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Pulmonary vein isolation using segmental versus electroanatomical circumferential ablation for paroxysmal atrial fibrillation

Over 3-year results of a prospective randomized study

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Abstract

Purpose We tested the hypothesis that electroanatomic pulmonary vein (PV) antra encircling for the PV isolation will improve the outcome in treatment of paroxysmal atrial fibrillation (PAF), compared with segmental PV isolation.

Methods Fifty-four patients underwent segmental PV isolation (group 1) and 56 patients circumferential PV isolation (group 2) for symptomatic PAF in a randomized study.

Results Following single ablation procedure, at the 48±8 month follow-up, 30 (56%) and 32 (57%) patients in groups 1 and 2 remained free of arrhythmia (P=0.41). After repeat ablation, 43 (80%) and 45 (80%) patients in groups 1 and 2 were free of arrhythmia without antiarrhythmic drugs (AADs); 48 (89%) and 51 (91%) patients in groups 1 and 2 did not have arrhythmia recurrences without or with AADs.

Conclusion This study demonstrates no advantage in long-term arrhythmia-free clinical outcome after circumferential PV isolation in patients with frequent PAF.

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Keywords Atrial fibrillation · Catheter ablation · Pulmonary vein · Outcome

1 Introduction

Pulmonary vein (PV) isolation has been widely accepted as a treatment of paroxysmal atrial fibrillation (PAF). Advantages of two different ablation approaches have been debated. The first approach, segmental PV isolation, is based on mapping of PV potentials by a multipolar ring catheter under fluoroscopy guidance, with a clear endpoint of full electrical disconnection of the left atrial (LA) myocardium and PV muscular fibers [1, 2]. The second approach, circumferential ablation of the PV antra guided by electroanatomic navigation, has been proposed as a method for combining PV isolation and modification of the arrhythmogenic substrate for the maintenance of PAF. Pioneers of this method have not consistently validated the completeness of PV isolation by means of direct PV mapping using a ring catheter [3, 4]. Previous studies comparing segmental and circumferential ablation either used different procedure endpoints and types of radiofrequency (RF) energy application for the respective techniques, or were not randomized, and reported contradictory outcomes in shorter follow-up time [5–7].

In the present prospective randomized study, with the endpoint of PV isolation, long-term clinical efficacy and safety were compared between segmental and circumferential ablation approaches in patients with PAF and without major structural heart disease.

2 Methods

The study was introduced in March 2001 and ethical approval was obtained for the study protocol. All patients were informed about the principles of the study, and all gave written informed consent. Patients were included if they met the following criteria: (1) age 18–80 years; (2) symptomatic PAF, ≥1 episode of PAF per month in the last six months; (3) PAF refractory to class I,III antiarrhythmic (AA) drugs (4) absence of major structural heart disease.

2.1 Rationale of the study

This study was designed to test the hypothesis that combination of substrate modification and full PV isolation by the electroanatomic PV antra encircling would provide additional improvement of the long-term clinical outcome over the segmental PV disconnection alone. To compare the ablation approaches, the same end point and its validation, as well as an ablation catheter with identical tip electrodes and identical power and temperature limits were used.

2.2 Patient characteristics

Between June 2001 and December 2003, 110 consecutive patients underwent PV isolation for symptomatic PAF. A majority of the patients had episodes of PAF daily or several times a week. Patients were randomly assigned to segmental PV isolation (54 patients, group 1) or to PV isolation created by the electroanatomically navigated continuous circumferential lesions around the PV antra (56 patients, group 2; see below). There were no significant differences in the baseline clinical characteristics between the groups (Table 1).

2.3 Preablation management

Patients were anticoagulated to maintain INR between 2 and 3 for at least 6 weeks prior to the ablation. Warfarin was discontinued and replaced by LMW heparin 5 days before the procedure. Transesophageal echocardiography (TEE) was performed to exclude thrombi and to evaluate the PV ostial diameter and flow.

2.4 Electrophysiological study and catheter ablation

Three catheters were introduced through the venous access. A 10-pole catheter (Daig, St. Jude, Minnetonka, MN, USA) was positioned in the coronary sinus (CS). Following a double transseptal puncture, two 8 F sheaths were inserted in the LA and a 10-pole ring catheter (Lasso, Biosense Webster, Diamond Bar, CA, USA) and a mapping/ablation catheter were placed in the LA and PVs. After the transseptal puncture, a bolus of heparin was given followed by infusion to maintain ACT between 250 and 350 s.

Preablation and postablation angiograms of each target PV were performed in all patients via an 8 F transseptal sheath whenever it was technically possible. Angiograms were obtained in the LAO and RAO projection, and the PV ostial diameter was measured via comparison with the diameter of the transseptal sheath inside the vein. Preablation and postablation diameters of the PV ostia were measured at the same level, i.e., at the transition of the PV antrum into the PV tubular segment. PV stenosis with lumen loss as defined below was evaluated throughout the main vessel and its distal branching.

The ring catheter was kept in a stable position 5–10 mm distal to the ablation site until complete isolation of the recorded PV potentials; it was subsequently withdrawn toward the ostium and maneuvered around the PV antrum to exclude residual proximal PV potentials. Then the ring

Table 1 Patient baseline characteristics

	Total	Group I	Group II	*P* value
Patients (*N*)	110	54	56	
Females (*N*)	21 (19%)	11 (20%)	10 (18%)	0.96
Age (years)	52±11 (21–74)	51±11 (25–74)	53±10 (21–74)	0.64
Symptom duration (years)	7±6 (1–26)	7±4 (1–20)	8±6 (1–26)	0.93
Patients with AF daily	58 (53%)	27 (50%)	31 (55%)	0.88
Patients with AF weekly	100 (91%)	50 (93%)	50 (89%)	1.0
Ineffective AA drugs	4±1 (2–8)	4±1 (2–7)	4±1 (2–8)	0.46
Amiodarone	60 (55%)	31 (57%)	29 (52%)	0.87
Arterial hypertension	58 (53%)	28 (52%)	30 (54%)	1.0
LV EF (%)	60±6 (35–70)	59±7 (35–70)	60±4 (45–70)	0.74
LA diameter (mm)	39±5 (27–50)	38±5 (30–50)	40±5 (27–50)	0.09

Data are shown as mean±SD. LV EF=left ventricular ejection fraction, LA=left atrium.

catheter was inserted into the next vein in the order of left upper, left lower, right upper, and right lower PV. All PVs were revisited with the ring catheter during sinus rhythm (SR) at the end of the procedure. In case of LA–PV reconnection, ablation was continued until full PV disconnection lasting for at least ten minutes was achieved. Cavo-tricuspid isthmus (CTI) ablation was performed at the beginning or end of the procedure depending on the initial presence of SR or atrial fibrillation (AF).

Bipolar electrograms were filtered at a band-pass setting of 30–500 Hz, and recorded digitally (Cardiolab System, Prucka Engineering, Sugar Land, TX, USA). Bipolar pacing was performed from the CS or LA appendage at twice the diastolic threshold with a pulse width of 2 ms (UHS 20, Biotronik GmbH & Co, Berlin, Germany). RF energy was applied with a Stockert (Biosense-Webster, Diamond Bar, CA, USA) generator. The temperature and power limits were 54°C and 30 W in both groups.

2.5 Segmental PV disconnection

Following the above-mentioned common steps, patients were randomized for the ablation approach according to the date of birth. Patients born on an even-numbered day were randomized for segmental PV isolation under fluoroscopy and electrophysiological guidance (group 1). Ablation was performed with a standard 7 F 4-mm-tip ablation catheter (Celsius, Biosense Webster, Diamond Bar, CA, USA). The ablation targeting myocardial LA–PV breakthroughs was guided by the ring catheter. The RF energy was applied as proximal as possible and was finished at the moment of stable complete PV disconnection. Thus, RF energy applications did not inevitably cover the entire circumference of the PV ostia.

2.6 Electroanatomic PV antrum disconnection

Patients born on an odd-numbered day were randomized to the wide-area electroanatomic PV encircling (group 2). The ablation procedure included additional three-dimensional LA and PV reconstruction (Carto, Biosense Webster, Diamond Bar, CA, USA). Ablation was performed with a 7 F 4-mm-tip deflectable catheter (NaviStar, Biosense Webster, Diamond Bar, CA, USA). Ipsilateral PVs were encircled as a unit by a common lesion (Fig. 1) except for six early patients, in whom right lower PV was not targeted. Continuous lesions were always completed, even if the full PV disconnection was accomplished during prior RF energy deliveries. Conversely, if PV disconnection was not present after completion of the PV encircling, conduction gaps in the circumferential lesion were identified and ablation was continued until full PV disconnection was achieved. RF energy was delivered cautiously within the encircled area only in rare unavoidable cases.

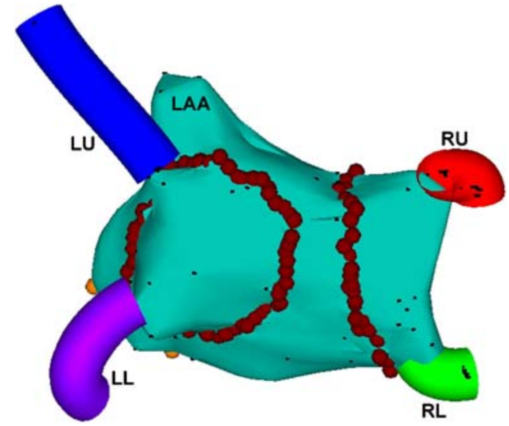

Fig. 1 Electroanatomic circumferential lesions. In group 2, the PVs were continuously encircled by electroanatomically navigated RF lesions common for the ipsilateral veins. *LU*, *LL*, *RU*, *RL* left upper, left lower, right upper, and right lower pulmonary veins; *LAA* left atrial appendage

2.7 Procedural endpoints and definitions

The endpoint of the procedure was full isolation of all PVs. Ablation of a single right lower PV was not performed in 5 and 6 patients of the respective groups.

Full PV isolation was defined as complete elimination of all high-frequency PV potentials recorded by the ring catheter during SR or atrial pacing. Observation of dissociated PV ectopy was considered as additional evidence of full PV disconnection. Pacing within the isolated PV was not consistently performed. Full PV disconnection during ongoing AF was defined as elimination of all high-frequency potentials recorded within the PV; nevertheless, because AF converted into SR spontaneously or as a result of ablation in all the patients, PV isolation was always confirmed during SR or atrial pacing at the end of the procedure.

Incomplete PV isolation was defined as residual tiny potentials adjacent to the PV ostium. Such "incomplete" PV isolation was deliberately left in some cases, when the dominant potentials of the vein had already been eliminated, the PV did not exhibit ectopic activity, a different PV was clearly arrhythmogenic, and in cases where further RF energy applications to eliminate these residual potentials were considered unnecessary and potentially harmful.

PV stenosis was defined as 50% reduction in the PV diameter. Additionally, the incidence of PV ostial narrowing ≥3 mm and/or ≥25% <50% of the preablation PV luminal diameter was compared between the groups.

2.8 Postablation management

After ablation, heparin was stopped and LMW heparin was restarted until warfarin, re-administered the following day, reached its full therapeutic effect. Warfarin was stopped not earlier than 6 weeks to 3 months after the ablation, according to the clinical outcome. TEE to exclude thrombi and to evaluate ostial diameter and flow was performed after 6 weeks and then after 6 months in selected patients. To exclude pericardial effusion, transthoracic echocardiography was regularly performed after ablation.

AA medication taken before ablation was usually maintained for the next 1 to 3 months and then discontinued in the absence of clinically significant AF recurrences. If the arrhythmia recurred following cessation of the AA medication, the AA drug was usually re-initiated as the first option.

2.9 Repeat ablation

A repeat ablation was offered to all patients with arrhythmia recurrences, although it was declined by some patients who considered their symptoms as significantly improved. Patients undergoing repeat ablation were not randomized for different ablation approaches, the repeat ablation for PAF consisted of electroanatomic PV antrum encircling with PV re-isolation validated by a ring catheter. Roof and posterolateral mitral isthmus linear lesions were added in some of the patients. In rare patients with persistent and permanent AF, the ablation often included additional LA linear and focal lesions, and occasionally CS ablation to target areas of complex fractionated potentials and converting LA monomorphic tachycardia, and to achieve SR restoration as an additional endpoint.

2.10 Follow-up

After ablation, patients were scheduled for regular visits at the outpatient department at 6 weeks, 3, 6, 9, and 12 months, and every 6 months thereafter. The examination focused on arrhythmia-related symptoms and evaluation of the standard 12-lead ECG, 24-h Holter ECG recordings, and other ECG documentation taken by the local cardiologists. Trans-telephonic ECG monitoring was performed whenever required. The patients were considered to have an arrhythmia recurrence if there was documented AF or a history of irregular palpitations suggestive of AF lasting more than 30 seconds.

2.11 Clinical endpoints

The primary clinical endpoint of the study was freedom from any atrial tachyarrhythmia off class I and III AA medication after the first ablation procedure. Secondary clinical endpoints included the efficacy of the first ablation procedure in achieving full PV isolation and peri-procedural and long-term complications. Overall long-term freedom from any atrial tachyarrhythmia with or without AA medication following repeat ablations performed on a non-randomized basis was also assessed.

2.12 Statistical analysis

Continuous variables were expressed as a mean±SD, noncontinuous variables as proportions (percentages). Continuous variables with normal distribution were compared by means of the Student's *t* test. Continuous variables with abnormal distribution were compared using a Kruskal–Wallis ANOVA test. Categorical data were compared using a chi-square test with the Yate's correction. Arrhythmia-free survival was evaluated using a Kaplan–Meier analysis, and the group differences were compared using a Cox regression analysis of proportional hazard. A value of $P<0.05$ was considered to indicate statistical significance.

3 Results

3.1 Procedure, fluoroscopy, and radiofrequency energy application times

The mean procedure time of 255±55 (160–420) minutes in group 1 was significantly shorter compared to the time of 279±42 (190–360) minutes in group 2 ($P=0.04$). The mean fluoroscopy time of 46±13.4 (25–76) minutes in group 1 did not significantly differ from the fluoroscopy time of 45.5±14.9 (17–75) minutes in group 2 ($P=0.18$).

The mean RF energy delivery time of 20.9±8.7 (7.9–46.8) minutes to isolate the left PVs in group 1 was shorter compared to the mean RF time of 36.7±11.5 (19.8–63.4) minutes in group 2 ($P<0.001$). The RF application time of 15.8±5.2 (8–46.8) minutes required for isolation of the right PVs in group 1 was shorter in comparison to the time of 27.8 ±9.2 (12.8–48.5) minutes in group 2, ($P<0.001$).

3.2 Characteristics of the targeted PVs and results of PV isolation

During the first ablation, 415 PVs were isolated. The left common PV was identified angiographically in a total of 16 (15%) patients: in 9 (17%) and 7 (13%) patients in groups 1 and 2, respectively. An atypical roof medial PV, which was contiguous neither to the left- nor to the right-sided PV, was found in 2 patients. The right medial PV was not calculated separately from the right upper PV. All identified PVs were isolated in 99 (90%) patients: in 49 (91%) patients in group 1 and in 50 (89%) patients in group 2. A single right inferior PV was not targeted in five patients in group 1 and 6 patients in group 2.

Four hundred and one (97%) PVs were isolated fully; incomplete PV isolation was accepted in 14 (3%) PVs in 14 patients. Of the targeted PVs, 380 (92%) were investigated by angiography prior to and after the ablation (angiography was not compared in 33 right lower PVs and 2 atypical

PVs). The groups did not differ in the number or proportion of PVs targeted and fully isolated, and in the number of PVs investigated angiographically (Table 2).

3.3 AF-free clinical outcome following first ablation

Since the beginning of the follow-up 6 weeks after ablation, there was no difference in the primary clinical endpoint of the study between the groups at any stage of the follow-up (Fig. 2). Within the first 6 months, AF recurred in 17 patients (31%) in group 1 and in 18 (32%) patients in group 2. AF further recurred after discontinuation of amiodarone by the visits at 9 and 12 months in three patients in each group. At the 48±8 month follow-up, 30 patients (56%) in group 1, and 32 patients (57%) in group 2 remained free of atrial tachyarrhythmia recurrence (P=0.41).

3.4 Late AF recurrences

Late AF recurrence after long-term freedom from AF off AA medication occurred in 3 (6%) patients in group 1 and in 3 (5%) patients in group 2 between months 18 and 30. In each group, late isolated AF episodes in 1 patient were suppressed by re-administration of an AA drug. Recurrent PAF in 3 patients and a permanent form of AF in 1 patient were successfully cured by one or two repeat ablations.

3.5 Repeat ablations

Thirty-seven (34%) patients underwent a second ablation, 18 patients (33%) in group 1 and 19 patients (34%) in group 2. PV–LA conduction recovery of a clear or suspect ectopic PV was found in 16 (89%) patients in group 1 and in 16 (84%) patients in group 2. Substrate-related AF was found in two patients in group 1 (one late PAF recurrence, one persistent AF) and in three patients in group 2 (three persistent AF).

Ten (9%) patients underwent three ablations, five patients in each group. PV–LA reconnection as a source of PAF recurrence was found in three patients in group 1 and in two patients in group 2. Persistent LA macroreentry tachycardia recurred in the remaining two patients in group 1 and in one patient in group 2, who underwent the first repeat ablation for PAF. Two patients in group 2, who had the first repeat ablation for permanent AF, underwent a third ablation for permanent AF or permanent LA macroreentry tachycardia.

3.6 Overall long-term clinical outcome

During the follow-up time of 48±8 (36–66) months, no patient died. All patients had a minimum follow-up of 36 months; 81, 52, 30, and 17 patients respectively were seen after 42, 48, 54 and 60 months. At the end of the follow-up including repeat ablations, 43 (80%) patients in group 1, and 45 (80%) patients in group 2 remain free of any arrhythmia and AA drugs. An additional 11 patients (five in group 1 and six in group 2) are free of arrhythmia recurrence on a previously ineffective class I or III AA drug; amiodarone is taken by 2 patients in group 1 and 3 patients in group 2. Thus, 48 patients (89%) in group 1, and 51 patients (91%) in group 2 are free from any atrial tachyarrhythmia in the long term.

Of the 11 patients with arrhythmia recurrences, four patients in whom permanent AF developed (two patients in each group) resorted to rate control. Remaining four patients in group 1 and three patients in group 2, who continue to have sporadic short episodes of PAF, consider their status a significant clinical improvement and decline to undergo a repeat ablation.

3.7 Complications

There were no atrial-esophageal fistulae, embolic complications, or significant pericardial effusion (>5 mm) associated with the first ablation procedure. One patient had a femoral arterial pseudoaneurysm which was cured by pressure. In one repeat complex LA ablation, the patient experienced an

Table 2 Comparison of the isolated pulmonary veins

	Total	Group 1	Group 2	P value
No. of PVs isolated/identified	415/426 (97%)	203/208 (98%)	212/218 (97%)	1.0
No. of LU(C)PVs isolated/pts	110/110 (100%)	54/54 (100%)	56/56 (100%)	1.0
No. of LLPVs isolated/pts	94/94 (100%)	45/45 (100%)	49/49 (100%)	1.0
No. of RUPVs isolated/pts	110/110 (100%)	54/54 (100%)	56/56 (100%)	1.0
No. of RLPVs isolated/pts	99/110 (90%)	49/54 (91%)	50/56 (89%)	1.0
No. of other PVs isolated	2	1	1	
No. of PVs fully isolated	401/415 (97%)	195/203 (96%)	206/212 (97%)	0.99
No. of PVs with angiography	380/415 (92%)	184/203 (91%)	196/212 (92%)	0.95

Data are shown as mean±SD.
PV pulmonary vein, *LU*, *LC*, *LL*, *RU*, *RL* left upper, left common, left lower, right upper, and right lower PV

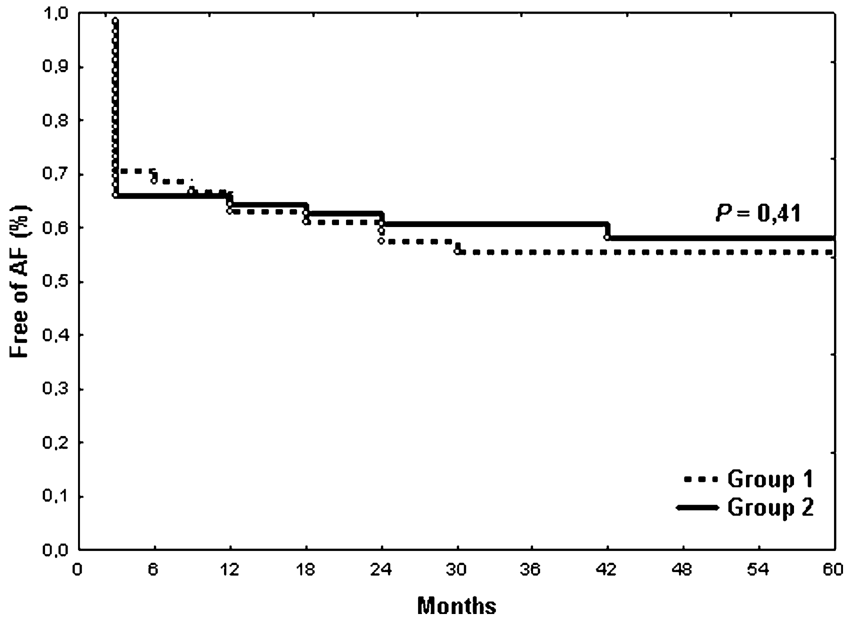

Fig. 2 Atrial fibrillation-free long-term clinical outcome (Kaplan–Meier curve). The AF recurrence-free postablation clinical course was not different between the groups at any stage of the 60-month follow-up period (individual minimum follow-up was 36 months)

early cerebral embolic complication with a sequel of hemianopsia. None of the patients experienced a late thromboembolic complication.

No immediate PV stenosis, defined as a lumen loss exceeding 50%, occurred in either group, and none of the patients developed clinical signs of pulmonary hypertension, despite higher immediate occurrence of less prominent PV ostial narrowing ranging from ≥25% to <50% that was found in 22 (12%) of 184 PVs in group 1 compared to 2 (0.5%) of 196 PVs in group 2 ($P<0.001$), and despite significant decrease in the mean PV ostial diameter from the preablation 13.2±2.5 (9–25) mm to the post-isolation 12.4±2.6 (5–25) mm ($P=0.005$) in group 1 compared to a non-significant reduction from 13.2±2.6 (8–27) mm to 13±2.5 (7–27) mm in group 2. Accordingly, comparison of the preablation and postablation TEE revealed no obvious aggravation of PV narrowing other than that expected from the angiography, except in 1 patient in whom two contra-lateral PVs exhibited 50–60% stenosis and accelerated turbulent flow without clinical signs of pulmonary hypertension. Of the 23 PVs with the angiographical ≥25%<50% narrowing, only 15 PVs eventually exhibited accelerated turbulent flow at the 6-week and 6-month TEE examinations (14 PVs in group 1 and 1 PV in group 2).

4 Discussion

4.1 Main findings

This prospective randomized study was designed to test the hypothesis that continuous circumferential lesions associated with full PV antrum isolation will have a beneficial effect on long-term clinical outcomes and safety compared with segmental PV isolation in patients with frequent PAF. The chief findings of the study are the following: (1) both techniques were similarly effective in achieving full PV isolation, although the duration of RF energy delivery to achieve this end point by circumferential ablation was significantly longer; (2) AF-free clinical outcome of both approaches was not different at any stage of the follow-up; (3) both approaches were similarly safe, although incidence and extent of a lesser immediate PV ostial narrowing were higher after the segmental PV isolation.

4.2 Immediate ablation results

Except for functionally insignificant remnants of the ostial potentials in 3% of the ablated PVs, effective PV disconnection was achieved in all PVs in both groups. The RF energy application time was significantly longer for the electroanatomic encircling of both the left and right PVs, clearly owing to the presence of thicker and continuously arranged myocardium at the level of the PV antrum [8]. The RF energy delivery time was similar to those reported in some previous studies [6, 7], but longer compared to the experience of Oral et al. [5], which may be attributed to the effort to ablate the PV ostia as proximally as possible by the segmental approach, and to the endpoint of full PV isolation and the use of the standard 4-mm-tip electrode for the electroanatomic ablation.

The mean procedure time difference of 25 min between the two ablation techniques roughly correlates with the time to acquire a detailed three-dimensional LA–PV map. Procedure times required for both approaches in the study of Karch et al. [6] were similar. Surprisingly equal mean fluoroscopy time for both approaches (46 min) may be related to our level of experience with the LA ablation in the years 2001–2003 when the electroanatomic position of the catheter was frequently correlated with its position on fluoroscopy. For that reason, fluoroscopy time saved during the electroanatomic ablation had been obviously lost during acquisition of the three-dimensional map.

4.3 Complications

No major complication occurred in either group including significant immediate PV stenosis and evolution of clinical signs of PV stenosis. In the literature, significant PV stenosis, defined as 50% PV lumen loss and evaluated by means of angiography, CT or MR, occurred in 2% to 8% of PVs isolated with segmental ablation [2, 9–11]. Advanced experience and electroanatomic navigation were associated with a less than 1% incidence of PV stenosis [4, 5, 12]. By demonstrating higher incidence of less significant ≥25%<50% PV ostial narrowing after the segmental ablation (12% vs. 1%), which agrees with the published experience [2, 10, 11], this study corroborates via a randomized prospective comparison the clinical experience suggesting trend toward lower risk of PV stenosis associated with the electroanatomic encircling approach, even if it is associated with the strict endpoint of full PV isolation.

4.4 Long-term clinical outcome

This study shows a similar long-term freedom from atrial tachyarrhythmias after segmental and circumferential ablation. In concord with previous experience, the majority of the AF recurrences occurred within the first 6 months after ablation, and if the arrhythmia recurred later, it was typically associated with the fading effect of discontinued amiodarone. PV–LA conduction recovery was confirmed at the repeat ablation as the dominant source of AF recurrences, as shown by previous studies [13–15].

As it was documented earlier [16], true late recurrences were rare, and their clinical presentation was diverse, ranging from isolated AF episodes to permanent AF. PV–LA reconnection was found during repeat ablation in two of these patients. As late recovery of the PV–LA conduction followed by a delayed AF recurrence is less likely, it is probable that these two patients failed to recognize earlier asymptomatic AF recurrences. Following repeat ablations using a nonrandomized tailored ablation strategy, after optimizing the AA medication, and respecting the decision of some patients to accept their less optimal clinical outcome and not to undergo a repeat ablation, the long-term freedom from tachyarrhythmia off AA medication was achieved in 80% of patients, and with or without the use of previously ineffective AA drugs in 90% of patients in both groups for a very long time.

Previously, contradictory results have been reported for shorter follow-up times. Two studies demonstrated clinical superiority of the circumferential ablation with or without the routine assessment of PV isolation. In one of the studies, better results of the electroanatomic ablation can be attributed to the use of an 8-mm-tip electrode catheter compared to the 4-mm-tip electrode for the segmental PV isolation [5]. The latter study was not randomized, presented significantly shorter follow-up time for the electroanatomic ablation, included a higher proportion of patients with a structural heart disease, and a mitral isthmus linear lesion was added in some patients undergoing the electroanatomic approach; all of these factors might have influenced the success rate toward the side of circumferential ablation [7]. Contrary to these studies, Karch et al. [6] have reported worse clinical outcome of electroanatomic encircling despite the use of an 8-mm tip or irrigated-tip ablation catheter, which can be probably ascribed to lower efficacy in achieving effective PV disconnection.

4.5 Clinical implications

Using the same procedure endpoint of PV isolation, the same tip electrode on the ablation catheter, and the same power and temperature settings, the resultant clinical outcomes were similar independent of the ablation technique employed. Except for some very experienced operators, a majority of the centers performing AF ablation have abandoned the segmental approach without the support of three-dimensional LA imaging. The results of this study emphasize the importance of full PV isolation for optimizing the clinical outcome and the advantage of combining both approaches.

Advocates of circumferential PV ablation present an excellent clinical outcome without consistent validation of PV disconnection by the ring catheter, probably as a result of their individual skill and the use of higher energy output, providing more effective lesions with less risk of the late tissue recovery. However, for those operators having limited experience with LA ablation, a combination of both ablation techniques and strict assessment of full PV isolation should be warranted. Use of more efficient means of RF energy delivery, such as irrigated ablation, will further increase ablation efficacy [17] and improve the long-term outcome compared to that achieved in this study with the standard 4-mm-tip electrode.

The results were obtained in a selected group of patients, in whom the PV ectopic activity was believed to represent the dominant arrhythmia mechanism. Substrate modification by continuous circumferential lesions and additional linear or CS lesions is without doubt required to improve the outcome in patients with preexisting LA structural changes and particularly in patients with persistent and permanent AF [18–20].

4.6 Limitations

Few patients in whom the right lower PV was not targeted and incomplete PV isolation represented by tiny proximal residual PV potentials in 3% of ablated PVs can be considered a methodological limitation. However, the proportions of patients with this suboptimal ablation were identical in both the groups and did not influence the inter-group comparison.

Secondly, the AF recurrences might have been underestimated. However, this study included only highly symptomatic patients, who distinguished their frequent AF episodes. Very long-term absence of any documented AF together with completely asymptomatic clinical course provided a reliable index of successful ablation in symptomatic patients who presented with multiple ECG recordings documenting AF prior to the ablation. Finally, the distribution of patients with AF episodes occurring daily or at least once a week (around 90%) was equal in both groups and thus did not influence the inter-group comparison.

The contradictory results of this study and other previous studies [5, 6] can be partly explained by the selection of the patients. Patients with paroxysmal AF and no or minimal heart disease might equally benefit from segmental approach to PV isolation. The ultimate answer could be given by a large multi-center study.

5 Conclusion

This study demonstrated no superiority of PV isolation achieved by electroanatomic continuous PV antra encircling over segmental PV isolation for the arrhythmia-free long-term outcome, and underlined the importance of full PV isolation for the permanent elimination of PAF. Circumferential ablation is potentially safer as suggested by the immediate PV ostial narrowing, albeit mostly clinically insignificant. The results were obtained in a selected group of patients without major structural heart disease and with very frequent PAF, in whom PV ectopic activity is a dominating mechanism of AF initiation and maintenance.

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