The radiofrequency modified maze procedure. A less invasive surgical approach to atrial fibrillation during open-heart surgery

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Abstract

Objective: Patients with mitral valve disease and suffering of atrial fibrillation of more than 1 year’s duration have a low probability of remaining in sinus rhythm after valve surgery alone. Intraoperative radiofrequency ablation was used as an alternative to simplify the surgical maze procedure. Methods: Seventy-two patients with mitral valve disease, aged 63 ± 11 years ranging from 31 to 80 years, underwent valve surgery and radiofrequency energy applied endocardially, based on the maze III procedure to eliminate the arrhythmia. The right-sided maze was performed on the beating heart and the left-sided maze during aorta cross-clamping. Results: Surgical procedures included mitral valve repair (n = 38) or replacement (n = 34) and in addition tricuspid valve repair (n = 42), closure of an atrial septal defect (n = 2) and correction of cor triatriatum (n = 1). The left-sided maze needed 14 ± 3 min extra ischemic time. There were two in-hospital deaths (2.7%) and three patients (4.2%) died during follow-up of 20 ± 15 months. Among 67 surviving patients, 51 patients (76%) were in sinus rhythm, two patients (3%) had an atrial rhythm and eight patients (12%) had persistent atrial fibrillation or atrial flutter. Four patients had a pacemaker implanted, in one patient because of sinus node dysfunction. Doppler echocardiography in 64 patients demonstrated right atrial contractility in 89% and left atrial transport in 91% of patients. Conclusions: Intraoperative radiofrequency ablation of atrial fibrillation is an effective and less invasive alternative for the original maze procedure to eliminate atrial fibrillation. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Atrial fibrillation; Mitral valve disease; Radiofrequency

1. Introduction

Mitral valve disease is predisposing patients to persistent atrial fibrillation (AF) and in general, the arrhythmia will persist even after valve surgery [1–3]. Studies have revealed that chronic AF not only impairs cardiac function by the loss of ‘atrial kick’ but also increases the risk of thromboembolic complications [4–6]. As a result, during the last decade, several non-pharmacological techniques have been designed to either ablate the arrhythmia or ameliorate its detrimental effects [7–12]. The maze procedure has offered a curative treatment of AF, as it restores sinus rhythm and AV synchrony with demonstrable atrial transport, in patients with lone AF as well as in patients with organic heart disease [2,7–9,13,14]. However, in patients undergoing complex cardiac procedures, surgeons are reluctant to expose their patients to the risks of the maze procedure. To simplify the maze procedure intraoperative radiofrequency (RF) energy has been used to eliminate AF [15–17]. In this study we performed an RF-modified maze procedure in patients with chronic AF who underwent mitral valve surgery.

2. Materials and methods

2.1. Patient characteristics

Between November 1995 and June 2000, seventy-two consecutive patients with AF caused by mitral valve (MV) disorders underwent a RF modified maze III procedure combined with MV surgery. The group consisted of 26 men (36%) and 46 women (64%), whose age ranged from 31 to 80 years with an average of 63 ± 11 years (mean ± SD). Sixty-one (85%) patients were in New York Heart Association (NYHA) class III. The cause of mitral valve
disorder, which was the primary indication for surgery, were prolapse \((n = 27)\), rheumatic \((n = 18)\), idiopathic annulus dilatation \((n = 13)\), degenerative \((n = 11)\), and prosthesis dysfunction \((n = 3)\). Four patients \((5.6\%)\) had previously undergone mitral valve surgery. All patients had documented AF for at least 1 year’s duration before operation with an average of 6.1 ± 4.7 years (Table 1). The average size of the left atrium, as measured on an M-mode tracing taken from a two-dimensional parasternal long-axis view \((Sonos 5500, Hewlett Packard)\) was 50 ± 9 mm \((range 31–80 mm)\).

In all patients ventricular rate control medication, i.e. calcium blockers and/or digoxin, was allowed until the day before surgery. Oral anticoagulant therapy (coumadin or warfarin) for the prevention of thromboembolism secondary to chronic AF, was discontinued 2 days before surgery. Oral anticoagulant therapy (coumadin or warfarin) for the prevention of thromboembolism secondary to chronic AF, was discontinued 2 days before surgery. Oral anticoagulant therapy (coumadin or warfarin) for the prevention of thromboembolism secondary to chronic AF, was discontinued 2 days before surgery.

### 2.2. Surgical procedure

Radiofrequency energy was used to create long continuous endocardial lesions under direct vision with a hand-held cooled tip probe. The RF energy was administered using a continuous sinusoidal unmodulated waveform of 500 kHz \((HAT 2005, Sulzer-Osypka GmbH, Grenzach-Wyhlen, Germany)\) and delivered in an unipolar mode between the 4-mm tip electrode of a specially designed probe and a 10 × 16-cm external backplate electrode that was underneath the back of the patient. The ablation probe had a thermistor embedded centrally in the distal part of the tip electrode for continuous monitoring of catheter tip temperature.

The ablation procedure was done in a bloodless operating field and temperature guided energy applications were performed with a preselected catheter tip temperature of 60°C. The tip was irrigated with saline at a flow rate of 4 ml/min.

The heart was exposed through a median sternotomy and suspended in a pericardial cradle. Cardiopulmonary bypass was instituted using standard aortic and bicaval cannulation

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Clinical characteristics of study patients*</th>
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</thead>
<tbody>
<tr>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>Patient number</td>
<td>72 (100)</td>
</tr>
<tr>
<td>Female</td>
<td>46 (64)</td>
</tr>
<tr>
<td>Age (year)</td>
<td>63 ± 11</td>
</tr>
<tr>
<td>Rhythm characteristics</td>
<td></td>
</tr>
<tr>
<td>Permanent AF before surgery</td>
<td>72 (100)</td>
</tr>
<tr>
<td>Duration of AF (years)</td>
<td>6.1 ± 4.7</td>
</tr>
<tr>
<td>Functional class</td>
<td></td>
</tr>
<tr>
<td>NYHA II</td>
<td>10 (14)</td>
</tr>
<tr>
<td>NYHA III</td>
<td>61 (85)</td>
</tr>
<tr>
<td>Echocardiographic data (mm)</td>
<td></td>
</tr>
<tr>
<td>PSLA</td>
<td>50 ± 9</td>
</tr>
<tr>
<td>LVEDD</td>
<td>54 ± 8</td>
</tr>
</tbody>
</table>

* AF, atrial fibrillation; LVEDD, left ventricle end-diastolic dimension; NYHA, New York Heart Association; PSLA, parasternal long axis.

and moderate hypothermia \((28°C)\). The operative procedure was based on the maze III procedure as described by Cox et al. [9]. In our RF modification, all atrial incisions currently used in the maze III were replaced by endocardial linear ablation lines as illustrated in Fig. 1 except for the incisions to enter the left and right atrial cavity. According to the original maze III both appendages were excised as well. There was no need for additional cryosurgical applications.

The right-sided maze was performed on the beating heart without cross-clamp. The left-sided maze procedure was started after the heart was arrested with cold cardioplegic solution and the aorta cross-clamped. Both left and right pulmonary veins were isolated separately. Concomitant procedures, e.g. tricuspid valve repair, were performed immediately after aortic cross-clamping and prior to completing the left-sided maze and the mitral valve procedure. During rewarming the left atrium was closed and the cross-clamp released. The heart was then de-aired extensively prior to defibrillation and to closing of the right atrium. Occasionally atrial pacing or atroventricular pacing was needed to wean off bypass.

### 2.3. Follow-up

Early postoperative care was similar to that for routine open-heart surgery. Cardiac rhythm was continuously monitored after surgery until stable rhythm returned. Temporary epicardial wires attached to the right ventricle as well as to the right atrium were used to pace the patient, to monitor the rhythm, or to overdrive the atrium. Postoperative atrial arrhythmias were treated with sotalol 80–120 mg or ami-

### 2.4. Statistical analysis

Continuous variables were expressed as mean ± standard deviation. Means were compared using Student’s \(t\)-test. In the case of non-normal distribution, the nonparametric Wilcoxon test was used. A \(P\) value less than 0.05 was considered statistically significant.

### 3. Results

#### 3.1. Operative data

The mean cardiopulmonary bypass time and aortic cross-clamp time were 195 ± 46 min and 94 ± 30 min, respec-
tively, including $14 \pm 3$ min ischemic time to perform the left-sided part of the maze procedure. Seventy-two patients underwent 117 concomitant cardiac procedures (Table 2) included MV repair ($n = 38$), MV replacement ($n = 34$), tricuspid valve repair ($n = 42$), closure of atrial septal defect ($n = 2$) and correction of cor triatriatum ($n = 1$).

### 3.2. In-hospital mortality and morbidity

There were two in-hospital deaths (2.7%). One 68-year-old woman died intraoperatively due to rupture of the mitral annulus and another 64-year-old woman, who was operated on for redo MV replacement, died of coma vigil due to a late tamponade. The non-fatal in-hospital complications are summarized in Table 3.

### 3.3. Survival and events

All surviving patients ($n = 67$) were followed for at least 3 months after surgery and the average duration of follow-up was $20 \pm 15$ months (range 3–54 months). Fifty-eight patients had a follow-up for more than 1 year. There were three late deaths (4.2%) including one sudden cardiac death and two non-cardiac deaths.

<table>
<thead>
<tr>
<th>Table 3 Concomitant cardiac procedures$^a$</th>
<th>$n$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV repair</td>
<td>38 (52.8)</td>
</tr>
<tr>
<td>TV repair</td>
<td>23</td>
</tr>
<tr>
<td>Closure ASD</td>
<td>1</td>
</tr>
<tr>
<td>Correction of cor triatriatum</td>
<td>1</td>
</tr>
<tr>
<td>MV replacement</td>
<td>30 (41.7)</td>
</tr>
<tr>
<td>TV repair</td>
<td>18</td>
</tr>
<tr>
<td>Closure ASD</td>
<td>1</td>
</tr>
<tr>
<td>Redo MV replacement</td>
<td>4 (5.6)</td>
</tr>
<tr>
<td>TV repair</td>
<td>1</td>
</tr>
</tbody>
</table>

$^a$ ASD, atrial septal defect; MV, mitral valve; TV, tricuspid valve.

<table>
<thead>
<tr>
<th>Table 3 In-hospital morbidity$^a$</th>
<th>$n$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rethoracotomy</td>
<td>4 (5.6)</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>5 (7.0)</td>
</tr>
<tr>
<td>Recurrent AF/AFL</td>
<td>10 (15)</td>
</tr>
<tr>
<td>AV sequential PM</td>
<td>3 (4.2)</td>
</tr>
<tr>
<td>RV perforation</td>
<td>1 (1.4)</td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (1.4)</td>
</tr>
</tbody>
</table>

$^a$ AF, atrial fibrillation; AFL, atrial flutter; AV, atrioventricular; PM, pacemaker; RV, right ventricle.
3.4. Cardiac rhythm and atrial transport

At 6 months follow-up 64 survivors were free of atrial tachyarrhythmias. In these patients transthoracic or transesophageal Doppler echocardiography was performed and demonstrated right atrial contractility in 89% (57 of 64) and left atrial transport in 91% (58 of 64) of the patients. In the most recent follow-up the number of survivors with persistent AF or atrial flutter increases to ten (15%) including two patients who underwent His bundle ablation and received a ventricular rate responsive pacemaker because of symptomatic AF. In the remaining group of patients sinus rhythm was documented in 51 (76%), a regular atrial rhythm in two (3%) and an AV sequential pacemaker was implanted in four (6%) patients. Of these patients, one patient received an AV sequential pacemaker prior to surgery in combination with His bundle ablation and another patient needed the same type of pacemaker due to sinus node dysfunction.

In the group of 57 patients who were free of AF or atrial flutter, antiarrhythmic drug therapy was maintained in 17 patients (30%). Ten patients were on sotalol 80–120 mg and seven patients on amiodarone 200 mg.

4. Discussion

In the majority of patients who undergo MV surgery in chronic AF at the time of operation, the arrhythmia will remain after surgical correction of the underlying cardiac disease [1,2]. However, in patients with intermittent AF or AF duration of less than 1 year, MV surgery alone is sufficient to restore sinus rhythm in the majority of patients [1,18]. In this study we included only patients with a history of AF of at least 1-year duration and in whom it is unlikely that sinus rhythm will be regained after valve surgery.

The Cox’s maze procedure [7–9] has apparently remained an universally applicable and potentially effective treatment to restore sinus rhythm in patients with chronic AF and concomitant structural heart disease [19–21]. However, this surgical procedure involves extensive incision and suturing of the atria and in an attempt to simplify the original maze, our group [16] and others [15,17] used RF energy intraoperatively to create linear ablation lines endocardially, under direct visual guidance, to eliminate AF. The RF ablation pattern we used is based on the maze III concept [9], but most of the atrial incisions of the original maze procedure are replaced by RF lesions. As a consequence, the extra cardiac arrest time to complete the left-sided part of the maze procedure was only 10–15 min.

The aim of AF surgery is restoration of sinus rhythm and reestablishment of atrial mechanical function. This was achieved in the majority of the patients in our study, which is comparable with the surgical maze III in patients with long-standing AF and structural heart disease [20–24]. Cox and associates [25] demonstrated that preservation of atrial transport function was 93.6% in the right atrium and 85.1% in the left atrium after the maze III when evaluated by transthoracic Doppler echocardiography, although when additional techniques were used such as transesophageal Doppler echocardiography or magnetic resonance imaging, preservation of transport function was 98% in the right atrium and 94% in the left atrium. The high percentage of atrial contractility in this patient group in contrast to other studies [13,23,26] can be explained by the use of transesophageal Doppler echocardiography to assess atrial transport function while others have relied on transthoracic Doppler echocardiography as a means to show atrial contractility. Furthermore, we have observed immediate recovery of left atrial function in the majority of patients undergoing intraoperative RF ablation for chronic AF, using transesophageal Doppler echocardiography in the operating theatre [27].

Finally, radiofrequency ablation applied at limited epicardial and endocardial sites in patients with AF during MV surgery showed promising results [15,28], but in contrast to our patient population, these studies also included patients with paroxysmal AF and AF duration less than 1 year and, according to recent studies [1,18] these patients have a higher likelihood to remain in sinus rhythm after surgery.

References


Appendix A. Conference discussion

Dr U. Von Oppell (Cape Town, South Africa): In order to get a full-thickness contiguous radiofrequency ablation lesion in the right or left atrium muscle, one needs to know the temperature of the probe and the duration of application, as the lesion created is a product of temperature plus time. What was the temperature of your probe and what was the duration of application of your probe at any one single site?

In addition, how many patients were maintained on anti-arrhythmic medication postoperatively?

Dr Sie: Let’s start with the second question. We have to look at the number of patients that are still on anti-arrhythmic medication. Our primary goal was to restore sinus rhythm and to restore atrial contractility, and all the secondary effects and secondary goals we didn’t look at it yet, but we still have to do that.

An answer to the first question regarding the transmurality of the lesion is that during the procedure we are trying to give as much energy as possible to make a transmural lesion but without disrupting the tissue. So whenever I feel insecure whether the lesion will be transmural or not, e.g. because of the thickness of the tissue in a certain area, I will go back to that particular area and repeat the ablation. During the procedure I am actually dragging the probe along the wall of the atrium endocardially, and whenever it starts to pop up, I will stop the procedure at that specific site and then move on.

Dr S. Benussi (Milan, Italy): My perplexity is actually the opposite to that of my colleague. Aren’t you concerned by using the drag technique, without any temperature control system, to go too deep, and to damage or to disrupt in any way the underlying structures, such as the esophagus or the circumflex artery?

Another question that can be interesting is, how can you obtain such very good results on atrial transport function recovery by reproducing exactly the same lesion set that is performed in the Maze procedure with incisions? What is the difference and what do you think is the rationale for that?

And one last question is about your atrial flutter. About a 15% occurrence of atrial flutter with this kind of procedure is actually quite strange, because you are supposed to have cut through the isthmus. So which kind of flutter is that? Is that conventional right atrial flutter?

Dr Sie: We try to prevent this post-maze flutter by ablation of the isthmus. We performed some postoperative studies with the CARTO system and found that there still was a gap along the tricuspid annulus in some of our patients. So currently we are somewhat more aggressively ablating at this particular annular site. What was the second question you asked?

Dr Benussi: The concerns about the excessive transmurality.

Dr Sie: The difference with the Cox-maze is that in the Cox-maze both pulmonary veins are totally encircled and isolated. We know that especially in enlarged atria, the enlargement will grossly take place between the left and the right pulmonary veins. By isolating this particular part you will exclude a considerable amount of tissue. In our RF modification we try to preserve as much tissue as possible by isolating left and right pulmonary veins separately.

Regarding the concern about damaging the surrounding tissue, as you have seen on the histological slide, one of the limitations of the RF technique is the depth of the lesion. So we are more concerned about transmurality. We did not experience any damage of the surrounding tissue whatsoever.

Dr J. Melo (Carnaxide, Portugal): In your accepted abstract you have reported 122 patients. You have shown us 72 patients only. So your success rate in the other 50 was the same?

Dr Sie: At our latest update of June 2000 a total of 158 patients were enrolled in our study and followed up for at least 3 months. The series I just presented was confined to a subgroup of 72 patients undergoing the RF-maze procedure concomitant with solely mitral valve surgery. The mortality rate was lower in the subgroup with 2.4% instead of 4.2% for the total group. The success rate in the subgroup was comparable with the total group.