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Circular Mapping and Ablation of the Pulmonary Vein for Treatment of Atrial Fibrillation

Impact of Different Catheter Technologies

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OBJECTIVES We conducted this study to compare the efficacy and safety of different catheter ablation technologies and of distal versus ostial pulmonary veins (PV) isolation using the circular mapping technique.

BACKGROUND Electrical isolation of the PVs in patients with atrial fibrillation (AF) remains a technical challenge.

METHODS Two hundred eleven patients (163 men; mean age 53 ± 11 years) with symptomatic AF were included in this study. In the first 21 patients (group 1), distal isolation (≥5 mm from the ostium) was achieved targeting veins triggering AF. In the remaining 190 patients (group 2), ostial isolation of all PVs was performed using 4-mm tip (47 patients), 8-mm tip (21 patients), or cooled-tip (122 patients) ablation catheters.

RESULTS Distal isolation was able to eliminate premature atrial contractions (PACs) and AF in six of 21 patients (29%) and 10 of 34 PVs. After a mean follow-up time of 6 ± 4 months, no patients treated with the 8-mm tip catheter experienced recurrence of AF, whereas 21% (10 of 47 patients) and 15% (18 of 122 patients) of the patients ablated with the 4-mm tip and the cooled-tip ablation catheters experienced recurrence of AF after a mean follow-up of 10 ± 3 and 4 ± 2 months, respectively. Significant complications including stroke, tamponade, and severe stenosis occurred in 3.5% (8/211) of patients.

CONCLUSIONS Catheter technologies designed to achieve better lesion size appeared to have a positive impact on procedure time, fluoroscopy time, number of lesions, and overall efficacy. Although distal isolation can be achieved with fewer lesions, ostial isolation is required in the majority of patients to eliminate arrhythmogenic PACs and AF. (J Am Coll Cardiol 2002;40:464–74)
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Ablation of ectopic triggers of atrial fibrillation (AF) has been reported to eliminate AF (1,2). Mainly, two different strategies had been developed to map and eliminate pulmonary veins (PVs) triggers: focal ablation targeting single or multiple foci in the arrhythmogenic PV trunk, or electrical isolation of the PV by circumferential PV lesions (1–4). Recently, distal ablation of PV triggers applying segmental lesions at the site of earliest conduction identified by circumferential mapping technique has been suggested to be effective (5). We initiated this study to compare the efficacy and safety of different catheter ablation technologies in PV isolation using circumferential mapping. Moreover, we assessed the effect of distal isolation of the PVs in the initial group of patients.

METHODS

Patients characteristics. Two hundred eleven patients (163 men; mean age 53 ± 11 years) with symptomatic paroxysmal (113 patients), persistent (34 patients), and permanent (64 patients) AF (duration 5.5 ± 3.6 years) were referred to our laboratory for electrophysiology study and catheter ablation. All patients signed a written informed consent. Data were collected based on a protocol approved by the institutional ethics committee. All antiarrhythmic drugs (3 ± 1 drugs) were discontinued five half-lives before the ablation. In all but three patients amiodarone was withdrawn one month before the procedure. Structural heart disease was present in 24% of patients (51/211). Immediately prior to the procedure transesophageal echocardiography was performed in all study patients. A spiral computerized tomography (CT) scan was performed two or three months after the procedure. In the first 21 patients (13 men, mean age 52 ± 10 years) distal isolation was initially performed (group 1). In addition, in group 1 only veins showing firing were targeted. In the remaining 190 patients (group 2) (148 men, mean age 53 ± 11 years), ostial isolation was exclusively performed. In this group all PVs were isolated.

Mapping and ablation catheters. Three multipolar electrode catheters and a bipolar esophageal lead were used to map beats triggering AF (6). A custom-made catheter (Cardiac Assist Device Inc., Cleveland, Ohio) was placed in the coronary sinus (CS). The proximal eight electrodes were positioned between the superior vena cava (SVC) and the

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Abbreviations and Acronyms

AF = atrial fibrillation
LA = left atrium
LLPV = left lower pulmonary vein
LUPV = left upper pulmonary vein
PAC = premature atrial contractions
PV = pulmonary vein
PVP = pulmonary vein potential
RLPV = right lower pulmonary vein
RUPV = right upper pulmonary vein

high crista terminalis, whereas the distal eight electrodes were in the CS. A transesophageal recording lead was used to record the left atrial posterior wall activation. Mapping of left atrium (LA) and PVs was completed after approaching the LA via the transseptal approach. Two separate transseptal accesses were obtained. A 6-French multielectrode, deflectable tip circular catheter (Cardiac Assist Device Inc.) with 2 mm interelectrode space in 76 patients, or a loop catheter (Lasso, Biosense-Webster, Baldwin Park, California) with deflectable shaft in 135 patients were used to map pulmonary vein potentials (PVPs). The diameter of the circular loop of the deflectable tip and the Lasso catheter ranged from 1 to 2.5 cm and 1 to 2.0 cm, respectively, chosen to fit the PV circumference according to the preablation venogram. Depending on the diameter, the custom-made circular mapping catheter (Cardiac Assist Device Inc.) had 12, 14, or 16 electrodes.

In group 1, a quadripolar 4-mm tip (Biosense Webster) ablation catheter was exclusively used for distal and ostial PV isolation. Quadripolar 4-mm tip, 8-mm tip (Biosense Webster), and cooled-tip catheters (EP Technologies, Sunnyvale, California) were used for ablation in 47, 21, and 122 patients of group 2, respectively. In the first 95 patients the 4-mm tip and the cooled tip catheters were used in alternating fashion. The 8-mm tip catheter was used in 11 consecutive patients during the first month and in the other 10 patients during the third month of this experience. The ostium of the PVs was confirmed by performing PV vein angiography during adenosine (range 12 to 24 mg) induced asystole. In addition, electrical mapping of PV- and LA potentials was also used to target proximal lesions. In this respect, any PVPs recorded in front of the LA-PV junction defined by angiography were considered extension of the PVs sleeves and were targeted for ablation. The PV angiogram was obtained in 30° left anterior oblique and 30° right anterior oblique views. Fifteen to 20 cc of manually injected contrast was used for each angiogram. Intravenous heparin was titrated to maintain the activated clotting time >300 s after the transseptal puncture.

Electrophysiologic study and ablation. In patients presenting to the electrophysiology laboratory with sustained AF, external DC cardioversion was performed. Before ablation, isoproterenol infusion (2 to 20 μg/min) was given only to patients with no or few premature atrial contractions (PACs). Isoproterenol infusion was initiated at a dose of 2 μg/min for 3 min and then increased by 3 μg/min every 2 min and up to 20 μg/min until AF was initiated. Documentation of single or multiple ectopies conducted from a certain PV and initiating AF by rapid firing on at least three separate occasions defined an arrhythmogenic PV. If circumferential recording during sinus rhythm revealed double or multiple potentials at a certain site, the first low-frequency spike was considered LA potential, and the latest high-frequency spike reflected PVP (Fig. 1). If LA potentials were superimposed to the PVP, distal CS or right atrial pacing was performed to achieve their separation. During ectopic beats a reversal of activation was observed, that is, high-frequency PVP preceded the LA potential (Fig. 1D).

Once origin from the right or left PVs was documented (6), two circular mapping catheters were placed in the upper and lower veins on the site of interest. After the PV with the earliest activity conducted to the atrium was identified, the circular multipolar catheter was positioned to map that particular PV circumferentially. Circumferential mapping was initiated in the distal PV trunk 5 mm from the PV-LA junction, looking for the most distally recorded PVP (Fig. 1). During ectopies the earliest PVP was considered as the origin of arrhythmogenic beat (Fig. 2). PV ostium mapping was conducted after positioning the circular mapping catheter at the junction between PV and LA defined based on the PV angiogram and the intracardiac electrogram.

Distal isolation performed in group 1 was defined as successful abolition of PVP mapped 5 mm from the ostium of the arrhythmogenic PV (Figs. 3B and C). This approach was initially considered because the circular mapping catheter tended to be more stable inside the vein. Radiofrequency (RF) ablation was performed targeting the earliest circumferentially recorded PVP during sinus rhythm or CS pacing, and subsequently if needed targeting contiguous sites showing earlier PVP. Ostial isolation (at the PV-LA junction) was performed in the same fashion. Distal isolation was performed only in the first 21 patients. Subsequently, considering the results observed in this group of patients, ostial isolation was exclusively used in the remaining 190 patients. For the purpose of documentation, the PV circumference was divided into 16 sectors. Failure of distal and/or proximal isolation to eliminate arrhythmogenic PACs initiating AF was considered if we were still able to record spontaneous or isoproterenol-induced (at a maximum dose of 20 μg/min) AF originating from the targeted veins despite successful circumferential abolition of PVPs. Group 1 patients were not included in the analyses comparing different ablation technologies.

Target temperature was 55°C for the RF energy delivery through the 4-mm and 8-mm tip catheters. A 35°C target temperature was chosen for RF energy delivery through the cooled-tip catheter. At each site energy was delivered for 40 s. After ablation, PV venograms were repeated to assess for stenosis. At the end of the procedure, patients were given a crushed aspirin (325 mg) orally and coumadin was restarted.

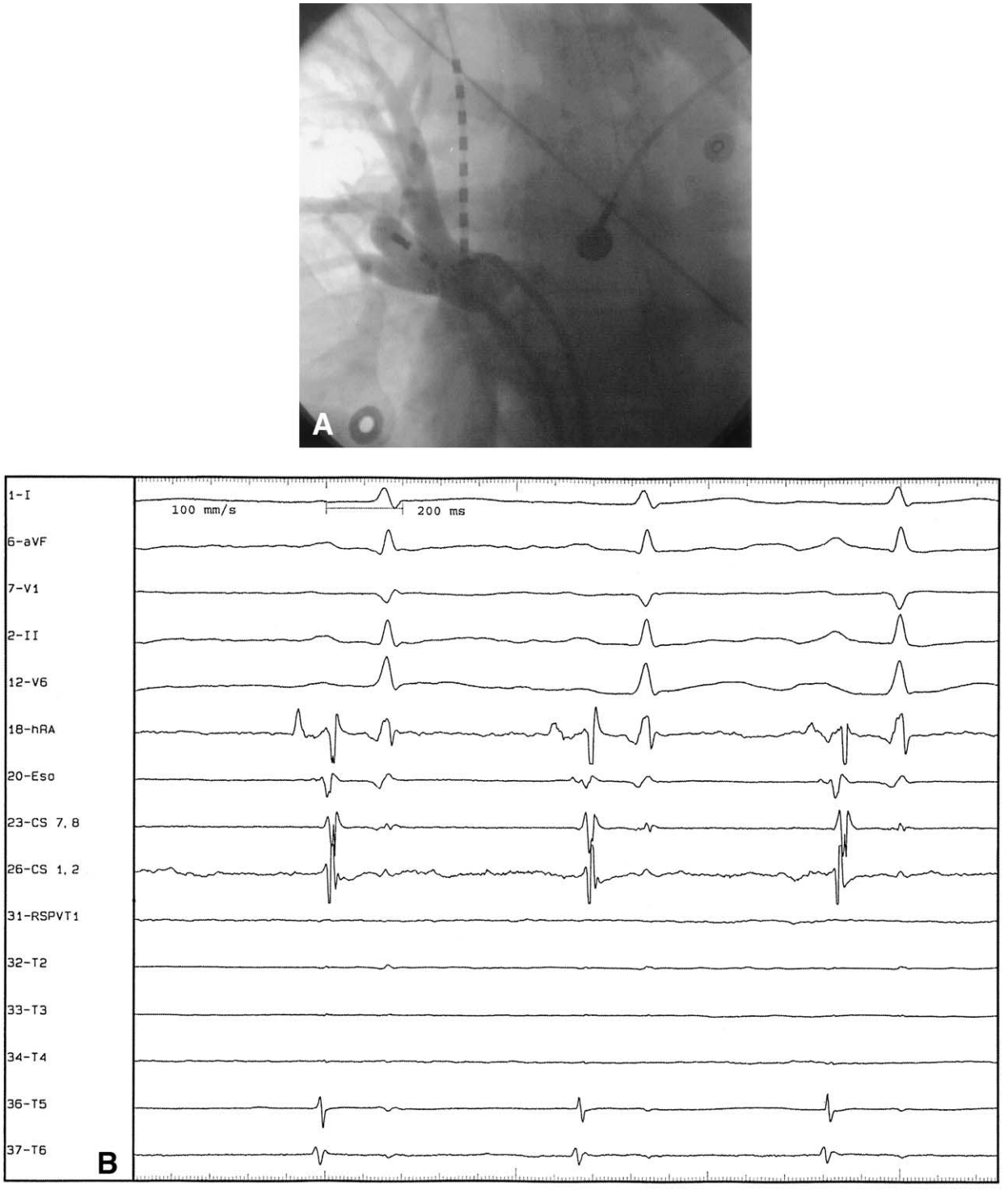
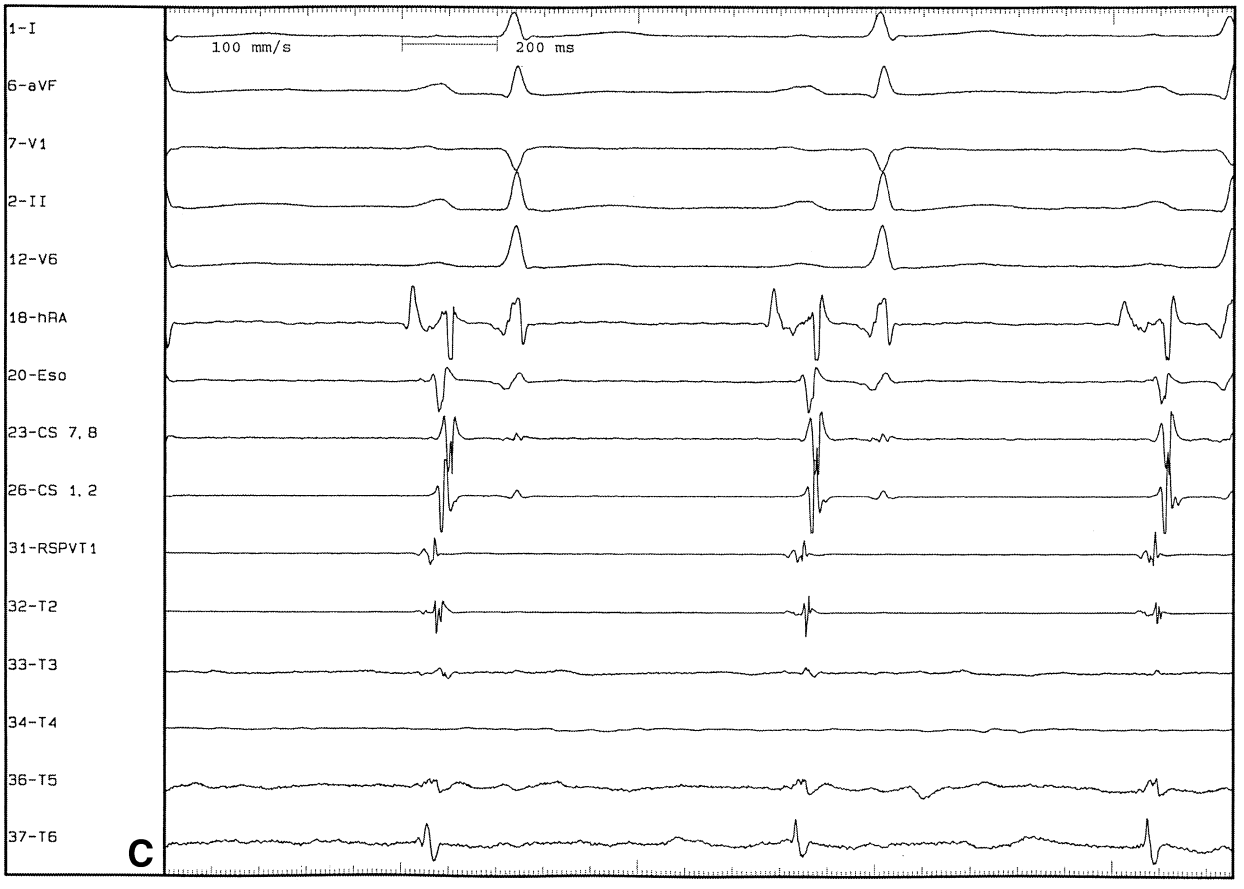
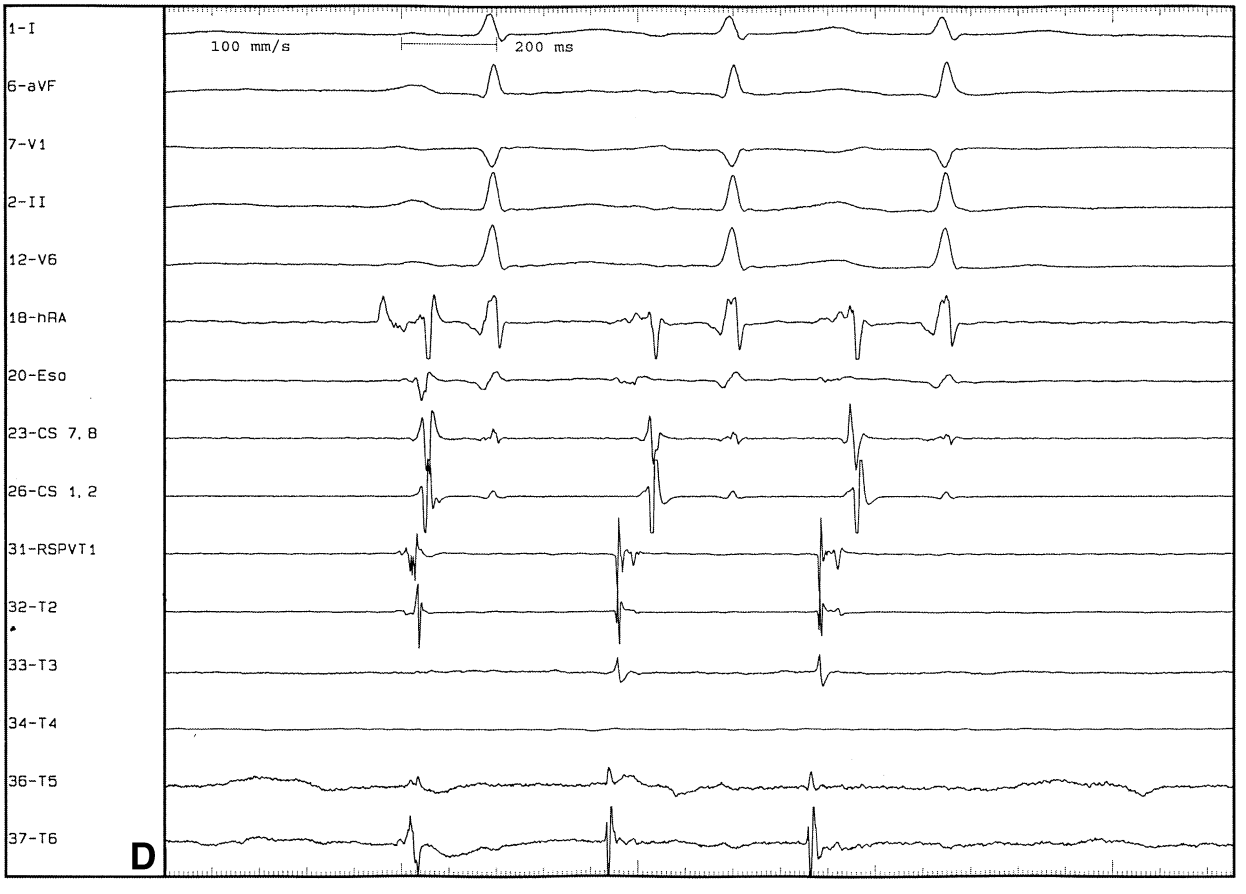


Figure 1. Pullback mapping in a right upper pulmonary vein using the circular mapping catheter shown in **panel A**. One cm inside the vein **(B)**, pulmonary vein potentials (PVPs) appeared barely present. Five mm from the ostium PVPs are recorded at T1, T2, T5, and T6 **(C)**. Ultimately at the ostium, local pulmonary vein (PV) electrograms are seen at every bipole except T4 **(D).** After ostial isolation, requiring 19 lesions, no local ostial PV activity is observed **(E)**. V_1 and aVF represent surface electrocardiographic recordings. ESO = esophageal recording; hRA ds = high right atrium (hRA ds applies to Fig. 3C); CS = coronary sinus recording; T1–T6 = distal to proximal bipolar recordings from the circular catheter (CC). *Continued on next page.*

Follow-up. If no complications occurred, patients were discharged home next day. All patients were discharged on oral anticoagulation (warfarin). Follow-up was scheduled at one, three, six, and 12 months post ablation. After two to three months, anticoagulation was stopped unless patients experienced recurrence of AF, or if more than 70% narrowing of the treated PV was proven by the spiral CT scan, or if other thromboembolic risk factors were known. Patients





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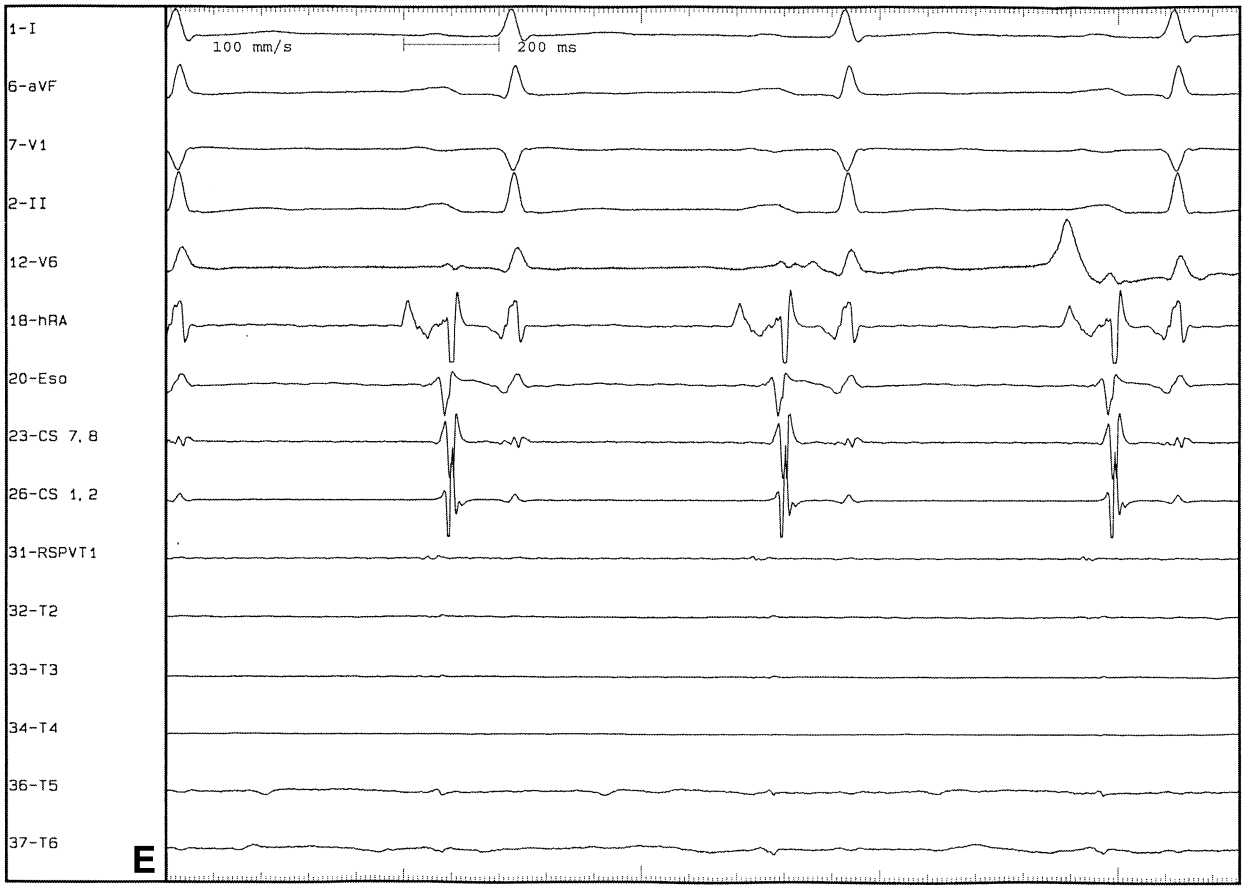

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were also monitored with Holter recording before discharge, at three- and six-month follow-up. In case of recurrence of symptoms, event recorder monitoring was also considered. Recurrence during the first three weeks after ablation was not considered a true recurrence unless it persisted beyond that time frame. Two to three months after the ablation, a spiral CT scan of the PVs was obtained in all patients.

Statistical analysis. Continuous variables are expressed as mean ± SD. Continuous variables were compared by Student *t* test. Differences among groups of continuous variables were determined by analysis of variance. Categorical variables were compared by Fisher exact test. A Kaplan-Meier analysis with the log-rank test was used to determine the probability of freedom from recurrent AF. A Cox multivariate regression analysis was performed to determine the clinical predictors of freedom from symptomatic AF. A value of $p < 0.05$ was considered statistically significant.

RESULTS

All patients had documentation of symptomatic episodes of paroxysmal (113 patients), persistent (34 patients), or permanent (64 patients) AF on several 24-h Holter monitor recordings (median number of Holter 3, range 2 to 5). One hundred ten patients presented to the electrophysiology laboratory in sinus rhythm (SR), 90 were in AF, and 11 in atrial flutter/fibrillation. In 22 of 110 patients in SR, spontaneous ectopies and AF were documented. DC cardioversion was followed by spontaneous reinitiation of AF in 40 of the 101 patients with sustained AF or flutter. Isoproterenol was applied for the initiation of APCs and AF in 15 patients in group 1 and in the first 51 patients in group 2. In 71% of group 1 patients and 69% of group 2 patients, in whom isoproterenol was administered pre-ablation, isoproterenol was required to initiate ectopies triggering AF. Table 1 illustrates patients' characteristics.

Pulmonary vein ectopy. In group 1, arrhythmogenic ectopic foci originated from a single vein in 12 patients, from two veins in six patients, from three veins in two patients, and from four veins in another patient, for a total of 34 arrhythmogenic PV foci in 21 patients.

In group 2, arrhythmogenic ectopic foci originated from a single vein in 65 patients. Firing from two veins occurred in 47 patients, from three veins in 31 patients, and from four veins in 19 patients, for a total of 330 arrhythmogenic PV foci in 190 patients. This included 110 right upper pulmonary veins (RUPV), 122 left upper pulmonary veins (LUPV), 36 right lower pulmonary veins (RLPV), and 62 left lower pulmonary veins (LLPV). In group 2 all PVs were isolated regardless of the mapping information.

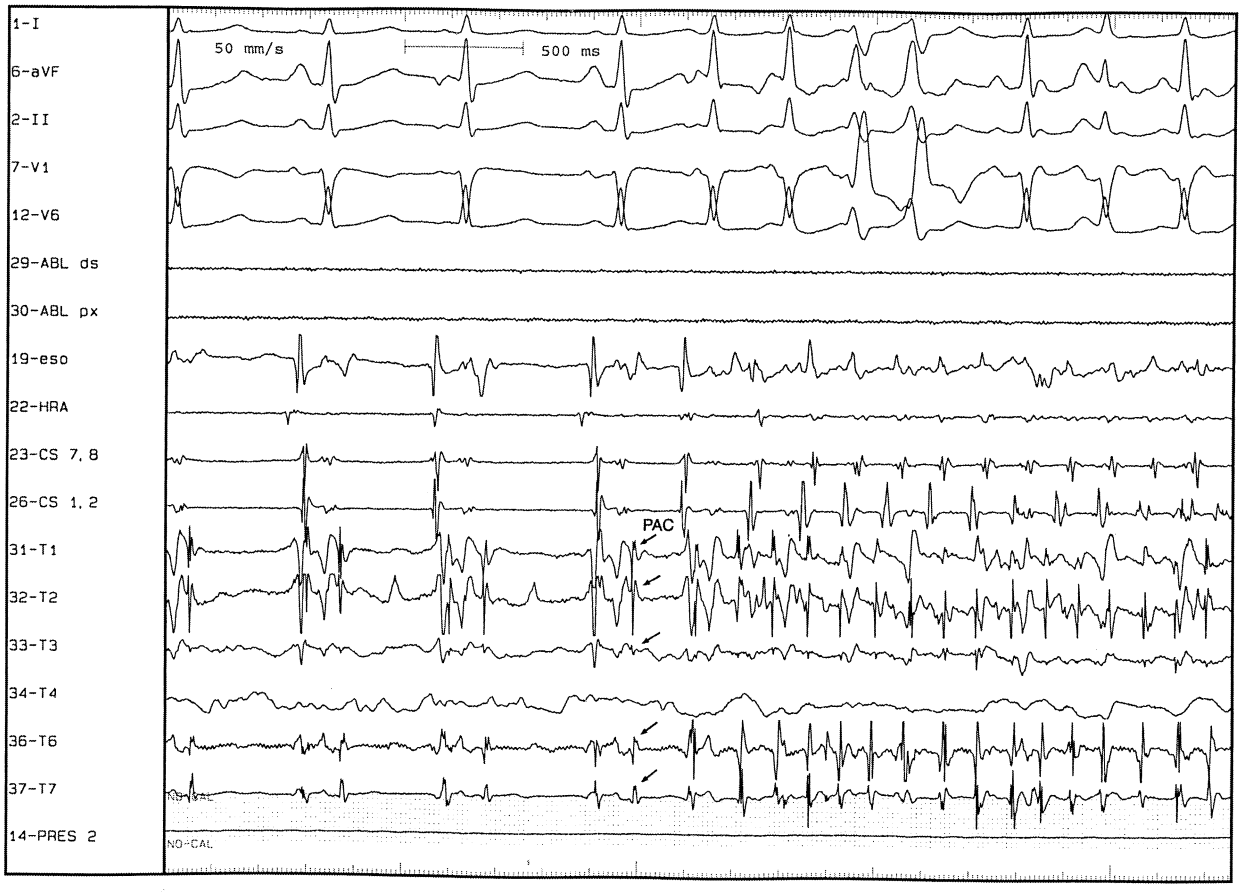


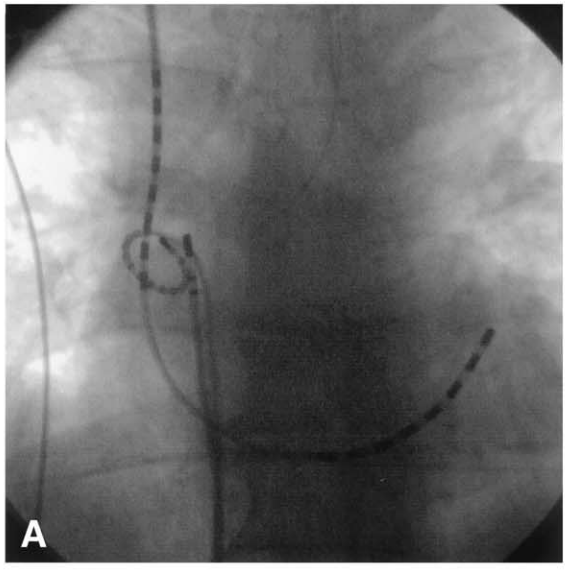
Figure 2. Intracardiac recordings showing concealed premature atrial contraction (PAC), which eventually managed to activate the atrium and initiate AF. Differently from what we observed distally in the vein, ostial initiations appeared to have a more longitudinal activation sequence. Note simultaneous activation in T1, T2, T3, T6, and T7. Bipole T4 does not record any PVP, but appeared to correspond to the take off of a branch. See Figure 1 for abbreviations.

Distal and ostial isolation. Distal isolation was performed in the first 21 patients (group 1). As mentioned before, this approach was considered because the circular catheter was more stable when distally deployed. Lesions were delivered targeting the site with the earliest activation on the circular mapping catheter in 34 arrhythmogenic PVs. RF energy was delivered using the 4-mm tip ablation catheter 6 ± 2 mm into the RUPV, 5 ± 2 mm into the LUPV, 7 ± 1 mm into the RLPV, and 6 ± 1 mm into the LLPV. A mean of 5 ± 2 RF (3 ± 1 min) were needed for distal isolation (Table 2). After distal isolation, PV ectopies initiating AF from the treated vein were still present in 15 (71%) of 21 patients (Fig. 3C). In veins still capable of initiating ectopies and AF after distal isolation (24 of 34 PVs), ostial isolation was conducted. In 1 LUPV ostial isolation was not attempted because of evidence of nearly complete occlusion after distal ablation.

Ostial isolation was performed in 712 PVs in group 2. In one patient the procedure was terminated due to evidence of neurologic embolic event before proximal isolation of the RUPV was achieved. In 48 patients (25%) angiographic evidence of a single ostium of either both left PVs (32 patients, 17%) or both right PVs (16 patients 8%) was documented. To obtain ostial isolation, a mean of 10 ± 4 RF lesions (8.6 ± 2 min) per vein were delivered.

After ostial isolation, no PACs triggering AF were initiated from all but one PV despite an average infusion rate of isoproterenol of 14.3 ± 4.7 μg/min in group 2. In one patient, isolation of a large RUPV ostium appeared difficult and was abandoned because of evidence of neurologic embolic event. The mean procedure and fluoroscopy times were significantly lower using the 8-mm tip (3 ± 1 h and 51 ± 8 min) and cooled-tip (4.6 ± 1 h and 88 ± 24 min) ablation catheter compared with the 4-mm tip (5.5 ± 3 and 110 ± 40 min) ablation catheter (Table 2), $p < 0.05$. The procedure time included the transesophageal echocardiogram performed in the laboratory before the ablation.

Initiation of premature atrial contractions and AF with isoproterenol. Seventy-one percent of group 1 patients (15/21) and 69% of group 2 patients (35/51) required isoproterenol for initiation of ectopies triggering AF. Preablation the mean dose of isoproterenol needed for induction was 14 ± 2 μg/min. None of the patients had AF at a dose of 2 μg/min. After isolation of the culprit arrhythmogenic PV, firing from a different vein was seen with a mean isoproterenol of 9.2 ± 2.2 μg/min (range 6 to 10 μg/min) and 17.2 ± 4.2 μg/min (range 10 to 20 μg/min) in 24% (5/21) and 35% (7/21) of group 1 patients, and 8.2 ± 3.2 μg/min (range 6 to 10 μg/min) and 16.2 ± 4.2 μg/min



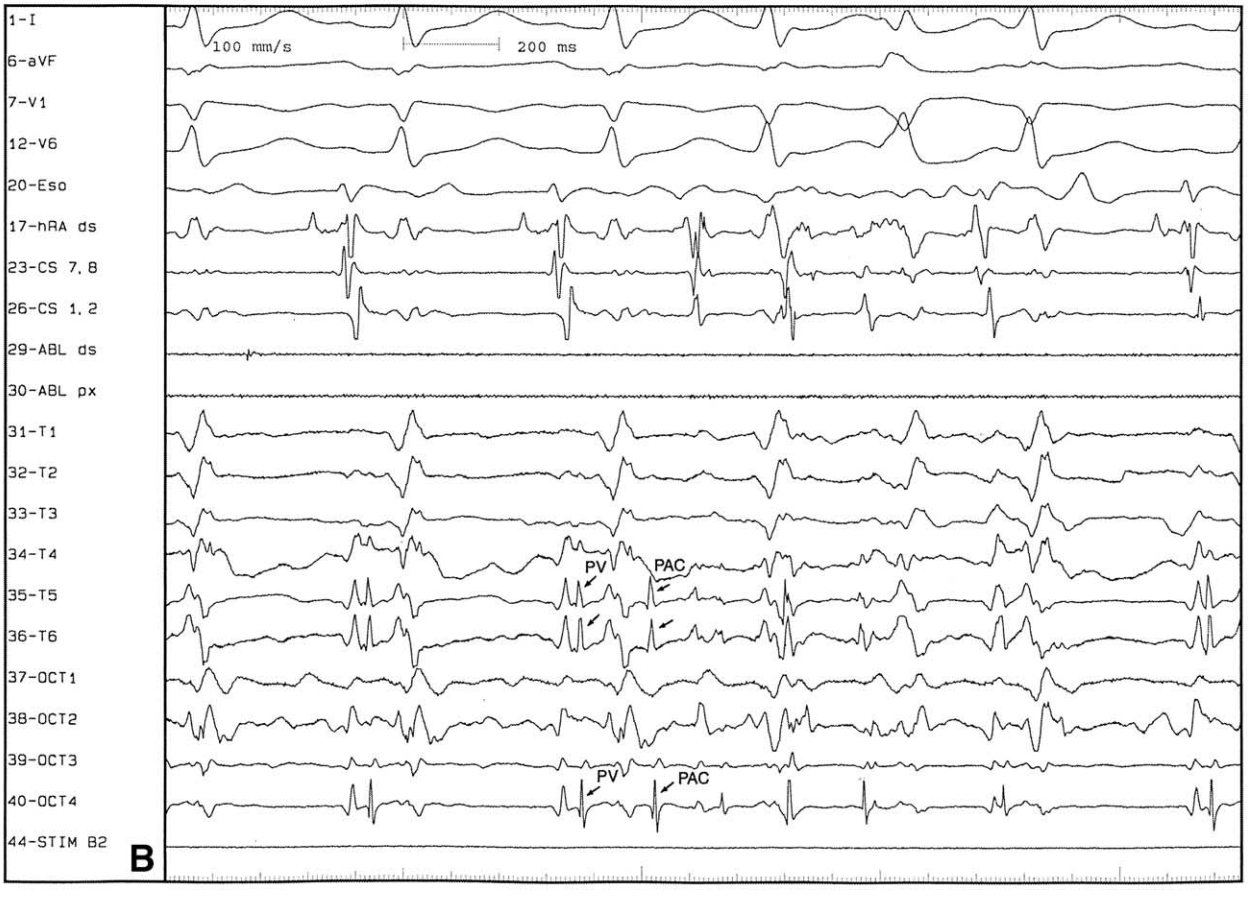
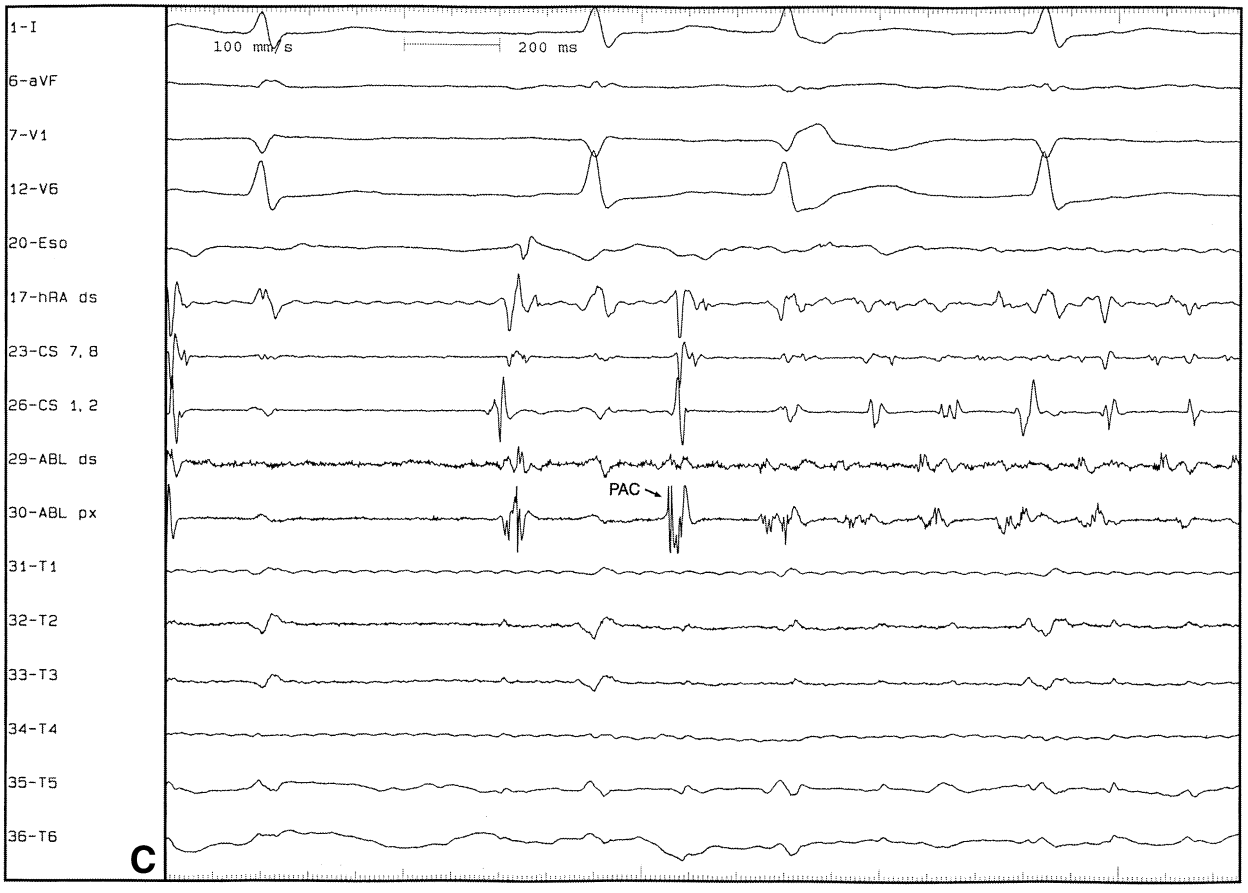


Figure 3. Intracardiac recordings from the circular mapping catheter placed in the RUPV as shown in **panel A.** Deployment of the catheter 5 mm from the ostium demonstrated early local PV activation at the T5, T6 bipolar recordings **(B).** Distal isolation **(C)** was achieved with four lesions directed in the proximity of the T5, T6 segments. Note the absence of PVPs from T1 to T6 recordings on the circular catheter. However, AF is not yet abolished and appeared to originate more proximally. In this patient successful elimination of AF was obtained by ostial isolation. OCT1–OCT4 = distal to proximal longitudinal bipolar recordings. See Figure 1 for other abbreviations. *Continued on next page.*

(range 10 to 20 μg/min) in 28.5% (54/190) and 40% (76/190) of group 2 patients, respectively. Isoproterenol-induced PACs post PVs isolation in group 1 originated from the SVC in two patients and from different PVs in 10 patients. A mean isoproterenol infusion rate of 12 ± 3 μg/min, 15 ± 4 μg/min, and 17 ± 3 μg/min could induce arrhythmogenic PACs from two PVs in five patients, from three PVs in three patients, and from four PVs in two



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patients in group 1. The arrhythmogenic PACs originated from the left atrial posterior wall in the proximity of the RUPV in two, from the SVC in 10, and from a different PV in 117 group 2 patients. A mean isoproterenol infusion rate of 13 ± 3 μg/min, 16 ± 4 μg/min, and 18 ± 3 μg/min could induce arrhythmogenic PACs from two PVs in 48 patients, from three PVs in 29 patients, and from four PVs in 12 patients.

Circumferential distribution of ostial PV potentials. The ostial circumference of the PVs was divided into 16 sectors based on the maximum number of electrodes present on the 2-cm loop catheter. The number of sectors showing PVPs on the circular catheter, at which RF energy was delivered to complete ostial isolation, were documented. PVPs were seen and required ablation in all infero-anterior sectors of the RUPV ostia. Distal and ostial isolation data are presented in Table 3.

Complications and follow-up. Pulmonary vein venograms performed immediately after distal isolation in group 1 showed >70% narrowing of the LUPV in one patient and RUPV in one patient, respectively. Moderate stenosis (50% to 70% narrowing) of the LUPV was seen in two patients, and mild narrowing (<50%) of two LUPV, one RUPV, and one LLPV in four patients. In group 1, the spiral CT scan

Table 1. Patients' Demographics

Patient Characteristics	Group 1	Group 2
No. of patients	21	190
Mean age (range), yrs	52 ± 10 (25–70)	53 ± 11 (24–75)
Gender, male/female	13/8	142/48
AF: paroxysmal/persistent/chronic	16/3/2	102/29/59
Duration of AF, yrs	3 ± 3 (0.5–5)	5.5 ± 3.6 (0.5–14)
Structural heart disease, n	5	46
Hypertension	6	15
Sick sinus syndrome	2	12
Left atrial diameter, mm	4.1 ± 0.9	4.3 ± 0.6
Left ventricular ejection fraction, %	56 ± 10	53 ± 6
Number of failed AAD	3 ± 1	3 ± 1

AAD = antiarrhythmic drugs; AF = atrial fibrillation.

Table 2. Group 2 Patients Separated According to Ablation Catheter Used

	Radiofrequency		
	4-mm Tip	**8-mm Tip**	**Cooled-Tip**
Patients	47	21	122
Age	53 ± 13	56 ± 8	54 ± 11
SHD	19% (9/47)	20% (4/21)	27% (33/122)
Fluoroscopy time (min)	110 ± 40	51 ± 8*	88 ± 24*†
Procedure time (h)	5.5 ± 3	3 ± 1*	4 ± 1*
Lesions/PV (min)	15 ± 3 lesions (10 ± 2)	5 ± 2 lesions* (3 ± 1)	7 ± 4 lesions (4.5 ± 2.5)
Follow-up (months)	10 ± 3	8 ± 4	4 ± 2*
Recurrence	10 (21%)†	none	18 (15%)†
Stroke	2% (1/47)	none	<1% (1/122)
Tamponade	none	none	1.5% (2/122)
Severe PV stenosis	2% (1/47)	none	<1% (1/122)

*$p < 0.05$ versus 4-mm tip; †$p < 0.05$ versus 8-mm tip.
PV = pulmonary vein; SHD = structural heart disease.

showed severe PV stenosis in three patients, one of whom had stenosis in both the LUPV and LLPV. All three patients had dilatation. Among the patients undergoing ostial isolation (group 2), mild stenosis (<50% narrowing) was seen in 12 patients. Moderate stenosis was seen in six patients. Severe stenosis was seen in the left superior PV of one patient, and in the left inferior PV in another patient, one of whom had undergone a repeat ablation procedure. One patient developed aphasia documented at the end of the ablation, which nearly resolved after 48 h. Another patient developed right-sided hemiplegia, which nearly resolved after one week. Two patients developed tamponade due to right atrial perforation in one patient and CS perforation in the other patient. Only the latter patient underwent emergency open heart surgery.

During a mean follow-up time of 11 ± 3 months, AF recurrence was documented in five patients (24%) in group 1. Four of these patients underwent repeat procedure during which recurrence appeared associated with firing from veins not targeted during the first procedure. The fifth patient with recurrence was the one with a large LLPV, which could not be proximally isolated during the initial procedure. This patient underwent a second procedure with a larger custom-made circular catheter and was cured.

Figure 4 demonstrates the arrhythmia-free survival curve of group 2 patients based on the ablation catheter used. In Tables 2 and 4 the mean follow-up time and recurrences in group 2 patients related to the ablation catheter used and type of AF are shown. After a mean follow-up time of 8 ± 4 months, all patients treated with the 8-mm tip catheter had no recurrence of AF, whereas 21% (10 of 47 patients) and 15% (18 of 122 patients) of the patients ablated with the 4-mm tip and the cooled-tip ablation catheters had recurrence of AF after a mean follow-up of 10 ± 3 and 4 ± 2 months, respectively. Fifteen of these patients underwent repeat procedure during which recurrence appeared associated with firing from previously treated PVs in nine patients. In four patients treated with amiodarone up to one month or less before ablation, veins targeted during the first procedure showed recovered conduction in segments electrically inactive during the first procedure. Firing from a focus in the posterior wall of the LA in the vicinity of the RUPV ostium was responsible for recurrence in two patients. Ten patients responded to previously ineffective drug therapy. Three patients still have AF and are waiting for a second procedure. One patient with a single right PV ostium (ostium larger than 4 cm) and large electrically silent areas in the LA did not improve after ablation.

Table 3. Number of Sectors Isolated in Relation to Distal or Ostial Pulmonary Vein Isolation

	RUPV	**RLPV**	**LUPV**	**LLPV**	**Total**
Distally isolated pulmonary veins	14	1	11	8	34
Sectors					
0–4	28%	100%	14%	10%	
5–8	56%	0%	60%	51%	
9–12	11%	0%	22%	35%	
13–16	0%	0%	4%	0%	
Ostially isolated pulmonary veins	190	174	190	158	712
Sectors					
0–4	0%	6%	1%	3%	
5–8	9%	20%	10%	15%	
9–12	22%	33%	12%	30%	
13–16	69%	41%	77%	52%	

LLPV = left lower pulmonary vein; LUPV = left upper pulmonary vein; RLPV = right lower pulmonary vein; RUPV = right upper pulmonary vein.

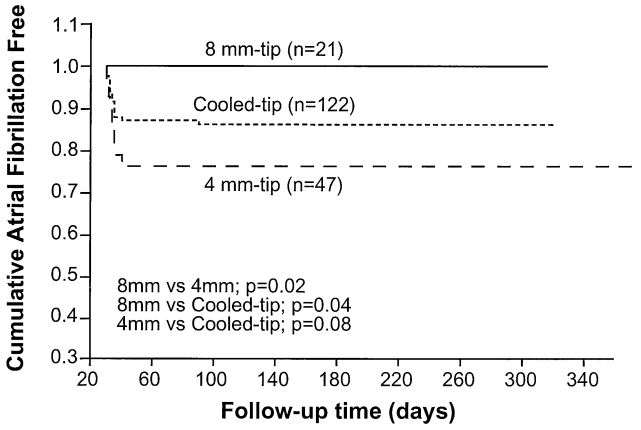

Figure 4. Atrial fibrillation free survival curves after pulmonary veins isolation in patients ablated with the 4-mm tip **(dashed line)**, the 8-mm tip **(dotted line)**, and the cooled-tip **(solid line)** catheter are shown. Recurrence rate appeared to be higher with the 4-mm tip catheter ($p < 0.05$).

DISCUSSION

Primary finding. In the present study, with the use of circumferential mapping of the PVs we were able to demonstrate that distal isolation could be achieved with segmental ablation of the PV circumference, whereas nearly complete circumferential ablation of the PV ostium is needed in the majority of patients to achieve ostial isolation. Moreover, distal isolation was able to eliminate APCs and AF onset originating from the treated vein in only 29% of the patients treated with this approach. Despite the smaller number of patients treated with the 8-mm tip catheter, this technology appears to be superior to the 4-mm tip and cooled-tip ablation catheters in terms of AF recurrence, fluoroscopy, and procedure time. Because of the higher stenosis and recurrence rates after distal isolation compared with the ostial isolation, only ostial isolation was performed in the last 190 study patients. Another important finding in our study is that isolation of focal triggers from the PV is effective in achieving cure in patients presented with AF independently from the duration of the arrhythmia and the LA size.

Mapping and ablation. The strategy most commonly used to map and ablate PVPs that trigger focal AF is the application of RF energy at the source or exit site of these triggers using longitudinal mapping (2,7). Chen et al. (2) reported that 61% of PV triggers initiated distally (>20 mm) inside the PV and the rest were located around the ostium. Despite successful distal isolation of the arrhythmogenic PV in all our patients, unlike Chen's data, we demonstrated that the majority of the arrhythmogenic PV triggers (71%) were still firing from the PV. It is difficult to compare our study results with those published by Chen et al. (2), because two different mapping techniques were used to locate the arrhythmogenic triggering site. Chen et al. (2) used longitudinal mapping with one single multipolar catheter placed in the PV. Using this approach only a certain segment or sector of the PV could be simultaneously mapped, which could have resulted in misleading results. In our study the use of circular mapping was applied to record the activation of the whole PV circumference simultaneously. Another possible reason for the differences between our data and those documented by Chen could be the different approach applied in our study to assess ablation success. We applied high doses of isoproterenol (up to 20 μg/min) to prove that distal or ostial isolation of the treated PV was successful in eliminating PACs and AF. In the distally isolated PVs, 60% of the PACs were induced from the PV ostium at an isoproterenol dose greater than 10 μg/min. The maximum isoproterenol dose applied by Chen and others to assess successful ablation was 6 μg/min.

Haïssaguerre et al. reported a similar circular mapping technique of PVP. This approach provided permanent monitoring of PVPs during ablation allowing the application of RF energy at segments considered critical to conduction distal to the mapping point (5), so that isolation could be achieved with fewer strategically placed lesions. More specifically, they suggested that with circular mapping ablation lesions could be directed to sites showing earliest local PVPs. These sites may represent preferential conduction pathways, ablation of which could achieve PV isolation with a limited number of lesions.

Similarly to Haïssaguerre and co-workers' series, in our series distal isolation could be obtained with few lesions targeting segments showing preferential conduction. On the other hand, ostial isolation required ablation lesions around most of the vein circumference depending on the treated PV. In addition, in our series we demonstrated the inability of distal isolation to eliminate PACs and AF in nearly 71% of patients with focal AF. Complete ostial isolation was

Table 4. Group 2 Patients Separated According to Type of Atrial Fibrillation

	Paroxysmal AF	Persistent AF	Permanent AF
Patients	102	29	59
Mean age (yrs)	53 ± 11	52 ± 8	65 ± 12*
Mean duration of AF (yrs)	4 ± 2	4 ± 4	7 ± 4*
Left atrial diameter (mm)	4 ± 0.5	4 ± 0.6	4.7 ± 0.7*
Follow-up (months)	9 ± 3	7.5 ± 4	7.5 ± 2
Recurrence	15% (15/102)	17% (5/29)	14% (8/59)
Chronic cure	94% (96/102)	90% (26/29)	89% (54/59)
Controlled on AAD	4% (4/102)	10% (3/29)	7% (4/59)

$p < 0.05$ versus paroxysmal and persistent AF.
AAD = antiarrhythmic drugs; AF = atrial fibrillation.

indeed needed to abolish the arrhythmogenic foci responsible for AF in the majority of patients.

Risk of stenosis. Focal ablation within the PV has been associated with PV stenosis (3,8). Haïssaguerre et al. reported 3% PV stenosis rate after RF energy delivery in the PV. Lin et al. (3) reported the presence of significant narrowing in 42% of focally ablated patients. Robbins et al. reported 11% PV stenosis during a multicenter trial for treatment of chronic AF, where lesions were mainly delivered in the PV (9). In our series, distal isolation showed chronic severe stenosis in three of 21 patients (14%). Of the 190 patients receiving ostial isolation only two (1%) had significant stenosis. It is conceivable that ostial isolation will reduce the occurrence of this complication. This could reflect the thickness of the PV ostium and lack of PV smooth muscle cells in that region, which could respond with scarring and contraction to thermal injury.

Pulmonary veins isolation with different catheter technologies. The use of 8-mm tip and cooled-tip ablation catheters appeared to be associated with significantly shorter fluoroscopy time, procedure time, and number of delivered lesions compared with the conventional 4-mm tip approach. This can be explained by the larger lesions created by the 8-mm tip and cooled-tip (10) ablation catheters. Of interest, in our preliminary experience there were no recurrences in the group of patients treated with the 8-mm tip catheter. The PV muscular sleeves are extensions of left atrial fibers originating before the PV-LA junction as reported by Ho et al. (11) and Saito et al. (12). Applying RF energy at the PV-LA junction using the 8-mm tip may ablate more effectively the extension of the PV sleeves into the LA. This tissue could be relevant to the initiation of AF, and ablation of the more proximal portion of the PV sleeves may be responsible for the better success seen with the 8-mm tip catheter.

Pulmonary veins isolation in paroxysmal, persistent, and chronic AF. A few studies have reported on the effect of PV isolation in treating patients with paroxysmal AF (2,4,7). Less information is available in patients presenting with chronic AF (13). Recently Haïssaguerre and co-workers demonstrated a 60% long-term success after PV isolation in patients with chronic AF. Left atrial diameter has been shown to be an important factor in determining the response of AF to therapy (14,15). In the present study, isolation of focal triggers initiating in the PV appeared an effective cure for AF independently from the duration and left atrial size. Indeed around 80% of patients presenting with chronic AF and dilated LA were still in sinus rhythm at follow-up.

Limitations. This study was not randomized. In addition, only a small number of patients was ablated using the 8-mm tip ablation catheter. We did not consider mild or moderate narrowing as clinically important. A longer follow-up is needed to assess the significance of this finding.

Conclusion. The reported recurrence rates of AF after focal ablation have been quite high, with the majority of patients requiring two or more procedures (1–3). Overall, the results obtained in the present study with circular mapping are encouraging. Circular mapping–guided ablation appeared to simplify and facilitate isolation of the PVs. Although distal isolation can be achieved by limited ablation lesions, it appears to have a higher risk of stenosis and it may be effective in only a third of the patients. It appears imperative that an effort is made to deliver lesions only at the ostium to avoid or limit PV stenosis, which remains a problem if one applies RF lesions at the sites where the circular catheter is more stable. Delivering RF energy with an 8-mm tip catheter seems to be a promising approach that improves success rate and decreases both procedure and fluoroscopy times.

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