Midterm results after the mini-maze procedure

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Abstract

**Objective:** Atrial fibrillation (AF) is the most common arrhythmia. However, its precise electrophysiologic mechanism is still not well understood. Chronic symptomatic AF resistant to medical therapy, can successfully be treated by the Maze III procedure (M III). However, there are several publications dealing with alternative surgical techniques. This study describes technique and midterm results of a Minivariant of the M III procedure. **Methods:** During a 38-month period we performed either an M 111 (seven patients) (group I) or a MINI-operation (45 patients) (group II) with chronic symptomatic AF and additional cardiac pathology. Patients were controlled 3.6 ± 0.9 and 14.9 ± 2.2 months after operation by means of thorough electrophysiologic assessment, right heart catheterization, magnetic resonance imaging (MRI), echocardiography, stress-EGG and 24-h-ECG. **Results:** There was no significant differences between the two groups with regard to sex, age and duration of AF. Echocardiographic left atrial diameter (LAD) was 75 ± 11 mm in group I and 67 ± 8 mm in group II ($P = 0.01$). Whereas right atrial diameter was 62 ± 8 mm in group I and 56 ± 7 mm in group II (NS). Perioperative data ($n = 52$): aortic cross clamp time was 127 ± 40 min in group I and 87 ± 21 min in group II, ($P = 0.0002$). Cardiopulmonary bypass time was 185 ± 71 min in group I and 137 ± 46 mm in group II, ($P = 0.02$). Postoperative data: there was no difference between the two groups with regard to sinus rhythm, prolonged sinus node recovery time, pacemaker (PM) in AAI-mode, inducible atrial fibrillation, reduction of left and right atrial size after a follow-up interval of 3.6 months and 1 year, respectively. **Conclusion:** Midterm results are identical after M III and MINI. MINI is less complex compared to the M III procedure and there is a significant reduction of crossclamp- and ECC-time. We recommend the MINI especially for polymorbid patients, and for those with poor left ventricular function. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Atrial fibrillation; Arrhythmia; Maze procedure

1. Introduction

Atrial fibrillation (AF) is one of the most prevalent arrhythmias [1] and therefore a major health care problem. Electrophysiologic studies have demonstrated, that AF is a reentry arrhythmia, which is characterized by macroreentry loops [2]. However, the precise electrophysiologic mechanism of AF is still not well understood [3,4]. It is associated with significant morbidity and mortality and is frequently resistant to medical therapy. Its incidence increases with each decade of life, functional class, duration of mitral valve disease and left atrial size [5]. AF may be associated with two major complications. Firstly, loss of atrial contraction results in formation of intracardiac thrombus with significant risk of systemic embolism. Secondly, irregularity of cardiac rhythm and high ventricular rate may impair left ventricular function [6]. AF requires treatment in order to prevent these potential complications, such as antiarrhythmic medications and anticoagulation. However, these drugs have well known adverse effects. In 1980 Cox et al. described left atrial isolation procedure [7] and in 1982 Scheinman et al. introduced catheter fulguration of His bundle [8]. In 1985 Guiraudon et al. described the corridor procedure for treatment of AF [9]. However, none of these techniques could eliminate all detrimental sequelae of AF. Due to absence or insufficient atrial contraction hemodynamic parameters were not improved, and danger of thromboembolism persisted. After accomplishing various electrophysiological animal experiments Cox et al. performed the Maze I procedure in 1987 [10]. Thereafter he modified the technique and currently the Maze III (M III) procedure is the technique of choice for the management of atrial fibrillation resistant to medical therapy [11]. The aim of the M III operation is to interrupt all potential macroreentry loops by multiple left and right atrial incisions, but with preservation of atrial transport function and sinus node function. Many surgeons are still reluctant to perform the M procedure.
III operation, since this procedure is rather complex and time-consuming, especially during the learning period. In patients with reduced ventricular function or patients with additional cardiac pathology there is even more concern in performing this operation. For this reason we developed a MINI-variant of the M III operation, based on several publications [12–16]. The aim was to reduce ischemic time but to eliminate the most frequent reentry circuits notwithstanding.

2. Patients and methods

During a 38-month period we performed the M III in seven patients (group I) and the MINI in 45 patients (group II). Both procedures were combined with an additional cardiac operation. Patient characteristics and baseline data are given in Table 1. There were no significant differences between the groups except for LA diameter. No patient responded to antiarrhythmic therapy and all had symptomatic permanent (50 patients), or paroxysmal (two patients) AF longer than 6 months. All patients reported severe symptoms related to tachycardia, impaired hemodynamic function or both.

In group I there were only patients with mitral valve disease, one patient had an additional tricuspid insufficiency and three patients had additional coronary artery disease (CAD). In group II the patients had more complex cardiac pathology (Table 1).

2.1. Surgical procedures

The aim of the MINI was to reduce aortic crossclamp-time, to minimize injury of structures at risk, e.g. circumflex coronary artery and coronary sinus, but to interrupt the most frequent reentry circuits.

The first seven patients in this series underwent the standard M III procedure as described by Cox. To decrease the operative risk and to reduce crossclamp-time and ECC-time we modified the procedure and did not perform the following incisions as compared to M III: endocardial incision to tricuspid and mitral annulus and incision of interatrial septum. Furthermore, cryoablation was not performed during MINI (Fig. 1a,b).

Informed consent was obtained from all patients. After median-sternotomy and bicaval cannulation the patient was put on normothermic cardiopulmonary bypass (CPB). After aortic cross clamping cold ante- and retrograde blood cardioplegia was corrected version administered. Maze-incisions were performed first, followed by the valve and/or coronary artery bypass graft (CABG) operation. Closure of right atrial incisions was done on the beating heart. The additional procedures are listed in Table 2.

Patients who showed persistent AF postoperatively were treated with antiarrhythmic agents (Sotalol). If patients did not respond to medical therapy, electrical cardioversion was done before discharge and antiarrhythmic medication was continued. If a patient showed bradycardia 3 weeks postoperatively, an electrophysiological evaluation was performed and a permanent pacemaker was implanted when indicated. All patients were anticoagulated with warfarin for at least 3 months. If significant atrial transport function was demonstrated by echo and/or magnetic resonance imaging (MRI) and no mechanical device was implanted anticoagulation was discontinued at this time.

2.2. Follow-up

All patients were controlled 3.6 ± 0.9 months (range 2.5–
7 months) and 14.9 ± 2.2 months (range 12–19 months) postoperatively. The patients were hospitalized and the following diagnostic procedures were performed: ECG, 24-h-ECG, echocardiography, MRI, right heart catheterisation and electrophysiological evaluation.

To classify atrial transport function and to decide if anticoagulation could be discontinued, all patients were examined by echocardiography and MRI, except patients with a permanent pacemaker which had echocardiography only. Pulsed Doppler flow was measured across both atrioventricular valves. Left atrial contribution to left ventricular filling was judged by A-wave measurements. Atrial contraction and ‘output’ of LA and RA was examined by MRI. When echo showed A-wave greater than 70 cm/s and MRI moderate or good atrial contraction anticoagulation was discontinued except in patients with a mechanical valve prosthesis.

Left atrial size was assessed by measuring the two diagonal dimensions (mediolateral and superoinferior by the apical long-axis). The right atrial dimensions were measured in the apical four-chamber imaging plane. The ellipsoid square dimension of both atria was calculated and compared with the preoperative data of each patient.

Interatrial conduction-time and sinus node recovery time (SNRT), was measured during electrophysiological control. Furthermore, high frequency stimulation was applied.

2.3. Statistics

Differences between the two groups were analyzed using impaired t-test and continuous variables with Mann–Whitney test. Numbers are expressed as mean ± standard deviation. Nominal variables were tested by Fisher’s test. Differences were considered statistically significant when P-value was less than 0.05.

3. Results

3.1. Intraoperative data

Perioperative data are given in Table 2. All patients were extubated within 12 h after the operation. Even though we performed more complex operations in group II we found a significant reduction of clamp-time (P = 0.0002) and ECC-time, (P = 0.02).

3.2. Mortality and morbidity

There was one early death in group II due to acute tamponade on postoperative day 11. Immediate thoracotomy showed rupture of the ascending aorta. The 65-year-old man was extubated 5 h after the operation (MINI combined with CABG) and the postoperative course was uneventful. The patient showed sinus rhythm (SR) postoperatively and echocardiography 1 day before the fatal event was normal. There was no late death in these series.

One of the MINI patients (2.2%) and one of M III (14%) had reexploration because of postoperative bleeding, one patient of the Mini suffered from acute pancreatitis.

3.3. Post-operative rhythm

The most frequent rhythm after operation was a junc-

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**Table 2**

<table>
<thead>
<tr>
<th></th>
<th>M III (n = 7)</th>
<th>MINI (n = 45)</th>
<th>P-value</th>
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<tbody>
<tr>
<td>ECC (mm)</td>
<td>185 ± 71 (126–298)</td>
<td>137 ± 46 (70–284)</td>
<td>0.02</td>
</tr>
<tr>
<td>AO (mm)</td>
<td>127 ± 40 (88–195)</td>
<td>81 ± 21 (33–132)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Type</td>
<td>MVRec. 2</td>
<td>MVRec. 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MVRep. 5</td>
<td>MVRep. 23</td>
<td></td>
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<tr>
<td></td>
<td>AVRep. 6</td>
<td>AVRep. 6</td>
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<tr>
<td></td>
<td>TVA 1</td>
<td>TVA 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CABG 3</td>
<td>CABG 12</td>
<td></td>
</tr>
</tbody>
</table>

* ECC, extra corporal circulation; AO, aortic occlusion; MVRec., mitral valve reconstruction; MVRep., mitral valve replacement; AVRep., aortic valve replacement; TVA, tricuspid valve annuloplasty; CABG, coronary artery bypass grafting.
tional rhythm in both groups (6 in group I and 32 in group II). All patients were paced by atrial or sequential stimulating mode postoperatively. During the first 2 weeks there were no differences between the MINI or the M III with regard to frequency of junctional rhythm. Postoperative atrial arrhythmias developed in six of seven patients in group I (86%) and in 27/45 patients in group II (60%) (NS), all of them occurring within the first 12 postoperative days. These arrhythmias were treated initially with sotalol and digoxin and as of late 1995 with sotalol only. If this medication did not convert atrial arrhythmias within 3 days, an electrical cardioversion was performed (three patients in group I and 12 patients in group II) (NS). Mean length of hospitalization was 1914 days in group I (range 14±24) and 1215 days in group II (range 5±28) (NS).

3.4. Follow up

All seven M III patients and 34 of the MINI had first follow-up. All patients were in New York Heart Association functional class I or II. Table 3 shows rhythm and sinus node function in both groups at time of discharge.

Correlation between preoperative atrial diameter and rhythm at time of first follow-up is depicted in Table 3.

Twenty-six of 34 patients of the MINI group (76%) had a stable SR and induction of AF was not possible versus four of seven patients in group I (57%) (NS). Two patients of group I and four patients of group II had successful cardioversion; one patient of group II had ablation because of AFL. After that in all of these patients induction of AF/AFL was not possible. In two versus three patients cardiac inversion because of AF at first follow-up was unsuccessful, but all these patients had a preoperative atrial diameter greater than 70 mm.

One of the M III (14%), and four of the MINI (9%) showed sinus node dysfunction and were pacemaker dependent (AAI-mode) at first follow-up. In group I one patient and in group II two patients showed AF combined with sick sinus syndrome (SSS) with the depend of a DDD-PM.

There was a significant correlation between preoperative left atrial diameter and postoperative SSS or AF as described by others. We also found correlation between preoperative duration of AF and age of the patients and postoperative SR and SSS in group II.

In group I three of the four patients with SR showed adequate atrial transport function (ATF), also the including one patient with pacemaker (PM).

In group II 27 of 34 patients with SR and with AAI-stimulation, respectively showed sufficient atrial transport function after 3 months. Anticoagulation was discontinued in patients without mechanical valves. No thromboembolic events occurred postoperatively in any of these patients. All M III and 22 of the MINI had 1 year follow-up, and were in NYHA class I or II. All patients with AF at 3 months follow-up (two in group I and three in group II) still had AF after 1 year (Table 4). Two patients of the MINI group recovered from their SSS and the pacemaker was switched off. All patients with SR or AAI-pacing had adequate atrial contraction documented by echo and MRI.

4. Discussion

AF is a common and sometimes fatal arrhythmia. The Maze procedure is a surgical treatment for AF developed by Cox et al. in 1991 [10]. Cox et al. suggested that the macroreentry circuits which cause AF be eliminated by the maze incisions. The Maze procedure establishes sinus rhythm in the majority of patients but the procedure is time-consuming. In 49 patients operated by Cox undergoing

Table 3
Comparison between patients with or without AF at first follow-up (n = 41)

<table>
<thead>
<tr>
<th>M III (n = 7)</th>
<th>MINI (n = 34)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR (n = 4)</td>
<td>AF (n = 2)</td>
<td>SSS (n = 1)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>66 ± 7</td>
<td>71 ± 5</td>
</tr>
<tr>
<td>Duration of AF (years)</td>
<td>7 ± 8</td>
<td>4 ± 1</td>
</tr>
<tr>
<td>LAD max pre OP (mm)</td>
<td>70 ± 9</td>
<td>88 ± 4</td>
</tr>
<tr>
<td>RAD max pre OP (mm)</td>
<td>58 ± 5</td>
<td>72 ± 4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M III (n = 7)</th>
<th>MINI (n = 34)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR (n = 26)</td>
<td>AF (n = 4)</td>
<td>SSS (n = 4)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>61 ± 10</td>
<td>68 ± 10</td>
</tr>
<tr>
<td>Duration of AF (years)</td>
<td>6 ± 5</td>
<td>9 ± 7</td>
</tr>
<tr>
<td>LAD max pre OP (mm)</td>
<td>67 ± 7</td>
<td>74 ± 6</td>
</tr>
<tr>
<td>RAD max pre OP (mm)</td>
<td>56 ± 4</td>
<td>61 ± 10</td>
</tr>
</tbody>
</table>

* LAD max pre OP, maximal left atrial diameter preoperatively; RAD max pre OP, maximal right atrial diameter preoperatively.

Table 4
Rhythm/sinus node function after 1 year (n = 29)

<table>
<thead>
<tr>
<th>Rhythm</th>
<th>MIII (n = 7)</th>
<th>MINI (n = 22)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>5</td>
<td>16</td>
<td>NS</td>
</tr>
<tr>
<td>SSS/PM (AAI-mode)</td>
<td>0</td>
<td>3</td>
<td>NS</td>
</tr>
<tr>
<td>AF</td>
<td>1</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>AF/DDD-PM</td>
<td>1</td>
<td>2</td>
<td>NS</td>
</tr>
</tbody>
</table>

* SR, sinus rhythm; SSS, sick sinus syndrome; PM, pacemaker; AF, atrial fibrillation; DDD-PM, double chamber pacemaker; AAP, single chamber pacemaker (atrium).
isolated Maze procedure, mean cardiopulmonary bypass time was 184 min (range 130–256 min) [17]. Therefore, some surgeons are reluctant to perform this operation especially in polymorbid patients, patients with poor left ventricular function and when an additional cardiac surgical procedure is necessary.

To minimize the potential risk, we developed a ‘Mini’-variant based on several descriptions in the literature [3,12–16]. The idea was to eliminate the time-consuming and risky incisions, but to fulfill the main goals of the Maze procedure such as reduction of atrial size, isolation of the pulmonary veins and interruption of the most frequent reentry circuits.

Although we did not perform all incisions proposed by Cox, 90% of patients in the Mini-Maze group with LA-diameter <70 mm showed SR after 1 year. Although we knew, that failure rate of Maze procedure in patients with atrial size greater 70 mm is high [14,15], we performed the procedure, since these patients were highly symptomatic and wished to have this operation absolutely.

With our Mini-variant we could reduce ECC- and clamp-time significantly although we performed more complex operation in the MINI-group.

Cox explained the effectiveness of the Maze procedure to cure AF by demonstrating the electrophysiological pattern of the wave front in the atrial myocardium. According to those electrical pathways it is impossible for macro-reentries to originate in any area of the atrium if the atriotomies are performed exactly as described. By dissecting all fibers and minimizing atrial size by sutures the pathways should be inhibited [17]. To date, Cox’s theory is not exactly proven. There are others who think that reduction of left and right atrial size is the key to eliminate AF. Batista et al. could eliminate AF by simply reducing left atrial size.

Kawaguchi et al. showed that normalizing left atrial size plays a pivotal role in terms of restoring sinus rhythm after the Maze procedure, Kamata et al. have shown, that atrial fibrillatory wave and left atrial diameter are independent predictors of sinus rhythm restoration after the Maze procedure [14,15,18]. In our series there was significant reduction of atrial size in both groups as well. However, there was no difference, between MINI and M III.

Cox showed that postoperative atrial dysrhythmias occur as a result of transient shortening of the atrial refractory period, permitting the generation of reentrant circuits within the limitations of the Maze incisions [17]. This theory also needs to be confirmed.

Clinical studies have shown that AF is associated with sick sinus, abnormal intra-atrial conduction, atrial enlargement and decreased atrial refractoriness. In patients with AF significant damage of sinus node, the perinodal tissue, and the sinus nodal artery is observed [19–21].

Four MINI (9%) and one M III (14%) patients still required a pacemaker at first follow-up because of SSS. The SSS is known to be induced by longstanding AF [19]. Others think that SSS develops due to atrial enlargement [22].

In an animal model Elvan et al. could show that chronic AF induces sinus node dysfunction, prolongs intra-atrial conduction time and shortens atrial refractoriness [20].

We did not perform an electrophysiological evaluation preoperatively. Thus, preoperative sinus node function was unknown. We think that SSS which is diagnosed postoperatively exists already before surgery but is hidden by AF. In our series we found a significant correlation between postoperative AF or SSS and preoperative duration of AF in the MINI group. There is evidence that results after Maze procedures are better with regard to restoration of sinus rhythm in patients with isolated AF. On the other hand, if combined mitral valve disease is present, the need for pacemaker implantation is lower when compared to patients with isolated AF. We did not find such a trend, since we only treated one patient with isolated AF.

Up to now, we don’t know if the underlying heart disease influences the success rate of MINI. Twelve of the MINI patients had AF combined with CAD, and all but one patient had stable SR after the procedure. However, this patient had a left atrial diameter (LAD) greater than 70 mm. But the role of ischemia in the genesis of AF in patients with CAD is unknown.

There are obviously multiple factors which influence the results of M III and the MINI. Structural alterations of left and right atrium may play a major roll in this context [4,23,24].

References

Appendix A. Conference discussion

Dr Y. Louagie (Mont Yvoir, Belgium): J. Cox insists very much on the left atrial incision performed towards the mitral annulus and on cryoablation of the coronary sinus to prevent early recurrence. You obviously omitted that part of the procedure. I am very interested by your results since they are good, even in the absence of that part of the procedure. Could you comment on that? In order to shorten crossclamp time, you can do the right part of the operation on the beating heart. Did you realize the right atrial incisions on the beating heart?

Dr Szalay: Yes, all right atrial incisions are performed on the beating heart.

Dr U. von Oppell (Cape Town, South Africa): What is the incidence of long-term requirements for postoperative antiarrhythmic medication in your two groups?

Dr Szalay: Directly after operation, antiarrhythmic medication was stopped because most of the patients showed junctional rhythm, and when the patient developed atrial fibrillation, we gave them sotalol and digoxin, and after the 3 months follow-up about half of the patients still needed this medication.

Dr J. Melo (Carnaxide, Portugal): I was a bit surprised with your two different patient populations, because even though your Maze population had the larger left atrium, your mini-Maze population had many more tricuspid procedures, and I was surprised to see that in a population with larger left atrium they had much less tricuspid procedures. What is the reason for that?

Talking about atrial transport function, we have to consider that we have two atria, right and left. So when we are talking about atrial transport function, you are talking on both atria or either one of them is waiting. Can you give us some details on that?

Dr Szalay: In the Maze III group we found larger left atrium preoperatively, because in this group we had only mitral valve disease. However, in the second group we also had patients with ischemic heart disease or aortic valve disease. I can not explain why we had to perform more tricuspid valve reconstructions in the mini-Maze group.

We documented the atrial transport function by echo and MRI. Atrial transport function was significant in both atria and significant means that atrial transport function was greater than 70 cm/s. Documented by echo.

Dr Melo: Do you believe that your better results with the mini-Maze is because those patients had smaller left atrium?

Dr Szalay: No. We found the same atrial reduction, and I don’t think that this is the reason.