Atrial Fibrillation

Left Atrial Versus Bi-Atrial Maze Operation Using Intraoperatively Cooled-Tip Radiofrequency Ablation in Patients Undergoing Open-Heart Surgery

Safety and Efficacy

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OBJECTIVES

We sought to determine whether limited left atrial Maze surgery encircling each of the pulmonary veins, using cooled-tip radiofrequency (RF) ablation, is as effective as the bi-atrial approach?

BACKGROUND

The original Cox/Maze operation effectively restores sinus rhythm (SR) in patients with atrial fibrillation (AF). Ablation procedures aimed at eliminating pulmonary vein foci have produced promising short-term success.

METHODS

This was a prospective analysis of patients with chronic AF undergoing open-heart surgery in addition to the Maze operation, using intraoperatively cooled-tip RF ablation either in the left atrium alone (group A) or in both atria (group B).

RESULTS

Patients in group A (n = 21) and group B (n = 49) did not differ in terms of their baseline characteristics. Concomitant open-heart surgical procedures included mitral valve replacement (3 vs. 25), mitral valve plasty (0 vs. 2), mitral and aortic valve replacement (1 vs. 1), aortic valve replacement (4 vs. 6) and coronary artery bypass grafting (13 vs. 15) in groups A and B, respectively. Follow-up ranged from 1 to 50 months. The overall cumulative rates of SR were 82% in group A and 75% in group B, without a statistically significant difference (p = 0.571). Bi-atrial contraction was revealed in 92.3% of patients in SR in group A and in 79.2% in group B. The cumulative survival rates were 90.5% in group A and 77.9% in group B (p = 0.880).

CONCLUSIONS

A left or bi-atrial Maze operation using intraoperatively cooled-tip RF ablation can safely be combined with open-heart surgery. A left atrial Maze procedure seems to be as effective as the bi-atrial procedure and restores SR in 82% of patients. (J Am Coll Cardiol 2002;39: 1644–50) © 2002 by the American College of Cardiology Foundation

Atrial fibrillation (AF) is often associated with other cardiac diseases, thus compromising the patient's clinical outcome. Restoration of sinus rhythm (SR) with atrioventricular resynchronization may be difficult in patients with chronic or permanent AF or other risk factors for AF (1–3).

The Maze procedure as an open-heart surgical approach, established by James Cox and associates, was found to effectively restore SR and atrial contraction in patients with intermittent or chronic AF. During the original procedure, linear lesions in the right and left atria were produced to prevent the occurrence of multiple reentrant wavelets identified during AF (4–12). This original Maze operation is extensive and time-consuming and requires great surgical skill. In contrast, more recently, Haissaguerre et al. (13) and Chen et al. (14) showed that the origin of AF may be confined to rapidly firing foci of the pulmonary veins.

Transvenous catheter ablation techniques have shown promising short-term results when ablating or isolating the pulmonary vein foci (15–17).

In our study, we employed two major modifications to facilitate the original Maze procedure: cooled-tip radiofrequency (RF) ablation was used to perform electrophysiologically transmural linear lesions, and the number of lesions was minimized by confining the procedure to the left atrium only. The efficacy of augmenting open-heart surgery with the modified Maze procedure only in the left atrium, using cooled-tip RF ablation, in patients with AF was evaluated, and the outcomes were compared with those of patients who had bi-atrial Maze surgery.

METHODS

This study was conducted as a prospective, nonrandomized analysis. The primary end point of our study was the occurrence of SR during postoperative follow-up. The secondary end points included survival, adverse events and atrial transport function.
Patients. Between March 1997 and February 2001, all patients undergoing a combination of open-heart surgery and the modified Maze procedure, using intraoperatively cooled-tip RF ablation, were included. Written, informed consent was given by all patients before their inclusion into the study. All patients had at least one year of chronic or permanent AF or unsuccessful direct-current shock cardioversion six months before inclusion.

Surgical procedure. All surgical procedures were performed in the Clinic of Cardiothoracic Surgery, “Bergmannsheil” University Hospital, Bochum, Germany. The additional Maze procedure was performed using cooled-tip RF ablation. According to the site of ablation, patients were prospectively assigned to one of two groups: group A had left atrial ablation only, with ablation lines around each pulmonary vein’s ostium, interconnections between the ostial lines and connecting lines to the mitral valve annulus and left atrial appendage; and group B had bi-atrial RF ablation, as previously described by Khargi et al. (18), with ablation lines in the right and left atria. Ablation lines in the left atrium did not differ between groups A and B (Fig. 1).

Follow-up. Postoperative follow-up was performed in the Department of Cardiology, “Bergmannsheil” University Hospital. Follow-up was performed on postoperative days 1 and 12 and after 3, 6 and 12 months, and then yearly. Some patients were also seen one month postoperatively. The anti-arrhythmic drug was sotalol (80 mg twice daily) for at least six months, up to April 1999. Then, drug treatment was switched to metoprolol succinate in an equipotent dosage (at least 47.5 to 95 mg/day).

At each follow-up visit, a clinical history and electrocardiogram were obtained. Sinus rhythm was defined as a supraventricular rhythm with P waves detectable on the standard 12-lead electrocardiogram. Holter monitoring was performed six months postoperatively.

After six months, echocardiography was performed, including transmitral and transtricuspid Doppler echocardiography. Detection of E and A waves was considered as atrial contraction.

All data were collected between March 1997 and February 2001.

Statistical analysis. Continuous variables are expressed as the mean value ± SD. The Student unpaired t test was used for comparison of variables between the two groups. Differences were considered statistically significant at p < 0.05.

The survival rates and cumulative rates of SR were calculated according to the Kaplan–Meier method, and the groups were compared using the log-rank test, with a statistically significant difference assumed at p < 0.05.
RESULTS

Seventy patients were included during the study period and had completed at least one month of follow-up. Group A consisted of 21 patients and group B of 49 patients. The patients did not differ in terms of their baseline characteristics (age, duration of AF before surgery, left atrial dimensions and preoperative ejection fraction) (Table 1). All patients had an indication for open-heart surgery, independent AF. Concomitant procedures performed in groups A and B included mitral valve replacement (3 vs. 25), mitral valve plasty (0 vs. 2), combined mitral and aortic valve replacement (1 vs. 1), combined mitral valve replacement (4 vs. 2), aortic valve replacement (4 vs. 6) and aorto-coronary bypass grafting (13 vs. 15) (Table 1).

Follow-up. All 70 patients completed at least one month of follow-up. The duration of follow-up ranged from 4 to 20 months (mean 11 ± 10) in group A and 1 to 50 months (mean 18 ± 14) in group B, with statistically significant longer follow-up durations in group B (p < 0.05).

In group A, 19 patients completed three months of follow-up; 17 patients completed six months; and 7 patients completed 12 months. In group B, 39 patients completed three months of follow-up; 36 patients completed six months; 29 patients completed 12 months; 21 patients completed 24 months; 7 patients completed 36 months; and 2 completed 48 months.

Cardiac rhythm. The cumulative rates of SR for complete follow-up were 82% (17 of 21 patients) for group A and 75% (34 of 49 patients) for group B, without a statistically significant difference (p = 0.571). The cumulative rates of SR evolved during follow-up in the two groups (group A vs. group B): at one month, 63% vs. 55%; at three months, 82% (16 of 19 patients) vs. 65% (26 of 39 patients); and at six months, 82% (14 of 17 patients) vs. 68% (24 of 36 patients). Only one patient in group B converted to SR more than six months after the procedure (at 24 months) (Fig. 2).

With completed follow-up in groups A and B, 16 of 21 patients and 34 of 49 patients, respectively, were in SR. The

Table 1. Baseline Patient Characteristics and Surgical Procedures

<table>
<thead>
<tr>
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<th>Group A</th>
<th>Group B</th>
<th>p Value</th>
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<tbody>
<tr>
<td></td>
<td>Left Atrial Maze*</td>
<td>Bi-Atrial Maze*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n = 21)</td>
<td>(n = 49)</td>
<td></td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>69 ± 9</td>
<td>65 ± 9</td>
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<tr>
<td>LA dimension (mm)</td>
<td>47 ± 8</td>
<td>51 ± 10</td>
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<td>Ejection fraction (%)</td>
<td>56 ± 10</td>
<td>59 ± 10</td>
<td>0.453</td>
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<tr>
<td>AF duration (yrs)</td>
<td>13 ± 17</td>
<td>9 ± 8</td>
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<tr>
<td>Range</td>
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<td>1–15</td>
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<tr>
<td>Follow-up (months)</td>
<td>11 ± 10</td>
<td>18 ± 14</td>
<td>0.046</td>
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<tr>
<td>Range</td>
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<td>1–50</td>
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<tr>
<td>MVR</td>
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<td>25</td>
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<tr>
<td>MVP</td>
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<td>2</td>
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<tr>
<td>MVR + AVR</td>
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<td>1</td>
<td></td>
</tr>
<tr>
<td>AVR</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>ACB (+ MVR)</td>
<td>13 (4)</td>
<td>15 (2)</td>
<td></td>
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*In addition to anti-arrhythmic surgery. Data are presented as the mean value ± SD or number of patients.

ACB = aorto-coronary bypass surgery; AF = atrial fibrillation; AVR = aortic valve replacement; LA = left atrial; MVP = mitral valve plasty; MVR = mitral valve replacement.

Figure 2. Cumulative rates of sinus rhythm during postoperative follow-up (group A = left atrial Maze procedure; group B = bi-atrial Maze procedure).
mode of conversion to SR was spontaneous in all patients in group A and in all but one patient (who had long-term success after direct-current shock cardioversion) in group B in SR (97% of all patients). Of the 15 patients still in AF in group B, 12 were electrically cardioverted (direct-current shock), with an immediate success rate of 27% (3 of 11 patients were in SR immediately after cardioversion); long-term success (SR at next follow-up visit) was achieved in only one patient (9.1% of cardioverted patients). No patient from group A was converted using direct-current shock. Overall, only 1 of the 12 patients who were cardioverted was converted to prolonged SR (8%).

One patient from group B converted from SR to AF 12 months postoperatively, when sotalol was replaced by metoprolol. After re-institution of sotalol, medication-stable SR was re-established.

Two patients from group B demonstrated atypical atrial flutter between one and three months of follow-up: one patient was converted to SR while increasing the sotalol dosage from 80 to 160 mg twice daily. In the other patient, catheter ablation was performed in the right atrium, closing a gap between the intercaval intraoperative ablation line and the upper caval vein. Long-term, stable SR was found after the procedure in both patients.

Holter monitoring revealed short runs of atrial tachycardia (<15% of the Holter interval) in two patients in SR in group A (12.5%) and 5 patients in group B (14.7%).

Doppler echocardiography. In groups A and B, 13 (81.3%) of 16 patients and 24 (70.6%) of 34 patients in SR, respectively, underwent Doppler echocardiography. Biatrial contraction was documented during transthoracic Doppler echocardiography in 12 of 13 patients in SR in group A (92.3%) and in 19 of 24 patients in SR in group B (79.2%). In group A, all of the patients in SR had documented right atrial contraction (100%). In group B, two patients (1 patient after 3 months and 1 patient after 6 months) had no detectable right atrial contraction on the transthoracic echocardiogram (92% with right atrial contraction).

Pacemaker indication and complications. Two patients in group B (4%) had permanent pacemakers implanted because of postoperative bradycardia (1 patient with DDD and 1 with VVI pacemaker). Implantation was performed during one to three months postoperatively. No patient in group A had an indication for postoperative pacemaker implantation.

Bleeding requiring transfusion occurred in three patients (1 in group A after aorto-coronary bypass grafting plus mitral valve replacement; 2 in group B [1 had renal bleeding with a lethal outcome after mitral valve replacement and 1 had gastrointestinal bleeding after aortic valve replacement]), all under standard anticoagulative therapy, as used after valve replacement. Pericardial effusion occurred in one patient in group A and in two patients in group B, without the need for further invasive therapy. Two patients in each group (1 after aorto-coronary bypass grafting and 1 after aortic valve replacement in group A and 2 after mitral valve replacement in group B) had transitory neurologic symptoms in the first days after the surgical procedure.

Duration of the surgical procedure. The mean bypass duration was 146 ± 34 min in group A and 179 ± 35 min in group B (p < 0.05). The mean aortic clamp duration was 98 ± 24 min in group A and 101 ± 20 min in group B (p = 0.53), showing a shorter duration in the group of patients with only the left atrial Maze operation.

Survival. The cumulative survival rates were not statistically significant different between the two groups (90% in group A vs. 78% in group B; p = 0.880) (Fig. 3). Two patients in group A died within 30 days after the operation: 1 patient died of mediastinitis 21 days postoperatively, and 1 died of postoperative severe pyoderma with sepsis after 28 days. In group B, six patients died during follow-up: one patient died 40 days postoperatively, due to renal bleeding; one died after 45 days, due to mediastinitis; one had sudden cardiac death after four months; one had progressive respiratory insufficiency at seven months; one had respiratory insufficiency at 16 months; and one died of an unknown cause (noncardiac or cerebral ischemia) after 33 months.

DISCUSSION

To the best of our knowledge, this study is a first analysis of data obtained in patients undergoing a modified Maze procedure in addition to another open-heart surgical procedure, comparing the left atrial approach with the bi-atrial Maze operation.

Background. The left atrial only approach was considered, based on the study findings of Haissaguerre et al. (13), who documented focal ectopies arising from the pulmonary veins, thus inducing paroxysmal AF. This mechanism was also considered to maintain permanent and/or persistent AF and may be stopped when ablating or isolating foci of the pulmonary veins. Sueda et al. (19) proposed a minimized left atrial approach for patients with mitral valve disease and documented left atrial foci during intraoperative AF mapping, with promising results regarding SR in 86% (13–16,19–21).

These findings lead to the concept of approaching the left atrium only during anti-arrhythmic surgery. In addition to isolating each of the four pulmonary vein’s ostia, an interconnection of the ablation line circles was performed, including additional ablation lines connecting the mitral valve annulus to the left atrial appendage.

Efficacy of the limited left atrial anti-arrhythmic procedure. This study was conducted to evaluate the efficacy and safety of the left atrial only approach during anti-arrhythmic surgery. In our experience with 70 patients, we retrospectively compared the outcomes of patients undergoing left atrial–only Maze surgery, using intraoperatively cooled-tip RF ablation, with the outcomes of patients undergoing bi-atrial Maze surgery, again using the RF ablation technique. Restoration of SR was documented in these patients, with a long duration of AF before the operation and large
left atrial dimensions in 81.6% of patients after the left atrial–only ablation procedure. Compared with patients undergoing bi-atrial ablation, who obtained SR at a rate of 74.5%, there was no statistically significant difference. These data are comparable to the results documented by different groups (5,7,8–11,22,23), who found restoration of SR between 72% and 99%, depending on the surgical procedure used and the patient cohort (e.g., concomitant underlying heart disease, idiopathic AF). Melo et al. (22) proposed a pulmonary vein isolation technique with one incision encircling the four pulmonary veins, producing SR with bi-atrial contraction in only 33% of the patients after one year. One-third of the patients remained in AF after this procedure. The left atrial approach we proposed, encircling each of the four pulmonary vein ostium, seems to produce a higher rate of SR.

**Failure of the anti-arrhythmic procedure.** The mechanisms for failure of the left atrial–only procedure still need to be investigated. On the one hand, there may be gaps in the ablation lines, causing recurrent reentry circles, or on the other hand, the origin of the arrhythmia was not in the left atrium, as proposed to be the case in 9% to 19% of patients with underlying mitral valve disease. The mechanism of AF may be different in terms of the underlying heart disease. Patients with right atrial foci should benefit from the bi-atrial approach, even though there is no higher rate of SR in these patients, as documented in our study. Further evaluation using modern electroanatomic mapping systems may be helpful in understanding the mechanisms in patients with failure (19,20,24).

**Atrial function after anti-arrhythmic surgery.** An important aim of restoring SR is to produce atrial contraction of both atria, to restore atrioventricular electromechanical synchrony and to decrease the risk of cardiac thromboembolism. In our study, bi-atrial contraction was restored in 92.3% of patients in SR after the left atrial approach and in 79.2% of patients in SR after the bi-atrial Maze operation. The outcome of these patients can be defined as complete success (score 4), when applying the Santa Cruz scoring system initiated by Melo et al. (22). The difference between the two groups may be the result of the fewer patients with mitral valve disease in the group undergoing left atrial incisions only, who seem to have a poorer prognosis for SR restoration and larger atrial dimensions. In contrast, the higher rate of effective bi-atrial contraction may be attributed to the minimized procedure itself. A smaller atrial area was isolated (preventing contraction), which may lead to more completely contracting atrial tissue (22). The left atrial incisions and ablation lines were the same in both groups. Our data are equivalent to the published data that document the occurrence of bi-atrial contraction in 66.7% to 99% of patients. Again, the results differ in terms of the applied surgical procedure and the baseline characteristics of the patients (22).

The rates of left atrial contraction may be underestimated by transthoracic echocardiography. Cox (4) proposed that left atrial contraction can more often be demonstrated by transesophageal echocardiography, compared with transthoracic echocardiography. The question remaining is whether patients without documented left atrial contraction (during transthoracic or transesophageal echocardiography)
should be anticoagulated, and to what extent (anticoagulation plus antithrombotic medication?).

**Safety of intraoperatively cooled-tip RF ablation.** The safety of adding the modified Maze operation (either left atrial or bi-atrial), as proposed in our study, can be derived from the low 30-day mortality and low complication rates. Two patients died within the first 30 days after the operation, and another death due to mediastinitis after 45 days might be associated with the anti-arrhythmic procedure added to the surgical procedure. Although these mortality rates are not higher than those associated with open-heart surgery, without additional anti-arrhythmic procedures, a mediastinal infection might become an acute postoperative complication. Antibiotic treatment and repeat operations have a high rate of failure, so that prevention by minimizing the procedure’s duration (or limiting the number of ablation lines) should be anticipated.

Our data are comparable to those published by different investigators, but again, the differing patient characteristics must be accounted for (5,7–11). Adding the anti-arrhythmic procedure to another open-heart operation may lead to higher mortality, even though there was no significant difference seen in a randomized study of patients undergoing mitral valve replacement with or without the Maze procedure (Deneke et al. [25]). This needs to be analyzed in further prospective, randomized studies including larger patient cohorts.

We found a shorter bypass time and aortic clamp duration in patients who received ablation in the left atrium only, which can be attributed to the shorter procedure, as it was restricted to one atrium. The bypass time was not significantly different between the two groups, because of the need for cardiopulmonary bypass for blood-free access to the left atrium.

We did not find any adverse events related to the postoperative care after the left atrial Maze procedure; in particular, there were no cases of pulmonary vein stenosis and no indication for pacemaker implantation. Pulmonary vein stenosis may occur when ablation is done inside the veins, which is one major drawback of focal catheter ablation of AF. The approach of encircling each of the pulmonary vein’s ostia diminishes the risk of this complication. During our whole experience, two patients received a permanent pacemaker due to postoperative bradycardia, which has been reported previously (5,8). Whether the requirement for pacemaker therapy was due to the Maze procedure or preoperative sinus node dysfunction cannot be evaluated. Some of the patients may demonstrate late stages of sick sinus syndrome, with an indication for pacemaker therapy, due to this disease itself (5).

**Anti-arrhythmic medication after anti-arrhythmic surgery.** Still under debate is the appropriate anti-arrhythmic medication after open-heart surgery and especially after anti-arrhythmic surgical procedures. Although Cox et al. (5) studied a high number of patients who received no anti-arrhythmic drug therapy postoperatively (94%), this may only be possible in patients with idiopathic AF. It has been widely established that sotalol should be administered in the early postoperative period, but it is less clear what to do in the long term. In the beginning of our experience, we treated patients with sotalol for at least six months (26).

**Cardioversion after anti-arrhythmic surgery.** Another descriptive finding is the low long-term efficacy of electric cardioversion in patients who have undergone anti-arrhythmic surgery. Only 50% of overall patients with AF agreed to direct-current cardioversion in the first six months after the operation. Only one patient had long-term success (96%), despite a rather aggressive cardioversion protocol. From this finding, we derived a stepwise action plan for these patients: all patients were put on metoprolol therapy, and spontaneous conversion was awaited during the first six months after the operation. Only if patients were still in AF for more than six months after the anti-arrhythmic surgery was direct-current shock cardioversion anticipated once during follow-up.

**Study limitations.** Our study was a retrospective analysis of a rather small number of patients. Randomization was not performed, but the two groups showed no statistically significant difference in terms of their baseline characteristics. This analysis was performed in patients over almost four years, during which time the device used to perform the cooled-tip RF ablation lines was changed twice, even though the pattern of the ablation lines was kept the same. This may have effects on the efficacy of the procedure, especially when considering that patients in group A were underwent the operation in the later phase of the observational period.

**Conclusions**

1. A left atrial anti-arrhythmic procedure establishing linear lesions encircling each ostium of the pulmonary vein, using cooled-tip RF ablation, can restore SR in patients with chronic AF.
2. Left atrial Maze surgery using intraoperative RF ablation can safely be combined with other open-heart surgical procedures and restores SR as effectively as the bi-atrial approach (in 81.6% of patients in chronic AF).
3. Bi-atrial contraction can be restored after the left atrial Maze procedure in 92.3% of patients in SR.
4. Direct-current shock cardioversion seems to show low long-term efficacy in patients who have undergone the Maze operation.

Larger prospective, randomized trials that can evaluate the left atrial-only approach for anti-arrhythmic surgery, as well as detect patients with a poorer prognosis for stable SR, are needed before this procedure can be universally accepted.

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REFERENCES


