of inferior PV in 2 cases), all of which were successfully re-isolated. No procedure related complications such as PV stenosis could be detected during the post-operative observation period in cases with inferior common PVs. In the other 321 cases, 298 cases (93%) remained in sinus rhythm during the 28±15 months of observation after 1.4±0.4 ablation procedures (7% of cases with antiarrhythmic drugs). There was no significant difference in the AF-free rate and the numbers of procedures between cases with and without inferior common PVs.

**Discussion**

This report describes the anatomical and electrophysiological characteristics of confluent inferior PVs in patients with AF. Although the true prevalence of this anomaly has yet to be elucidated, it was observed in 5 out of 326 cases (1.5%) that underwent PVI for AF at our institution. As for producing ectopic firings triggering AF, no clear evidence of arrhythmogenicity could be observed during the procedure in any of the 5 confluent inferior PVs.

There have been several reports concerning the anatomical abnormalities of PV, as detected by CT or MRI imaging. The most common abnormality reported so far is the confluent left PVs, which have been reported to be present in 3–29% of the cases who underwent 3-D imaging. In a report by Kato et al, a short common left trunk, in which the junction of the lower wall of the LSPV and upper wall of the LIPV lies outside the LA rim, could be seen in 22% (12 of 55 cases), while a long common left trunk was also present in 7% (4 of 55). In this study, we found that 1.5% of cases who underwent PVI of AF have another type of anomalous PV drainage with a conjunction of contralateral inferior PVs. Although the reason why the presence of this venous anomaly has been underestimated is not known, the increasing numbers of reported cases suggests that its prevalence is not extremely rare and the preoperative 3-D imaging will help to detect its existence.

As for the arrhythmogenicity of common PVs, Schwartzman et al recently reported the electrophysiologic characteristics of 14 left common PVs among 100 AF cases. They found that although the myocardium inside the left common PVs did not have any unique electrophysiological properties, it was a consistent source of arrhythmogenic ectopy. Contrary to the left common PVs, only small amounts of arrhythmogenic activities could be observed in the confluent inferior PVs in the present study. Although the reason for this discrepancy is not clear, it might be caused by the different arrhythmogenic activity between the superior and inferior PVs as previously proposed. For the detailed evaluation of arrhythmogenicity in this PV anomaly, further studies in a larger number of similar cases will be needed.

Several approaches targeting the ipsilateral PVs en bloc using linear ablation techniques, such as circumferential linear ablation using electroanatomical mapping or circumferential 2-by-2 PVI methods have so far been widely practised, however, it should be realized that these techniques were developed based on the normal PV anatomy with the contralateral PVs widely separated. In cases with confluent inferior PVs, blinded applications of RF energy on the LA posterior wall to make linear lesions might injure the inferior PVs. For the performance of smooth and safe ablation in cases with AF, preoperative determination of the anatomical features of LA and PV is therefore recommended.

From the embryological standpoint, the PV trunks are shown to derive from a common vessel (common PV), which becomes progressively absorbed within the LA. This incorporation transforms the branches of this common vessel into separately individual PV trunks, first into the right and left PV trunks and subsequently into the superior and inferior trunks. Although the detailed mechanisms about how the inferior common PVs are formed are still not known, they might be caused by either anomalous branching of the common PV or by the asymmetrical absorption of the common PV into the LA.

**Conclusions**

The anomaly of common inferior PVs was present in 1.5% of the examined group of cases with AF who underwent the PVI procedure. Preoperative determination of the PV-LA anatomy using either MDCT or MRI is recommended for the performance of smooth and safe ablation.

**References**


