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# Predictors of Successful Catheter Ablation for Atrial Fibrillation Using the Pulmonary Vein Isolation Technique

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**Abstract**

***Objectives***. Pulmonary vein isolation has been performed to cure atrial fibrillation(Af). However, the recurrence rate of Af is relatively high, and additional sessions are sometimes required. The predictors of successful pulmonary vein isolation were evaluated.

***Methods***. The study population consisted of 52 patients(41 men, mean age 55±9 years)with Af who underwent pulmonary vein isolation. A second session was required in 22 patients with recurrence of Af after the first session. Pulmonary vein isolation eliminated Af in 38 patients after 1 or 2 sessions. Patients with successful pulmonary vein isolation($n=39$)were compared with those with unsuccessful pulmonary vein isolation despite 2 sessions($n=13$).

***Results***. The patients in the successful group had significantly higher incidence of paroxysmal Af(92% vs 46%, $p<0.001$)and lower incidence of mitral regurgitation(10% vs 46%, $p<0.01$)than those in the unsuccessful group. However, there was no significant difference between the two groups with regard to age, history of Af, cardiopulmonary ratio, dimension of left atrium, ejection fraction, pulmonary vein diameter, and pulmonary vein number.

***Conclusions***. Type of Af and presence of mitral regurgitation are significant predictors of successful pulmonary vein isolation.

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**Key Words**

■**Atrial fibrillation**(**pulmonary vein isolation**) ■**Ablation-catheter**
■**Mitral regurgitation**

## INTRODUCTION

Atrial fibrillation(Af)is the most common type of arrhythmia in humans. Most cases of Af are initiated by premature beats from the orifices of the pulmonary veins or from the myocardial sleeves inside the pulmonary veins, so radiofrequency catheter ablation targeting pulmonary veins could cure Af[1–7]. Pulmonary vein isolation can be achieved by electrophysiological breakthroughs from the left atrium to the pulmonary vein[5]. More than 90% of pulmonary veins were electrically disconnected from the left atrium by targeting only certain segments of the ostial circumference, as guided by pulmonary vein potential. These results confirm that there are isolated fascicles that travel

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from the left atrium into the muscle sleeves that surround the pulmonary veins, and that ablation of these fascicles, as opposed to circumferential ablation at the ostium, is sufficient to isolate the veins. Segmental pulmonary vein isolation resulted in significant reduction in the symptom severity and improvement in the quality of life of patients with drug refractory paroxysmal Af[8]. However, prior studies of segmental pulmonary vein isolation found a large percentage of patients required additional ablation procedures[3,5].

The present study evaluated the predictors of successful pulmonary vein isolation for Af.

## SUBJECTS AND METHODS

### Study population

The study population consisted of 52 patients (41 men, mean age 55 ± 9 years) with paroxysmal ($n = 42$) or persistent Af ($n = 10$) who underwent pulmonary vein isolation or focal ablation. Cardioversion was implemented in the early stage (< 24 hr), because many patients in the persistent group had severe symptoms. Therefore, paroxysmal Af was defined as Af terminating spontaneously within 24 hr, and persistent Af as Af lasting more than 24 hr which required cardioversion to restore sinus rhythm.

No structural heart disease was present in 35 patients. Hypertension was present in 14 patients, mitral regurgitation in 10, coronary artery disease in 8, and cardiomyopathy in 2. Significant mitral regurgitation was defined as more than second degree flow by Doppler echocardiography. All antiarrhythmic drugs were discontinued for at least five half-lives before the study. Informed consent was obtained from all patients before the study.

### Catheter positions

Three multipolar electrode catheters (Daig Corp.) were positioned in the right atrial appendage, the His bundle area, and the distal coronary sinus. After an atrial transseptal procedure, a long sheath (8-French, Daig Corp. SL-1) was put into the left atrium through the foramen ovale of the atrial septum from the right femoral vein. Pulmonary vein angiography was performed with an angiocatheter (6-French, Baxter) to determine the position of the catheters relative to the ostium of the pulmonary veins. A 7-French deflectable, quadripolar ablation catheter (EPT) was inserted in the left atrium directly through the foramen ovale. Intravenous heparin was administered at 1,000 U/hr after the atrial transseptal procedure.

### Electrophysiological study

Bipolar intracardiac electrograms were recorded at a filter setting of 30 to 500 Hz and stored digitally on an EPMed system (EP MedSystems, Inc.) simultaneously with the surface electrocardiography. A unipolar electrogram was recorded from the distal electrode of the ablation catheter using a filter ranging from 0.05 to 500 Hz. A programmed stimulator (SEC-3102, Nihon Koden) was used to deliver electrical stimuli at twice the diastolic threshold for 2 msec. If Af was not spontaneously present, burst atrial pacing (10 to 20 beats), isoproterenol, or both were used to facilitate spontaneous Af. If the episode of induced Af was sustained for > 10 min, external cardioversion (with 100 to 300 J) was attempted to defibrillate Af, and the spontaneous re-initiation of Af was monitored.

### Pulmonary vein isolation

All pulmonary veins with distinct and late pulmonary vein potentials were targeted for ablation. After a targeted pulmonary vein was identified, a basket catheter (Constellation, EPT) or a circular 20-electrode catheter (Lasso, Webster) was deployed in the pulmonary vein through a transseptal sheath. Circumferential pulmonary vein electrograms were acquired simultaneously, and used to guide the ablation at the ostial sites with the earliest pulmonary vein potentials during sinus rhythm for the right pulmonary veins or distal coronary sinus pacing for the left pulmonary veins. The source of ectopy as well as the electrical inputs from the atria to pulmonary vein were determined. Radiofrequency pulses were delivered with the temperature preset to 50 ℃ (CABL-IT, Central Inc.) with a power limit of 30 W for 30 to 60 sec at ostial sites with the earliest pulmonary vein potentials while monitoring distal pulmonary vein potentials. If the activation sequence around the pulmonary vein ostium was changed, the bipole showing the new shortest atrio-pulmonary vein conduction was targeted. The endpoint was determined as elimination of atrio-pulmonary vein conduction based on abolition of distal pulmonary vein potentials.

### Follow-up

Heparin (500 U/hr) was continuously administered for 24 hr, and oral coumadin was continued

for 1 month with an international normalized ratio level of about 2.0. Follow-up examinations were performed at this institution, initially at 1 week, and subsequently at 1-month intervals. Clinical examination, electrocardiography, and 24-hour Holter recordings were made every 3 months and if symptoms suggested recurrence of the arrhythmia. Three dimensional computer tomography was obtained at 3 and 6 months after ablation to assess stenosis of the pulmonary veins. Ablation was considered successful if no recurrence of Af was present without drug administration during the follow-up.

### Comparison of parameters between successful and unsuccessful groups

Age, history of Af, type of Af, incidence of mitral regurgitation, cardiothoracic ratio, the dimension of the left atrium, the ejection fraction, pulmonary vein number, and the pulmonary vein diameter were compared between the successful and unsuccessful groups.

### Statistical analysis

Data are presented as mean $\pm$ SD. Unpaired *t*-test was used for comparison of parameters between the successful and unsuccessful groups. $p < 0.05$ was considered statistically significant.

## RESULTS

Pulmonary venous isolation was performed in all 52 patients. One, 2, 3 and 4 pulmonary veins were ablated in 10, 12, 25 and 5 patients, respectively. A total of 129 pulmonary veins, including 46 left superior, 42 right superior, 33 left inferior, and 8 right inferior pulmonary veins were ablated. The earliest pulmonary vein potentials were localized in a segment of the circumference of the ostium, whereas the remaining perimeter was activated sequentially later. Ablation limited to a single segment blocked atrio-pulmonary vein conduction and the ablation of the secondary breakthrough eliminated all distal pulmonary vein potentials in 84 pulmonary veins (65%). Multiple radiofrequency applications to more than two segments were required to eliminate all distal pulmonary vein potentials in 117 pulmonary veins (91%). Pulmonary vein disconnection could be achieved by less than 3 segmental ablations in 98% of all pulmonary veins. The electrical breakthrough points were mainly located in the inferior well in the superior pulmonary veins, and in the superior wall in the left inferior pulmonary vein.

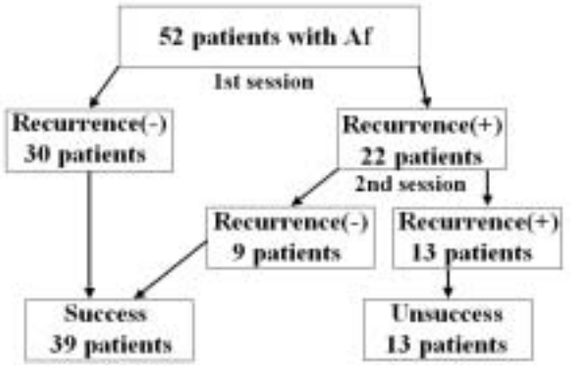


**Fig. 1 Outcome of pulmonary vein isolation**
After the first session, atrial fibrillation recurred in 22 patients, who underwent a second session. After the second session, atrial fibrillation recurred in 13 patients. Pulmonary vein isolation with 1 or 2 sessions eliminated atrial fibrillation in 39 patients.
Af = atrial fibrillation.

Af recurred in 22 patients after the first session. A second session was performed in 16 patients due to the recovery of atrio-pulmonary vein conduction (including 2 other pulmonary vein foci and 1 non-pulmonary vein focus), 3 patients with non-pulmonary vein foci (1 atrio-pulmonary vein conduction recurrence and 1 near ablated pulmonary vein are implicated), 2 patients with recurrence from pulmonary vein ostia proximal to the previous pulmonary venous isolation (1 atrio-pulmonary vein recurrence and 1 non-pulmonary vein), and 3 patients with recurrence from a different pulmonary vein (including 2 atrio-pulmonary vein conduction). Af recurred at a median of 3 days (range, 1 to 7 days) after the first procedure. Af recurred in 13 patients after the second session. During a mean follow up of $15 \pm 8$ months, pulmonary vein isolation with 1 or 2 sessions eliminated Af without antiarrhythmic drugs in 39 patients (**Fig. 1**). No complications including pulmonary vein stenosis were observed during follow-up.

### Comparison of the successful and unsuccessful groups

Patients with successful pulmonary vein isolation ($n = 39$) were compared with those with unsuccessful ablation ($n = 13$). The patients in the successful group had significantly higher incidence of paroxysmal Af (92% vs 46%, $p < 0.001$) and lower incidence of mitral regurgitation (10% vs 46%, $p < 0.01$) than those in the unsuccessful group.

**Table 1 Comparison of parameters between successful and unsuccessful groups**

| | Successful group ($n$=39) | Unsuccessful group ($n$=13) | $p$ value |
|---|---|---|---|
| Age (yr) | 57±9 | 53±9 | NS |
| Male/female | 32/7 | 9/4 | NS |
| Af history (months) | 43±40 | 62±43 | NS |
| Paroxysmal Af | 36 (92) | 6 (46) | <0.001 |
| Persistent Af | 3 ( 8) | 7 (54) | <0.001 |
| Hypertension | 13 (33) | 1 ( 8) | NS |
| Mitral regurgitation | 4 (10) | 6 (46) | <0.001 |
| Coronary artery diseases | 7 (18) | 1 ( 8) | NS |
| Cardiomyopathy | 1 ( 2) | 1 ( 8) | NS |
| Cardiopulmonary ratio (%) | 49±5 | 47±4 | NS |
| Left atrial dimension (mm) | 39±6 | 38±4 | NS |
| Ejection fraction (%) | 66±10 | 62±11 | NS |
| Pulmonary vein diameter (mm) | 18±12 | 18±9 | NS |
| Pulmonary vein number | 2±0.9 | 3±0.7 | NS |

Continuous values are mean±SD. ( ): %.
Abbreviation as in Fig. 1.

However, there was no significant difference between the two groups with regard to age, sex, history of Af, incidence of other organic heart diseases, left atrium dimension, ejection fraction, pulmonary vein diameter, and pulmonary vein number (**Table 1**).

## DISCUSSION

This study found that in patients who required a second procedure, recovery of conduction through the surrounding pulmonary veins was the most common reason for recurrent Af after pulmonary vein isolation. It is possible that some of the fascicles were too thick to be ablated with the conventional radiofrequency energy limited to 30 W. This would explain why a saline-irrigated ablation catheter, which creates deeper lesions than a conventional ablation catheter, was needed to isolate about 10% of pulmonary veins[5]. Recovery of atriopulmonary vein conduction may be prevented if the power of the radiofrequency energy applications is not limited to 30 W. However, a conservative approach to ablation is favored to minimize the risk of pulmonary vein stenosis.

Another reason for recurrence of Af after pulmonary vein isolation is unmasked foci from the pulmonary vein ostial edge or atrial tissue. Previous studies have demonstrated that the foci that trigger paroxysmal Af arise from areas other than the pulmonary veins in 5% to 15% of patients[1,2]. Pulmonary vein isolation should be supplemented by some other type of ablation procedure directed at the atrial tissue. The ideal catheter ablation strategy remains to be determined.

In the present study, the patients in the successful group had significantly higher incidence of paroxysmal Af than those in the unsuccessful group. This finding is consistent with a previous study which reported that the efficacy of pulmonary vein isolation in patients with persistent Af was only 29%[6]. Pulmonary vein isolation performed intraoperatively under direct visualization in patients with chronic Af restored sinus rhythm in only about 33% of patients[9]. These results suggest that the pulmonary veins are less critical in generating Af once the Af has become persistent. Electrophysiological and anatomic remodeling may occur during persistent Af and allow the atria to continue fibrillating independent of the pulmonary veins. Therefore, it may be preferable to intervene with catheter ablation before paroxysmal Af progresses to persistent Af.

In contrast to the findings of the present study, another study reported that pulmonary vein isolation was equally effective in patients with paroxysmal and persistent Af, with about 60% of patients being free of recurrent Af 9 months after circumferential ablation at the ostia of the pulmonary veins[10]. The explanation for this discrepancy is

unclear but may be related to differences in patient selection or technique.

In the present study, the other significant predictor of successful pulmonary vein isolation was the presence of mitral regurgitation. Atrial stretch induced by increased volume overload may precipitate Af through some effect on atrial refractoriness. Elevation of atrial pressure might cause electrical remodeling, which may increase the stability of Af and be involved in the transition of paroxysmal Af to persistent Af. A limitation of this study is that left atrial dimension was only 39±5mm with all patients, because the enrollment of patients with paroxysmal and persistent Af was intentionally restricted. Also, drugs including diuretics may have influenced the results.

## CONCLUSIONS

The present study demonstrated that the type of Af and the presence of mitral regurgitation were significant predictors of successful pulmonary vein isolation. Therefore, paroxysmal Af without mitral regurgitation may be eligible for pulmonary vein isolation.


## 要　　約

### 肺静脈隔離術を用いた心房細動に対するカテーテルアブレーションの成功予測因子

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東條　秀明　　松本　直道　　朔　啓二郎

**目　的**: 肺静脈隔離術は心房細動の治療目的に施行されている．しかし，心房細動は再発率が比較的高く，追加のセッションがしばしば必要とされる．我々は肺静脈隔離術の成功予測因子を評価した．

**方　法**: 対象は肺静脈隔離術を経験した発作性または持続性心房細動患者52例(男性41例，平均年齢55±9歳)である．発作性心房細動は24時間以内に自然停止する心房細動，持続性心房細動は24時間以上続く心房細動と定義した．最初のセッション後，22例の患者で心房細動の再発がみられ，2回目のセッションを施行した．39例の患者で1または2回の肺静脈隔離術が施行された．肺静脈隔離術の成功群(39例)と，2回の肺静脈隔離術にもかかわらず不成功であった群(13例)とを比較検討した．

**結　果**: 成功群では，不成功群より発作性心房細動の占める割合が有意に高く(92% vs 46%，$p<0.001$)，僧帽弁閉鎖不全の頻度が有意に低かった(10% vs 46%，$p<0.01$)．しかし，両群間で，年齢，心房細動歴，他の基礎疾患，左房径，左室駆出率，心胸郭比に有意差はみられなかった．

**結　論**: 心房細動のタイプと心臓弁膜症の存在が，肺静脈隔離術の成功規定因子として重要と考えられた．

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