

Ablation of Permanent Atrial Fibrillation in Cardiac Surgery. Short-Term and Mid-Term Results

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Introduction. Surgical ablation of atrial fibrillation is currently a simple procedure that can be done during cardiac surgery in most patients. A number of different energy sources now available allow to easily create ablation lines in the atria. We describe our experience during the previous three years.

Patients and method. In 93 patients with cardiac problems treated with surgery and permanent atrial fibrillation (longer than 3 months), surgical ablation of the arrhythmia was done at the same time. Mean duration of the atrial fibrillation was 6 years (range 0.3 to 24 years). Mean (SD) preoperative size of the atrium as measured echocardiographically was 51.7 (8.8) mm (range 35 to 77 mm).

Results. Five patients died in the hospital (5.3% in-hospital mortality). After a mean follow-up of 10 months, 83.8% of the patients had recovered and maintained sinus rhythm, and 16.1% of the patients remained in atrial fibrillation. A permanent pacemaker was implanted in 3 of these patients. Among the 82 patients followed for more than 6 months, the prevalence of sinus rhythm was 84.1%. Echocardiographically documented contractility in both atria was observed in 50% of the patients. Major complications related to the ablation procedure occurred in 3.5% of the patients, and consisted of a perivalvular leak 2 months after surgery, a circumflex artery spasm, and an atrio-esophageal fistula.

Conclusions. Surgical ablation of permanent atrial fibrillation is a simple procedure associated with low morbidity and mortality, and with recovery of sinus rhythm in most patients. The main problem with the procedure is the incidence of early postoperative arrhythmias.

Key words: Atrial fibrillation. Surgery. Ablation.

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Ablación de la fibrilación auricular permanente en la cirugía cardíaca. Resultados a corto y medio plazo

Introducción y objetivos. Actualmente la ablación quirúrgica de la fibrilación auricular (FA) es un procedimiento simple que puede realizarse en la mayoría de los pacientes durante la cirugía cardíaca. Diferentes fuentes de energía para la ablación permiten crear con facilidad las líneas de ablación en las aurículas. Presentamos nuestra experiencia durante los últimos 3 años.

Pacientes y método. En 93 pacientes con diferentes afecciones quirúrgicas cardíacas y FA permanente (> 3 meses) se asoció la ablación quirúrgica de la arritmia. La antigüedad media de la FA fue de 6 años (rango, 0,3-24). El tamaño preoperatorio por ecocardiografía (ECO) de la aurícula izquierda (AI) fue de 51,7 ± 8,8 mm (rango, 35-77).

Resultados. La mortalidad hospitalaria fue de 5 pacientes (5,3%). Tras un seguimiento medio de 10 meses, el 16,1% de los pacientes siguen en FA permanente y el 83,8% han recuperado y mantenido el ritmo sinusal; 3 pacientes necesitaron la implantación de un marcapasos definitivo. Analizando el resultado en los 82 pacientes con un seguimiento mayor de 6 meses, la prevalencia del ritmo sinusal fue del 84,1%. Se evidenció función contráctil biauricular (ecocardiográfica) en el 50% de los pacientes. Las complicaciones mayores relacionadas con el procedimiento de la ablación fueron del 3,5%: 1 *leak* perivalvular al segundo mes postoperatorio, 1 espasmo de la arteria circunfleja y 1 fístula auriculoesofágica.

Conclusiones. La ablación quirúrgica de la FA permanente puede realizarse de forma simple, con baja morbilidad quirúrgica, con recuperación del ritmo sinusal en la mayoría de los pacientes. La incidencia de arritmias en el postoperatorio inicial es el principal problema del procedimiento.

Palabras clave: Fibrilación auricular. Cirugía. Ablación.

INTRODUCTION

Ablation of atrial fibrillation (AF) during cardiac surgery is becoming increasingly common. Sources of

ABBREVIATIONS

AF: atrial fibrillation.
 RF: radiofrequency.
 ECO: echocardiography.
 ECC: extracorporeal circulation.
 LA: left atrium.
 RA: right atrium.

energy for surgical ablation include radiofrequency (RF) discharges, microwaves and cryoablation. Ultrasound waves and lasers may also be used in the near future. Ablation is a quick and simple procedure that can treat AF by electrically isolating atrial regions.¹⁻⁶

Atrial fibrillation is of particular interest to surgeons because it is common in preoperative patients—prevalence is as high as 16% in Spain even if we only include the permanent form of AF. Prevalence is particularly high in patients with mitral valve disease—as many as 60% suffer from permanent AF⁷ compared to 0.6% of the general population.⁸ A recent study has reported that AF doubles the risk of mortality.⁹ The clinical repercussion of AF is probably greatest in patients who are indicated for cardiac surgery and, moreover, the ablation technique is probably easiest during a surgical procedure.

In the present study, we report our experience with 93 patients in whom cardiac surgery was associated with ablation of permanent AF.

PATIENTS AND METHODS

Between June 2000 and June 2003, 93 patients with heart disease requiring surgery and permanent AF for more than 3 months underwent ablation of the arrhythmia during cardiac surgery. All patients were informed of the procedure and gave their informed written consent. Patient selection was not arbitrary. This depended on patients' age, preoperative health status and the surgeon's criteria. Initially, there were no exclusion criteria, but later we excluded patients with a presurgical assessment indicating high risk and those with atrial calcification. The study group was formed of 31 men and 62 women aged between 39 years and 78 years (mean, 61±9 years). The preoperative duration of AF was documented by electrocardiography and ranged from 3 months to 24 years (mean, 6.0±5.7 years). Table 1 shows the main clinical and echocardiographic characteristics of patients and their arrhythmias. At the time of the intervention, all patients were receiving some type of antiarrhythmic agent, usually digoxin or amiodarone. Twenty patients (21.5%) had a history of thromboembolism. Most of the patients (80.7%) pre-

TABLE 1. Clinical Characteristics and Preoperative Echocardiographic Atrial Size*

	Population (n=85)
Clinical Characteristics	
Age, years	61±9
Men/women, n	31/62
f-wave amplitude, mV	0.150±0.236
Duration of AF, years	6.0±5.7
<3 years, n	36
3 to 6 years, n	18
>6 years, n	39
Number of previous antiarrhythmics tried	2.2±0.8
Time on anticoagulants, years	4.8±5.4
Reoperation, n (%)	15 (16.1)
History of thromboembolic episode, n (%)	20 (21.5)
Atrial size in ECO	
LV shortening fraction (%)	34.5±7.0
LA anteroposterior diameter, mm	51.9±9.0
LA volume, mL	124.5±72.0
RA anteroposterior diameter, mm	52.6±12.8
RA volume, mL	72.2±42.1

*Data are expressed as mean ± standard deviation or in percentage of patients.

RA indicates right atrial; LA, left atrial; ECO, echocardiography; AF, atrial fibrillation; LV, left ventricular.

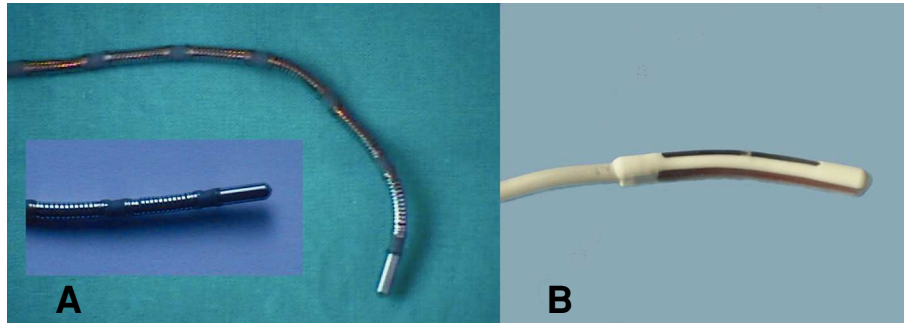
sented with left atrial (LA) dilatation, defined as an anteroposterior atrial diameter greater than 45 mm.

The reasons for heart surgery varied, though the most common was mitral valve disease. The type of primary heart disease and the corresponding surgical procedures are shown in Table 2. The preoperative score to assess surgical risk in this group of patients was 5.2±2.8 according to the EuroSCORE predictive model¹⁰ and 5.8±2.3 according to the model of St. Luke's Medical Center (Chicago, United States of America).¹¹ These scales suggested that the risk of hospital mortality for this group of patients was intermediate, which corresponded to 5.9% for the EuroSCORE model and 6.4% for the model of St. Luke's Medical Center.

Surgical Ablation Protocol

Compartmentalization of both atria and isolation of pulmonary veins were carried out by ablation lines using the lesion set described by Cox¹² for the maze intervention. The same lesion sets as those described previously in this journal were used for all patients.¹³ Briefly, the ablation procedure began in the right atrium (RA) without extracorporeal circulation (ECC). Two separate lines were ablated on the epicardium, the first along the *crista terminalis* from the superior to inferior vena cava, including the cavotricuspid isthmus, and the second, perpendicular to the first from the inferior right pulmonary vein to the tricuspid annulus along the right appendage. Next, the heart-lung appa-

Fig. 1. Surgical ablation catheters. A: unipolar multielectrode surgical probe with a malleable shaft, with 7 10 mm coil electrodes with 3 mm spacing. B: continuous microwave probe with 4 mm antenna.



ratus was connected and ECC was initiated. Systemic hypothermia of 30°C was induced. LA ablation started from the endocardium under moderate hypothermia. The ostia of the left and right pulmonary veins were independently isolated by 2 circumferential lesions connected to one another by a new line along the posterior atrial wall. Two further ablation lines connected the circumference of the left pulmonary veins with the mitral annulus and the left appendage. Once ablation was finished, the cardiac surgery was performed.

A unipolar RF energy source was used in the first 85 patients, whereas microwave energy was used in the last 8 patients. Radiofrequency energy was applied with a ThermaLine® (Boston Scientific Corporation, Natick, MA) surgical probe with a malleable shaft, at a power of 100 W for 120 seconds and a temperature set-point of 85°C (Figure 1). Microwave energy was applied with the Flex 4® (AFx Inc., Fremont, CA) malleable surgical probe at a power of 65 W for 65 seconds for the epicardial lesions and 65 W for 45 seconds for the endocardial lesions.

Pre and Postoperative Protocol and Management

Administration of the patients’ normal antiarrhythmic drugs was not discontinued before the intervention. Intravenous amiodarone treatment was started

during the operation and continued at 1200 mg/day for the first 48 hours, followed by oral doses of 200 mg/day of the same drug for the first 3 months after the operation. Patients in stable sinus rhythm then stopped taking the drug. If amiodarone was contraindicated, sotalolol was administered orally (80 to 160 mg/day). The anticoagulants were discontinued after 3 months in patients with no mechanical heart prosthesis and with effective atrial contraction according to the echocardiographic examination. Atrial contraction was considered effective when an A-wave was present with an A/E ratio of >0.25 (where A corresponds to peak A-wave velocity and E to peak E-wave velocity).

Episodes of postoperative AF/flutter during follow-up were treated with external electrical cardioversion. A maximum of 3 applications per patient were allowed after hospital discharge. If the patient experienced further recurrences, the surgical procedure was considered an ineffective treatment of the arrhythmia and other alternatives were sought.

The preoperative and postoperative echocardiographic examinations measured atrial diameter in millimeters in addition to the normal echocardiographic parameters. The atrial volume was calculated from measurement of the diameters along the 3 perpendicular axes assuming an elliptical shape.¹⁴ The atrial contribution to ventricular filling was assessed by Doppler echocardiography, measuring the peak velocity of

TABLE 2. Primary Cardiac Surgical Procedures*

Mitral valve repair	6	Coronary bypass	3
Mitral valve replacement	33	Mitral valve repair and coronary bypass	1
Mitral valve repair and tricuspid valve surgery	6	Mitral valve replacement and coronary bypass	2
Mitral valve replacement and tricuspid valve surgery	5	Mitral valve replacement, tricuspid valve surgery, coronary bypass	1
Mitral and aortic valve repair	1	Mitral valve replacement, aortic valve repair and coronary bypass	1
Mitral valve replacement and aortic valve repair	3	ASD ostium secundum	2
Mitral and aortic valve replacement	14	ASD ostium primum (AV canal)	2
Mitral, aortic valve repair and tricuspid valve surgery	2	Ascending aorta and aortic valve replacement	1
Mitral aortic valve replacement and tricuspid valve surgery	4		
Aortic replacement	4		
Aortic surgery	1		
Aortic replacement and tricuspid valve surgery	1		

*AV indicates atrioventricular; ASD, atrial septal defect.

atrial contraction (A-wave) in m/s and the A/E ratio. The follow-up electrocardiographic and echocardiographic examinations were performed on hospital discharge, after 3 and 6 months, and then every year. Holter monitoring was only used when the patient reported new episodes of palpitations or symptoms suggestive of chronotropic insufficiency.

The data are expressed as mean ± standard deviation or as frequency (percentage). The corrected χ^2 test was used to analyze the variables related to postoperative recurrence of AF, whereas the Fisher exact test was applied for categorical variables. Ordinal variables were compared using the Student *t* test for normal distributions and the Mann-Whitney test for non-normal distributions. The AF/flutter free survival curve was calculated using the Kaplan-Meier method. The mean duration of follow-up in this study was 292 days (range: 31-1036 days). Eighty-two patients (88.1%) had a follow-up longer than 6 months; mean follow-up for these patients was 332 days (range: 174-1036 days). Statistical significance was set at $P < .05$.

RESULTS

According to our experience, ablation of permanent AF during cardiac surgery has a success rate of 83.8%. Analysis of procedural success by period showed that the incidence of sinus rhythm and arrhythmias was variable. During the postoperative hospital stay, 74.1% of the patients presented some type of supraventricular arrhythmia, 2 patients (2.1%) had sinus node dysfunction, 6 patients (6.4%) had nodal rhythm for more than 7 days, 18 patients (19.3%) had first-degree atrioventricular block, 1 patient had type-1 second-degree atrioventricular block, 4 patients (4.2%) had third-degree atrioventricular block (2 patients with atrioventricular canal defect), 4 patients (4.2%) had paroxys-

mal atrial flutter, 6 patients (6.4%) had chronic AF, 7 patients (7.5%) had paroxysmal episodes of AF, and 37 patients (39.4%) had persistent AF recurrence. One patient had a permanent pacemaker implanted before hospital discharge. With the patients who died during the postoperative period in hospital excluded, 64 patients (72.7%) had recovered sinus rhythm on discharge, 1 patient maintained atrial flutter, and 23 patients (26.1%) had persistent AF.

During the follow-up period following hospital discharge, 6 patients (6.8%) presented sinus node dysfunction. Of these, 3 had received a permanent pacemaker. Six patients (6.8%) had to be re-hospitalized due to recurrence of AF/flutter, 5 because of paroxysmal episodes of AF/flutter and 1 patient because of supraventricular paroxysmal tachycardias. Of the 82 patients who were followed up for more than 6 months, 84.1% recovered sinus rhythm. Currently, 16.1% still have permanent AF/flutter and 83.8% have recovered and maintained sinus rhythm. Figure 2 shows the survival curve for postoperative AF/flutter free survival.

In the univariate statistical analysis, the factors associated with the failure of the antiarrhythmic procedure were duration of the arrhythmia ($P < .02$) and the preoperative LA volumes ($P < .009$). Sex, age, amplitude of the f-wave in the electrocardiogram, type of valve disease and type of energy applied were not related to failure of the technique. Likewise, RA volume did not influence success, which brings into question whether right atrial lesion sets are needed (Table 3).

Three patients (3.2%) had major complications that could, in our opinion, be attributed to the ablation procedure—all of these occurred with RF energy application. One 47-year-old patient with mitral valve replacement suffered cardiogenic shock with severe hypokinesia of the lateral wall in the postoperative

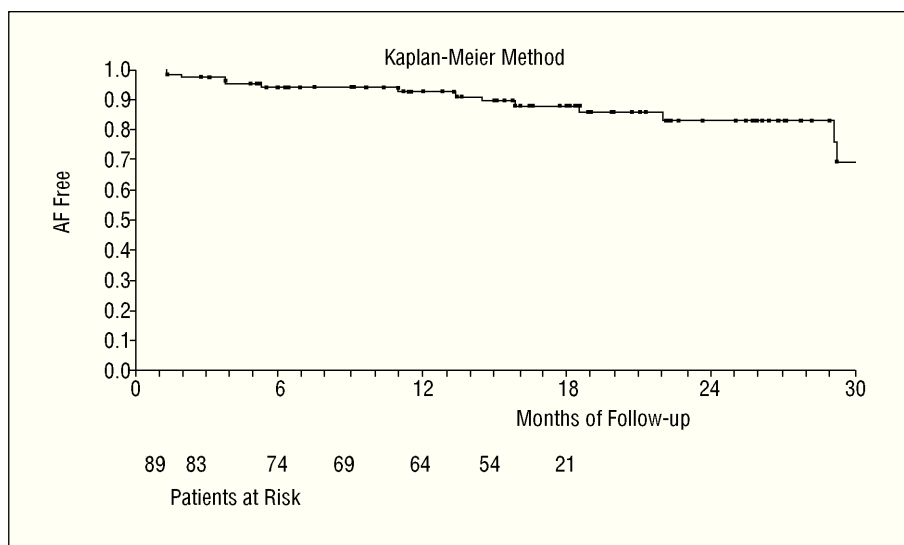


Fig. 2. Survival curve for postoperative recovery of sinus rhythm. AF indicates atrial fibrillation.

TABLE 3. Factors Implicated in Postoperative Recurrence of Permanent Atrial Fibrillation (AF) in Patients With Cardiac Surgery*

	SR Group (n=78)	AF Group (n=15)	P
Age, years	60±9	64±9	NS
f-wave amplitude, mV	0.164±0.255	0.074±0.061	.06
AF duration, years	5.4±4.7	9.0±5.8	.02
Preoperative LA volume, mL	114±70	170±66	.009
Postoperative LA volume, mL	81±28	102±38	.09
Preoperative RA volume, mL	73±45	63±19	NS
Postoperative RA volume, mL	57±29	52±15	NS

*Data are expressed as mean ± standard deviation. RA indicates right atrial; LA, left atrial; SR, sinus rhythm.

echocardiogram on arrival at the intensive care unit. She required immediate balloon counterpulsation and had to undergo further surgery for saphenous vein bypass to the circumflex artery. The cardiogenic shock might have been caused by a coronary vasospasm due to ablation. However, the subsequent coronary angiography allowed us to discard lesions in the coronary tree, including the circumflex artery. A 73-year-old patient with mitral valve replacement and 3 bypass operations died 19 days after the procedure. He was rehospitalized with acute sepsis associated with repetitive episodes of cerebral ischemia, clinically similar to endocarditis but with a normal transesophageal echocardiogram. Computed brain tomography showed multiple gas embolisms that were hard to interpret given their large size. No postmortem examination findings are available, but we think the underlying cause could have been the development of a fistula between the LA and the esophagus, as described by other authors during similar surgery.¹⁵ One 69-year-old patient with mitral valve replacement needed to undergo further surgery 3 months after the initial procedure because of a severe perivalvular leak. We attribute this complication to the use of RF because the echocardiogram was normal 5 days after the procedure and because the leak was located at a point on the RF line that joined the mitral annulus with the left pulmonary veins.

In-hospital mortality was 5.3%—similar to the value expected from predictive models. The causes of death were sudden death on Day 23 after the procedure in a patient with mitral valve replacement, respiratory distress syndrome in a 56-year-old patient with complete atrioventricular channel and severe pulmonary hypertension, and multiorgan failure in 3 patients with prolonged postoperative intubation. The postoperative in-hospital complications varied. One patient presented with a transient cerebral ischemic accident on Day 3 after the procedure, 6 patients required further surgery due to hemorrhage, and 2 patients needed intraaortic balloon counterpulsation

support. The mean stay in hospital was 13.8±8.5 days (range: 6-65 days). Although there was no control group, the hospital stay was often extended several days until stable heart rhythm was obtained or, at times, to perform electrical cardioversion before discharge. Three patients (3.2%) died during follow-up after hospital discharge: one patient with atrioventricular canal defect, probably related to complete transient block noted immediately after the procedure; one with aortic valve replacement because of brain hemorrhage related to treatment with acenocoumarol, and 1 patient was thought to have died of late atrial perforation (atrioesophageal fistula). The overall mortality at the end of the study, after an average follow-up of approximately 10 months, was 8.6%. In principle, we only attribute the death of the patient with atrioesophageal fistula to the surgical technique of AF.

We could not find visual evidence for perforation of the LA during the surgical application of endocardial RF. In contrast, 3 point perforations occurred during epicardial ablation with RF of the RA, attributable to excess energy. In 14% of the applications with multi-electrode RF application, the ablation lines had gaps of healthy tissue—that is, no decoloration associated with white coagulation tissue due to RF application was apparent. Ablation of such areas was repeated. Ablation with RF was often ineffective in areas of fatty tissue or epicardial fibrosis due to reintervention. In all patients, the RA lesions could be made without ECC.

Effective atrial contractile function, as documented by echocardiography, was reestablished in 50% of the patients. Biatrial contraction was observed in 34 of the 64 patients in sinus rhythm at the time of hospital discharge (53.1%) with a mean mitral A-wave velocity of 0.385±0.379 m/s and a mean mitral A/E ratio of 0.482±0.369. Of the 74 patients without AF at the end of follow-up, 37 (50%) had biatrial contraction with a mean mitral A-wave velocity of 0.580±0.501 m/s and a mitral A/E ratio of 0.466±0.543; 20 (27%) had RA contraction only with a tricuspid A-wave velocity of 0.576±0.596 m/s and a tricuspid A/E ratio of 0.588±0.453; and 17 patients (22.9%) lacked contraction in either atrium. All patients with LA contraction also maintained RA contraction. Although the echocardiographic assessment of systolic atrial contraction is subject to the variability of ventricular preload and afterload, only a slight improvement in the mitral and tricuspid A/E ratio was observed—the differences were not statistically significant.

DISCUSSION

The aim of this study is to report our experience and findings in intraoperative ablation of permanent AF in patients undergoing heart surgery. Using a biatrial lesion set, the permanent AF was treated very effective-

ly—83.8% of the patients recovered sinus rhythm. Mortality during surgery in this group of patients was similar to that expected with predictive surgical models and corresponded to that of the heart disease itself. Therefore, we consider intraoperative ablation as an associated procedure that does not increase in-hospital mortality. Nevertheless, major complications are associated with the ablation procedure—a rate of around 3%—which represents an important degree of surgical morbidity. This forces us to reconsider our protocols and the types of energy source. The complications reported in our study were similar to those described by other groups.^{15,16} It is difficult to predict which patients are at a higher risk due to ablation during cardiac surgery because of the anatomical variability of patients, both in atrial wall thicknesses and in the conductive properties of the tissue.

The intraoperative ablation systems currently available have been shown to be easily applied and have a high therapeutic effectiveness, but this effectiveness is lower than that obtained from classic maze procedures based on cutting and suturing atrial tissue.^{2-6,15,17-21} In recent editorials, Dr. James L. Cox,²² one of the pioneers of AF surgery, warned of these poorer outcomes and attributes them to the lesions not being fully transmural. He suggests that cryoablation should be the preferred intraoperative energy source because it ensures a high degree of transmural and does not damage neighboring structures. At present, no comparative studies of different energy sources are available for ablation during cardiac surgery, though according to the experience of several surgery groups^{23,24} and our own experience, RF ablation does not usually cause macroscopic lesions in fatty regions or with epicardial fibrosis. Santiago et al²⁵ have described a lower RF transmural in atria of patients with mitral valve disease compared with healthy tissue. The authors attributed this to structural and conductive differences of the atrial wall itself.

The incidence of AF/flutter immediately after the operation was 45.8%—similar to the incidence described in the literature.^{4,15,26} The patients experienced a phase of postoperative electrical instability in the first 3 months after the operation before settling on the final rhythm resulting from the ablation procedure.^{3,4,21} After the first 3 months, around 80% of the patients recovered sinus rhythm.^{3,4,15,18,27} Different factors seem to be implicated in the etiopathogenic mechanisms of postoperative recurrence of AF, for example, failure to produce transmural lesions or discontinuous ablation lines,^{24,26} inflammatory processes of surgical trauma (atriotomies, postischemic tissue edema, pericarditis, etc) or greater postoperative adrenergic tone. Given that the incidence of postoperative AF in isolated myocardial revascularization is between 25% and 40%,^{28,29} it was difficult to determine the percentage of our patients with recurrence

of postoperative AF/flutter due to primary failure of the ablation technique. Currently, a percutaneous postoperative procedure can be considered to close possible gaps in the surgical ablation lines, as described by several authors in patients in whom the surgical ablation procedure is ineffective after the first 3 months.³⁰

Contraction of both atria was effectively recovered (A/E ratio >0.25) in 50% of the patients with sinus rhythm in this study. Ablation lines have a harmful effect on atrial contraction.^{3,31} Melo et al³ report a 42% recovery of right atrial contractility and a 30% recovery of left atrial contractility in 25 patients with mitral surgery and left atrial maze intervention with RF after 6 months of follow-up. Other studies have published better results, with an echocardiographic recovery of 65%² and 100%,³² although with less strict criteria for effective contraction.

This study has several limitations, mainly derived from the nonstandard sample selection, composed of patients with heart disease requiring surgery and permanent AF. The study included patients with different types of heart disease, although most had mitral valve disease. We did not carry out histologic studies with which to compare macroscopic surgical observations or a postoperative electrophysiological study to demonstrate the effectiveness of the procedure. The assessment of the effectiveness of the procedure is essentially clinical—the Holter study was only carried out in patients with symptoms. The antiarrhythmic treatment during the first months is another important limitation of the findings of this study, particularly because of the short period of follow-up in a type of surgery that requires long-term study.

Our initial experience with surgical ablation of permanent AF to electrically isolate the 2 atria showed an effectiveness of 83.8% without increasing the risk of the primary surgical procedure. The ablation procedure accounted for 3.2% of the major complications. Right atrial epicardial ablation can be performed in all patients without ECC. Although only 26.8% of the patients had recurrence of AF after hospital discharge, postoperative arrhythmias—occurring in 74.1% of the patients—were a major problem. This surgery does not offer immediate results and requires close patient monitoring during the first months, though most patients do eventually attain sinus rhythm.

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