Surgical Ablation of Atrial Fibrillation Using the Epicardial Radiofrequency Approach: Mid-Term Results and Risk Analysis

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Background. The minor technical and time requirements with respect to the maze operation combined with a comparable efficacy has led to an increasing popularity of left atrial approaches to treat atrial fibrillation. We report our experience with a left atrial procedure based on extensive use of epicardial radiofrequency ablation in an effort to minimize cardiac arrest time.

Methods. A total of 132 consecutive patients with atrial fibrillation (121 chronic, 11 paroxysmal) undergoing open heart surgery had combined intraoperative ablation. An original set of left atrial lesions was performed using a radiofrequency linear catheter. Most of the ablations were performed epicardially before aortic cross-clamping. Patients with contraindications to the epicardial approach had the whole lesion set performed endocardially.

Results. The mean cardiac arrest time spent for open heart ablations was significantly shorter (5.2 ± 0.9 minutes with modern catheters) when the epicardial approach was used (107 of 132 patients, 81%). Hospital mortality was 0.8%. Freedom from atrial fibrillation was 77% 3 years after the operation. Of all the variables analyzed, only age at surgery and early postoperative arrhythmias increased the risk of recurrent atrial fibrillation. Overall 3-year survival was 94%. The 3-year actuarial freedom from stroke was 98%. No patient required implantation of a permanent pacemaker. Atrial contractility was recovered in all patients with stable sinus rhythm.

Conclusions. Left atrial radiofrequency ablation allows recovery of sinus rhythm and atrial function in the great majority of patients with atrial fibrillation who undergo open heart surgery. The epicardial radiofrequency approach is a safe and effective means to cure atrial fibrillation with negligible technical and time requirements.

To date, the results of the maze operation [1] remain unequaled by any other surgical approach to treat atrial fibrillation (AF).

The most common situation in which the cardiac surgeon has to deal with AF ablation is when the arrhythmia is combined with organic heart disease requiring surgery. In this context, the maze operation significantly increases operative morbidity because of the additional atrial incisions required, which consistently prolong the aortic cross-clamp time [2].

Clinical investigation has recently focused on two aspects. First, surgical approaches limited to the left atrium, such as left atrial isolation [3] and the maze-like approach of Sueda and colleagues [4, 5], proved to cure AF in about 75% of the patients. Second, surgical use of alternative physical means to achieve atrial scars instead of cutting and suturing has led to a reduction of operation time and bleeding. After the initial report by Melo and colleagues [6] in 1997, we and others [7–10] have described the effectiveness of intraoperative radiofrequency ablation.

Starting from 1998, our group concentrated on the epicardial use of linear RF catheters on the beating heart to further reduce the aortic cross-clamping time required for the ablating procedure and to minimize endocardial trauma. The RF ablation lines were performed according to a simple original lesion set limited to the left atrium, involving a separate encircling of left and right pulmonary veins [7, 11].

Below we report our midterm results on AF cure and atrial function recovery, analyzing the influence of clinical and technical variables on the outcome.

Material and Methods

Patient Population

Starting in February 1998, patients with AF undergoing elective open heart surgery were also given combined...
intraoperative left atrial RF ablation. Indications for the concomitant treatment of the arrhythmia were chronic AF lasting at least 6 months and paroxysmal AF with documented weekly episodes despite use of antiarrhythmic medications.

From February 1998 to September 2001, a total of 132 patients were enrolled. Of these, 121 patients (91.7%) had chronic AF lasting from 6 to 480 months (mean 41.8 ± 66.7 months, median 12 months). Eleven patients (8.3%) had paroxysmal AF refractory to medications (number of drugs, 3 ± 1).

Of the 132 patients, 129 (97.7%) were affected by mitral valve disease, with a concomitant organic heart disease present in 37 of 132 cases (28%). Fifteen patients (11.4%) had had a previous heart operation.

Preoperative data are summarized in Table 1. Informed written consent was obtained from each patient.

**Table 1. Preoperative Data**

<table>
<thead>
<tr>
<th>Patients</th>
<th>132</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female</td>
<td>64/68</td>
</tr>
<tr>
<td>Age at surgery, (y)</td>
<td>58.5 ± 10.5</td>
</tr>
<tr>
<td>NYHA I (patients)</td>
<td>7 (5.3%)</td>
</tr>
<tr>
<td>NYHA II (patients)</td>
<td>72 (54.5%)</td>
</tr>
<tr>
<td>NYHA III (patients)</td>
<td>53 (40.2%)</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>59 ± 5.9</td>
</tr>
<tr>
<td>LA diameter (mm)</td>
<td>57.2 ± 11.7</td>
</tr>
<tr>
<td>Paroxysmal AF (patients)</td>
<td>11 (8.3%)</td>
</tr>
<tr>
<td>Chronic AF (patients)</td>
<td>121 (91.7%)</td>
</tr>
<tr>
<td>Duration of chronic AF (months)</td>
<td>41.8 ± 66.7</td>
</tr>
<tr>
<td>Permanent pacemaker (patients)</td>
<td>3 (2.3%)</td>
</tr>
</tbody>
</table>

**Underlying heart disease**

- Mitral rheumatic: 71 (53.8%)
- Mitral degenerative: 58 (43.9%)
- Aortic valve disease: 7 (5.3%)
- Tricuspid regurgitation: 31 (23.5%)
- Coronary artery disease: 1 (0.8%)
- HOCM: 1 (0.8%)
- Atrial septal defect: 1 (0.8%)
- Aneurism of ascending aorta: 1 (0.8%)
- Prior heart surgery: 15 (11.4%)

**AF** = atrial fibrillation; **HOCM** = hypertrophic obstructive cardiomyopathy; **NYHA** = New York Heart Association functional class.

Preoperative Management

Baseline 12-lead electrocardiogram, chest roentgenography, and transthoracic echocardiography were performed on admission. All patients underwent transesophageal echocardiography the day before surgery or in the operating room after the induction of anesthesia to exclude the presence of a left atrial thrombus.

No antiarrhythmic prophylaxis was administered before surgery. Oral anticoagulation was stopped and a continuous drip of heparin was administered until 6 hours before surgery, to decrease the risk of intracavitary thrombus formation.

Operative Technique

Three different linear RF catheters were used during the study period, reflecting the advances of engineering research in the field.

From February 1998 to September 1998, before any commercial surgical RF catheter became available, a cooled-tip (C-T) multiple electrode (four to six ablating tips) custom-made RF catheter was used. Only one tip at a time could be activated (1 minute each tip, about 1 cm/min). Because the tool was devised to work in a liquid medium, during ablations the pericardial cavity was filled with 37°C normal saline. A power of 45 W for both epicardial and endocardial lesions was used.

In October 1998 we started using temperature-controlled (T-C) catheters. The first generation tool (T-C1) was malleable with 7 electrodes on the distal end (ThermaLine, Boston Scientific, Natick, MA). The system allowed RF current to be delivered for up to 2 minutes. All 7 electrodes could be activated simultaneously, thus yielding 12-cm-long lesions in 2 minutes. Each electrode had two thermocouples providing feedback on the tissue–catheter contact temperature. The RF current was delivered for 2 minutes to keep this temperature at a constant preset value of 75° to 85°C for epicardial ablations and 65° to 75°C for endocardial ablations.

From December 2000 onward, a second-generation temperature-controlled (T-C2) catheter was used (Cobra, Boston Scientific). This closely resembled the former version, but the generator allowed ablation time to exceed 2 minutes. The settings that we adopted were 3 minutes at 80° to 85°C for epicardial ablations and 2 to 2.5 minutes at 70° to 75°C for endocardial ablations.

The ablation technique has been previously described in detail [7]. The lesion set is shown in Figure 1A. Through a median sternotomy, after heparin administration, the interatrial groove was dissected free of fat tissue with diathermy. A posterior hemiencircling ablation around the orifices of the right pulmonary veins was performed epicardially off pump. After institution of cardiopulmonary bypass, the operating table was tilted...
15 degrees to the right side and the heart was gently lifted toward the surgeon by the second assistant’s right hand or through pericardial traction stitches (such as the Lima stitch) to expose the left pulmonary veins. The Marshall fold was divided with diathermy and an encircling lesion was performed around the orifices of the left pulmonary veins. The left encircling line was then connected with the base of the left appendage through another epicardial ablation. After aortic cross-clamping, the heart was arrested with antegrade and retrograde cold blood cardioplegia. The isolation of the right pulmonary veins was completed by a standard left atriotomy. Two linear ablations were performed endocardially. The first connected the two encirclings on the posterosuperior atrial wall. This lesion was kept cranial, opposite the transverse sinus, to prevent any possible damage to the esophagus. The last ablation connected the left appendage to the posterior aspect of the mitral annulus. To protect the circumflex artery from heat trauma, two precautions were taken during the last ablation: (1) low flow retrograde cardioplegia was administered while ablating; and (2) the lesion line reached the mitral posterior annulus far from the antero-lateral commissure.

The auricle was then excluded through a double layer running 4-0 polypropylene suture. The mitral valve procedure was completed and the left atriotomy was sutured in the standard fashion.

In our early experience (February to June 1998), a slightly modified lesion set (Fig 1B) was used in a few cases [7] in which the left appendage was preserved, before deciding its routine obliteration.

In patients with contraindication to epicardial ablation, the whole ablation procedure was performed endocardially after cross-clamping, following the same lesion set.

**Postoperative Management and Follow-Up**

Heparin continuous drip was started after the resolution of postoperative bleeding and continued until therapeutic values of prothrombin time were reached with oral anticoagulant medications.

Antiarrhythmic prophylaxis was carried out on a routine basis. Amiodarone (intravenous bolus of 300 mg, followed by a continuous infusion of 1,200 mg/24 h until postoperative day 1; and oral administration of 200 mg every 8 hours until discharge, followed by a maintenance regimen of 200 mg/d) was administered to 119 of 132 (90.2%) patients. Of the 13 patients with contraindications to amiodarone: 8 (6.1%) were administered propafenone and 1 (0.8%) sotalol, whereas 4 (3%) did not receive any antiarrhythmic medication. After discharge, such medications were continued for at least 6 months and were than tapered off in the presence of a stable sinus rhythm (SR).

Standard 12-lead echocardiography, Holter, and transthoracic ECG monitoring were performed 1, 3, 6, and 12 months after operation and then on a yearly basis.

Transmitral and tricuspid flow velocities were measured with pulsed Doppler echocardiography: a sample volume was positioned at the level of the tip of the atrio-ventricular valve in the apical four-chamber view. Peak velocities of the early (E wave) and of the late filling wave (A wave) were determined as the average of three consecutive beats. A peak A wave velocity of 10 cm/s was arbitrarily considered as the cut-off for an effective atrial contraction [12].

Recurrences of the arrhythmia after surgery were treated by optimizing the medical treatment. Patients who had AF despite optimal medical therapy had at least one attempt at external DC-shock cardioversion.

Successful treatment of the arrhythmia was defined as the absence of refractory AF in patients with chronic AF before operation and absence of any episode of sustained arrhythmia in patients with paroxysmal AF preoperatively.

Six months after surgery, oral anticoagulants were discontinued in patients with stable SR and with documented atrial contraction after mitral valve repair or replacement with a biological prosthesis.

**Statistical Analysis**

Values are expressed as mean ± standard deviation unless stated otherwise. Comparisons between the groups of patients ablated with the three different catheters were performed using analysis of variance and t test for unpaired data, as appropriate. Distribution of survival times was estimated with the Kaplan-Meyer method. Event-free proportions and 95% confidence interval (CI) are reported.

The following variables were analyzed for possible association with AF recurrence at follow-up: (a) preoperative variables: age, sex, left atrial diameter, type (chronic vs paroxysmal) and duration of AF, ejection fraction, New York Heart Association functional class, type of mitral disease (degenerative vs rheumatic), presence and type of associated organic disease, and prior heart surgery; (b) operative variables: type of surgical procedure involving reconstructive versus replacement valve surgery, duration of cardiopulmonary bypass and cardiac arrest, type of RF catheter used (C-T, T-C1, or T-C2), auricular exclusion (involving the described modification of the lesion set [Fig 1B]), and use of the epicardial approach versus complete endocardial ablation; and (c) postoperative variables: type of antiarrhythmic prophylaxis, occurrence of early (predischarge) postoperative arrhythmias, and length of intensive care unit and hospital stay.

Comparisons among survival curves were made by means of the log-rank test for categorical variables. The risk of AF recurrence for the continuous variables was investigated by means of Cox proportional-hazards regression model. Hazard ratio and 95% CI are reported. Multivariate proportional-hazards regression models were used to evaluate the association between the risk of AF recurrence and other variables that resulted at univariate analysis in p values of less than 0.1. All p values are two tailed.
Results

Operative Results, Morbidity, and Mortality

Open heart procedures performed are summarized in Table 2.

We used the C-T custom-made catheter to ablate the first 23 (17.4%) patients. All other patients were treated with temperature-controlled devices: 71 patients (53.8%) with the T-C 1 catheter and 38 (28.8%) with the T-C 2.

A total of 25 patients (18.9%) with contraindications to the epicardial approach had all ablations performed endocardially: 17 patients because of epicardial thickening and adhesions reflecting a past flogistic event (due to prior surgery in 15 cases), rendering exposure of the pulmonary veins more dangerous and transmurality more difficult from the epicardial side; 5 patients with evidence of a thrombus in the left appendage, due to the risk of thromboembolism during manipulation of the heart; and 3 patients with a permanent pacemaker, so as not to dislodge the ventricular wires or to damage the heart when lifting it to expose the left pulmonary veins. Of 132 patients, 107 (81.1%) had a standard epicardial approach. In 13 patients (9.8%) the left appendage was preserved (Fig 1B).

Mean aortic cross-clamp time was 73 minutes, with 9.2 minutes required for endocardial ablations. Mean cardiopulmonary bypass time was 111 minutes. Both aortic cross-clamp time and time spent for endocardial ablations were significantly shorter in patients operated on with the epicardial approach compared with those ablated only endocardially (Table 3). Cardiac arrest time due to ablations was also significantly shorter in patients treated with modern catheters (T-C1 and T-C2). Performing a standard epicardial approach with modern linear RF catheters limited the ablation related open heart time to 5.2 minutes.

No procedure-related complications were recorded. Mean total bleeding was 358 mL. Only three patients (2.3%) required reexploration for bleeding. One patient (0.8%) had a deep sternal wound infection requiring sternectomy and rectus muscle flap reconstruction. Mean duration of intensive care unit stay was 1.8 days. Patients were discharged 6.6 days after the operation.

One 76-year-old woman who had previously experienced a stroke died on postoperative day 12 (hospital mortality, 0.8%) due to bilateral pneumonia causing prolonged ventilatory support and septicemia after mi-

Table 2. Concomitant Surgical Procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Patients, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral repair</td>
<td>58 (44%)</td>
</tr>
<tr>
<td>Annuloplasty</td>
<td>7 (5.3%)</td>
</tr>
<tr>
<td>Edge to edge</td>
<td>35 (26.5%)</td>
</tr>
<tr>
<td>Quadrangular resection</td>
<td>14 (10.6%)</td>
</tr>
<tr>
<td>Anterior leaflet extension</td>
<td>2 (1.5%)</td>
</tr>
<tr>
<td>Mitral commissurotomy</td>
<td>14 (10.6%)</td>
</tr>
<tr>
<td>Mitral replacement</td>
<td>56 (42.4%)</td>
</tr>
<tr>
<td>Biological</td>
<td>11 (8.3%)</td>
</tr>
<tr>
<td>Mechanical</td>
<td>45 (34.1%)</td>
</tr>
<tr>
<td>Repair of mitral prosthetic leak</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>Tricuspid annuloplasty</td>
<td>31 (23.5%)</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>7 (5.3%)</td>
</tr>
<tr>
<td>Myectomy-mytomy</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>ASD repair</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>CABG</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>Replacement of ascending aorta</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td>Two or more procedures</td>
<td>37 (28%)</td>
</tr>
</tbody>
</table>

Total number of patients undergoing procedures was 132.

ASD = atrial septal defect; CABG = coronary artery bypass grafting.

Table 3. Time Requirements With Different Ablation Approaches and Different Types of Radiofrequency Catheter

<table>
<thead>
<tr>
<th>Time Required</th>
<th>With Epicardial Approach (107 patients)</th>
<th>Only Endocardial Ablation (25 patients)</th>
<th>p Value (t test)</th>
<th>Type of Catheter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ablation time during ACC (min)</td>
<td>6.6 ± 3.4</td>
<td>17.7 ± 4.4</td>
<td>&lt;0.0001</td>
<td>C-T (23 patients)</td>
</tr>
<tr>
<td>ACC time (min)</td>
<td>71 ± 17</td>
<td>82 ± 19</td>
<td>0.009</td>
<td>T-C1 (71 patients)</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>111 ± 25</td>
<td>108 ± 22</td>
<td>NS</td>
<td>T-C2 (38 patients)</td>
</tr>
</tbody>
</table>

| Type of Catheter | | Type of Catheter |
|------------------|------------------|
| C-T (23 patients) | 14.2 ± 5.7 | 7.4 ± 4.6* | 7.7 ± 5.1* | <0.001 |
| T-C1 (71 patients) | 79 ± 20 | 71 ± 17 | 72 ± 16 | 0.16 |
| T-C2 (38 patients) | 127 ± 23 | 108 ± 22* | 104 ± 19* | <0.001 |

* t Test: p = 0.001 vs C-T.

ACC = aortic cross-clamping; CPB = cardiopulmonary bypass; C-T = cooled-tip catheter; T-C1 = first-generation temperature-control catheter; T-C2 = second-generation temperature-control catheter.
Extracardial valve replacement with a biological prosthesis. Two other patients, who both had undergone mitral valve replacement with a mechanical prosthesis, died after discharge on postoperative days 17 and 22. The causes were, respectively, cardiac arrest possibly related to myocardial infarction and stroke related to inadequate anticoagulation.

During follow-up (mean 16.9 ± 14.2, median 13 months), 3 more patients died: 1 patient from sudden death, 1 due to stroke (in a patient with refractory AF), and 1 from mediastinal lymphoma. Overall 3-year survival was 94% (95% CI 88% to 99%; Fig 2). The 3-year actuarial freedom from stroke was 98% (95% CI 96% to 100%).

Heart Rhythm
A total of 127 patients (96.2%) recovered SR after surgery. In-hospital arrhythmias such as AF, atrial flutter, and atrial tachycardias occurred in 65 patients (49.2%).

Three months after surgery, heart rhythm had stabilized. Freedom from atrial fibrillation was 79% (95% CI 72% to 86%) at 1 year and 77% (95% CI 69% to 85%) at 3 years after surgery (Fig 3).

No patient in this series required implantation of a permanent pacemaker at any time after surgery.

Of all variables considered, only age, preoperative AF duration, and in-hospital postoperative arrhythmias resulted in univariate analysis in a p value of less than 0.1.

Age was significantly associated with AF recurrence when investigated with the Cox proportional hazard regression model (hazard ratio for age, 1.09; 95% CI 1.01 to 1.15; p < 0.001). One-year increases in duration of chronic AF before surgery added to the risk of AF recurrence, although without reaching statistical significance (hazard ratio 1.04; 95% CI 0.998 to 1.08; p = 0.06). One-year freedom from AF recurrence was significantly lower in patients experiencing in-hospital postoperative arrhythmias: 67% (95% CI 55% to 79%) versus 90% (95% CI 82% to 98%; log rank test p = 0.001).

When these variables were tested in a multivariate proportional-hazards regression model, only age and early postoperative arrhythmias were independently associated with AF recurrence (Table 4).

Ten patients (7.6%) experienced typical counterclockwise atrial flutter on average at 9 ± 6.3 months after surgery. No preoperative factor, including presence of tricuspid disease, was significantly related to postoperative flutter. All patients with flutter underwent electrophysiologic study and were successfully cured with RF ablation of the cavo-tricuspid isthmus.

During follow-up, 2 patients underwent transseptal left atrial mapping. The first patient, a 67-year-old woman, developed a highly symptomatic 2:1 paroxysmal atrial tachycardia refractory to medical treatment after mitral valve replacement with a mechanical prosthesis and was studied 29 months after surgery. The second patient, a 58-year-old man, developed refractory persistent AF 9 months after mitral commissurotomy and aortic valve replacement. Because of the strong resolve of the patient (who was so disturbed by the arrhythmia that he was contemplating suicide), we scheduled him for electrophysiologic assessment 3 years after the operation. Trans-septal left atrial mapping was performed with a three-dimensional electroanatomical system (Carto, Biosense-Webster, Diamond Bar, CA). Both studies showed an optimal isolation of the area around the right pulmonary veins. In contrast, the voltage map showed some spots of normal or near normal activation within the left pulmonary veins. In contrast, the voltage map showed some spots of normal or near normal activation within the left pulmonary veins.

Table 4. Multivariate Cox Proportional Hazard Model of Predicators of AF Recurrence

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hazard Ratio (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery (1-y increase)</td>
<td>1.07 (1.02–1.12)</td>
<td>0.004</td>
</tr>
<tr>
<td>Preoperative AF duration (1-y increase)</td>
<td>1.04 (0.98–1.07)</td>
<td>0.23</td>
</tr>
<tr>
<td>Early postoperative arrhythmias (yes or no)</td>
<td>2.48 (1.20–5.12)</td>
<td>0.015</td>
</tr>
</tbody>
</table>

AF = atrial fibrillation; CI = confidence interval.
Comment

In 1998 we developed a simple surgical technique to treat AF during open heart surgery by means of RF ablation [7, 11]. The lesion set is performed mainly epicardially, before aortic cross-clamping, and only the left atrium is addressed. In the reported series, the actuarial freedom from AF 3 years after surgery was 77%. Older age and the occurrence of arrhythmias before discharge were independent predictors of failure.

When AF is not treated during surgery, the rate of spontaneous SR recovery is in the range of 15% to 20% [14, 15]. Even with an extensive use of antiarrhythmic medications and aggressive electrical cardioversion, the reported rates of late SR maintenance remain below 25% [16, 17].

Interestingly, other surgeons with wide experience with ablation approaches limited to the left atrium report late results very similar to ours. Viganò and colleagues [3] report a 77% rate of SR recovery late after mitral valve surgery with left atrial isolation. Sueda and colleagues [4, 5] report a 74.5% freedom from AF 3 years after mitral surgery combined with the “simple left atrial procedure,” involving isolation of the posterior wall of the left atrium and cryoablation lines towards the mitral annulus.

In the past decade, the maze operation proved to be the most effective treatment option for AF [1]. Also, when combined with other open heart procedures, the maze operation allows SR recovery in a great proportion of patients. Kim and colleagues [18] report, in this context, a success rate of about 90%. Yuda and coworkers report a 70% freedom from AF at late follow-up after mitral valve surgery combined with a modified maze procedure [19].

However, despite its effectiveness, most surgeons do not commonly perform the maze procedure neither as a stand-alone operation nor in patients undergoing other cardiac procedures. This reluctance is mainly due to the pulmonary veins and to eliminate the possibility of reentry circuits within the left atrium [7, 11].

Extensive use of epicardial ablation is particularly convenient, as it limits the additional cardiac arrest time required for open heart ablations with modern tools to about 5 minutes. Epicardial ablation did not lead to a worse success rate in our experience, but it shortened significantly overall cross-clamp time. In addition, epicardial ablations can further limit the extent of endocardial trauma due to heating, which can potentially lead to thromboembolism.

In this series, only 2 patients experienced stroke, for an actuarial freedom of 98%, 3 years after surgery. In 1 of these patients, stroke was clearly related to inadequate anticoagulation. Other clinical variables such as hospital mortality, bleeding and other major complications, intensive care unit and hospital length of stay, and survival demonstrate the absence of any relevant impact of the combined RF procedure on normal postoperative recovery from open heart surgery.

Postoperative Rhythm

Similarly to what is reported by others, about one-half of our patients had some form of supraventricular arrhythmia before discharge. This, of course, turned out to be a predictor of late failure of the ablation procedure. However, given that about two-thirds of the patients experiencing arrhythmias are likely to recover stable SR, these patients must receive close clinical follow-up.

Most of the recurrences of AF were observed within 3 months from surgery. Heart rhythm then stabilized, allowing a safe withdrawal of anticoagulant medications in patients without mechanical valve prostheses.

No patients required a permanent pacemaker after surgery. This, in our opinion, is due to the absence of any right atrial procedure. The need for atrial or atrioventricular permanent pacing varies from 3.2% to 25% [1, 22] in patients operated on with the maze procedure.

Postoperative atrial flutter was easily managed in all patients by our interventional cardiologists through percutaneous isthmus ablation.

Interestingly, 2 cases of postoperative arrhythmias originating from the left atrium were mapped and treated percutaneously. In one of the patients, relapsing permanent AF was effectively treated by closure of a gap within the left encircling lesion. Growing experience with percutaneous circumferential ablation of the pulmonary veins [13] opens the way to a more comprehensive approach to secondary AF that can probably lead to an improvement of late success rates of the surgical ablation.

Atrial Contractility

In our experience, recovery of right and left atrial contractility occurred in all patients with stable SR after surgery. These data are in contrast to the rate of atrial contraction restoration reported by others after the maze procedure, ranging from 63% to 90% [2, 23, 24]. In our opinion, this discrepancy is due to the myocardium-preserving nature of the lesion set that we adopted. Only a narrow strip of left atrial myocardium around each pair of pulmonary veins is electrically excluded by the ablation procedure. We speculate that late restoration of a significant [12] left atrial contraction can potentially be obtained in virtually all patients regaining SR after AF.
surgery. Should our results be confirmed by further evidence, this would mean that minimization of myocardial exclusion and scarring due to the surgical technique itself plays a major role in favoring atrial function recovery.

Technical Aspects
Because of the design of the lesion set, some precautions should be taken not to damage the circumflex artery and the esophagus. In most of the cases, performing the mitral lesion far from the anterolateral commissure can prevent the risk of ablating on an important coronary branch sited in the AV groove. By cooling the lumen through continuous low-flow retrograde cardioplegia, the risk of coronary heat trauma is further reduced. As previously mentioned, the connecting line between the encirclements should be performed on the posteroseverior aspect of the left atrium, facing the transverse sinus [7]. Ablating in a lower site would lead the lesion line to cross the esophagus anteriorly, raising the risk of esophageal trauma.

To further improve the effectiveness of epicardial ablation, normothermic total cardiopulmonary bypass can probably enhance the depth of RF lesions by reducing the convective cooling of blood flow within the atrial chamber. Finally, besides helping to expose the left pulmonary veins, interruption of the Marshall ligament can play a role in modulating sympathetic innervation of the atria. There is, in fact, growing evidence of a potential role of this structure in the pathogenesis of atrial tachyarrhythmias [25].

In conclusion, a simple left atrial lesion set performed with RF allows durable recovery of SR and atrial function in the great majority of patients with AF having concurrent open heart surgery. The epicardial RF approach is a safe and effective means to treat AF, with minimal technical and time requirements. Such a treatment option is therefore particularly suitable for patients with AF who are scheduled to undergo any type of cardiac operation.

References

DISCUSSION

DR THEODORE C. KOUTLAS (Greenville, SC): In your study you compared your results to people with an endocardial approach in your limited group of patients who did not qualify for an epicardial approach in your study. Have you compared results to a larger group that you have performed ablation endocardially?

DR BENUSSI: No, we did not, since only a minority of patients were ablated endocardially. In fact, we chose from the very beginning to follow a procedure that could allow us to keep aortic cross-clamp time the shortest possible.

DR KOUTLAS: Do you see any other advantages other than a shorter cross-clamp time doing it with this approach?

DR BENUSSI: Yes. Another potential advantage that possibly reflects in the low rate of stroke is that, of course, doing most of the lesions epicardially decreases the likelihood of endocardial heat trauma and therefore the risk of radiofrequency-related thromboembolism.

DR KEVIN ACCOLA (Orlando, FL): I enjoyed your paper and presentation of your experience with epicardial radiofrequency ablation. My question: Did you evaluate left atrial size or consider the massive left atriums that we sometimes see in these patients and correlate them with your success rate? Did the atrial size influence your failures as well as the recurrence of the atrial fibrillation? In the larger left atriums, did you also see increased requirements for postoperative cardioversion upon discharge? In our experience, we have found that larger left atriums are resistant to maintenance of a sinus rhythm postoperatively. These patients seem to require more frequent cardioversions than patients with a moderately enlarged left atrium.

DR BENUSSI: We did include the left atrial diameter in both the univariate and the multivariate analysis, but it turned out to have no impact at all on the outcome of the procedure; and I can tell you that the mean preoperative left atrial diameter in patients with relapsing atrial fibrillation and in those with stable sinus rhythm after surgery, was exactly the same, 5.7 cm.

DR ROBERT J. BREWER (Detroit, MI): I enjoyed that as well, and we are very interested in some of this sort of work. With the epicardial approach did you have any issues with epicardial fat causing problems with the ablation, and did you have to do any further dissection to do that? And do you think this would be applicable? It is an interesting approach to apply to patients, and have you applied it to patients for whom you are doing coronary bypass who are in chronic atrial fibrillation for example?

DR BENUSSI: Yes, that is a good point. The epicardial fat has to be absolutely removed, because it strongly impedes the transmission of radiofrequency to the myocardium. In particular, a wide dissection is always needed before ablat ing in the Waterston groove. But also on the left side there are some instances in which the epicardium is particularly thick, and this requires some dissection of the epicardial fat before ablating. Another technical point is that to favor a swift positioning of the catheter around the left pulmonary veins, most of the times we find useful to interrupt the ligament of Marshall. In our recent experience, however, we have been interrupting the ligament of Marshall in all patients, since it has been hypothesized to play a role in the genesis of some forms of atrial fibrillation due to its high content of adrenergic nerves.