The Heart Surgery Forum #2007-1165
11 (2), 2008 [Epub April 2008]
doi: 10.1532/HSF98.20071165

Online address: http://cardenjennings.metapress.com

Long-term Outcomes of Surgical Radiofrequency Ablation for Atrial Fibrillation in 3 Groups of Patients

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ABSTRACT

Background. Left atrial surgical radiofrequency ablation represents an applicable and technically less demanding method for treating paroxysmal or permanent atrial fibrillation (AF) as a concomitant procedure. The aim of this study was to review the long-term outcomes of radiofrequency linear ablation for the treatment of AF limited to the left atrium in 3 groups of patients undergoing cardiac surgery.

Methods. The study population consisted of 357 consecutive patients, who were divided into 3 groups on the basis of the underlying disease: group I, 126 patients with nonischemic mitral valve disease; group II, 164 patients with coronary artery disease and aortic and/or ischemic mitral valve disease or who underwent other concomitant procedures; and group III, 67 patients with coronary artery disease only.

Results. Follow-up times were between 6 and 48 months (mean, 28.3 ± 9.4 months). The 30-day hospital mortality rate was 2.80% (10 patients). Total mortality during the follow-up period reached 4.48% (16 patients). At discharge, 66% of group I patients, 64% of group II patients, and 69% of group III patients were in sinus rhythm. After 24 months, 60% of group I patients, 75% of group II patients, and 67% of group III patients were in sinus rhythm. A subgroup analysis of the patients with permanent AF showed that only 54% of these patients in group I, 52% in group II, and 67% in group III had a restored sinus rhythm at 24 months. Subgroup analysis also revealed that only 6 (27%) of 22 patients with a left atrium diameter >60 mm maintained a sinus rhythm during long-term follow-up. Biatrial contraction was restored in 75% of the patients with a stable sinus rhythm after 6 months of follow-up. Seven patients (2%) with symptomatic postoperative recurrent atrial arrhythmias underwent subsequent catheter ablation.

Conclusion. Left atrial surgical radiofrequency ablation represents an applicable and technically less demanding method for treating paroxysmal or permanent AF as a concomitant procedure. Our results demonstrate the feasibility of this procedure for paroxysmal and persistent AF, with minimal risks to the patient. For permanent AF, further investigation and extensive intervention are essential.

Received August 6, 2007; received in revised form November 19, 2007; accepted December 6, 2007.

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INTRODUCTION

Atrial fibrillation (AF), the most frequent arrhythmia in patients with valvular heart disease and/or coronary artery disease, is present in >3.5% of the population older than 60 years and occurs in approximately 9.0% of octogenarians [Fuster 2006]. Because of the high incidence of asymptomatic arrhythmias, these frequencies are presumed to be underestimates. Variation in the prevalence of AF has been well established (1.1% in men versus 0.8% in women, 2.2% in the elderly white population versus 1.5% in the elderly black population, and so forth). Nearly 50% of patients in the end stage of chronic heart failure in New York Heart Association class IV experience AF. AF leads to a decrease in ventricular filling because of the considerable loss of atrial contraction. Overall, AF is often associated with a high risk of thromboembolic events (3%-7% annually, demonstrated in the Boston Area Anticoagulation Trial for Atrial Fibrillation [BAATAF], Canadian Atrial Fibrillation Anticoagulation [CAFA], Stroke Prevention in Atrial Fibrillation I-III [SPAF I-III], and Copenhagen Atrial Fibrillation, Aspirin and Anticoagulation [AFASAK] studies), cardiac chamber dilatation, and decreased cardiac output. Due to the difference between the onset and maintenance of the arrhythmia sequent upon the difference in pathophysiology of electrical and structural remodelling between paroxysmal and permanent AF distinguishing in surgical treatment is essential. Nonpharmacologic treatment modalities play an important role along with effective modern therapies in relieving symptoms and improving the prognosis [Melby 2006].

The last decade has witnessed the development of different strategies for surgical ablation in treating AF in patients for whom concomitant cardiac surgery has been planned. Several modifications of the linear ablation procedure have focused on compartmentalizing the left atrium and isolating pulmonary veins by means of various techniques that use different energy sources (cryoablation,

radiofrequencies, microwaves, ultrasound, and so forth), and such approaches have demonstrated relatively high success in patients with AF and mitral valve disease [Vojacek 2005]. Less is known about the clinical outcomes of patients with AF accompanying aortic valve disease and/or coronary artery disease.

The aim of this study was to review the long-term outcomes of radiofrequency linear ablation for AF limited to the left atrium in 3 groups of patients undergoing cardiac surgery.

METHODS

Study Population

The study population consisted of 357 consecutive patients (197 men and 160 women; mean age, 68 ± 9 years; range, 25-84 years) who underwent linear radiofrequency ablation of the left atrium in our institution between July 2000 and May 2005. The patients were divided into 3 groups according to the underlying disease. Group I comprised 126 patients with AF in the setting of nonischemic mitral valve disease. Group II included 164 patients who had AF associated with coronary artery disease and aortic and/or ischemic mitral valve disease or were undergoing other concomitant procedures. Group III consisted of 67 patients with AF accompanying coronary artery disease only. The incidences of permanent AF were 81% in group I, 71% in group II, and 57% in group III. The clinical characteristics of the study population are summarized in Table 1. Subsequent comparison of the groups revealed a significant difference among the 3 study groups in the diameter of the left atrium (group I, 55 ± 6 mm; group II, 52 ± 7 mm; group III, 47 ± 7 mm) (Table 2).

The demographic profile of the study population is shown in Table 1. An analysis of the 3 groups (Tables 2 and 3) demonstrated that despite the high incidence of chronic AF, only half of the patients were receiving effective anticoagulation therapy or at least antiaggregation therapy. The results of the analysis of preoperative data for the 3 groups are summarized in Table 2. We used the nomenclature guidelines of the American College of Cardiology and the European Society of Cardiology and therefore refer to AF as paroxysmal, persistent, or permanent [Fuster 2006]. The study was designed according to the guidelines of our institutional ethics committee.

Table 1. Clinical Characteristics of the Study Population (n = 357)*

Variable	
Mean age (range), y	68 (25-84)
Female sex	45%
Diabetes mellitus	22%
Hyperlipidemia	27%
COPD	21%
Hypertension	59%
CVA	12%
TIA	5%
Renal insufficiency	7%
CCS class III-IV	25%
NYHA class III-IV	67%
History of endocarditis	2%
Anticoagulants	37%
Preoperative ASA	6%
Ejection fraction	52% ± 13.5%†

*COPD indicates chronic obstructive pulmonary disease; CVA, cerebrovascular accident; CCS, Canadian Cardiovascular Society; NYHA, New York Heart Association; ASA, atrial septal aneurysm.

†Mean ± SD.

Table 2. Analysis of Group Preoperative Data*

	Group I (n = 126)	Group II (n = 164)	Group III (n = 67)
Age, y	64 ± 11†‡	68 ± 8	70 ± 6
Chronic AF, n	102 (81%)	116 (71%)	38 (57%)
Left atrium size, mm	55 ± 6†‡	52 ± 7§	47 ± 6
Ejection fraction, %	61 ± 12	50 ± 15	55 ± 12
LVEDD, mm	57 ± 6	57 ± 5	55 ± 6

*All but the chronic atrial fibrillation (AF) data are presented as the mean ± SD. LVEDD indicates left ventricular end-diastolic diameter. †$P < .05$, group I versus group II. ‡$P < .05$, group I versus group III. §$P < .05$, group II versus group III.

Saline-Irrigated Radiofrequency Ablation

All operations were performed via median sternotomy with the patient on cardiopulmonary bypass with standard aortic cannulation and either bicaval or right atrial cannulation. Cold antegrade blood or crystalloid cardioplegia and moderate hypothermia (32°C-33°C) were used during cross-clamping. The left atrium was entered directly via dissection of the Waterston groove after the administration of cardioplegia. Continuous endocardial lesions were created around pulmonary venous ostia and between the mitral annulus and pulmonary veins. The ablation was performed with a saline-irrigated radiofrequency probe built for the purpose, and a commercially available radiofrequency current generator (Atakr II RF Power Generator, model 4802 electrosurgical unit; Medtronic, Minneapolis, MN, USA) and a volume perfusion pump (Doltron, Uster, Switzerland) were used. The initial saline flow rate was 10 mL/min, and the radiofrequency

Table 3. Use of Antiarrhythmic Drugs in Subgroups of Patients in Sinus Rhythm (SR) after 12 Months of Follow-up*

Group I	
Permanent AF (SR)	28%
Paroxysmal AF (SR)	7%
Group II	
Permanent AF (SR)	10%
Paroxysmal AF (SR)	13%
Group III	
Permanent AF (SR)	40%
Paroxysmal AF (SR)	18%

*AF indicates atrial fibrillation.

energy was set at 25 to 35 W. Some adjustments were made at the discretion of the surgeon. All lesions were performed endocardially prior to the concomitant surgical procedures with the patient on cardiopulmonary bypass. In all cases, the left atrial appendage was either removed or sewn from the inside. In the latter cases, the appendage was left in place and closed from the inside.

Echocardiography

Transthoracic echocardiography evaluations were performed with commercially available echocardiographic equipment (Vivid 7 [GE Healthcare, Milwaukee, WI, USA] or Acuson Sequoia [Siemens Medical Solutions, Mountain View, CA, USA]) in all patients before and after the procedure, before discharge, and during follow-up intervals. M-mode measurements were performed according to the recommendations of the American Society of Echocardiography. The atrial transport function in patients in sinus rhythm was evaluated after the procedure via pulsed Doppler echocardiography and was expressed as the atrial filling fraction (ie, the ratio of the tricuspid or mitral flow time-velocity integral of the A wave to the total diastolic filling). We arbitrarily considered a peak A-wave velocity of >20 cm/s as indicative of effective atrial contraction.

Postoperative Care

After cardiac surgery procedures, standard postoperative care was provided to all patients, initially in the intensive care unit and later on the surgical ward. Closed electrocardiographic monitoring was provided to detect all kinds of arrhythmias. Early postoperative atrial arrhythmias were treated with a continuous intravenous infusion of amiodarone (daily dose, 1200 mg) with subsequent conversion to oral intake (daily dose, 200 mg) until the second follow-up control evaluation at 3 months. Subsequent continuation of amiodarone treatment was left to the discretion of the attending physician. In cases of drug intolerance or a contraindication, sotalol was used as an alternative (daily dose, 160 mg). In addition, the majority of the patients received a beta-blocker. Oral anticoagulants were prescribed for a minimum of 3 months after surgery (warfarin, with an adjustment of the dosage according to an international normalized ratio target of 2.0-2.5). Anticoagulation treatment was continued in patients with persistent arrhythmia and/or a mechanical heart valve.

Follow-up

Patients were followed at intervals of 1, 3, 6, 12, 24, and 36 months after the procedure. The follow-up time ranged from 6 to 48 months (mean, 28.3 ± 9.4 months). Follow-up was completed in 12 months in 96% of the cases. The examinations scheduled during the follow-up included a 12-lead electrocardiographic evaluation, Holter monitoring, and a transthoracic echocardiographic examination (left atrium size, left ventricular ejection fraction, left ventricular end-diastolic diameter, and transmitral and transtricuspidal Doppler). The primary end point of the study was the occurrence of sinus rhythm during the follow-up. The secondary end point included signs of reversed remodeling of the left atrium based on echocardiography measurements.

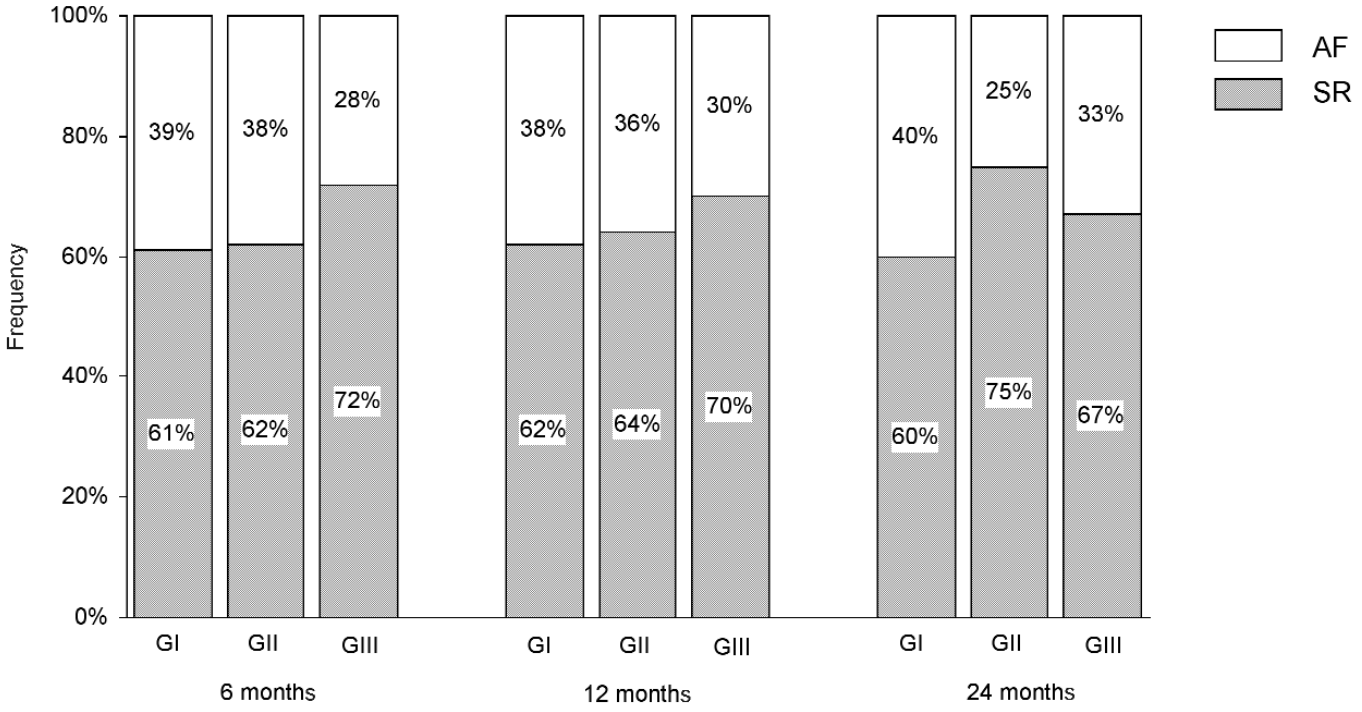

Figure 1. Rates of sinus rhythm (SR) and atrial fibrillation (AF) during the postoperative period in groups I, II, and III. *$P < .05$, group II versus group I.

Statistical Analysis

Results are presented as the mean ± SD for continuous variables and as absolute and relative frequencies for discrete ones. Groups were compared by means of the unpaired Student *t* test and the chi-square test. The paired *t* test was used for comparison of pre- and postoperative parameters. Final *P* values were obtained by correction with the Holms sequential multiple-test procedure for 3 groups. All tests were 2-tailed, and a *P* value <.05 was considered statistically significant.

RESULTS

The mean length of hospital stay was 8.7 ± 5.1 days. The early (30-day) postoperative mortality rate was 2.80% (10 patients). No death was directly associated with the ablation procedure. The total mortality rate during the follow-up reached 4.48% (16 patients). A permanent pacemaker was implanted for a bradycardia indication in 15 cases (4.40%). Two patients (0.56%) received an implanted cardioverter/defibrillator for secondary prevention of malignant ventricular arrhythmias. Transitory ischemic attack was observed in 3 cases (0.84%), and stroke occurred in an additional 6 cases (1.68%). Mitral valve thrombosis occurred in 2 cases (0.56%).

Rhythm Analysis during Follow-up

At discharge, 66% of the patients from group I, 64% from group II, and 69% from group III were in sinus rhythm; Figure 1 illustrates the further development of sinus rhythm during follow-up. The groups showed no differences at the 6- and 12-month follow-up evaluations. The frequency of patients in sinus rhythm was significantly higher in group II than in group I at the 24-month follow-up. Considering that the basis for permanent AF is different from that for paroxysmal AF, we performed a subgroup analysis, the results of which are summarized in Figure 2. Patients with paroxysmal AF in groups I and II achieved a restored a sinus rhythm significantly more frequently than the patients with permanent AF in these 2 groups. There were no differences between these 2 patient subgroups in group III.

The proportion of patients on antiarrhythmic drugs is shown in Table 3. In group I, 28% of the patients with permanent AF are on antiarrhythmic therapy (1 patient on flecainide, the remainder receiving amiodarone), 10% of the patients in group II with permanent AF are on antiarrhythmic therapy (amiodarone or propaphenon), and 40% patients in group III with permanent AF are on antiarrhythmic therapy (all on amiodarone).

Fifty-six patients (15.7%) presented with any type of regular postincisional arrhythmias during follow-up. Most of such arrhythmias were transient in nature during the early (3 months) postoperative period and disappeared spontaneously or after electrical cardioversion; however, 7 patients (2%) who had symptomatic recurrent atrial arrhythmias resistant to direct-current shocks and were receiving antiarrhythmic therapy underwent subsequent cathether ablation. An electroanatomical mapping system was used to guide

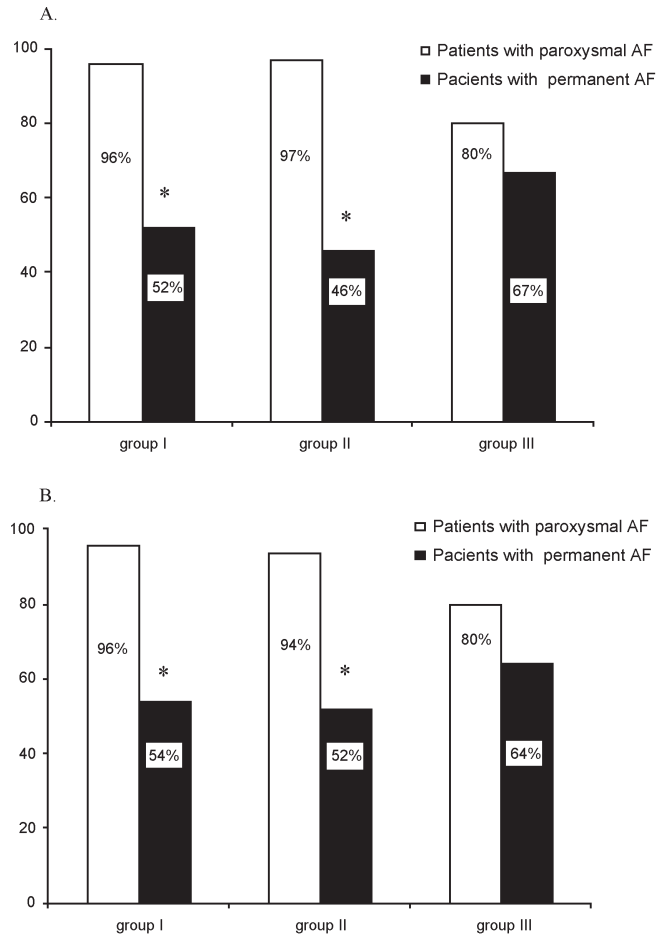

Figure 2. Restoration of sinus rhythm (SR) after the ablation procedure in patients with paroxysmal and permanent atrial fibrillation (AF) at 6 months (A) and 24 months (B) of follow-up. *$P < .05$, patients with paroxysmal AF versus patients with permanent AF.

cathether ablation in all cases, with the exception of typical atrial flutter. The results are summarized in Table 4.

Atrial Size and Transport Function

A statistically significant decrease in the size of the left atrium was observed in the patients in groups I and II at 6 months after surgery (Table 5). The small number of patients in group III precluded documentation of a statistically significant decrease in the size of the left atrium in this group. A subgroup analysis revealed that only 6 (27%) of 22 patients (95% confidence interval, 8%-46%) with a left atrium diameter >60 mm maintained a sinus rhythm during long-term follow-up [Fuster 2006]; this frequency was significantly different from that for the patient group with diameters <6.0 cm. Biatrial contraction was restored in 75% of the patients, with a stable sinus rhythm restored after 6 months of follow-up.

DISCUSSION

To our knowledge, this study is the first to compare the outcomes of surgical ablation of the left atrium for AF in

Table 4. Patients Who Underwent Catheter Ablation after Surgery for Various Postoperative Arrhythmias*

Patient No.	Surgery	Mapping	Success	Tachycardia Type
1	CABG	CARTO†	+	Typical flutter
2	CABG	—	+	Typical flutter
3	MVR	CARTO	+	LA macroreentry
4	MVR	CARTO	+	LA macroreentry
5	ASD	CARTO	+	Postincisional RA
6	MVP, TVR, ASD	CARTO	+	LA macroreentry, postincisional RA, typical flutter
7	MVR	—	+	Typical flutter

*CABG indicates coronary artery bypass grafting; MVR, mitral valve replacement; LA, left atrium; ASD, atrial septal defect; RA, right atrium; MVP, mitral valve prolapse; TVR, tricuspid valve replacement.

†CARTO is a trademark of Biosense Webster, Diamond Bar, CA, USA.

patients grouped according to the underlying disease and to subsequently present electrophysiological findings for patients with recurrent tachyarrhythmia following the ablation procedure. Our results can be summarized as follows: The primary end point of long-term restoration and maintenance of sinus rhythm was achieved by 24 months in 60% to 75% of the cases. A higher success rate in restoring the sinus rhythm was observed in all groups of patients with the paroxysmal and persistent forms of AF. A significant postoperative decrease in the diameter of the left atrium was observed predominantly in patients who underwent concomitant valve surgery and was not observed in patients who had associated coronary artery disease (Table 5). A left atrium size >60 mm was a predictor of procedure failure, a result that is in accordance with the findings of other investigators [Topkara 2006]. The transport functions of both atria were restored in 75% of the patients who remained in sinus rhythm. Regular postincisional tachyarrhythmia occurred in 15.7% of the patients and was transient in the majority of cases. Catheter-based ablation for symptomatic arrhythmias was necessary in 7 patients.

Table 5. Preoperative and Postoperative Echocardiography Parameters*

Group	Follow-up	LA Diameter, mm	LVEDD, mm	Peak A, cm/s
I	Preoperative	55 ± 6	57 ± 6	NA
	6 Months	49 ± 5†	55 ± 5	63 ± 6
	12 Months	47 ± 4	54 ± 6	NA
	24 Months	47 ± 6	54 ± 5	NA
II	Preoperative	52 ± 7	57 ± 5	NA
	6 Months	49 ± 4†	57 ± 4	71 ± 9
	12 Months	49 ± 5	54 ± 7	NA
	24 Months	49 ± 6	54 ± 3	NA
III	Preoperative	47 ± 6	55 ± 6	NA
	6 Months	47 ± 7	55 ± 5	66 ± 8
	12 Months	46 ± 8	54 ± 6	NA
	24 Months	NA	NA	NA

*Data are presented as the mean ± SD. LA, left atrium; LVEDD, left ventricular end-diastolic diameter; NA, data not available.

†$P < .05$, versus preoperative data.

Our results did not show any statistically significant differences in outcomes between the groups, except between groups I and II at the 24-month follow-up with respect to the underlying disease. In other words, the long-term maintenance of sinus rhythm is not determined by the particular heart disease [Grubitzsch 2007]. We confirm recently published findings [Yuda 2001; Melo 2004; Sie 2004; Halkos 2005; Khargi 2005; Topkara 2006] that the rate of conversion to sinus rhythm in simplified ablative procedures is mainly related to the size of the left atrium and the duration of AF. The significance of different ablative patterns or different sources of energy (eg, microwaves, highly focused ultrasound, cryoablation, radiofrequencies, or lasers) has not yet been demonstrated in any randomized study. In this study, we documented a higher failure rate in patients with a left atrial size >60 mm (success rate, 27%; 95% CI, 8%-46%). We conclude that more extensive intervention (reduction in atrium size) is advisable for this type of enlarged left atrium [Badhwar 2006; Marui 2006, 2007]. The results with regard to our statistically significant subanalysis of 22 patients with a left atrium >60 mm are otherwise discouraging. Less invasive or even catheter-based ablation should be avoided, because the only positive result of the ablative procedure for our patients was restoration of a stable sinus rhythm along with recovery of the atrium's transport function [Albirini 1997; Yashima 1997; Yuda 2001]. In our series, we documented the reestablishment of the atrial transport function in 75% of the patients with a stable sinus rhythm, which was essential for reducing the warfarin dosage and the use of antiarrhythmic drugs (Table 3); there were no statistically significant differences between the groups. This result is attributable to the favorable hemodynamic response caused by correcting the underlying disease [Fayad 2005] and restoring and maintaining the sinus rhythm [Kawaguchi 1996]. For this reason, we also resected or sewed the atrial appendage in all cases in the study to prevent thrombus formation.

Prompted by the studies of several investigators [Haissaguerre 1998; Melo 2004; Sueda 2005], who identified pulmonary vein foci as triggers of the majority of paroxysmal AF cases, we are trying to simplify the method as much as possible to maximize positive outcomes for patients with paroxysmal or persistent AF.

The development of minimally invasive [Jeanmart 2006; Abadie 2006] or totally endoscopic ablation procedures for even isolated AF will determine our future progress; however, further electrophysiological research into the basis of permanent AF is required. We cannot expect an increase in the success rate with minimally invasive surgery similar to that of the Cox maze procedure unless there is major scientific and technical progress.

Finally, several reports regarding postincisional recurrent tachyarrhythmia have been published in the last few years [Kobza 2004; Nilsson 2006]. In our series, we found atrial arrhythmias besides AF postoperatively in approximately 16% of the patients. Seven patients were treated via catheter-based ablation. Typical atrial flutter was a common finding, and macroreentry circuits in the left atrium caused by gaps in the connective ablative lines because of nontransmural lesions, especially close to the mitral annulus, were detected by electroanatomical mapping. With regard to the occurrence of postincisional tachyarrhythmias, which are sometimes tolerated even less well by patients, there is a desperate need for randomized studies to compare invasive, interventional treatment with pharmacologic therapy in patients with AF [Zimetbaum 2006].

CONCLUSION

The use of surgical radiofrequency ablation of the left atrium for the treatment of AF as a concomitant procedure in different patient groups represents an applicable and technically less demanding method [Gehi 2006]. Our results have demonstrated the feasibility of this procedure for paroxysmal and persistent AF, with minimal risk to the patient and no differences in outcomes for patients with different heart diseases. For permanent AF, further investigation and extensive intervention are essential.

ACKNOWLEDGMENTS

This study was supported by an institutional research grant from the Ministry of Health of the Czech Republic, MZO 00023001, and by grant MSMT 1M0510. The authors thank Frantisek Straka, MD, and Janka Skrobakova, MD, for echocardiography measurements during the study.

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