Catheter Ablation of Atrial Fibrillation in Patients with Chronic Lung Disease

Running title: Roh et al.; Ablation of atrial fibrillation in lung disease

Seung-Young Roh, MD; Jong-Il Choi, MD, PhD; June Young Lee, PhD;
Jae-Jin Kwak, MD; Jae-Seok Park, MD; Ji-Bak Kim, MD; Hong-Euy Lim, MD, PhD;
Young-Hoon Kim MD, PhD

1Division of Cardiology, 2Department of Biostatistics, Korea University Medical Center,
Seoul, South Korea

Address for Correspondence:
Young-Hoon Kim MD, PhD
Korea University Medical Center
126-1, 5ga, Anam-dong, Seongbuk-gu
Seoul, 136-705
Republic of Korea
Tel: +82-2-920-5445
Fax: +82-2-927-1478
E-mail: yhkmd@unitel.co.kr

Abstract:

Background- Chronic lung disease (CLD) is one of the important underlying diseases of atrial fibrillation (AF). The outcomes after radiofrequency catheter ablation (RFCA) of AF in patients with CLD have not yet been reported. We investigated the electroanatomical alterations in pulmonary veins (PVs) in CLD patients with AF and assessed their effect on the outcomes for RFCA of AF.

Method and Results- We assessed 15 patients who had CLD and underwent RFCA of AF. CLD included chronic obstructive pulmonary disease (COPD), a tuberculosis-destroyed lung (TDL), and interstitial lung disease (ILD). For controls, we selected 60 sex-, age- and procedure era-matched non-CLD patients who received RFCA for AF (4 controls for each 1 CLD patient). Eight patients had COPD, 6 had TDL, and 1 had ILD. PV morphology in the affected lung was significantly altered i.e., obliteration, pulling of the PVs towards the destroyed lung, or compensatory bulging of the PV antrum. These alterations were related to arrhythmogenicity in 6 out of 15 (40%) patients with CLD. Non-PV foci were more common in the CLD group (4/15, 26.7%) than in the control group (3/60, 5.0%, \( p=0.025 \)). All non-PV foci were located in the right atrium (RA). The AF recurrence rate in the CLD group (26.7%, 4/15) was similar to that in the control group (18.3%, 11/60, \( p=0.45 \)).

Conclusions- Significant alteration of PV anatomy was related to arrhythmogenicity and non-PV foci from the RA were commonly observed in the CLD group. RFCA can be carried out safely for AF in CLD patients with a comparable success rate to that in patients with normal lungs.

Key words: ablation; atrial fibrillation; lung; catheter ablation; pulmonary heart disease
Introduction

Cardiac arrhythmias, including atrial fibrillation (AF), occur frequently in patients with chronic lung disease (CLD). In addition, changes in pulmonary vascular structure and hemodynamics can result from chronic hypoxia in lung diseases such as chronic obstructive pulmonary disease (COPD), or can be caused by the destruction of lung parenchyma by the chronic inflammation that characterizes diseases such as tuberculosis and interstitial lung disease (ILD). These changes in pulmonary vascular structure and hemodynamics may comprise the basis for AF perpetuation and/or the triggers that initiate AF.

When AF and CLD co-occur, morbidity and mortality increase and quality of life decreases. In addition, some drugs that are used to improve lung function and relieve dyspnea in patients with CLD, such as methylxanthines or beta-2-agonists, also have the potential to cause tachycardia and arrhythmia, so they should be administered with caution. Furthermore, anti-arrhythmic drugs (AADs) used to control AF, such as sotalol and propafenone, have the potential to provoke bronchial spasm and decrease lung function. One of the detrimental side-effects of amiodarone is pulmonary fibrosis. Accordingly, pharmacologic treatment of AF in patients with CLD requires special caution and is of limited value.

Recently, radiofrequency catheter ablation (RFCA) has been demonstrated to be an effective therapy for various subsets of AF. However, the outcomes for RFCA of AF in patients with CLD have not yet been reported. The purpose of this study was therefore to investigate anatomical alterations in the pulmonary veins (PVs) of CLD patients with AF and to compare the clinical outcomes of RFCA for AF between CLD and control patients.

Methods

Patients
A total of 752 consecutive patients who underwent RFCA for paroxysmal or persistent AF between April 2000 and May 2009 were reviewed. Patient history and chest radiographic findings were retrospectively reviewed, and 15 patients with chronic lung disease, including COPD (n=8), tuberculosis-destructive lung (TDL, n=6), and ILD (n=1), were included in this study. COPD was defined according to the GOLD (Global Initiative for Chronic Obstructive Lung Disease) criteria: forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC) < 0.70 in a pulmonary function test, or emphysematous changes on chest radiography with more than a 20 pack-years smoking history or medical treatment history. Patients with a destroyed lung or lung involvement greater than 30% of the total lung volume, as observed on chest radiography and chest computed tomography (CT) images, were defined as having TDL or ILD (Figure 1). For each CLD patient, we selected 4 control patients who were matched for sex, age (±2 years) and procedure era (±1 year). After reviewing the chest X-rays and clinical history of all patients, we selected patients who did not have lung disease to be in the control group. In total, the control group included 60 patients without CLD who underwent AF ablation.

**Imaging Studies**

All PV angiographic CT and 3-dimensional (3-D) reconstruction images were performed within 24 hours prior to RFCA in all patients (Figure 1). The 3-D PVCT image was merged with 3-D LA-PV geometry acquired using a multi-electrode catheter on NavX (St Jude Medical, Inc., USA). Trans-thoracic echocardiography and trans-esophageal echocardiography were performed prior to RFCA in all AF patients. We also assessed whether a thrombus was present within the LA appendage.

**Catheter Ablation Procedure**
In the case of 1 patient who was treated by catheter ablation in 2000, we used focal ablation at the PV, guided by a Lasso catheter (Biosense Webster Inc., CA, USA). From 2005 to 2007, we used noncontact mapping-guided 4-PV ablation and non-PV foci ablation for 2 patients. Starting in 2007, we performed circumferential ablation of 4-PVs guided by NavX (St Jude Medical, Inc., USA) with PV isolation for 12 patients. Since 2008, we added multiple linear ablations at the LA roof and perimital isthmus, and also utilized 3-D automated complex fractionated atrial electrogram (CFAE) mapping-guided ablation for 3 patients with sustained AF after pulmonary vein isolation (PVI). Multipolar catheters were positioned at the His recording area, the RA lateral wall, and the coronary sinus (CS). Double trans-septal punctures and multi-view pulmonary venograms were performed. We then inserted a quadripolar catheter into the ascending aorta as a reference catheter for the NavX mapping system and mapped the LA geometry.

Before PVI, we tried to identify arrhythmogenic foci if the ectopic foci spontaneously initiated paroxysmal AF. In patients with a sinus rhythm at baseline, AF was induced by burst pacing at the high right atrium (HRA) and CS from 250 ms to the atrial refractory period under the effect of isoproterenol (10 μg/min). Internal DC cardioversion was subsequently performed with a decapolar catheter in the HRA as an anode, with another decapolar catheter inside of the CS acting as a cathode. The arrhythmogenic foci were identified if they caused immediate re-initiation of AF within 2 minutes after cardioversion. We performed internal DC cardioversion at least three times during infusion of isoproterenol and during its washout in order to acquire reproducible results for the identification of arrhythmogenic foci. We then investigated the relationship between the arrhythmogenic PVs and anatomical distortion of the PVs. After PVI and/or multiple linear ablations at the LA, we repeated the same protocol at least 3 times, to identify consistent non-PV foci initiated AF. We applied the same protocol in patients
with persistent AF to localize arrhythmogenic foci.

The end point of PVI was elimination of PV potentials on the 10-bipole ring-shaped catheter at each PV. PVI was not performed at the obliterated PVs in which the PV potential was not recorded (Figure 2). Efficient localization of non-PV foci at the specific areas in the RA was achieved by keeping a decapolar catheter at the RA that covered the area from the RA septum to the high crista terminalis and another duo-decapolar catheter at the RA that covered high and low crista terminalis, and the cavo-tricuspid isthmus, including the CS ostium. A quadripolar catheter was inserted into the SVC (Figure 2, panel C). Then, we performed an internal DC cardioversion of the induced AF during infusion and washout of the isoproterenol and waited for 2 minutes to define immediate re-initiation of AF.

If AF was sustained after PVI, 3-D automated CFAE were mapped during 6 seconds of AF using NavX software. CFAE map settings were a refractory period of 49 ms, P-P sensitivity >0.1 mV, and duration of 30 ms. Additional ablation was performed guided by the CFAE map, until AF was terminated or organized to an atrial tachycardia (AT), or the fractionated activity was eliminated.

We documented the occurrence of post-procedure complications including bleeding or cardiac tamponade in both groups. In patients with CLD, respiratory-related complications related to deep sedation, hypercapnia, or respiratory suppression during or after the procedures were carefully monitored while maintaining sedation or when inhalation of a low to high content of oxygen was continued. We also measured and compared the procedure time, oxygen saturation, and drug dosage of thiopental sodium, midazolam, and fentanyl to assess safety in both groups. Bleeding events, including pulmonary hemorrhage that occurred during or after anticoagulation, were compared between the two groups.
Follow-up

Patients were followed-up by means of clinical assessment, ECG, ambulatory electrocardiographic monitoring, and event-triggered monitoring. Initial post-ablation follow-up took place at 1 and 3 months, and every 6 months thereafter. Beyond this interval, outpatient clinic visits every 6 months with 24-48 hours Holter monitoring were scheduled. All patients were instructed to maintain their personal records with descriptions of every episode of symptomatic palpitations and, in the case of persistent arrhythmia episodes, to obtain electrocardiographic documentation of the underlying rhythm. A successful outcome over the follow-up period was defined as the lack of electrocardiographically recorded SVT or AF, and no PAF (duration > 30 seconds) on Holter monitoring. We compared AF recurrence rate, the interval to the recurrence of AF, and the rate of taking AADs after ablation in both groups.

Statistics

Variables were expressed as mean ± SD or number and its percentages, as appropriately. In order to account for our matched sampling design, continuous variables were compared using a linear mixed-effects regression model, where the group variable (i.e., the CLD or control groups) was considered as a fixed effect and the subject identification variable as a random effect. Categorical variables were compared with a conditional logistic regression model. A comparison of time to recurrence of AF between CLD and control groups was made using a stratified Cox’s proportional hazard regression model. A value of P < 0.05 was considered statistically significant. Data were analyzed using SPSS (version 15.0, SPSS Inc., Chicago, IL, USA).

Results

The clinical characteristics of the CLD and control groups are compared in Table 1. No
significant differences were noted between the two groups in terms of echocardiographic parameters of the LA or laboratory findings before the procedure, including hemoglobin, electrolyte, and transaminase. No significant difference was observed in the mean LA diameter/BSA between the two groups (23.7±4.9 mm/m² in the control group vs. 23.0±6.2 mm/m² in the CLD group, \( p = 0.51 \)). The mean pulmonary arterial systolic pressure measured by pulsed wave Doppler was significantly higher in the CLD group (35.4±8.9 mmHg vs. 31.6±4.8 mmHg, \( p = 0.04 \)). The clinical characteristics of the 15 patients in the CLD group are summarized in Table 2. The mean age was 60.2±11.0 years and 13 patients (86%) were male. Ten of the 15 patients had paroxysmal AF, while five patients had persistent AF.

**Electrophysiological Characteristics of Atrial Fibrillation in Patients with Chronic Lung Disease**

Figure 1 shows four representative chest radiographs and 3-D PV CT images. Figure 1A shows the chest radiograph and CT of patient number 6 (Table 2). The chest PA (postero-anterior view) shows a destroyed left lung and the CT image shows obliteration of the left superior PV (LSPV) and distal tributaries of the left inferior PV. The right PVs of the corresponding lung were normal. The obliterated LSPV had residual electrical PV potentials, which functioned as the arrhythmogenic focus initiating AF in this patient. Figure 1B shows the results for patient number 11 (Table 2). The chest X-ray shows a destroyed left lung and left-deviated major bronchi. The corresponding left PVs were obliterated on CT, while the right PVs were normal, with increased vascularity of the distal tributaries. The obliterated left PVs did not exhibit PV potentials on the ring-shaped catheter. The right superior PV had an arrhythmogenic focus in this patient, therefore, PVI was performed only at the right PVs (Figure 2). Figure 1C shows the images of patient number 9. Chest PA revealed an emphysematous lung and CT revealed a
dilated LSPV ostium. Both upper PVs were pulled down by overinflated emphysematous lung, forming a ‘V’ shape on the roof of the LA body. An arrhythmogenic focus was identified at the dilated LSPV in this patient. Figure 1D shows the images for COPD patient number 8. A bulging and dilated LSPV was seen on CT and the right inferior PV originated from the left common pulmonary trunk. The bulged LSPV was arrhythmogenic.

As illustrated in the representative examples, the PV morphology was altered in the affected lungs, e.g., they bulged, shrank, or were obliterated. The significant alterations in PV morphology were related to arrhythmogenicity; for example, all three COPD patients had arrhythmogenic foci from bulged PVs. In patients with TDL, two shrunken PVs that had clear PV potentials were arrhythmogenic, however, one of the obliterated PVs without PV potential was not arrhythmogenic, while the opposite site of the PVs showing compensatory enlargement functioned as trigger sites for AF (Figure 2). Thus, we concluded that severely modified and bulged PVs were arrhythmogenic as long as the PV potential was existed, while obliterated PVs without PV potential were not arrhythmogenic. Sixty percent of patients (9/15) demonstrated arrhythmogenic foci before ablation, while PVs were arrhythmogenic in only 40% of patients (6/15). Moreover, the number of CLD patients was too small to determine whether anatomical alterations in the PVs were truly responsible for the initiation and maintenance of AF. We failed to engage the catheter into one RIPV, of which the ostium was acutely angulated, so we ablated whole circumference of both PV antra while guided by a deflectable size-adjustable Lasso catheter.

Non-PV foci were provoked in 4 of 15 (26.7%) patients with CLD after PVI, for which the incidence was higher than that in the control group (3/60, 5.0%, $p =0.025$). Interestingly, non-PV foci in all patients were exclusively from the RA, including the CS, the SVC, the low crista terminalis, and the neck of the RA appendage. Patient number 2 showed AT, the earliest
activation site of which was the high RA near the SVC and RA junction. We mapped the SVC with a Lasso catheter and performed the SVC isolation by segmental ablation 1-2 cm above the junction between the SVC and RA. In patient number 10, we performed linear ablation on the cavo-tricuspid isthmus (CTI) and confirmed the bidirectional block across CTI, thereafter, tachycardia was no longer inducible. In patient number 12, atrial flutter post-PVI was induced and sustained, which was terminated and no longer induced after linear ablation at the crista terminalis. In patient number 13, the earliest activation site of the AT was low crista terminalis, which was targeted and terminated during ablation.

**Effect of Catheter Ablation on Symptoms and Outcome**

Many symptoms of CLD and AF are often confused and patients cannot clearly distinguish them. We performed catheter ablation for the patients that complained of symptoms after sufficient medical treatment of CLD or for those who had symptoms that worsened without the aggravation factors of CLD, for example, superimposed infection. We also investigated the correlation of AF with symptoms recorded on Holter monitoring.

The symptom status pre- and post-ablation is illustrated in Table 3. The rate of relief was high for patients who complained of palpitation or fluttering (8 out of 11), or syncope (2 out of 2) as the main symptom. But dyspnea (2 of 4) and chest pain (3 of 3) persisted after the procedure. On the contrary, dyspnea or shortness of breath was attenuated or relieved in 81% (49/60) of control group patients. The rate of symptom relief was clearly different between the paroxysmal AF group (8/10, 80%) and persistent AF group (1/5, 20%). We believe that distinguishing between symptoms is more difficult in patients with persistent AF than in patients with paroxysmal AF.

The mean total procedure time for RFCA was similar in both groups (253 ± 94 min in CLD vs. 255 ± 77 min in the control group; \( p = 0.98 \)). The doses of sedative drugs required to maintain
sedation without respiratory suppression in the CLD group were not significantly different from those in the control group (thiopental sodium: 1569±597 mg vs. 1327±374 mg, \( p = 0.01 \); midazolam: 6.1±4.5 mg vs. 5.9±2.8 mg, \( p = 0.83 \); fentanyl: 59±77 mg vs. 84±51 mg, \( p = 0.15 \)). In this study, ablation of AF in CLD patients was safely performed with no clinical signs of over-sedation or respiratory suppression due to hypercapnia. During sedation, supplemental oxygen (0-3 L/min) was used to maintain optimal \( O_2 \) saturation (92-100%).

We applied the same anticoagulation strategy in CLD patients as in the controls. Differences between the two groups in terms of the rate of complications following anticoagulation or the incidence of thrombosis in CLD patients were not evident. We performed post-procedure chest X-rays in order to observe potential pulmonary hemorrhage or congestion, but there were no pulmonary parenchymal changes in any of the CLD patients.

The rate of AAD use was not significantly different between the two groups (44.1% in the control group vs. 46.7% in the CLD group, \( p = 0.85 \)). We performed a follow-up CT at 7 months after the 1st procedure in only one patient (Figure 3). On pre-procedure CT, we found LSPV enlargement and a relatively shrunken LIPV. On follow-up CT, bulging was attenuated after circumferential antral ablation. Unfortunately, follow-up CT data was not available for all patients; however, none of the patients complained of symptoms suggestive of PV stenosis, such as aggravation of dyspnea, hemoptysis, chest pain, pneumonia-like infiltration on chest X-ray.

During an average follow-up of 46.6±25.5 months, the AF recurrence rate in the CLD group (26.7%, 4/15) was somewhat higher than that in the control group (18.3%, 11/60), but this difference was not statistically significant (\( p = 0.45 \)). In 9 patients who were followed for more than 3 years, the recurrence rate of the CLD group was higher than that of the control group (4/9, 44% vs. 11/36, 31%, \( p = 0.45 \)). We analyzed the recurrence using the Kaplan-Meier method, as shown in Figure 4. The recurrence rate of the CLD group was higher than that of the control
group in the first 46 months of follow-up. Thereafter, there was not a significant difference in recurrence rate between the two groups ($p=0.49$). Nevertheless, the last two recurrent events in the CLD group were occurred at 15 months and 109 months, while, in the control group, the last event was at 47 months. This made the two survival curves crossed-over at the later follow-up periods. The non-significance in recurrence rate between groups was partly due to those events, so that a definite interpretation of the test result should not be made until more data is available.

**Discussion**

The major findings of this study are: 1) AF patients with CLD have significant alterations in PV anatomy due to lesions in the affected lung, and these morphological alterations are closely related to AF arrhythmogenicity; 2) non-PV foci in the RA are observed more often in patients with CLD than in those with normal lungs; and 3) RFCA can be carried out safely for AF in CLD patients with a comparable success rate to that in patients with normal lungs.

**Pulmonary Vein Anatomical Variations in Patients with AF**

Several reports have indicated that specific anatomic and morphologic features of PVs, such as a common ostium or bulging of the PV, are associated with AF induction. A few studies have reported that a unique PV morphology is related to the occurrence of AF, and therefore the ablation strategy needs to be customized according to the type of PV anatomical alteration. Hof et al. reported that the most commonly observed PV variation in patients with lone AF was a right-sided middle PV in 23%, followed by a common left trunk in 16%. They found, however, that PV anatomy did not have any effect on the outcome of RFCA for AF because PV variations were equally distributed among the different ablation procedures, and therefore PV anatomy was not a predictor of outcome.
The presence of a common inferior trunk, either individually or combined with the left superior PV, is an uncommon anatomical variety of PV\textsuperscript{13,14}, as shown in our study. In a larger patient series, the incidence of a common inferior trunk was 0.9% in patients with AF\textsuperscript{15}, which was the most infrequent anomaly. This study confirms the importance of assessing PV anatomy in patients with CLD before ablation. Identification of alterations in PV anatomy and coexisting tachyarrhythmias\textsuperscript{16} allows for the tailoring ablation strategies, which may minimize unnecessary ablation, a reduction in procedure times and procedure-related complications. Three-dimensional imaging prior to ablation was certainly required in these patients.

**Pulmonary Hypertension and Pulmonary Vein Morphology**

CLD causes hypoxemia and acidosis, and these lead to increased pulmonary vascular resistance. Increased levels of inflammatory factors such as angiotensin, PGI\textsubscript{2}, endothelin, and serotonin also induce pulmonary arterial and venous hypertension. These inflammatory factors may also become triggers of fibrosis and cause structural remodeling of pulmonary vessels.\textsuperscript{17} In our study, pulmonary arterial pressure was higher in the CLD group than in the control group (35.4±8.9 mmHg vs. 31.6 ±4.8 mmHg, \(p=0.04\)). This hemodynamic factor may contribute to alter the morphology of the LA and PV structures, and subsequently lead to AF.

**Non-PV Foci in Patients with Chronic Lung Disease**

Non-PV foci initiate AF with an incidence ranging from 3.2% to 55%\textsuperscript{18-23}. Non-PV foci are known to be associated with a higher recurrence of AF after RFCA. Identification of non-PV foci in AF ablation is therefore important in order to increase the long-term efficacy of catheter ablation. In our study, the incidence of non-PV foci-initiated AF in CLD patients was higher than
that in the control group. Interestingly, all non-PV foci originated from the RA side. Hemodynamic overloading or stretching of the RA due to pulmonary hypertension may contribute to a higher prevalence of non-PV foci from the RA in CLD patients. It is not yet clear whether the high prevalence of AF in patients with CLD is directly attributable to the higher incidence of non-PV foci in these patients. In our study, most AFs in CLD patients were successfully treated by PV isolation in conjunction with ablation of non-PV foci.

**Ablation Strategy**

The specific characteristics of AF have been noted in CLD patients, but in our study, the AF recurrence rate and post-ablation AAD use rate in the CLD group were not significantly different from those in the control group. This indicates that RFCA is as effective in the CLD group as it is in the control group. However, anatomic alterations of PVs require additional consideration when performing ablation. In CLD patients with an obliterated PV, special caution is needed to avoid stenosis of the ipsilateral or contralateral sites of normal PVs by more proximal ablation at the PV antrum rather than ostial ablation. Furthermore, early identification and effective elimination of non-PV foci may increase the efficacy of RFCA for AF in these patients.

**Study Limitations**

In this study, the number of CLD patients with AF was too small to draw definitive conclusions. Fifteen patients (2.0%) out of 752 consecutive patients who underwent RFCA were found to have CLD. Four (50%) out of 8 COPD patients underwent a pulmonary function test within at least 6 months before RFCA, which fulfilled the GOLD criteria, but the other 4 patients were defined as having COPD based on significant emphysematous changes on chest radiography with a long-standing history of heavy smoking and a treatment history of oral bronchodilators.
Assessment of the relationship between LA-PV electroanatomical alteration and arrhythmogenicity was limited because only 60% of the patients demonstrated spontaneous or induced arrhythmogenic foci before ablation.

Conclusions

Significant alterations in PV anatomy provide pro-arrhythmia grounds for AF in CLD patients. Non-PV foci in the RA were observed more frequently in the CLD group than in the control group. RFCA can be carried out safely for AF in CLD patients with a comparable success rate to that in patients with normal lungs.

Conflict of Interest Disclosures: None

References:


19. Hwang C, Wu TJ, Doshi RN, Peter CT, Chen PS. Vein of marshall cannulation for the


Table 1. Clinical Characteristics of the Patients with Atrial Fibrillation in Chronic Lung Diseases

<table>
<thead>
<tr>
<th></th>
<th>Control (n=60)</th>
<th>CLD (n=15)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/Female</td>
<td>52/8</td>
<td>13/2</td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td>60.2 ± 10.6</td>
<td>60.2 ± 11.0</td>
<td></td>
</tr>
<tr>
<td>Paroxysmal</td>
<td>40 (66%)</td>
<td>10 (66%)</td>
<td></td>
</tr>
<tr>
<td>Persistent</td>
<td>20 (33%)</td>
<td>5 (33%)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>8 (13%)</td>
<td>2 (13%)</td>
<td>&gt; 0.99</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>2 (3%)</td>
<td>2 (13%)</td>
<td>0.17</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>2 (3%)</td>
<td>1 (7%)</td>
<td>0.57</td>
</tr>
<tr>
<td>LV EF, %</td>
<td>56.8 ± 5.4</td>
<td>54.6 ± 5.5</td>
<td>0.14</td>
</tr>
<tr>
<td>LA diameter/BSA, cm/m²</td>
<td>23.7 ± 4.9</td>
<td>23.0 ± 6.2</td>
<td>0.51</td>
</tr>
<tr>
<td>LA volume/BSA, mL/m²</td>
<td>33.6 ± 12.5</td>
<td>35.9 ± 16.1</td>
<td>0.57</td>
</tr>
<tr>
<td>E/E'</td>
<td>9.6 ± 5.3</td>
<td>10.2 ± 4.2</td>
<td>0.76</td>
</tr>
<tr>
<td>PA systolic pressure, mmHg</td>
<td>31.6 ± 4.8</td>
<td>35.4 ± 8.9</td>
<td>0.04</td>
</tr>
<tr>
<td>Hb, g/dl</td>
<td>14.3 ± 1.5</td>
<td>14.1 ± 1.8</td>
<td>0.62</td>
</tr>
<tr>
<td>Na, mmol/L</td>
<td>140.5 ± 2.3</td>
<td>140.4 ± 2.4</td>
<td>0.85</td>
</tr>
<tr>
<td>K, mmol/L</td>
<td>4.2 ± 0.4</td>
<td>4.1 ± 0.4</td>
<td>0.70</td>
</tr>
</tbody>
</table>

*Data are presented as mean ±SD. CLD: chronic lung disease; LV: left ventricle; LA: left atrium; EF: ejection fraction; BSA: body surface area; PA: pulmonary artery; Hb: hemoglobin. *P-values are calculated using a linear mixed model.*
### Table 2. Baseline Characteristics of Each Patient in the Chronic Lung Disease Group.

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Age, yr</th>
<th>Type of AF</th>
<th>Lung disease</th>
<th>Other diseases</th>
<th>FVC</th>
<th>FEV1</th>
<th>FEV1/FVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>70</td>
<td>Paroxysmal</td>
<td>TDL</td>
<td></td>
<td>86</td>
<td>107</td>
<td>1.24</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>56</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>Old MI</td>
<td>116</td>
<td>62</td>
<td>0.53</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>65</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>42</td>
<td>Paroxysmal</td>
<td>TDL</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>71</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td></td>
<td>89</td>
<td>65</td>
<td>0.73</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>49</td>
<td>Paroxysmal</td>
<td>TDL</td>
<td></td>
<td>37</td>
<td>39</td>
<td>1.05</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>75</td>
<td>Paroxysmal</td>
<td>ILD</td>
<td></td>
<td>76</td>
<td>87</td>
<td>1.14</td>
</tr>
<tr>
<td>8</td>
<td>Male</td>
<td>67</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>MR</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Male</td>
<td>57</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>HTN, DM</td>
<td>92</td>
<td>58</td>
<td>0.63</td>
</tr>
<tr>
<td>10</td>
<td>Male</td>
<td>42</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Male</td>
<td>49</td>
<td>Persistent</td>
<td>TDL</td>
<td></td>
<td>73</td>
<td>66</td>
<td>0.90</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>75</td>
<td>Persistent</td>
<td>COPD</td>
<td></td>
<td>92</td>
<td>69</td>
<td>0.75</td>
</tr>
<tr>
<td>13</td>
<td>Male</td>
<td>67</td>
<td>Persistent</td>
<td>TDL</td>
<td>HCMP</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Male</td>
<td>57</td>
<td>Persistent</td>
<td>COPD</td>
<td>DM</td>
<td>NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Male</td>
<td>63</td>
<td>Persistent</td>
<td>TDL</td>
<td></td>
<td>86</td>
<td>80</td>
<td>0.93</td>
</tr>
</tbody>
</table>

*AF*, atrial fibrillation; *COPD*, chronic obstructive pulmonary disease; *DM*, diabetes mellitus; *FEV1*, forced expiratory volume in 1 second; *FVC*, forced vital capacity; *HCMP*, hypertrophic cardiomyopathy; *HTN*, hypertension; *ILD*, interstitial lung disease; *MI*, myocardial infarction; *MR*, mitral regurgitation; *TDL*, tuberculosis destructive lung; *NA*, non available.

### Table 3. Main symptom of CLD patient and post-ablation change

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of AF</th>
<th>Lung disease</th>
<th>NYHA Functional class</th>
<th>Pre-procedure Symptom</th>
<th>Post-ablation Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Paroxysmal</td>
<td>TDL</td>
<td>II</td>
<td>Palpitation, dyspnea</td>
<td>Relieved</td>
</tr>
<tr>
<td>2</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>II</td>
<td>Palpitation, chest pain</td>
<td>Not relieved</td>
</tr>
<tr>
<td>3</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>II</td>
<td>Dyspnea</td>
<td>Relieved</td>
</tr>
<tr>
<td>4</td>
<td>Paroxysmal</td>
<td>TDL</td>
<td>I</td>
<td>Syncope, fluttering</td>
<td>Relieved</td>
</tr>
<tr>
<td>5</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>III</td>
<td>Palpitation</td>
<td>Relieved</td>
</tr>
<tr>
<td>6</td>
<td>Paroxysmal</td>
<td>TDL</td>
<td>III</td>
<td>Dyspnea</td>
<td>Not relieved</td>
</tr>
<tr>
<td>7</td>
<td>Paroxysmal</td>
<td>ILD</td>
<td>II</td>
<td>Palpitation, syncope</td>
<td>Relieved</td>
</tr>
<tr>
<td>8</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>I</td>
<td>Palpitation, insomnia</td>
<td>Relieved</td>
</tr>
<tr>
<td>9</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>II</td>
<td>Palpitation</td>
<td>Relieved</td>
</tr>
<tr>
<td>10</td>
<td>Paroxysmal</td>
<td>COPD</td>
<td>I</td>
<td>Palpitation</td>
<td>Relieved</td>
</tr>
<tr>
<td>11</td>
<td>Persistent</td>
<td>TDL</td>
<td>I</td>
<td>Palpitation, tremor</td>
<td>Not relieved</td>
</tr>
<tr>
<td>12</td>
<td>Persistent</td>
<td>COPD</td>
<td>II</td>
<td>Dyspnea</td>
<td>Not relieved</td>
</tr>
<tr>
<td>13</td>
<td>Persistent</td>
<td>TDL</td>
<td>II</td>
<td>Fluttering</td>
<td>Relieved</td>
</tr>
<tr>
<td>14</td>
<td>Persistent</td>
<td>COPD</td>
<td>II</td>
<td>Fluttering, chest pain</td>
<td>Not relieved</td>
</tr>
<tr>
<td>15</td>
<td>Persistent</td>
<td>TDL</td>
<td>I</td>
<td>Tremor, chest tightness</td>
<td>Not relieved</td>
</tr>
</tbody>
</table>

*AF*, atrial fibrillation; *NYHA*, New York Heart Association; *COPD*, chronic obstructive pulmonary disease; *ILD*, interstitial lung disease; *TDL*, tuberculosis destructive lung;
Figure Legends:

**Figure 1.** Chest radiographs and pulmonary vein CT 3-dimensional reconstruction images of the representative patients in the chronic lung disease group. Panels A and B are images of the patients with a lung destroyed by tuberculosis. Panels C and D are images of patients with chronic obstructive pulmonary disease. A red dot indicates the site of arrhythmogenic focus-initiated atrial fibrillation in each patient.

*CT=computed tomography*

**Figure 2.** A representative example illustrating ablation summary in patient with tuberculosis-destructive left lung. Panel A. Chest X-ray shows hazy, collapsed left lung with tracheal deviation to the left. Panel B. Three-dimensional reconstruction images of computed tomography of pulmonary veins. Left pulmonary veins indicated by a red arrow are totally occluded. Panel C. Fluoroscopic image showing position of the catheters (left anterior oblique view) at the SVC, high RA, RA septum, coronary sinus, and a Lasso catheter at the ostium of RSPV. A quadripolar catheter is positioned at the non-coronary aortic cusp as the reference of NavX mapping system. Panel D. Intracardiac electrograms showing the APC from RSPV initiated atrial fibrillation. Note a prominent pulmonary vein potential during sinus rhythm is reversed with APC. Panel E. The ablation summary on the 3-dimensional CT merged with NavX shell of the left atrial image, right anterior oblique and left anterior oblique view, respectively. The ablation points marked by white dots indicate right pulmonary veins isolation, in conjunction with linear ablation along the crista terminalis, septum, and cavotricuspid isthmus of the right atrium indicated by ball marks.

*APC=atrial premature contraction, CSd and CSp=coronary sinus distal and proximal,*
HRA=high right atrium, LAA=left atrial appendage, L1-10= 10 bipolar electrograms of Lasso catheter, LRA=low right atrium, RA=right atrium, RIPV=right inferior pulmonary vein, RSPV=right superior pulmonary vein, SVC=superior vena cava.

**Figure 3.** Panel A. Pre-ablation pulmonary vein CT. Panel B: Four pulmonary veins isolation guided by noncontact mapping system. Panel C: Post-ablation 7 months follow up CT of patient 14 in Table 2. The enlarged left pulmonary vein trunk indicated by a red arrow in panel A had shrunk, without evidence of significant stenosis.

RIPV=right inferior pulmonary vein, RSPV=right superior pulmonary vein, LIPV=left inferior pulmonary vein, LSPV=left superior pulmonary vein

**Figure 4.** Kaplan-Meier analysis of atrial fibrillation-free survival in CLD and control group. There was no significant difference. P-value was calculated using a stratified Cox’s proportional hazard regression model.

CLD= Chronic lung disease
Patients with destructive lung due to Tuberculosis (A and B)

COPD Patients (C and D)

● : arrhythmogenic focus
AF free survival rate

Follow up period (months)

P = 0.49
Catheter Ablation of Atrial Fibrillation in Patients with Chronic Lung Disease
Seung-Young Roh, Jong-II Choi, June Young Lee, Jae-Jin Kwak, Jae-Seok Park, Ji-Bak Kim, Hong-Euy Lim and Young-Hoon Kim

Circ Arrhythm Electrophysiol. published online September 26, 2011;
Circulation: Arrhythmia and Electrophysiology is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2011 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-3149. Online ISSN: 1941-3084

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circep.ahajournals.org/content/early/2011/09/26/CIRCEP.110.960435

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation: Arrhythmia and Electrophysiology can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation: Arrhythmia and Electrophysiology is online at:
http://circep.ahajournals.org//subscriptions/