Endocardial and epicardial radiofrequency ablation in the treatment of atrial fibrillation with a new intra-operative device

João Meloa,b,*, Pedro Adragaob,a, José Nevesob,a, Manuel Ferreirab,a, Ana Timóteob,a, Teresa Santiagoa,b, Regina Riberaisob,a, Manuel Canadob,a

a Santa Cruz Hospital, Carnaxide, Portugal
b Heart Institute, Carnaxide, Portugal

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Abstract

Objective: Atrial fibrillation has been a difficult problem to solve in many surgical patients, especially in those with mitral valve pathology. This study evaluates the results of endocardial and epicardial radiofrequency ablation with a new intra-operative device in the treatment of atrial fibrillation.

Methods: We operated on 65 patients with atrial fibrillation, 58 of which had concomitant mitral surgery. Atrial fibrillation was chronic (over 1 year) in 46 patients (group A) and paroxysmal or recent onset in 12 (group B). Group C had lone atrial fibrillation (two), concomitant coronary artery disease (four) or a sarcoma (one). Bilateral pulmonary vein isolation with a new intra-operative device was performed through multiple dry lesions in all patients. Groups A and B had endocardial applications at 70°C during 60 s and group C had epicardial applications at 75°C. Three group C patients had epicardial applications off pump. Atrial wall biopsies were performed in nine patients from groups A and B. Results: There were no serious post-operative complications. At 1 month follow-up 54% of all patients were out of atrial fibrillation and 34% were in normal sinus rhythm with bilateral atrial contraction (Santa Crus Score 4). At 6 months follow-up, in spite of some crossover of patients among groups, similar results were obtained. The success of the procedure was 69% (Santa Crus scores 3 and 4) in mitral patients with a left atrial volume smaller than 200 cm³. Preliminary data on the transmurality of the lesions is presented. The patients submitted to epicardial radiofrequency ablation (group C) have satisfactory results at 1 month (six out of seven were out of AF). Conclusions: Both endocardial and epicardial RF applications are simple and quick to perform and do not pose an additional risk for most patients. Furthermore we believe that it is possible to perform bilateral epicardial radiofrequency ablation of the pulmonary veins without cardiopulmonary bypass. Further refinements of the technique are needed to assure transmurality of all lesions and better results. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Atrial fibrillation surgery; Radiofrequency catheter ablation; Pulmonary vein isolation; Arrhythmia surgery; Mitral valve surgery

1. Introduction

Surgery for atrial fibrillation remains a challenge due to a poor understanding of multiple underlying pathophysiological processes [1–5]. We have previously reported on the use of intra-operative radiofrequency (RF) catheter ablation with devices designed for percutaneous approaches, to treat atrial fibrillation in patients with concomitant mitral valve surgery [6–8]. Those catheters had four electrodes fired one at a time and applications were performed with the catheter immersed in saline solution. Specifically designed, shorter malleable intra-operative ablation catheters with seven electrodes fired simultaneously used on dry applications have since become available considerably shortening the ablation time, thus making it possible to extend our experience to other types of patients and pathologies.

2. Materials and methods

From October 1998 to August 1999 we operated on 65 patients with atrial fibrillation. Fifty-eight patients had concomitant mitral surgery. Of these, 46 patients (group A) had chronic atrial fibrillation (over 1 year duration) and 12 patients (group B) had paroxysmal or recent onset. Out of the seven patients in group C, two had lone atrial fibrillation, four had concomitant coronary artery disease and one had a sarcoma of the left atrium and AF was chronic.
in two and paroxysmal in five. Patients’ characteristics concerning age, sex, NYHA functional class, average duration of atrial fibrillation, etiology and associated pathologies are provided in Table 1.

2.1. Endocardial application of RF

The surgical technique used was bilateral isolation of the pulmonary veins as previously described by the authors [7]. All mitral patients, groups A and B, were operated under cardiopulmonary bypass. Standard techniques using a medium sternotomy were used in all but in seven patients. A left thoracotomy was performed in one patient to achieve left atrium volume reduction and in the remaining six, being mitral reoperations (five from group A and one from group B), the Port Access technique was used through a right thoracotomy. Moderate hypothermia and myocardial protection with cold crystalloid cardioplegia infused antegrade and retrogradely was routinely performed.

Measurement of the left atrium pressure was performed by direct puncture before starting extracorporeal circulation. In order to measure left atrium volume, a balloon was inserted in the left atrium of 46 patients on cardiopulmonary bypass and filled with saline solution to achieve the pressure measured in the beating heart. The volume of the left atrium was considered to be the same as the volume of saline required to fill the balloon. Bilateral isolation of the pulmonary veins was then performed endocardially with the technique previously described by the authors [7] using a seven electrode Thermaline malleable catheter manufactured by EP Technologies, Inc. The catheter was connected to an EPT 1000 XP radiofrequency generator through an EPT Meca APM switch box that allowed the selection of any combination of the electrodes. The latter were fired simultaneously and the system controlled the power delivered to the tissue during a chosen time interval, so as to attain the desired temperature set by the user. We applied the electrodes endocardially on a dry field, for 1 min and the temperature was set at 70°C.

In selected patients RF ablation was performed on the edge of the LA incision and a biopsy of that area was obtained to assess transmurality of the lesions.

2.2. Epicardial application of RF

Bilateral isolation of the pulmonary veins procedure was performed epicardially after median sternotomy in group C patients. To perform epicardial ablation of the pulmonary veins the sinus transversus fold from the upper right pulmonary vein to the upper left pulmonary vein was fully dissected, leaving the roof of the left atrium completely free from the posterior pericardium. The fascia between the lower right pulmonary vein and the inferior vena cava was opened. Next, the ablation device was moulded in a half circle shape and applied from the upper to the lower right pulmonary vein to encircle as much as possible of its superior, posterior, inferior and anterior epicardial surfaces. When required, a second application was performed on the anterior aspect of the pulmonary veins to achieve a full encircling lesion. The same procedure was then performed around the left pulmonary veins while the heart was lifted out of the chest with the surgeons left hand, and the ablation catheter was held with the right hand. Usually two catheter applications were required to ensure complete encircling of the right or the left pulmonary veins.

Operations were performed without cardiopulmonary bypass in the two patients with lone atrial fibrillation and in one with coronary artery disease. After radiofrequency ablation the left atrium appendage was tied from outside, except in the one patient with a left atrium sarcoma that had it sutured from the inside. In the patients operated under cardiopulmonary bypass the epicardial surgical technique was identical to the off pump cases.

The set temperature for these operations was 75°C.

2.3. Additional procedures

Mitral and additional associated procedures were performed in a conventional way following the arrhythmia treatment. Associated procedures included mitral valve replacement (53) or repair (five), aortic valve replacement (three), tricuspid repair (12), coronary artery bypass grafting (four), atrial septal defect closure (one), left atrium tumor removal (one).

2.4. Follow-up

Patients were assessed at 1 and 6 months after surgery. Rhythm was determined on the basis of 12-lead electrocardiogram and 24 h Holter monitoring. Hemodynamic response of atrial contraction was assessed by identification of a biphasic physiological wave at the level of the tricuspid

Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Sex (% F)</th>
<th>NYHA class</th>
<th>AF (months)</th>
<th>% TE events</th>
<th>Ethiology (% rhm)</th>
<th>Pathology (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n = 46)</td>
<td>59 ± 8</td>
<td>82</td>
<td>2.9 ± 0.5</td>
<td>52 ± 44</td>
<td>22</td>
<td>82</td>
<td>100</td>
</tr>
<tr>
<td>B (n = 12)</td>
<td>64 ± 8</td>
<td>83</td>
<td>2.2 ± 0.9</td>
<td>99 ± 168</td>
<td>9</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>C (n = 7)</td>
<td>60 ± 13</td>
<td>14</td>
<td>2.3 ± 0.8</td>
<td>39 ± 21</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

a NYHA class, New York Heart Association functional class; AF, atrial fibrillation; TE, thrombo-embolic; rhm, rheumatic; F, female.
and mitral valves using color-coded Doppler echocardiography. Results of atrial fibrillation surgery are presented using the Santa Crus scores as previously reported [8]. Briefly, score 0 is defined as persistence of atrial fibrillation and thus, a failure. Score 4 is given when normal sinus rhythm with bilateral atrial contraction is achieved, and is considered a success. Scores 1, 2 and 3 include intermediate, less successful grades, where atrial fibrillation is absent, but normal sinus rhythm is not attained. In score 1 the atria do not contract and are hemodynamically silent. In score 2 only the right atrium is beating and in score 3, because both atria have normal contractility we consider it a success.

Informed consent was obtained from all patients and the hospital ethics committee approved the surgical use of the radiofrequency ablation techniques.

2.5. Statistical analysis

Data is presented throughout the text as mean ± SD. Chi-square test was used to test for the dependence of LA volume on the success of the atrial fibrillation treatment.

3. Results

There was no early or late mortality. Table 2 shows the most relevant surgical data. Hospital stay was on average 14 ± 10 and 13 ± 1 days for groups A and B, respectively. In group C, hospital stay was 17 and 22 days for the 2 patients with lone atrial fibrillation and 7 ± 1 days for the remaining patients. The lone atrial fibrillation patients had atrial tachydysrhythmias after surgery. Paroxysmal AF, sinus tachycardia and braditachydisrhythmia were observed. Because of these arrhythmias they were kept longer in hospital.

Preliminary data from biopsies in nine patients (nine from group A and two from group B) showed that in seven cases the ablation procedure was not transmural. Fig. 1 shows one example of the two patients with documented transmural lesion (one from group A and the other from B) that were in sinus rhythm throughout the follow-up period. The follow-up at 1 and 6 months are complete and the results for each group are shown in Table 3. Six patients, out of the 25 in group A with six months follow-up (24%), changed score in this time period either improving their score (four patients) or relapsing into atrial fibrillation (two patients). Several factors, such as sex, mitral valve pathology, length of the operation, myocardial ischemic time and LA volume, that might correlate with the success of the procedure were studied but, at a level of significance of 5%, only the left atrial volume was found to be significant (P = 0.043 at discharge and P = 0.041 at 6 months). LA volume was assessed in 45 mitral patients of which 35 had chronic and ten had paroxysmal atrial fibrillation. The relation between left atrium volumes and scores at 1 and 6 months is shown in Table 4.

4. Discussion

The use of endocardial radiofrequency catheter ablation for surgical treatment of atrial fibrillation has been reported [6–12]. From our present and past experience it can be stated that its use is fast and safe: bleeding after surgery is the same as for conventional mitral surgery and we have seen no myocardial infarctions or high levels of myocardial enzymes resulting from coronary artery lesions [13]. The additional length of myocardial ischemic and operative time associated to AF surgery is negligible when appropriate instrumentation is used, thus allowing to extend the use of this technique to a greater number of patients. Owing to the malleability of the catheter we have started to perform epicardial procedures with and without cardiopulmonary bypass.

The results of the procedure expressed by scores [8], reported at an early stage before they can be regarded as definite, need to be improved. At 1 month follow-up 53.8% (35 out of 65) of all patients were out of atrial fibrillation and 34% (22 out of 65) were in normal sinus rhythm with both atria contracting. At 6 months follow-up, and in spite of some cross over of patients amongst groups, similar results were obtained. The remaining patients scored intermediate grades, as shown in Table 3. This technique provides much better results when applied to patients whose left atrium volume is smaller than 200 cm³. In this group 57.1% (16 out of 28) at discharge, and 75% (12 out of 16) at 6 months.

![Fig. 1. In spite of an artifact in the subendocardial layer, due to technical reasons, a transmural myocardial scar (arrow) can be seen.](image-url)
have no atrial fibrillation (scores 1, 2 and 3), whereas 42.8% (12 out of 28) at discharge and 68.8% (11 out of 16) at 6 months are in normal sinus rhythm with both atria contracting (score 4). Nevertheless, the reasons for the failures require a better understanding. They may be due to a variety of mechanisms involved in chronic and paroxysmal atrial fibrillation, namely the difficulty in assessing which mechanisms prevail in each patient, the location of arrhythmic foci or re-entry circuits in the atria or pulmonary veins. Moreover, limitations of the surgical technique, such as the transmurality of the lesions all along the ablation lines that appears to be crucial, should be considered. However, this has been difficult to prove by our histological studies and by electrophysiologic studies, as reported by several groups [14]. The results from biopsies show that many of the lesions, created with the present RF settings, were not transmural suggesting the need to increase the temperature of endocardial ablation in mitral patients.

The cure of chronic atrial fibrillation is the most difficult goal in many mitral patients maybe because they usually have very large atria and often have severe pathology of the atrial myocardium. Nevertheless, the possibility of curing atrial fibrillation in these patients deserves to be pursued because it is one of the major risks factors for late thromboembolic events [15–17]. Most published series have overall results varying from 50–94% [8,18]. The best results have been achieved with the maze operation as reported by Cox but it requires a long ischemic time and has a potential for bleeding. In patients whose left atrium volume is smaller then 200 cm³, our results compare favorably with alternative techniques [3,8,19–21]. If mitral patients have larger left atrial volumes we advise that additional procedures or alternative surgical techniques should be considered.

Another application made possible by the new intraoperative devices is epicardial radiofrequency ablation with and without cardiopulmonary bypass. Our early results concerning the epicardial use of radiofrequency in patients submitted to coronary revascularization and in patients with lone atrial fibrillation are very promising even though the number of patients involved is small. These patients usually have small left atria with a thin wall without fibrosis, and transmurality should therefore be easier to achieve than in mitral patients. The current methods and equipment still do not ensure transmurality of all radiofrequency lesions. Further studies on the energy delivered and the temperature achieved across the atrial wall are necessary.

After this initial experience, we believe that bilateral epicardial radiofrequency catheter ablation of the pulmonary veins can be performed without cardiopulmonary bypass. The indications for the use of RF surgical techniques performed in patients with atrial fibrillation without cardiopulmonary bypass, will eventually be very large, particularly in patients with concomitant coronary artery disease and patients with lone atrial fibrillation and pulmonary vein ectopic foci. The technique we used is simple and quick to perform and does not pose an additional risk for most patients. With more experience and improved equipment, surgery for atrial fibrillation will probably be an alternative to the percutaneous techniques, because it allows a better visualization and precision of radiofrequency ablation.

### Table 3
Follow-up results

<table>
<thead>
<tr>
<th>Santa Cruz score</th>
<th>1 month</th>
<th>6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
<td>Group B</td>
</tr>
<tr>
<td>0</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>

### Table 4
Left atrial volumes and results of atrial fibrillation treatment

<table>
<thead>
<tr>
<th>Santa Cruz score</th>
<th>Discharge (N = 46)</th>
<th>6 months follow up (N = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LA volume (&lt;200 cm³)¹</td>
<td>LA volume (&gt;200 cm³)¹</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>12</td>
<td>43</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>43</td>
</tr>
</tbody>
</table>

¹ Left atrial volume measured intra-operatively.
Treating atrial fibrillation is a major challenge and further studies are required to better understand the biophysics of endocardial and epicardial intra-operative radiofrequency catheter ablation.

References


Appendix A. Conference discussion

Dr S. Tugtekin (Dresden, Germany): Do you conclude from your data is that patients with an LA larger than 200 mm should be excluded from the ablation procedure?

Dr Melo: From the Maze procedure?

Dr Tugtekin: No, from the ablation procedure, because you have concluded that their results are much worse than patients with an LA smaller than 200 mm.

Dr Melo: I believe we have to learn a lot. I think we should not exclude them, because, as was discussed before, this procedure if performed properly is extremely safe. In mitral patients, even though the success rate is low in our experience, there are other techniques that have proven to be superior in large left atria. I am sure that we have to do more lines. We have to find a compromise between number of lines and contractility.

We need basic research, to know the causes of atrial fibrillation, either ectopic foci, reentry mechanisms or basically disturbances of refractory periods. The information available at this moment is obtained from percutaneous endocardial ablations, and the biophysics of these applications are completely different from surgical applications.

We have to achieve transmurality. Previous speakers have said that they don’t have transmurality. We would like to confirm their findings. Until we don’t achieve transmurality it will be difficult to understand why those procedures work.

Dr F. Schoendube (Aachen, Germany): I enjoyed very much your very good presentation, and it shows again that these results are really preliminary now again for atrial fibrillation. I have a two-fold question.

Number one is, what you just mentioned, transmurality. Well, it is well known that transmurality will get with these RF lesions during the time deeper and deeper. So it may be that a lesion which was not transmural at the operation will be transmural at three months. So patients will get into sinus rhythm afterwards. So my question is, what will you do during this time? Will you keep your patients on drugs or will you do repeated defibrillation of these patients to try to put them again into sinus rhythm?

And number two, do you rinse your patients with saline or do you do it still under the water, or what is your procedure with this Thermaline catheter to just rinse saline in the patient?

Dr Melo: Our first goal is to really understand what we are doing. Regarding transmurality and drugs, we have definitive proof from pieces removed from the atriotomy, that many lesions are not transmural because the cells are not swollen proves that those cells were not warmed up. After we had those results, we increased RF application to 2 min. We expect transmurality to improve with longer applications.

We don’t use prophylactic drugs because we want to confirm the results of the surgical procedure. If the patient is in atrial fibrillation while still in the hospital, he gets amiodarone and electrical cardioversion. Forty percent of our patients are out of drugs.

Regarding wet applications, this is a way of getting lesions deeper, but we are misleading the system, because you are artificially cooling the tissue surface.