Surgery for atrial fibrillation with radiofrequency ablation: four years experience

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Abstract

Objective: Atrial fibrillation (AF) is very common in patients undergoing open heart surgery. AF ablation with different sources of energy, enables the surgeon to create linear lesions rapidly and safely. However, results of these technologies need examination. We report the clinical results obtained in a 4-year experience using mono- and bipolar radiofrequency (RF) ablation of AF in a heterogeneous group of 183 patients. Methods: From May 2001 until December 2005 a total of 183 patients underwent pulmonary vein isolation using RF energy. In 73 cases, monopolar RF was used. Energy was applied in the endocardium in 40 cases and in the epicardium in 33 cases (Group B). From May 2003, bipolar RF was used in a total of 110 patients (Group C). Duration of AF, left atrial dimensions, age or reoperations, were not considered contraindications to ablation. Ablation procedure for AF ablation was associated with a variety of cardiac procedures, from isolated mitral valve procedure to complex ascending aorta operations. Results: In-hospital mortality was 3.8% in the whole group (range 2.7–6.1%). Mortality and morbidity were not related with the ablation procedure. At the follow-up time of 50.9 ± 3.3, 48.2 ± 3.1, 32.7 ± 0.9 months (Group A, B and C, respectively), sinus rhythm (SR) is present in a percentage of 75%, 67.7%, 79.4% of patients. Higher incidence of AF recurrence occurred in the first six months after surgery in all three groups. Late recurrence was higher in the epicardial group and overall freedom of AF was 64% in Group A, 46% in Group B and 71.1% in Group C (P = 0.01). Conclusions: Our results demonstrate that the epicardial monopolar RF ablation obtains worse results than the endocardial monopolar RF and the bipolar RF ablation. Bipolar RF theoretically grants transmurality and is easy and safe, and a complete ablation setting lines can be achieved. Bipolar RF enables extension of ablation to every patient on AF undergoing a cardiac operation.

Keywords: Atrial fibrillation; Radiofrequency ablation; Arrhythmia

1. Introduction

The Cox-Maze procedure is the most successful surgical treatment for atrial fibrillation (AF), eliminating the arrhythmia in more than 90% of patients [1,2]. This operation has not become popular due to its complexity and invasiveness.

In recent years, it has been of increasing interest trying to simplify this procedure, using new and different energy sources to create ablation lines. In the late 1990s, unipolar radiofrequency (RF) was introduced, obtaining rate of sinus rhythm (SR) restoration, ranging from 69% to 76.9% [3–5]. Many other authors have reported similar results using monopolar RF [6–8].

Unipolar RF applications have some limitations, such as high tissue temperature, resulting in neighboring mediastinal structure damage [9] and no predictable transmurality. Recently it has been demonstrated that narrow residual gaps may conduct AF, then transmural and complete lines of ablation must be created to guarantee total block [10]. Bipolar RF devices have been designed to ensure transmurality [11,12].

In this study we report and evaluate, retrospectively, the clinical results obtained in four years of experience surgically treating AF, in three different groups of patients: Group A using endocardial monopolar RF; Group B epicardial monopolar RF; and Group C, epicardial bipolar RF. The final purpose is to identify if BP RF is superior in terms of clinical results to the monopolar RF ablation. In other words if theoretical transmurality obtained with the use of BP RF corresponds with a higher incidence of SR restoration.

2. Materials and methods

Concomitant AF treatment with RF devices was performed in 183 patients between May 2001 and December 2005. In
the first 40 cases, unipolar endocardial RF was used (Group A), while in 33 cases (Group B) unipolar RF was applied on beating heart in the epicardial surface. Bipolar RF ablation was performed in 110 patients, beginning in May 2003 (Group C).

Indications for ablation were permanent AF in 93.4% of patients and persistent AF in 6.5%. Demographic and preoperative data are summarized in Table 1. Duration of AF, redo, low EF, advanced age or giant left atria were not considered as contraindications. The unique exclusion criterion was emergency surgery.

Surgical indications ranged from isolated mitral valve surgery to a very complex operation. Actually, in 70 patients (38.3%), the operations performed were complex procedures: pluri-valvular surgery, ascending aorta surgery, congenital cardiothorax, etc. BP RF ablation was also performed in addition to ventricular resynchronization in two cases and, in one of them, to a Core-Cap device implantation plus mitral valve repair. Mitral valve repair was performed in 7.1% of patients. Ablation procedure was associated with 16 reoperations (8.7% from the overall groups, 7–17.5% in Group A, 1–30% in Group B, 8–7.3% in Group C).

Informed written consent was given by each patient.

### 2.1. Ablation procedure

Endocardial monopolar RF ablation (Group A) was performed in 40 patients. All ablations were performed using the Cobra® system (Boston Scientific Corporation, San José, California). Ablation setting was 90 W RF power for 120 s. Once the heart was arrested and the left atriotomy achieved, a semicircular ablation line, in the endocardium, was performed to isolate the right pulmonary veins. Two lines around the left pulmonary veins were made. Both encirclings were connected with an ablation line in the posterior wall of the left atrium. A connecting line from the atriotomy to the mitral valve annulus was made.

Bipolar myocardial RF ablation (Group B) was performed in 33 patients. The device used was the same as previously described. Both right and left pulmonary vein encirclings were performed on beating heart on full cardiopulmonary bypass. The connecting line in between both encirclings was made in the left atrial roof through the transverse sinus. The connecting line to the mitral valve annulus was achieved in the endocardium when left atriotomy was performed. RF was delivered for 120 s at 90 W.

Bipolar RF ablation was used in 110 patients. The ablation system used was Cobra® Bipolar system (Boston Scientific Corporation, San José, California) in 102 patients (98.2%), while in the remaining patients the Cardioablate® BP (Medtronic Inc., Minneapolis, USA) was utilized. The Cobra® Bipolar ablation setting was 40 W for 40 s. The Cardioablate® BP was applied for 16–17 s until the transmurality was reached. Temperature as well as power were autoregulated.

After dissection of the epicardial reflection, the bipolar device was clamped around the atrial cuff containing the right pulmonary veins. On cardiopulmonary bypass and on beating heart, the heart was lifted and the left pulmonary vein’s encircling were performed. Both pulmonary vein ablations are repeated twice in order to avoid gaps. On cardioplegic arrest, the left atrial appendage (LAA) was opened and an additional ablation line connecting both encirclings in the transverse sinus was performed. The line toward the mitral annulus was performed from the LAA, or from the left atriotomy when achieved in cases of mitral valve surgery.

LAA was cut off in all 183 patients, and sutured from outside with a double suture of prolene 4/0. When giant left atria was present (defined as 60 mm of anteroposterior diameter), atrial reduction plasty was performed (58 patients–31.7% of the whole group, 15 patients–45% in Group A, five patients–15.2% in Group B, 35 patients–31.8% in Group C, P = 0.001). Conduction block validation was not achieved.

### 2.2. Perioperative management

Amiodarone intravenous administration started before the end of cardiopulmonary bypass at a dose of 300 mg and continued for 24 h at a dose of 900–1800 mg/24 h depending on the frequency. On the second postoperative day, 150–300 mg orally was prescribed. In the case of bradycardia or A–V block, amiodarone was avoided and pacing achieved.

Early electrical cardioversion (ECV) was performed in the case of AF maintenance or recurrence.

Warfarin was stopped after three months in cases of valve repair, bioprosthesis or CABG, when SR was documented.

All patients were re-examined at three, nine months and then yearly by standard 12-lead ECG and clinical examination.
Table 2
Surgical indication and procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral valve surgery</td>
<td>32.5%</td>
<td>15.2%</td>
<td>33.6%</td>
</tr>
<tr>
<td>Mitral aortic</td>
<td>20%</td>
<td>18.2%</td>
<td>11.8%</td>
</tr>
<tr>
<td>Mitral tricuspid</td>
<td>25%</td>
<td>12.1%</td>
<td>14.5%</td>
</tr>
<tr>
<td>Mitral tricuspid + aortic</td>
<td>20%</td>
<td>12.1%</td>
<td>9.1%</td>
</tr>
<tr>
<td>Aortic valve surgery</td>
<td>0%</td>
<td>23.6%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Aortic tricuspid</td>
<td>–</td>
<td>–</td>
<td>3.6%</td>
</tr>
<tr>
<td>Isolated CABG</td>
<td>–</td>
<td>–</td>
<td>1.8%</td>
</tr>
<tr>
<td>Valve + CABG</td>
<td>2.5%</td>
<td>6%</td>
<td>8.2%</td>
</tr>
<tr>
<td>Ascending aorta procedures</td>
<td>2.5%</td>
<td>9.1%</td>
<td>10.9%</td>
</tr>
<tr>
<td>– Bentall</td>
<td>–</td>
<td>–</td>
<td>7.3%</td>
</tr>
<tr>
<td>– Asc. aorta replac.</td>
<td>2.5%</td>
<td>9.1%</td>
<td>2.7%</td>
</tr>
<tr>
<td>– David</td>
<td>–</td>
<td>–</td>
<td>0.9%</td>
</tr>
<tr>
<td>Congenital cardiopathy</td>
<td>2.5%</td>
<td>3%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Pericarditis</td>
<td>–</td>
<td>3%</td>
<td>–</td>
</tr>
</tbody>
</table>

Asc. aorta replac., ascending aorta replacement; CABG, coronary artery bypass grafting.

2.3. Statistics

Continuous variables were normally distributed and described by arithmetic mean±S.D. Qualitative data were presented as absolute frequencies. Univariate analyses were performed for all relevant variables by means of chi-square for categorical variables and t-test for continuous variable. Multivariate analysis was performed for variable with a P-value > 0.2. One way analysis of variance was used for group comparisons. Actuarial survival was estimated by Kaplan–Meier.

3. Results

The open heart procedures are detailed in Table 2. Cardiopulmonary bypass time was 137.8±41 min (Group A), 128±30 min (Group B) and 125±40 min (Group C) (P=0.2). Cross-clamp time was 113±33.2 (Group A), 96.9±27.6 (Group B) and 94.9±32 (Group C) (P=0.01). These very long surgical times are perfectly justified, because of the complexity of the operations. Other surgical and postoperative data are shown in Table 3.

Table 3
Surgical and postoperative data

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Group A (n=40)</th>
<th>Group B (n=33)</th>
<th>Group C (n=110)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPB time</td>
<td>137.8±4.1</td>
<td>128.9±29.7</td>
<td>125.2±39.9</td>
</tr>
<tr>
<td>X-Clamp time</td>
<td>113.1±33.2</td>
<td>96.8±27.6</td>
<td>94.9±32.4</td>
</tr>
<tr>
<td>Postoperative complications (no., %)</td>
<td>8 (20%)</td>
<td>7 (21.2%)</td>
<td>24 (21.8%)</td>
</tr>
<tr>
<td>Renal failure (dialysis) (no., %)</td>
<td>3 (7.5%)</td>
<td>4 (12.1%)</td>
<td>5 (4.5%)</td>
</tr>
<tr>
<td>Respiratory insufficiency (48 h of MV) (no., %)</td>
<td>2 (5%)</td>
<td>3 (9.1%)</td>
<td>5 (4.5%)</td>
</tr>
<tr>
<td>Myocardial infarction (no., %)</td>
<td>0</td>
<td>1 (3%)</td>
<td>3 (2.7%)</td>
</tr>
<tr>
<td>Cardiac failure (no., %)</td>
<td>1 (2.5%)</td>
<td>0</td>
<td>8 (7.3%)</td>
</tr>
<tr>
<td>Arrhythmia (no., %)</td>
<td>0</td>
<td>0</td>
<td>4 (3.7%)</td>
</tr>
<tr>
<td>Temporary A–B Block (no., %)</td>
<td>2 (5%)</td>
<td>0</td>
<td>2 (1.8%)</td>
</tr>
<tr>
<td>MOF (no., %)</td>
<td>2 (5%)</td>
<td>3 (9.1%)</td>
<td>4 (3.6%)</td>
</tr>
<tr>
<td>Mediastinitis (no., %)</td>
<td>0</td>
<td>0</td>
<td>3 (2.7%)</td>
</tr>
<tr>
<td>30 days mortality (no., %)</td>
<td>2 (5%)</td>
<td>1 (3%)</td>
<td>4 (3.6%)</td>
</tr>
<tr>
<td>ECV</td>
<td>10 (27.8%)</td>
<td>12 (38.7%)</td>
<td>32 (30.8%)</td>
</tr>
</tbody>
</table>

No complication related to the ablation procedure occurred (esophageal or bronchial tree injuries). Re-exploration for bleeding was required in 5.4% (10 patients). Median ICU and hospital stay days were 2 and 15 days, respectively.

Acute renal failure was present in 6.5% (12 patients).

In-hospital mortality in Group A was 5% (two patients). Causes of death were respiratory and liver insufficiency. In Group B a total of two patients died (6.1%). Causes of death were tamponade (high INR7) and multiorgan failure. Early mortality in Group C was 2.7% (three patients) and causes of death were cardiac failure, left ventricle rupture in a patient with massive calcifications of the mitral valve annulus and sepsis.

At arrival in the intensive care unit 82.5%, 81.9%, 90.9% (Group A, Group B, Group C, respectively) were on sinus rhythm. During the hospital stay, 27.8%, 41.4% and 31.7% patients (%) experienced recurrence of AF (Group A, Group B, Group C, respectively). ECV was performed in all these patients. At discharge, 25%, 15.2% and 5.5% of patients (Group A, Group B, Group C, respectively) (P=0.03) were on AF, independently of full admirodarone administration and ECV.

Late follow-up was achieved in all surviving patients with an overall follow-up time of 42.8±18.9 months in Group A, 32.5±14.1 months in Group B and 17.4±10 months in Group C.

Overall incidence of SR at the end of the follow-up is 75% in Group A, 67.7% in Group B, and 79.4% in Group C (P<0.01) (Fig. 1). Late AF recurrence was identified by ECG, and it occurred in: Group A 28.6%, Group B 41.9%, and Group C 15.7% (P (A–B)=0.3, P (A–C)=0.5, P (B–C)=0.08). Overall freedom of AF for all groups was 64.9%, 46% and 71.1%, respectively (P (A–B)=0.3, P (A–C)=0.5, P (B–C)= 0.05) (Fig. 2). These are patients who have always been on sinus rhythm from the operation until the end of the follow-up.

Of patients on SR, 40.4% were not taking any antiarrhythmic drugs. One patient required catheter ablation for atrypical atrial flutter (from Group B).

CPB, cardiopulmonary bypass; X-Clamp, cross clamp; MV, mechanical ventilation; MOF, multorgan failure; ECV, Electrical cardioversion.
incidence of AF recurrence lower probability of SR restoration and then a higher of preoperative EF: when lower than 40% is related with episodes even after six months. The occurrence of AF was exceptions, only in two cases, patients were free of antiarhythmic therapy (all from Group C). Oral anticoagulation therapy (OAT) was stopped in a total of 35 patients, corresponding to the 39% of patients on SR and with tissue prosthesis, or valve repair, or CABG. Cumulative time without OAT is 23.9 ± 15.8 months. In the follow-up, five embolic events occurred, four TIA (all patients were on OAT, 50% of them were on AF and three had a tissue bioprosthesis) and one fatal ICTUS, one month after OAT suspension, in a patient on SR and with an aortic tissue valve. In the follow-up, a total of 11.1% in Group A, 3.2% in Group B and 2.9% in Group C required pacemaker implantation because of atrio-ventricular block or extreme bradycardia ($P (A-B)=0.5$, $P (A-C)=0.05$, $P (B-C)=0.2$).

4. Discussion

This report documents the mid-term results obtained with the application of radiofrequency (RF) energy for atrial fibrillation (AF) ablation in cardiac surgical patients. Three groups are compared, depending on the type of device used: unipolar or bipolar, and the approach: endocardial or epicardial.

The rationale for restoring SR in patients undergoing cardiac surgery with concomitant AF includes (1) improving survival, (2) reducing the risk of thromboembolism, (3) eliminating the need for oral anticoagulation, (4) reducing symptoms associated with high heart rate, and (5) restoring atrial contraction and then improving cardiac output [13].

The Cox-Maze procedure has evolved to become the most successful surgical treatment for AF, but because of its complexity and invasiveness has not become popular among surgeons. Thanks to the increased understanding of pathogenesis of AF and development of new ablation technologies, a great interest in surgically curing AF has occurred. Many different sources of energy have been proposed and used in different ways. However, RF (either in the monopolar version, and most recently, in the bipolar version) is the most frequently used [3,6,14–23].

Different energy sources, different lesion sets, different types of patients and surgical indications, make it difficult to identify factors which influence the rate of success/failure [7,12,23,24].

In our department we have four years experience treating AF with different modalities of RF: monopolar RF applied in the endocardial surface (Group A), in the epicardial surface (Group B) and bipolar RF (Group C). The results obtained are analyzed and compared between groups.

Our results demonstrate that restoration of SR is particularly effective using the endocardial monopolar RF ablation and the bipolar RF ablation (75% and 79.4%, respectively), while with the epicardial monopolar RF ablation the SR rates obtained are significantly lower (67.7%, $P=0.01$). Moreover, the recurrence of AF, being higher in the first six months after the operation in all groups, has a greater incidence in the epicardial monopolar group. Our data document that the probability of SR restoration after AF recurrence is lower in the BP group, demonstrating that in those patients whom the procedure is not immediately successful, the risk of AF maintenance is higher. Those data, however, have no statistical significance.

In our experience, we have performed the ablation procedure to each patient undergoing a cardiac operation and suffering from AF (permanent or persistent). Long duration of atrial fibrillation, dimensions of left atrium, reoperations, old age, or low EF% have not been considered as contraindication, even if that decision may be arguable for many of our colleagues. Our results demonstrate that the only predictor factor of ablation failure is the low preoperative EF (< 40%), with an incidence of ablation failure of 65.3% vs. 32.1% when EF is 40% ($P=0.03$). The other risk factors have been evaluated and no significant correlations have been found, and multivariate analysis has not been performed. Moreover, in cases of atrimegaly, a reduction plasty of the left atrium may help ablation effectiveness.
We did not report complications related to the ablation procedure such as esophageal injuries or bronchial tree, excluding a very low incidence of atrio-ventricular block, being significantly higher in the endocardial monopolar group. The incidence of atypical flutter was very low with only one case reported and successfully treated by previous mapping, with percutaneous ablation.

We agree with Benussi et al. [25] that the high rate of recurrence of AF and other supraventricular arrhythmias, most of them in the immediate postoperative period and in the first six months, justifies the routine use of antiarrhythmic drugs for at least six months after the operation. In some cases pharmacological cardioversion may not be sufficient and electrical cardioversion (ECV) must be performed. In our experience, the higher the incidence of AF recurrence in the first six months may be related to a main etiopathology: the lack of complete fibrosis of the lesion.

In accordance with the major experts in this field [13] the ablation pattern must include the lesion toward the mitral valve annulus, and it has been always included in our patients. In the BP group (Group C), the execution of this line may be difficult, since it can be insufficient and leave a gap or, contrary, damage the circumflex artery. Our results demonstrate that, when performed correctly, the ablation line is safe and effective.

The present paper has many limitations, first of all the retrospective analysis. The patient population is markedly heterogeneous, in terms of surgical indication and procedures. That demonstrates the feasibility of the ablation procedure with RF in all the three modalities, but, at the same time, the rate of SR restoration can be conditioned by the nature of the AF and the operation performed. Moreover, when talking about AF recurrence, this can be underestimated because of no ECG verification of asymptomatic episodes. More sophisticated statistical methods would be needed to correctly estimate AF events. Another limitation is that conduction block, by pacing the pulmonary veins, has not been assessed; it is therefore possible that some patients received incomplete lesions, contributing to ablation failures. Transmurality and completeness of the lesion are not assumed, and other pathology analyses as well as postoperative catheterism would be advisable to assess these two very important factors.

We can conclude that bipolar radiofrequency is effective in curing atrial fibrillation in more than 85% of patients. Even if similar results have been obtained with the endocardial monopolar RF ablation, the BP ablation is easier to perform, is not time consuming and has a lower incidence of atrio-ventricular block as well as lower incidence of AF recurrence. Moreover, the epicardial application of the BP device allows the surgeons to extend indication to all the patients on AF (either permanent, persistent or even paroxysmal) and undergoing cardiac surgery, even in complex operations. Our results demonstrate that RF can be performed even in cases of long duration of AF, giant atrium or reoperations. The worst results obtained with the epicardial monopolar approach, in spite of the initial enthusiasm, led us to abandon that approach.

References


