Clinical Research

Treatment of Paroxysmal Atrial Fibrillation with Radiofrequency Ablation of Pulmonary Vein Foci

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Introduction: Pulmonary veins have been found to play an important role in generating paroxysmal atrial fibrillation. Ablation of arrhythmogenic pulmonary veins appears to be one of the approaches to cure lone atrial fibrillation, when antiarrhythmic drugs have been proven to be ineffective. The purpose of this study was to describe our experience of pulmonary vein ablation in veins where firing foci were found.

Patients and method: The study population consisted of 32 consecutive patients with drug refractory paroxysmal atrial fibrillation. All patients were free of structural heart disease and were separated in two groups, according to the mapping and ablation procedure which was applied. Group A included 13 patients (9 men and 4 women, mean age 52.6±10.7 years) with a mean of 8.8±5.2 episodes of paroxysmal atrial fibrillation per month, and had received a mean number of 3.07±1.3 antiarrhythmic drugs. Ablation of pulmonary veins was performed between January 1997 and August 2001. All patients were selected according to existence of frequent atrial ectopic beats in the ECG or 24 hours Holter monitoring. In this group a single mapping and ablation electrode was used and ablation targeted according to the earliest electrical activity originating from within the pulmonary veins. The electrophysiological end point was the disappearance of these ectopic beats. Group B, consisted of 19 patients (16 men and 3 woman, mean age 54.3±9.8 year) with a mean of 8.7±10.7 episodes of paroxysmal atrial fibrillation per month, who had received a mean number of 2.5±0.6 antiarrhythmic drugs. Ablation of pulmonary veins was performed between August 2001 and May 2002. In this group the mapping and ablation was targeted to dissociate or to eliminate pulmonary electrical activity from the atria, using a circumferential 10 pole mapping electrode (Lasso catheter).

Results: In group A five patients (38.5%) remained asymptomatic and six patients (46%) had a reduction in the overall number and severity of symptoms during a follow-up period of 27.7±16.9 months. In group B, ten patients (52.6%) were asymptomatic and seven patients (36.8%) had a significant reduction in the overall number and severity of symptoms during 4.5±3 months of follow-up. The mean procedure time was 25 min shorter in group B ($p<0.03$). The total number of radiofrequency catheter applications was higher in group B (41±25.6 vs 14±7.8 applications in group A, $p<0.01$). One patient from group A developed left inferior pulmonary vein stenosis without any clinical consequences.

Conclusion: According to our experience, ablation or isolation of focal foci in pulmonary veins appears to be a safe and effective method of treatment of paroxysmal atrial fibrillation, but its effectiveness is less compared to other supraventricular arrhythmias.

Atrial fibrillation is the most common sustained cardiac arrhythmia and its prevalence increases with age. Structural heart disease is an important risk factor for the development of this arrhythmia but it can be also been detected in the absence of any cardiovascular disease. In most cases it is associated with

increased morbidity and mortality[1], while frequent episodes of paroxysmal atrial fibrillation lead to atrial electrical and cellular changes. Early treatment may be essential for preventing atrial remodeling[2,3].

Firing foci inside the pulmonary veins have been proven to induce paroxysmal atrial fibrillation[4-7,11] Proposed mechanisms for generation of abnormal focus activity include increased automaticity and triggered activity, or small reentrant circuits between a small number of cells[4,7]. Radiofrequency ablation can eliminate these foci and is an alternative method of treatment for paroxysmal atrial fibrillation[4,5,8-10].

The purpose of this study is to present our retrospective experience of radiofrequency catheter ablation to eliminate these arrhythmiogenic foci in patients with drug-refractory paroxysmal atrial fibrillation.

Method

The study population consisted of 32 consecutive patients with drug-refractory paroxysmal atrial fibrillation, associated with significant symptoms. Two additional patients were excluded from the procedure due to complications during transeptal catheterization.

Depending on the type of method used for pulmonary vein ablation, the patients were separated into two groups.

Group A consisted of 13 patients (9 men and 4 women, mean age 52.6±10.7 year) who were ablated between January 1997 and August 2001. Patients' mean number of episodes of paroxysmal atrial fibrillation per month was 8.8±5.2 and they had received a mean number of 3.07±1.3 antiarrhythmic drugs. In this group, a single quatripolar electrode was used for the mapping and ablation procedure (7F, Cordis Webster 14c).

The left atrium was mapped either through a patent foramen ovale (two patients) or by transeptal catheterization. Mapping was performed according to the earliest electrical activation when atrial ectopic beats were produced. When ectopic atrial beats were not observed, provocative manoeuvers including high-rate atrial pacing (200 bpm/min), isoproterenol infusion (2 μg/min), or both were performed. Recordings from the mapping electrode when it was placed inside the arrhythmiogenic pulmonary vein showed a low frequency potential representing atrial activity followed by a high-frequency potential representing pulmonary vein potential. There was a reversal of activation sequence during ectopy, preceding this high frequency potential from the pulmonary vein (Figure 1). Subsequent radiofrequency

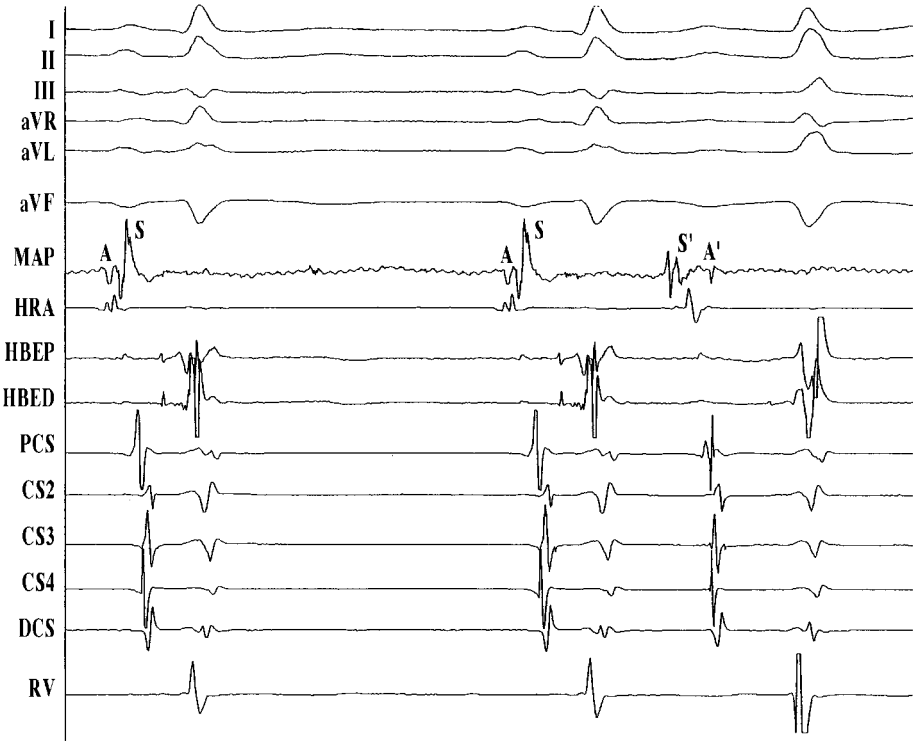
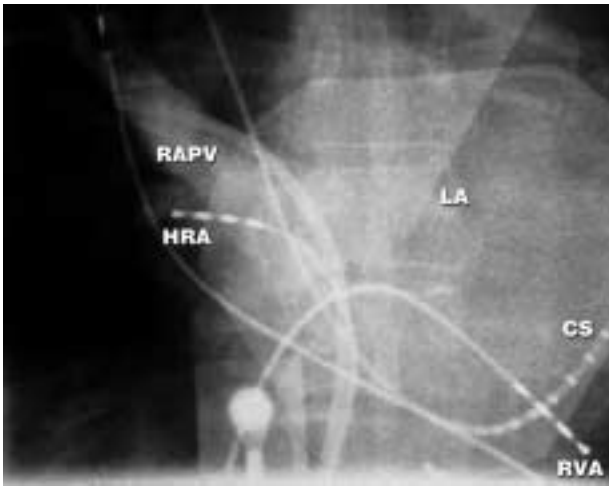


Figure 1. Electrical recordings of the right anterior pulmonary vein. Note the characteristic potential (S) from the recording catheter (MAP). During sinus rhythm potential of pulmonary vein (S) is following the atrial potential (A) and during atrial ectopic, is earlier of this (S′).



Picture 1. Eclectic angiography of the right anterior pulmonary vein (RAPV). RAPV: right anterior pulmonary vein, LA:left atrium. HRA: high right atrium. CS: coronary sinus, RVA: right ventricular apex.

applications were performed at this site of pulmonary vein. The end point of the procedure was to eliminate the pulmonary vein potential and ectopic beats. Radiofrequency energy was delivered at the distal electrode of mapping catheter with a maximum power output of 30 W and a 50°C target temperature.

Group B included 19 patients (16 men and 3 women, mean age 54.3±9.8 year) in whom radiofrequency ablations for paroxysmal atrial fibrillation were performed from August 2001 to May 2002. Patients had a mean number of 8.7±10.7 episodes of paroxysmal atrial fibrillation per month and had received a mean of 2.5±0.6 antiarrhythmic drugs. The target of this procedure was to isolate or to eliminate the pulmonary vein potentials. The left atrium and pulmonary veins were mapped either through a patent foramen ovale (three patients) or a transeptal catheterization. Two electrodes were introduced into the left atrium: a quatripolar electrode for the mapping and ablation procedure and a circumferential ten pole electrode catheter (Lasso, Biosense Webster). The selection of the diameter of this catheter was based on pulmonary vein angiography (Picture 1). The Lasso catheter was uncoiled to allow introduction into the transeptal sheath and after being deployed into the left atrium, was inserted into the desired pulmonary vein. Sequential recordings of transverse slices of pulmonary vein activity were performed at 5 and 10 mm from the left atrial - pulmonary vein junction defined by angiography. The high frequency pulmonary vein muscle potentials were recorded in bipolar mode by the 10 pole electrode and radiofrequency ablation was performed as proximally as possible (Picture 2). Segments of the pulmonary vein perimeter were targeted on the basis of the bipole(s) from the circumferential ten pole circular electrode in the place showing the earliest activation during sinus rhythm (Figure 2A, 3A). If pulmonary vein activation changed as a result of radiofrequency ablation, the ostial sector showing the earliest pulmonary vein potential was targeted. The end point was elimination of pulmonary vein muscle conduction distal to the ablation site(s) based on either abolition or dissociation of distal pulmonary vein potentials (Figure 2B, 3B). Radiofrequency energy was delivered at the distal quadripolar electrode (target 45°C) with a power limit of 25-30 W for 30-60 seconds at each site. In most cases an irrigated-tip catheter was used (thermocool irrigated-tip catheter, Webster).

Systemic anticoagulation was achieved in all patients with intravenous heparin (5.000 to 20.000 IU) to maintain a partial thromboplastin time of 60 to 90 seconds during the procedure.

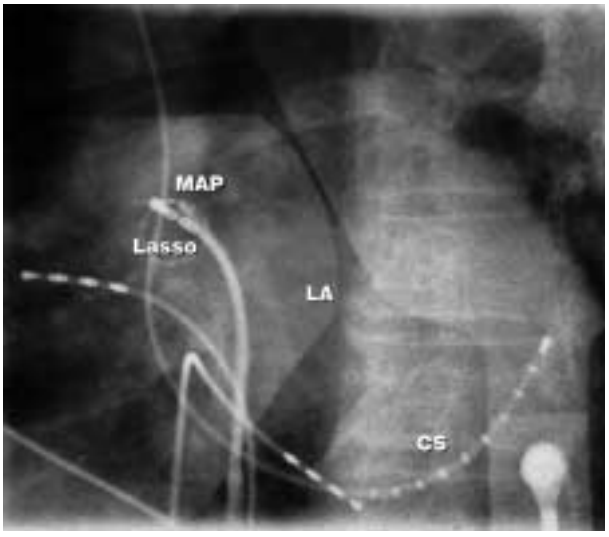
Before ablation, all patients underwent a 24-hour Holter monitoring. Transoesophageal echocardiography was performed in all patients in order to exclude left atrial thrombus, one day before the procedure. Clinical examination, chest x-ray, stress test, thyroid function and standard echocardiography tests were also done to rule out any pathological substrate (Table 1). All patients gave written, informed consent and all antiarrhythmic drugs except amiodarone were discontinued for five half-lives before the study.

Post ablation follow-up

All patients were monitored with full disclosure telemetry for at least 24 hours and received intravenous heparin for 48 hours, followed by acenocoumarol for 3 months after the procedure. Twenty-four hours after the procedure a transoesophageal echocardiogram was performed in all patients.

Follow-up

After the procedure only patients with early recurrences of atrial fibrillation (during the 24-hour observation period) were treated with a class I (propafenone) or class III (sotalol or amiodarone) antiarrhythmic drug.



Picture 2. Electrical recordings with Lasso catheter of the right anterior pulmonary vein (RAPV) and ablation with MAP catheter. LA: left atrium, CS: coronary sinus.

The patients' follow-up examinations were carried out in the outpatient clinic with a 24-hour Holter monitoring one month and subsequently every 3-6 months after the ablation procedure. All patients who reported symptoms also had a 24-hours Holter monitoring to document the cause of symptoms. In order to exclude pulmonary vein stenosis, a transoesophageal echocardiogram was performed 3-6 months after the ablation procedure.

Statistical analysis

Statistical analysis was performed with the SPSS 8.0 (Chicago, Illinois) software program. All variables were expressed as mean ± SD. A paired t-test was used to analyze changes in parametric data before and after an intervention in the same group. Independent sample t-tests were used to analyze changes in the same variable between two groups. A p value <0.05 was considered statistically significant.

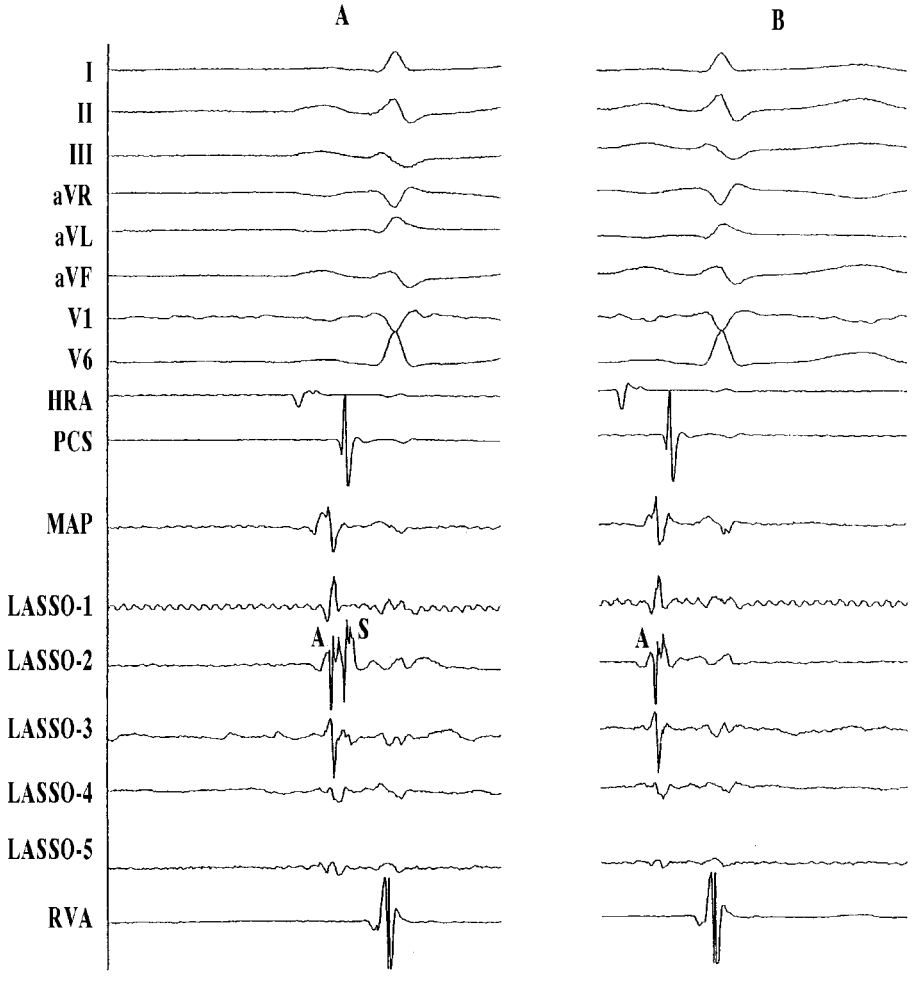


Figure 2. Electrical recordings of the left anterior pulmonary vein (LAPV). **2A:** Note the characteristic potential (S) from the LASSO 2 catheter. **2B:** Local ablation at LAPV ostium corresponding to Lasso 2, eliminated the characteristic potential (S).

Table 1. Patients' characteristics of group A and group B.

	Group A	Group B	p
Sex, M/F	9/4	16/3	–
Age	52.6±10.7	54.3±9.8	0.71
Recurrences of AF/month	8.8±5.2	8.7±10.7	0.64
Number of antiarrhythmic drugs	3.07±1.3	2.5±0.6	0.25
Left atrial dimensions	39±3.8	38.7±4.4	0.84
Fractional Shortening (%)	34.6±4.2	37.9±4.8	0.15
LVEDD (mm)	50.3±4	49.2±4.1	0.34
LVESD (mm)	34±3.8	33.5±4.7	0.78

AF: atrial fibrillation, LVEDD: left ventricular end diastolic diameter, LVESD: left ventricular end systolic diameter.

Results

During a mean follow-up period of 27.2±16.9 months, five patients (38.5%) from group A remained asymptomatic. Six patients (46%) had recurrences of paroxysmal atrial fibrillation (in the first five months) but the overall number of arrhythmia episodes showed a decreasing trend (from 8.83±4.4 to 3.83±2.58 episodes/month p<0.07). In two patients (15.5%) the ablation procedure was unsuccessful (Figure 4). Nine patients were treated with class I or III antiarrhythmic drugs (4 with amiodarone, 3 with propafenone, and 2 with sotalol) (Table 2).

In group B ten patients (52.6%) remained asymptomatic during a mean follow-up period of 4.5±3 months. Seven patients (36.8%) had recurrences of paroxysmal atrial fibrillation (in the first three months) but the overall number of paroxysmal atrial fibrillation episodes were also significantly reduced (from 6.42±6.55 to 1.15±1.33 episodes per month p< 0.039). In two patients (10.5%) the ablation procedure was unsuccessful (Figure 4). Nine patients were treated with class I or III antiarrhythmic drugs (5 with amiodarone, 3 with propafenone, and 1 with sotalol) (Table 2).

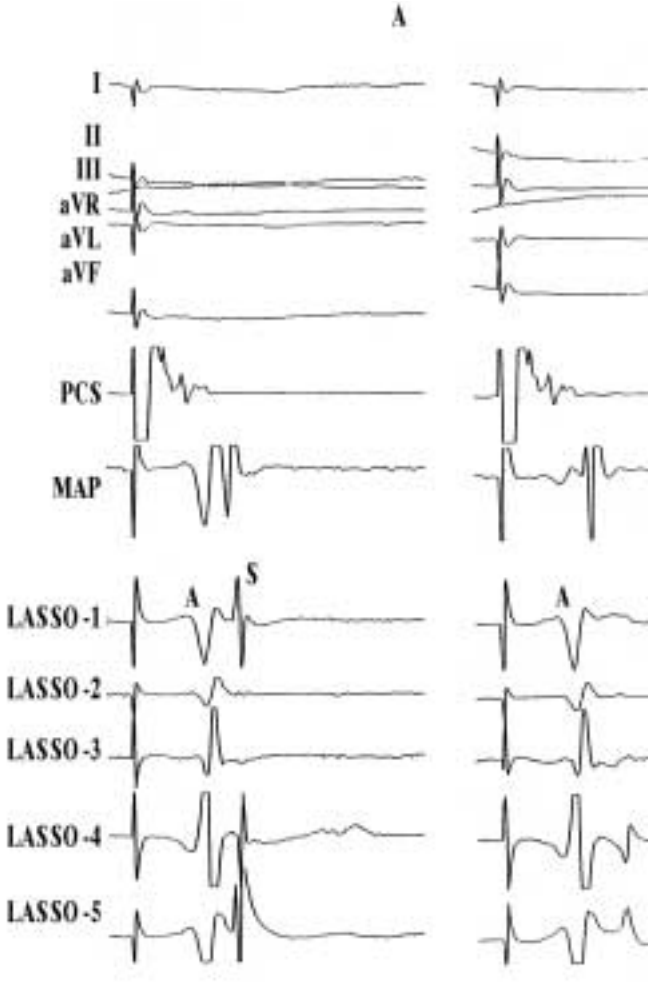


Figure 3. Pacing from DCS and electrical recordings of the left anterior pulmonary vein (LAPV). **3A:** Note the characteristic potential (S) from the Lasso catheter 1,4 and 5. Lasso 1 is the site of earliest breakthrough. **3B:** Local ablation at LAPV ostium corresponding to Lasso 1, eliminated all characteristics potentials (S).

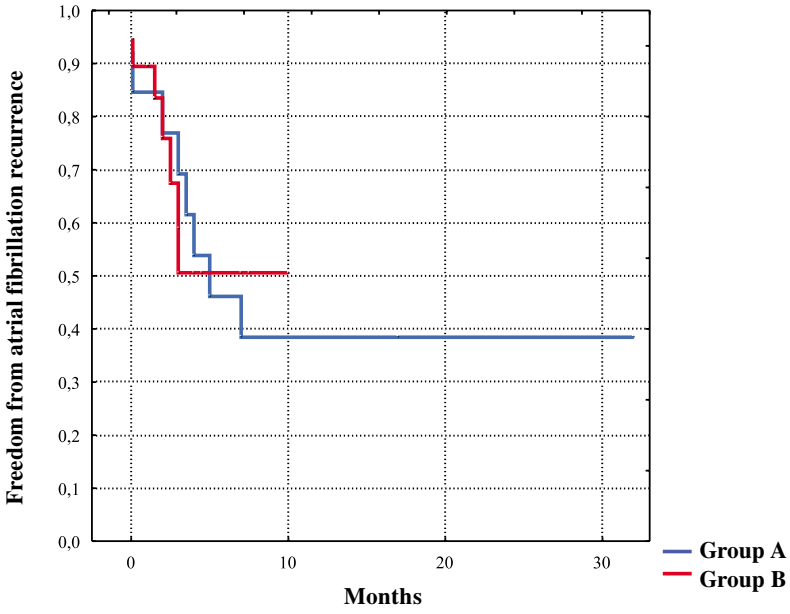


Figure 4. Kaplan Meier analysis. Freedom from atrial fibrillation recurrence in patients of group A and B, after pulmonary vein ablation, p:NS (non statistical significant).

Table 2. Results of group A and group B after ablation.

	Group A	Group B	p
Patient without PAF recurrences	5 (38.5%)	10 (52.6%)	
Patients with PAF recurrences:	6 (46%)	7 (36.8%)	
– Number of PAF recurrences/ month, before ablation	8.83±4.4	6.42±6.55	NS
– Number of PAF recurrences/ month, after ablation	3.8±2.58	1.15±1.33	0.034
Antiarrhythmic drugs. Number of patients	9/13	9/19	NS
Amiodarone	4	5	
Propafenone	3	3	
Sotalol	2	1	

PAF: paroxysmal atrial fibrillation, NS: non statistical significant.

In group A, a total of 16 arrhythmogenic pulmonary veins were mapped: 8 (50%) in the left superior, 6 (37%) in the right superior, 1 (6.5%) in left inferior and 1 (6.5%) in right inferior pulmonary vein. Three patients had two ectopic foci. Ablation was successful in 11 (84.6%) of 13 patients with elimination of pulmonary vein muscle potential. The mean total procedure time was 218.5±30.7 min and the mean fluoroscopy time was 43.5±10.3 min. Each patient had a mean number of 14±7.8 radiofrequency energy applications. In one patient typical atrial flutter which occurred during ablation was terminated after a linear ablation of the isthmus.

In group B a total of 28 arrhythmogenic pulmonary veins were mapped: 13 (46%) in right superior, 12 (43%) in left superior and 3 (11%) in left inferior pulmonary vein. Nine patients had two ectopic foci. Ablation was successful in 26 of 28 arrhythmogenic pulmonary veins (92.8%) resulting in their electrical isolation.

The mean procedure time was 193±42.9 min and the mean fluoroscopy time was 57±24.8 min. The mean number of radiofrequency energy applications was 41±25.6 per patient. In five patients typical atrial flutter occurred during ablation and was terminated after linear ablation of the isthmus (Table 3).

Complications

After ablation, an elective left inferior pulmonary vein angiography revealed a 90% stenosis in one patient of group A. The patient was completely asymptomatic and a new angiography six months later, showed that the vein was patent.

Discussion

We present our experience regarding the interventional therapy of paroxysmal atrial fibrillation with ablation of firing foci in the pulmonary veins in this paper. Initially we tried to eliminate the atrial ectopics from pulmonary veins (group A). Later, the

Table 3. Results of group A and group B during ablation.

	Group A	Group B	p
– PV potentials location			
LAPV	6 (37%)	12 (43%)	–
RAPV	8 (50%)	13 (46%)	–
LIPV	1 (6.5%)	3 (11%)	–
RIPV	1 (6.5%)	–	–
– Ablation of isthmus	1 (7,5%)	5 (26%)	0.19
– Total procedure duration (min)	218.5±30.7	193±42.9	0.03
– Fluoroscopy time (min)	43.5±10.3	57±24.8	0.15
Number of applications	14±7.8	41±25.6	0.01

LAPV: left anterior pulmonary vein, RAPV: right anterior pulmonary vein, LIPV: left inferior pulmonary vein, RIPV: right inferior pulmonary vein.

ablation procedure strategy changed and we performed electrical isolation of the pulmonary veins with characteristic potential recordings, (group B). Basic patient characteristics were not different between the two groups, however patients of group A had a longer follow-up period (27.2±16.9 months) compared to group B patients (4.5±3 months). Even though recurrences are more frequent during the first 3 to 5 months after the procedure, the different follow-up period is a disadvantage for accurate comparisons. A higher proportion of group B patients seems to be free of symptoms than group A patients (52% in group B compared with 38.5% in group A by Kaplan Meier analysis, Figure 4). There seem to be fewer atrial fibrillation recurrences per month in group B (from 6.42±6.55 before ablation to 1.15±1.33 $p<0.039$) (Table 2).

The better results in group B might be due to different methodology of mapping and ablation procedure. In group A, the procedure was guided by the atrial ectopics, the end point of the procedure was the elimination of these atrial ectopics and the procedure was terminated without checking the rest of pulmonary veins. On the other hand, in group B the philosophy of the procedure was different -all pulmonary veins were mapped with the assistance of the circumferential 10 pole lasso catheter. This resulted in the isolation of more firing foci independently of atrial ectopics. In addition, the isthmus was ablated in a higher proportion of group B than in group A (26% in group B vs. 7.5% in group A) because of atrial flutter appearance.

The total screening time was not different in both groups, however group B patients were given more radiofrequency current applications, (Table 3). The reason seems to be related to the methodology of the procedure.

The use of the circumferential lasso 10 pole electrode offers two advantages. First when this electrode is placed in every pulmonary vein, it offers the ability of electrical recording around the vein and secondly affords the opportunity to navigate the mapping electrode around the orifice of the pulmonary vein. So far this explains the significant reduction of the total time of the procedure, in combination with the better learning curve, which is reduced by 25 minutes in group B (Table 3).

Hence, the radiofrequency current is delivered outside the vein ostium. This might explain why no pulmonary vein stenosis was found in group B. The use of the irrigated electrode which is reported to produce smooth lesions with the use of the same amount of energy may have contributed to this[14,15]. One case of pulmonary vein stenosis in group A was observed, an incidence of 3% less than it reported by other centres[13].

Pericardial infusion with signs of pericardial tamponade as a result of the transeptal puncture was observed in two patients and both patients were successfully treated with pericardial drainage. In these patients the procedure was interrupted and they were not included in the study. In the literature, the incidence of pericardial tamponade during the procedure of pulmonary vein ablation ranges from between 0 to 11%[4]. Another complication which can occur during the procedure is the appearance of peripheral emboli with the occurrence of cerebral emboli being more severe. This ranges from between 0 to 10% in other centres[4], while no such case was noted in our centre, probably because of effective anticoagulant therapy with heparin during the procedure and the following 48 hours.

In both groups even though a significant number of patients experience recurrence of atrial fibrillation after the ablation procedure, they do however experience a significant improvement in the clinical outcome regarding the number and incidence of atrial fibrillation episodes. The recurrence of atrial fibrillation may be explained by the fact that some of the firing foci inside the veins during the ablation procedure were not found to be arrhythmogenic, especially in group A. These remaining foci fire less frequently and this might explain the reduction in the number of atrial fibrillation episodes. Another possible explanation is that the initial procedure is

not entirely effective with an incomplete blockade of the firing foci from the pulmonary vein[5].

The number of patients in whom atrial fibrillation recurs after the procedure, approaches 44% in the literature. The strategy of therapy for these patients is to repeat the procedure, leading to a success rate over 70%[9], which is partly complied with in our centre. This fact may explain the difference between our centre and others.

Other centres have reported an approximate 80 % success rate when all pulmonary veins were electrically isolated with electrophysiology criteria[12] or with anatomical approach leading to a success rate of 85%[10].

The fact that the firing foci is located in other parts of the atria[4,5] may be another reason behind the failure of the method in a few cases (5-15%).

In conclusion, according to our experience, ablation of firing foci or electrical isolation of pulmonary veins seems to be an effective therapy for patients with idiopathic paroxysmal atrial fibrillation. The effectiveness of this therapy increases with the use of circumferential 10 pole mapping electrode. Most of the patients independently of atrial fibrillation recurrence progress better clinically. In the future the use of new mapping systems will give better results. The safety and the good results of this method may afford us the opportunity to apply early treatment not only in idiopathic atrial fibrillation patients but also in patients with structural heart disease.

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