New Approach to Pulmonary Vein Isolation for Atrial Fibrillation Using a Multielectrode Basket Catheter

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Background  Pulmonary vein (PV) isolation using a circular catheter creates an entrance block from the left atrium (LA) to the PV, which eliminates paroxysmal atrial fibrillation (PAF). A new approach to PV isolation during distal PV pacing is to use a basket catheter.

Methods and Results  Fifty consecutive patients with PAF underwent basket-catheter-guided PV isolation. PV pacing was performed from the distal electrode pair of the basket catheter. The exit breakthrough point was targeted for segmental PV isolation. The endpoint was the elimination of bidirectional PV–LA conduction. A repeat ablation procedure was performed in 12 of 14 patients who had recurrence of AF. The recovery of PV–LA conduction was noted in 24 of the 48 PVs, and 5 PVs (21%) had unidirectional block. At 12 months, 80% of patients were free of AF without antiarrhythmic drugs. No PV stenosis >50% was detected at 12 months after the procedure.

Conclusions  This new approach for PV isolation during distal PV pacing using a basket catheter is useful for confirming bidirectional PV–LA conduction block. PV isolation that creates not only an entrance block but also an exit block at the PV–LA junction may be required to cure paroxysmal AF. (Circ J 2006; 70: 88–93)

Key Words: Atrium; Catheter ablation; Fibrillation; Pulmonary veins

Atrial fibrillation (AF) is the most common arrhythmia in humans, and most AF is initiated by premature beats from the orifices of the pulmonary veins (PVs) or from the myocardial sleeves inside the PVs. Therefore, radiofrequency (RF) catheter ablation that targets PVs should cure AF. A circular mapping catheter pioneered by Haissaguerre et al facilitates identification of the conduction pathways from the left atrium (LA) to the PVs, and permits segmental ablation to achieve PV isolation. However, PV isolation usually creates an entrance block from the LA to the PV, and an exit block from the PV to LA is not usually confirmed. Moreover, in the right PVs, it is sometimes difficult to discriminate PV and LA potentials during sinus rhythm.

Therefore, we developed a new approach to PV isolation during distal PV pacing using a multipolar basket catheter to confirm bidirectional conduction block between the PV and LA.

Methods

Patients  The study population consisted of 50 consecutive patients (35 men, 15 women; mean age 57±11 years) with symptomatic drug-refractory paroxysmal AF (PAF) who were referred for an electrophysiological study (EPS) and catheter ablation. PAF was defined as self-terminating within 7 days of onset; the mean duration of AF was 69±65 months, and the mean number of AF episodes per month was 12±9.

On echocardiography the mean LA diameter was 38±5 mm and the mean ejection fraction was 65±6%. A mean of 3.0±1.1 antiarrhythmic drugs had been administered unsuccessfully. None of the patients had been treated with amiodarone during the 6 months preceding the procedure.

EPS  Written informed consent was given by all patients. Patients received oral anticoagulant for at least 1 month before ablation. Antiarrhythmic drugs were discontinued 5 half-
lives before ablation. Three 6-French (F) quadripolar electrode catheters (Daig, USA) were placed in the right atrial appendage, His bundle area and coronary sinus (CS). A transseptal approach was performed with an 8.5F sheath for both puncture and to introduce a 31 mm, 64-pole basket catheter (Constellation, Boston Scientific, USA) dedicated to PV mapping. After transseptal puncture, 100 IU heparin/kg was given intravenously. During the procedure, heparinization was continued to maintain an activated clotting time of 250–350 s. A 4-mm-tip conventional ablation catheter (EP Technologies, USA) was also introduced into the LA for ablation. PV angiography was performed with an angiocatheter (6F, Baxter, USA) to determine the ostium of the PVs. The proximal part of the PVs was defined as the ostial side of the veins, and distal referred to the lung side of the veins.

A programmed stimulator (SEC-3102, Nihon Kohden, Japan) was used to deliver electrical impulses of 2-ms duration at twice the diastolic threshold, with the negative pole connected to the distal electrode of the pacing catheter. ECG leads and intracardiac electrograms filtered at 30–500Hz were recorded simultaneously with a polygraph (EPLab System DUO, Bard, USA).

### Basket Catheter-Guided PV Isolation

After transseptal access was gained, the basket catheter was inserted directly into the upper PVs. For introduction into the inferior PVs, the sheath was inserted first with the help of a steerable ablation catheter. Once the sheath was in place in the PV, the steerable catheter was removed and...
replaced by the basket catheter. The basket catheter was then deployed in the PV by slowly advancing it while simultaneously withdrawing the sheath. The proximal electrode (bipoles 7–8) of the basket catheter were located at the PV–LA junction (Fig 1). The location of the ostium was determined both by electrogram morphology and by noting the shape of the basket catheter as it conformed to the PV and ostial anatomy as confirmed by angiography.

The Astronomer system (Boston Scientific) was used for navigation inside the basket catheter. This system consists of a switching/locating device and an off-the-shelf laptop computer. The device and the laptop communicate via a standard RS-232 interface. The device delivers AC current (32 kHz, 320 μA) between the ablation catheter-tip electrode and a reference (skin patch) electrode, and the resulting electrical potentials are sensed at each basket catheter electrode. Based on the voltages sensed at each of the basket catheter electrodes, the Astronomer device determines whether the roving electrode is in close proximity to a basket catheter electrode and lights the corresponding elec-
Guided by the basket catheter and the Astronomer system, ablation was performed at the PV–LA junction, as ostial as catheter stability allowed.

PV pacing was performed from the distal (bipoles 1–2) electrode pair of all splines of the basket catheter. Stable pacing sites were considered only if the threshold was <5 V. The electrical entrance breakthrough points during distal CS pacing (for left PVs) or sinus rhythm (for right PVs) and the exit breakthrough points during PV distal pacing were determined. Fig 2 shows the exit breakthrough points of a left superior PV disclosed by PV distal pacing. In this case, during left atrial appendage pacing, the entrance breakthrough site was A–H 7–8. In contrast, the exit breakthrough point was detected at D–E 7–8. The exit breakthrough point was targeted for segmental PV isolation. Distal PV pacing easily discriminated PV and LA potentials in both the right and left PVs (Fig 3).

Circumferential electrograms around the PV–LA junction were used to guide ablation at ostial sites with the earliest atrial potentials during distal PV pacing. If unidirectional conduction block between the PV and LA was observed, ablation was continued until bidirectional conduction block was created (Figs 4, 5). The endpoint was considered to be bidirectional conduction block between the PV and LA based on both the inability to capture the LA during distal PV pacing and abolition of distal PV potentials (Fig 6).

**RF Ablation**

All PVs were targeted for isolation. However, when the PV diameter was <12 mm, ablation was not performed, because of concerns about PV stenosis. RF energy was delivered with a temperature-controlled, 4-mm-tip, deflectable catheter (EP Technologies). RF energy (EP Technologies) was delivered at a target temperature of 50°C and a maximum output of 30 W for 30–60 s at each ostial site. If the activation sequence around the PV–LA junction was changed, the bipole that showed the new earliest atrial potentials was targeted. After PV isolation, if premature atrial contractions were present or could be provoked by isoproterenol or by pacing maneuvers (incremental pacing or programmed stimulation), the origin of the premature atrial contractions was localized by activation mapping, and ablation was performed at this site.

**Follow-up**

Warfarin was re-administered and continued for 3 months with an international normalized ratio level of approximately 2.0. Follow-up was performed at the same institution, initially at 1 week and subsequently at 1-month intervals. Clinical examination, ECG and 24-h Holter recordings were made every 3 months and when symptoms suggested recurrence of an arrhythmia. Three-dimensional (D) computed tomography (CT) was performed at 6 months and 12 months after ablation to assess stenosis of the PVs. A change in the PV diameter as measured by 3-D CT between before and 12 months after ablation that showed a decrease in PV diameter of more than 25% was considered significant. Success of the procedure was defined as the absence of clinical symptoms of AF without antiarrhythmic drugs and documentation of stable sinus rhythm on 24-h Holter monitoring.

**Results**

**Basket Catheter-Guided PV Isolation**

The basket catheter could be introduced in all right and left superior and all left inferior PVs, but in only 42 right inferior PVs. PV isolation was performed in 192 targeted PVs (mean 3.8 per patient) that were isolated successfully. The threshold of the distal PV and PV–LA junction was...
3.1±0.5 V and 3.0±0.4 V, respectively. Segmental ablation at the exit breakthrough points during distal PV pacing blocked conduction from the PV to LA. Bidirectional conduction block between the PV and LA was confirmed by PV–LA dissociation in all PVs. The mean total ablation time and number of applications required to achieve complete isolation per PV was 11±6 min and 19±12 times for left superior PV, 8±4 min and 11±7 times for right superior PV, 6±4 min and 9±7 times for left inferior PV, and 6±5 min and 9±6 times for right inferior PV. A median of 5, 4, 3, and 2 splines were targeted in the left superior, right superior, left inferior, and right inferior PVs, respectively. The mean total duration of the procedure was 212±70 min and the mean total fluoroscopy time was 60±25 min.

Recurrence of AF
After the first ablation procedure, PAF recurred in 14 of the 50 patients (28%). A repeat ablation procedure was performed 38±7 days after the initial procedure in 12 patients. During the repeat procedures, the recovery of PV–LA conduction was noted in 24 of the 48 PVs (50%). Of these 24 PVs, 5 (21%) had unidirectional block (recovery of exit block 3, recovery of entrance block 2).

Follow-up
After 62 procedures in 50 patients, 80% of those who underwent ablation were free of AF at the 12-months follow up (after the most recent ablation) without the need for antiarrhythmic drug treatment. An additional 6 patients (12%) were free of AF with the aid of antiarrhythmic drug treatment. An additional 6 patients (12%) underwent ablation were free of AF at the 12-months follow up (after the most recent ablation) without the need for antiarrhythmic drug treatment. An additional 6 patients (12%) were free of AF with the aid of antiarrhythmic drug treatment.

Complications
One patient developed pericardial effusion, which was drained percutaneously. Mild PV stenosis (<50%) was seen in 12% of the patients, but no PV stenosis >50% was detected by 3-D CT at 12 months after the procedure.

Discussion
There are isolated fascicles that travel from the LA into the muscle sleeves that surround the PVs and ablation of these fascicles, as opposed to circumferential ablation at the ostium, may be sufficient to isolate the veins. Segmental ostial ablation electrically isolates the PVs, thereby eliminating the arrhythmogenic activity in the PVs that triggers and/or perpetuates episodes of PAF. Arentz et al. reported basket-catheter-guided PV isolation, which is a feasible and safe procedure for curing patients of AF by integrating PV anatomy and electrophysiology with a navigation system for the ablation catheter. However, they performed PV isolation by creating only the entrance block during sinus rhythm or CS pacing, and did not confirm the exit block by distal PV pacing. Using basket catheter mapping, we analyzed the activation map of PV and found that the entrance breakthrough points were sometimes different from the exit breakthrough points, and that PV–LA juncional reentrant circuits involving the exit and entrance breakthrough points were formed.

A circular mapping catheter can record circumferential PV potentials within the PV, whereas a basket catheter provides the following potential advantages: (1) 3-D reconstruction of PV activation from the ostium to deep inside the PV; (2) identification of the location of the PV ostium and of discharging foci in the PV, which can be easily detected by a single beat; (3) the nonfluoroscopic Astronomer navigation system enables precise and reproducible guidance of the ablation catheter; and (4) possibility of simultaneous distal pacing and proximal mapping.

In PV isolation, conduction from the LA to the PV is usually blocked during sinus rhythm or CS pacing, but it is possible that conduction from the PV to the LA may remain after entrance block from the LA to PV. Recovery of conduction over a previously ablated PV fascicle has been a consistent finding among patients who undergo a repeat procedure, and it is likely that incomplete ablation is related to unidirectional conduction block. However, it is sometimes difficult to confirm the conduction block from the PV to the LA. We have described a new approach for PV isolation during distal PV pacing using a basket catheter. Moreover, in the right PVs, it is sometimes difficult to discriminate PV and LA potentials during sinus rhythm, but distal PV pacing can easily discriminate these potentials. Segmental ablation at the exit site during distal PV pacing creates a conduction block from the PV to LA, and bidirectional conduction block between the PV and LA is also easily confirmed.

In addition, because of its length and structure, the basket catheter achieves a more proximal recording from the PV–LA junction and permits more proximal PV isolation, which also may be important for greater success. By allowing both circular and longitudinal mapping the basket catheter offers significant advantages over the more simple circular catheter.

When RF energy is delivered at the ostium and the maximum power is limited to 35 W, the risk of PV stenosis is reportedly low (3%). In this study, no instances of significant PV stenosis (>50%) occurred. A circular mapping catheter is usually placed inside the PV, and ablation is performed inside the PV because of the targeting of PV potentials. In contrast, basket-catheter-guided ablation is performed at the more proximal site of the PV because it targets atrial potentials. This technology may minimize the risk of PV stenosis by avoiding ablations inside the PV. Therefore, the use of complementary navigation systems or intracardiac echo may not be necessary when a basket catheter is used for PV isolation. Recently, Oral et al demonstrated that left atrial catheter ablation to encircle PVs is more effective than segmental ostial catheter ablation. However, left atrial catheter ablation sometimes has complications, including left atrial flutter and atrio-esophageal fistulas. Such severe complications were not observed in the present study, so basket-catheter-guided ostial ablation may be an alternative to left atrial catheter ablation.

Conclusion
Basket-catheter-guided PV isolation is an effective and safe procedure for curing patients of AF by integrating PV anatomy and electrophysiology with a navigation system for the ablation catheter. Also, this new approach for PV isolation during distal PV pacing is feasible and can easily confirm bidirectional conduction block between the PV and LA. PV isolation that creates not only an entrance block but also an exit block at the PV–LA junction may be required to cure AF.

References
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