Electrophysiological Breakthroughs From the Left Atrium to the Pulmonary Veins

Michel Haïssaguerre, MD; Dipen C. Shah, MD; Pierre Jaïs, MD; Mélèze Hocini, MD; Teiichi Yamane, MD; Isabel Deisenhofer, MD; Michel Chauvin, MD; Stéphane Garrigue, MD; Jacques Clémenty, MD

**Background**—The extent of ostial ablation necessary to electrically disconnect the pulmonary vein (PV) myocardial extensions that initiate atrial fibrillation from the left atrium has not been determined.

**Methods and Results**—Seventy patients underwent PV mapping with a circumferential 10-electrode catheter during sinus rhythm or left atrial pacing. After assessment of perimetric distribution and activation sequence of PV potentials, ostial ablation was performed at segments showing earliest activation, with the end point of PV disconnection. A total of 162 PVs (excluding right inferior PVs) were ablated. PV potentials were present at 60% to 88% of their perimeter, but PV muscle activation was always sequential from a segment with earliest activation (breakthrough). Radiofrequency (RF) application at this breakthrough eliminated all PV potentials in 34 PVs, whereas a secondary breakthrough required RF applications at separate segments in 77; in others, ≥2 segments were ablated. A median of 5, 6, and 4 bipoles from the circular catheter were targeted in the right superior, left superior, and inferior PVS, respectively, to achieve PV disconnection. Early recurrence of arrhythmia was observed in 31 patients as a result of new venous or atrial foci or recovery of previously targeted PVS, most related to a single recovered breakthrough that was reablated with local RF application.

**Conclusions**—Although PV muscle covers a large extent of the PV perimeter, there are specific breakthroughs from the left atrium that allow ostial PV disconnection by use of partial perimetric ablation. (Circulation. 2000;102:2463–2465.)

**Key Words:** fibrillation ■ veins ■ lung ■ ablation
of the PV perimeter were targeted on the basis of the bipole(s) from the circular catheter showing the earliest activation during sinus rhythm or pacing of the distal coronary sinus (or left atrial appendage). The ablation catheter was positioned correspondingly on fluoroscopy, and the local largest-amplitude PVP was first targeted for ablation. Subsequent RF applications were performed if needed at contiguous sites showing synchronous PVP. If PV activation changed as a result of RF ablation, the ostial sector now showing the earliest PVP was targeted. The end point was elimination of PV muscle conduction distal to the ablation site(s) based on either abolition or dissociation of distal PVPs and elimination of ectopic beats, spontaneous or induced by provocative maneuvers (isoproterenol and burst pacing). RF ablation of atrial foci, if present, was performed at the site of earliest activation.

RF energy was delivered at the distal electrode (Celsius, Biosense Webster) of the thermocouple-equipped catheter (target: 50°C) with a power limit of 25 to 30 W for 30 to 60 seconds at each site. If this power could not be reached (presumably because of reduced local blood flow), an irrigated-tip catheter (17 mL/min saline flow) was used with the same target temperature and power. Arrhythmogenic PVs were sequentially ablated, provided that the PV diameter was unchanged on angiography. PV angiography was repeated after 20 minutes of surveillance, with PV "stenosis" defined as a diameter reduction of >50% and a CT scan performed >3 months later in 36 patients to exclude late PV compromise.

Patients were discharged after day 3 under oral anticoagulant. Success was defined as elimination of AF without antiarrhythmic drug. Anticoagulants were interrupted 3 months after successful elimination of AF, unless there were other risk factors.

Statistical Analysis
Continuous variables are expressed as group mean value ± SD or median value (nongaussian distribution). Statistical significance was selected at a value of $P < 0.05$ with a Kruskall-Wallis or $\chi^2$ test.

Results
A total of 162 PVs were mapped, including 61 left superior, 55 right superior, and 46 left inferior. Eleven arrhythmogenic right inferior PVs could not be mapped but were ablated anatomically. Procedure duration and fluoroscopy times were 206 ± 49 and 65 ± 18 minutes, respectively.

Perimetric Distribution
At the atrial margin of the ostia, PVPs were present circumferentially (all bipoles displayed local PVPs), whereas inside the PVs, PVPs covered only various parts of the perimeter (from 3 to 10 bipoles), with a consistent reduction from proximal to distal (Table). The percentage of perimetric PV muscle coverage was higher ($P < 0.05$) for both superior PVs than for the left inferior PV.

Activation of PV Muscle in the Proximal PV
Muscle activation was never circumferentially synchronous in the PVs, during either sinus rhythm or atrial pacing, indicating preferential breakthrough(s) into the vein. The earliest PVPs were localized to a segment of the perimeter (median of 3 contiguous bipoles, range 1 to 4), whereas the remaining perimeter was activated sequentially later. The circumferential conduction time was 33 ± 15 ms (range 10 to 85 ms) during sinus rhythm.

RF Ablation
RF delivery was begun at the earliest activated ostial segment, with the circumferential catheter in a distal monitoring position.
could be difficult to localize precisely because they immediately induced sustained AF.

With a mean follow-up of 4±5 months after discharge, AF was completely eliminated in 51 patients (73%) without antiarrhythmic drug. No PV stenosis was noted during follow-up.

### Discussion

This study describes the results of PV ostial ablation guided by circumferential mapping data. It indicates that although PV muscle covers a large extent of PV perimeter, there are specific breakthrough(s) from the left atrium that allow ostial PV disconnection with minimal ablation.

The left atrial–PV breakthroughs were inferred from the mapping data showing sequential activation of the PV perimeter. Differing sequences during right (sinus rhythm) or left (pacing) atrial activation indicated differing breakthroughs, whereas an unchanged sequence did not necessarily indicate a single breakthrough, perhaps because of 1 input having a shorter conduction time and/or a nonoptimal pacing site. Mapping data were confirmed by results of ablation producing local elimination or prolongation of conduction and shifting of the breakthrough. The extent of perimetric ablation was thus less than the actual muscle coverage. During RF ostial ablation, monitoring of distal PVPs provided online demonstration of ablation effects, showing abrupt abolition of PVPs in 1 step in nearly half of the veins, indicating a distally interconnected PV network, whereas abolition in >1 step suggested distally separated PV fascicles. Recovery of all PV conduction after ablation was linked to a single recovered input in most, which was focally reablated.

The question of anatomic inputs (or their embryological development) to the PV has not been specifically addressed in the literature; however, a single breakthrough may be related to a myocardial band with oblique or circular course ending in a cul-de-sac, whereas either a dual band or fascicles described as “looping back in the left atrium” may be the substrate for dual-input muscle.

The findings of this study have practical implications. In addition to providing an immediate obvious end point, circumferential mapping optimizes RF ablation at the PV ostia by directing energy at specific segments and avoiding unnecessary applications at others, thus minimizing the risk of PV stenosis. However, this technique may not be applicable to RF ablation outside the PV ostia, which may require complete circumferential lesions to produce distal disconnection. Other limitations include the continued high recurrence rate of AF due to unmasked foci from the ostial edge or atrial tissue characterized by difficulty in precise mapping and absence of a similar end point.

### References

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