Long-Term Outcomes of Mechanical Valve Replacement in Patients With Atrial Fibrillation
Impact of the Maze Procedure

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Background—The long-term benefits of the maze procedure in patients with chronic atrial fibrillation undergoing mechanical valve replacement who already require lifelong anticoagulation remain unclear.

Methods and Results—We evaluated adverse outcomes (death; thromboembolic events; composite of death, heart failure, or valve-related complications) in 569 patients with atrial fibrillation–associated valvular heart disease who underwent mechanical valve replacement with (n=317) or without (n=252) a concomitant maze procedure between 1999 and 2010. After adjustment for differences in baseline risk profiles, patients who had undergone the maze procedure were at similar risks of death (hazard ratio, 1.15; 95% confidence interval, 0.65–2.03; P=0.63) and the composite outcomes (hazard ratio, 0.82; 95% confidence interval, 0.50–1.34; P=0.42) but a significantly lower risk of thromboembolic events (hazard ratio, 0.29; 95% confidence interval, 0.12–0.73; P=0.008) compared with those who underwent valve replacement alone at a median follow-up of 63.6 months (range, 0.2–149.9 months). The effect of superior event-free survival by the concomitant maze procedure was notable in a low-risk EuroSCORE (0–3) subgroup (P=0.049), but it was insignificant in a high-risk EuroSCORE (≥4) subgroup (P=0.65). Furthermore, the combination of the maze procedure resulted in superior left ventricular (P<0.001) and tricuspid valvular functions (P<0.001) compared with valve replacement alone on echocardiographic assessments performed at a median of 52.7 months (range, 6.0–146.8 months) after surgery.

Conclusion—Compared with valve replacement alone, the addition of the maze procedure was associated with a reduction in thromboembolic complications and improvements in hemodynamic performance in patients undergoing mechanical valve replacement, particularly in those with low risk of surgery. (Circulation. 2012;125:2071-2080.)

Key Words: ablation ■ atrial fibrillation ■ heart valve prosthesis ■ heart valve prosthesis implantation ■ surgery ■ valve replacement

Since the recognition of the maze procedure as an effective method of restoring normal sinus rhythm in patients with atrial fibrillation (AF), it has gained popularity as a concomitant procedure during surgery for structural heart diseases.1–4 The maze procedure has been found to result in symptom improvement, improved hemodynamics, a reduction in thromboembolic events, and even improved survival.5–8

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However, concerns still exist with regard to routinely combining the maze procedure with major cardiac surgery because it may increase surgical risks as a consequence of increased cardiac ischemic time and more extensive surgery.1,9 These arguments can be further justified when it comes to performing the maze procedure on patients undergoing mechanical heart valve replacement. Unlike patients undergoing valve repair or bioprosthetic valve replacement whose risks of thromboembolism or anticoagulation-related hemorrhage can be minimized by restoration of sinus rhythm, the benefits of the maze procedure may be limited to theoretical advantages of hemodynamic improvements in patients receiving mechanical valve replacement.1 In this regard, an evaluation of clinical results after mechanical valve replacement combined with the maze procedure compared with valve replacement...
replacement alone in a reasonably sized cohort of patients with valvular AF is clinically important. We therefore evaluated the long-term clinical outcomes of patients with valvular AF who underwent mechanical valve replacement with or without a concomitant maze procedure. For further measures, we compared functional status and echocardiographic parameters of left ventricular (LV) function and tricuspid regurgitation (TR) in these 2 groups of patients.

Methods

Patients

All patients undergoing major cardiac surgery are prospectively registered in the database at our institution, which records baseline patient characteristics, results of cardiac evaluations, detailed information on surgery, and perioperative complications. We screened this registry to identify patients with AF associated with left-side valve disease who underwent mechanical valve replacement between January 1999 and January 2010. To form a homogeneous study population, we excluded patients diagnosed with symptomatic coronary disease or infective endocarditis and those who underwent concomitant cardiac surgery for correction of congenital heart defects, aortic replacement, or tricuspid/pulmonic valve replacement. However, patients found to have incidental coronary lesions during preoperative screening, including the need for coronary artery bypassing, were not excluded. Finally, we identified 559 patients who met the enrollment criteria and formed the study population; of these, 317 patients concomitantly underwent the maze procedure (maze group) and 252 underwent mechanical valve replacement alone (control group). Some of these patients had been included in previous reports on surgical ablation of AF in patients undergoing mitral valve (MV) surgery.10,11 The decision to perform the maze procedure was influenced by several demographic (age), clinical (severity of symptoms, left atrium [LA] size), and procedural (replaced valve position) factors but was at the discretion of the attending surgeon; we had different attitudes regarding the performance of the maze procedure in patients undergoing mechanical valve replacement.

This study was approved by our institutional Ethics Committee/Review Board, which waived the requirement for informed patient consent because of the retrospective nature of the study.

Surgical Procedures

In the maze group, 285 underwent cryoablation and 32 underwent microwave ablation via an endocardial approach. The lesion sets for the maze procedure have been described previously.3,8,12 Briefly, LA ablation started with a longitudinal right-sided left atriotomy. Left-side ablation included separate left and right isolation lesions in 232 patients and a single box lesion in 85 patients to isolate pulmonary veins, with 2 connecting lines from the pulmonary isolation lesion to the LA appendage and the MV annulus, respectively. Additional epicardial coronary sinus ablation was performed on the opposite side of the MV annular lesion. LA size was reduced by resection of redundant atrial tissue between the inferior pulmonary veins and posterior mitral annulus. The LA appendage was amputated in 201 patients as part of the maze procedure and preserved in 88. Right-side ablation was followed by an oblique right atriotomy involving a cavotricuspid isthmus isolation lesion and a line from the isthmus lesion to the superior vena cava. During MV replacement, the surgeons attempted to retain as much subvalvular tissue as possible in a chordae-sparing manner.

Postoperative Management and Rhythm Assessments

Anticoagulation therapy was adjusted during outpatient visits at 3-month intervals to achieve a target international normalized ratio of 2.0 to 3.0, regardless of cardiac rhythm. Patients with inadequate international normalized ratio values were followed up weekly or monthly until the target international normalized ratio value was achieved.

Generally, follow-up electrocardiography assessments were performed at 3, 6, 12, 18, and 24 months after surgery and every year thereafter. For patients considered to have restored sinus rhythm, 24-hour Holter monitoring was done to validate that they were free of AF in the presence of symptoms suggestive of arrhythmia. Any 1 of the following 3 rhythms was considered postoperative AF if it had a duration of ≥30 seconds by the monitoring: AF, atrial flutter, or atrial tachycardia.1

Overall, 5274 ECGs (12 lead; 3233 [10.2 per patient] in the maze group and 2041 [8.1 per patient] in the control group) and 419 sets of 24-hour Holter monitoring data (398 in the maze group and 21 in the control group) were retrieved, and every patient had at least 1 record available. Among 1-year surviving patients (n=550), 494 (89.8%) had an ECG ≥1 year after the operation (median, 4.7 years; range, 1.0–11.4 years).

Patients in the maze group with postoperatively detected AF, atrial flutter, or paroxysmal atrial tachycardia were managed with the rhythm control strategy involving class I or III antiarrhythmic medications (amiodarone, sotalol, flecainide, or propafenone). Patients who failed to achieve freedom from AF after treatment with class I or III antiarrhythmic medications for a sufficient period of time were discontinued from those drugs and switched to the rate control strategy involving digitalis, β-blockers, or calcium channel blockers to control ventricular rate. Patients who did not undergo the maze procedure were managed with the rate control strategy.

Definitions and Data Collection

The primary end points were all-cause death and thromboembolic events. All-cause death rather than cardiac death was chosen as one of the primary end points because it is the most robust and unbiased index, requiring no adjudication to avoid inaccurate or biased documentation and clinical assessments.13 Thromboembolic events were clinically diagnosed, which may be manifested by a neurological event (stroke or transient ischemic attack) or a noncerebral (peripheral) embolic event. Peripheral embolism should have produced signs or symptoms attributable to complete or partial obstruction of a peripheral artery.14

Secondary end points were the composite of death, congestive heart failure (CHF) requiring hospitalization, and valve-related complications—including thromboembolic events, infective endocarditis, and bleeding complications secondary to anticoagulation—or a requirement for reoperation. A CHF hospitalization was defined as an unplanned, urgent admission for management of CHF. Any patient admitted for CHF had to show resting dyspnea and radiological signs of pulmonary edema and had to require intravenous diuretics. Bleeding secondary to anticoagulation was defined as any requirement for transfusion, unplanned hospital admission, or a hemostatic intervention.

Clinical follow-up was performed via outpatient clinic visits every 3 months (n=505). For those who were followed up at other hospitals (n=64), clinical information was obtained from telephone contacts. For validation of complete follow-up, information on mortality, data on vital status, and dates and causes of death were obtained through August 31, 2011, from the Korean National Registry of Vital Statistics. All deaths were considered of cardiac origin unless a noncardiac origin was established clinically or was determined at autopsy.

Statistical Analysis

Categorical variables, presented as frequencies and percentages, were compared by use of the χ² test or Fisher exact test. Continuous variables, expressed as mean±SD or median with range, were compared by use of the Student unpaired t test or the Mann-Whitney U test as appropriate. Cumulative incidence rates of individual and composite outcomes were estimated by the Kaplan-Meier method and compared by use of the log-rank test.
To reduce the effect of treatment selection bias and potential confounding, we adjusted for differences in baseline characteristics by weighted Cox proportional-hazards regression models and inverse probability of treatment weighting.15,16 With that technique, weights for patients receiving valve replacement alone were the inverse of 1—propensity score, and weights for patients receiving valve replacement plus the maze procedure were the inverse of the propensity score. Propensity scores were estimated without regard to outcome variables with the use of multiple logistic regression analysis. Prespecified covariates listed in Table 1 were included in the full nonparsimonious models for valve replacement plus the maze procedure versus valve replacement alone. The discrimination and calibration abilities of the propensity score model were assessed by means of C statistics and the Hosmer-Lemeshow goodness-of-fit value of \( P \geq 0.75 \), indicating that this model was well calibrated with strong discrimination.

To compare the echocardiographic parameters and functional status at last follow-up of the 2 groups, we determined propensity score—matched groups. Propensity score—matched pairs without replacement (a 1:1 match) were determined by use of a greedy 5-to-1 digit match algorithm.17 After propensity score matching, the echocardiographic and clinical parameters of the 2 groups were compared by use of paired \( t \)-tests or Wilcoxon signed-rank tests for continuous variables and McNemar tests or marginal homogeneity tests for categorical variables.

All reported \( P \) values were 2 sided, and a value of \( P<0.05 \) was considered statistically significant. SAS software version 9.1 (SAS Institute, Cary, NC) and SPSS version 12 were used for the statistical analyses.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

### Results

#### Baseline Patient Characteristics

The baseline demographic and clinical characteristics of the patients are shown in Table 1. Patients who underwent a concomitant maze procedure were younger, had fewer symptoms, and were more likely to have a history of previous cardiac surgery and to undergo concomitant aortic valve surgery than patients who underwent MV replacement alone. LV size was larger in the maze group, whereas LA size was larger in the control group. Other baseline characteristics were similar in the 2 groups, including distributions of the CHAD2 score and EuroSCORE (Table 1).

The aortic cross-clamping times (111.4 ± 35.8 versus 74.2 ± 42.8 minutes; \( P<0.001 \)) and cardiopulmonary bypass times (159.9 ± 48.7 versus 117.0 ± 61.8 minutes; \( P<0.001 \)) were significantly longer in the maze than in the control group.

#### Early Operative Results and Long-Term Rhythm Outcomes

There were 7 early deaths (1.2%) but no significant differences in early mortality or major morbidity rates between the 2 groups, including the rates of low-cardiac-output syndrome, bleeding requiring re-exploration, or permanent pacemaker implantation (Table 2).

Throughout long-term postoperative follow-up, patients who underwent the maze procedure showed superior freedom from AF compared with those who did not (Figure 1).
Freedom from AF off class I/III antiarrhythmic medications during each postoperative year ranged from 70.0% to 91.2% in the maze group and from 16.7% to 27.2% in the control group (P<0.001 for all postoperative time points).

**Overall Clinical Outcomes**

Median follow-up duration was 63.6 months (range, 0.2–149.9 months [3224.9 patient-years]). During the entire study period, 55 patients (9.7%) died and 23 (4.0%) experienced thromboembolic events, including nonhemorrhagic stroke in 20, transient ischemic attack in 2, and embolic renal infarction in 1. Other major adverse outcomes included readmission because of CHF in 16 patients (2.8%), anticoagulation-related hemorrhage in 60 (10.5%), heart valve reoperation in 13 (2.3%), and infective endocarditis in 2 (0.4%; Table 2). Figure 2 depicts the unadjusted overall survival, freedom from thromboembolism, thromboembolism-free survival, and major event-free survival in the 2 groups. The linearized rates of death, thromboembolic events, and the composite outcome were 1.9%, 0.4%, and 4.1% per patient-year, respectively, in the maze group and 1.5%, 0.9%, and 4.6% per patient-year, respectively, in the control group (P=0.73, P=0.059, and P=0.27, respectively).

Table 3 summarizes the adjusted hazard ratios for clinical end points in the maze group compared with the control group. Patients undergoing the concomitant maze procedure were at a significantly lower risk of thromboembolic events and showed comparable risks of death and the composite outcome.

Figure 3 shows treatment-related clinical outcomes in patients at low to medium (0–3; n=268) and medium to high (>3; n=301) risk as determined by EuroSCORE. In this subgroup analysis, the addition of the maze procedure had no significant effects on the risks of death in the low- (P=0.92) and high- (P=0.39) EuroSCORE groups. In the low-EuroSCORE group, however, the addition of the maze procedure significantly reduced the risks of thromboembolism (P=0.040) and the composite outcome (P=0.049), but these benefits were not observed in the high-EuroSCORE group.

### Table 2. Operative Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Maze Group (n=317)</th>
<th>Control Group (n=252)</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Early (within 30 d) death, n (%)</td>
<td>5 (1.6)</td>
<td>2 (0.8)</td>
<td>0.47</td>
</tr>
<tr>
<td>Patients with early major morbidity, n (%)</td>
<td>44 (13.9)</td>
<td>39 (15.5)</td>
<td>0.59</td>
</tr>
<tr>
<td>Low cardiac output syndrome</td>
<td>4 (1.3)</td>
<td>2 (0.8)</td>
<td>0.59</td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (0.3)</td>
<td>0</td>
<td>0.37</td>
</tr>
<tr>
<td>Ventricular tachycardia/fibrillation</td>
<td>2 (0.6)</td>
<td>0</td>
<td>0.21</td>
</tr>
<tr>
<td>Requirement for new dialysis</td>
<td>6 (1.9)</td>
<td>5 (2.0)</td>
<td>0.94</td>
</tr>
<tr>
<td>Surgical bleeding requiring re-exploration</td>
<td>16 (5.0)</td>
<td>16 (6.3)</td>
<td>0.50</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>18 (5.7)</td>
<td>14 (5.6)</td>
<td>0.95</td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>0</td>
<td>1 (0.4)</td>
<td>0.26</td>
</tr>
<tr>
<td>Surgical-site wound problem</td>
<td>7 (2.2)</td>
<td>5 (2.0)</td>
<td>0.85</td>
</tr>
<tr>
<td>Permanent pacemaker implantation</td>
<td>8 (2.5)</td>
<td>3 (1.2)</td>
<td>0.25</td>
</tr>
<tr>
<td>Primary outcomes, n (%)</td>
<td>32 (10.1)</td>
<td>44 (17.5)</td>
<td>0.010</td>
</tr>
<tr>
<td>Death</td>
<td>25 (7.9)</td>
<td>30 (11.9)</td>
<td>0.11</td>
</tr>
<tr>
<td>Thromboembolic events</td>
<td>7 (2.2)</td>
<td>16 (6.3)</td>
<td>0.013</td>
</tr>
<tr>
<td>Secondary outcomes, n (%)</td>
<td>64 (20.2)</td>
<td>76 (30.2)</td>
<td>0.006</td>
</tr>
<tr>
<td>Admission for CHF</td>
<td>6 (1.9)</td>
<td>10 (4.0)</td>
<td>0.14</td>
</tr>
<tr>
<td>Anticoagulation-related bleeding</td>
<td>27 (8.5)</td>
<td>33 (13.1)</td>
<td>0.077</td>
</tr>
<tr>
<td>Cardiac reoperation</td>
<td>2 (0.6)</td>
<td>11 (4.4)</td>
<td>0.004</td>
</tr>
<tr>
<td>Infective endocarditis</td>
<td>1 (0.3)</td>
<td>1 (0.4)</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>All clinical endpoints, n (%)</td>
<td>64 (20.2)</td>
<td>76 (30.2)</td>
<td>0.006</td>
</tr>
</tbody>
</table>

CHF indicates congestive heart failure.

Freedom from AF off class I/III antiarrhythmic medications during each postoperative year ranged from 70.0% to 91.2% in the maze group and from 16.7% to 27.2% in the control group (P<0.001 for all postoperative time points).
Echocardiographic and Functional Parameters at Late Follow-Up (>6 months)

Echocardiographic data >6 months after surgery were available for 459 of the 557 patients (82.4%) who survived >6 months. The median echocardiographic follow-up period was 52.7 months (range, 6.0–146.8 months). Among these patients, 103 pairs of patients could be yielded by propensity score matching for the comparisons of echocardiographic and functional parameters at late follow-up (55.4±35.6 months); there were no significant differences in baseline profiles between the 2 groups, including the echocardiographic follow-up duration (53.5±32.8 and 57.3±34.4 months in the maze and control groups, respectively; \( P=0.23 \)).

Figure 4 shows comparisons of preoperative and last follow-up (>6 months) echocardiographic parameters in the maze and control groups. Compared with preoperative findings, both groups showed significant reductions in LV systolic/diastolic dimensions and LA dimension, although a significant improvement in LV ejection was observed only in the maze group. At the last follow-up, patients in the maze group had significantly higher LV ejection fraction and significantly smaller LV and LA dimensions than patients in the control group.

Figure 5 shows the postsurgical changes in TR in both groups. In the entire propensity-matched cohort (n=206), the degree of TR was significantly lower in the maze group.

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Table 3. Adjusted Hazard Ratios for Clinical Outcomes of the Maze Procedure Compared With the Control Group

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>HR</th>
<th>95% CI</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>0.91</td>
<td>0.53–1.56</td>
<td>0.73</td>
</tr>
<tr>
<td>Propensity score*</td>
<td>1.13</td>
<td>0.63–2.01</td>
<td>0.69</td>
</tr>
<tr>
<td>IPTW</td>
<td>1.15</td>
<td>0.65–2.03</td>
<td>0.63</td>
</tr>
<tr>
<td>Thromboembolism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>0.42</td>
<td>0.17–1.03</td>
<td>0.059</td>
</tr>
<tr>
<td>Propensity score*</td>
<td>0.28</td>
<td>0.10–0.77</td>
<td>0.014</td>
</tr>
<tr>
<td>IPTW</td>
<td>0.29</td>
<td>0.12–0.73</td>
<td>0.008</td>
</tr>
<tr>
<td>Composite outcome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>0.83</td>
<td>0.59–1.16</td>
<td>0.27</td>
</tr>
<tr>
<td>Propensity score*</td>
<td>0.80</td>
<td>0.55–1.16</td>
<td>0.24</td>
</tr>
<tr>
<td>IPTW</td>
<td>0.82</td>
<td>0.50–1.34</td>
<td>0.42</td>
</tr>
</tbody>
</table>

HR indicates hazard ratio; CI, confidence interval; and IPTW, inverse probability of treatment weighting.

* Covariance adjustment on propensity score.
than in the control group \((P<0.001)\). These differences were also observed in the 31 pairs of patients who underwent concomitant tricuspid valve repair \((P=0.092)\) and in the 72 pairs who did not \((P=0.001)\).

Although both groups showed significant improvements in New York Heart Association functional class after surgery \((P<0.001)\), patients in the maze group tended to have better functional status than those in the control group \((P=0.098; \text{Figure 6})\).
Despite anticoagulation therapy, the rate of major systemic embolism after mechanical valve replacement remains 0.8%/y to 3%/y.18–21 This thromboembolic risk is enhanced by several risk factors such as advanced age, history of stroke, and the presence of chronic AF,21,22 with chronic AF regarded as the most significant but only correctable factor. In an effort to reduce this serious complication after mechanical valve replacement, several groups advocated combining the maze procedure to eliminate AF. Additional potential benefits of the concomitant maze procedure include better hemodynamic results by incorporating atrial kicking into the generation of cardiac output, elimination of palpitation symptoms, and consequent improvements in overall functional outcomes.1,5,23,24

**Discussion**

Despite anticoagulation therapy, the rate of major systemic embolism after mechanical valve replacement remains 0.8%/y to 3%/y.18–21 This thromboembolic risk is enhanced by several risk factors such as advanced age, history of stroke, and the presence of chronic AF,21,22 with chronic AF regarded as the most significant but only correctable factor. In an effort to reduce this serious complication after mechanical valve replacement, several groups advocated combining the maze procedure to eliminate AF. Additional potential benefits of the concomitant maze procedure include better hemodynamic results by incorporating atrial kicking into the generation of cardiac output, elimination of palpitation symptoms, and consequent improvements in overall functional outcomes.1,5,23,24

In contrast, combining the maze procedure with mechanical replacement has been criticized because (1) further reductions in thromboembolic risk are doubtful compared...
with anticoagulation therapy alone, (2) the increased
cardiac ischemic and cardiopulmonary bypass times
needed for the maze procedure may hamper early postoperative recovery, and (3) more troublesome bradyarrhythmia may occur more frequently.1,9 To address these possible drawbacks, several studies have assessed the effect of the maze procedure on long-term clinical outcomes in patients with valvular AF patients, but the results had been mixed. Unlike the reports showing that adding the maze procedure to mechanical valve replacement significantly reduced thromboembolic complications in AF patients, a review of 5466 patients followed up for a mean 6.6 years found that conversion to sinus rhythm did not improve long-term survival or reduce the incidence of embolic complications after valve surgery.9 Although patients with preoperative AF had poorer survival than patients without preoperative AF in the cited study, the authors concluded that AF may be a marker of advanced disease in these patients rather than a cause of poor outcomes.

Our data suggest that the risk of thromboembolic complications can be reduced by the concomitant maze procedure. In contrast, the survival and overall event-free survival rates were not affected by the maze procedure, indicating that the decreased incidence of thromboembolic events and improvements in hemodynamic profiles may not directly translate into improved survival or decreased incidence of overall adverse events.

It remains unclear whether the maze procedure should be combined with major cardiac surgery in high-risk patients. High-risk patients such as elderly patients and those with advanced heart failure or low LV ejection fraction may benefit more from restoration of sinus rhythm than low- or average-risk patients. At the same time, however, these vulnerable patients may have more difficulties in overcoming the early perioperative risks associated with increased procedural extent and prolonged cardiopulmonary bypass and aortic cross-clamping times. It remains unclear whether the benefits of the maze procedure can offset the risks added by this procedure. In this study, we found that the addition of the maze procedure in patients with low to intermediate EuroSCOREs (0–3) significantly reduced thromboembolic risks (hazard ratio, 0.18; \( P = 0.040 \)) and enhanced overall event-free survival (hazard ratio, 0.48; \( P = 0.049 \)), whereas these benefits were not observed in patients with intermediate to high EuroSCOREs. Further studies, including detailed analyses of early and late clinical outcomes, are needed to confirm our findings and to test the risk-benefit effects of the maze procedure in high-risk populations.

In agreement with previous reports, we observed that the addition of the maze procedure significantly improved LV function. For example, Stulak et al25 reported that surgical AF ablation in patients with lone AF improved LV ejection and reduced LV end-diastolic diameter significantly. In that study, the improvement in LV function appeared during the immediate postoperative period and was maintained for a median of 48 months. Several underlying mechanisms may explain this phenomenon. First, restoration of atrioventricular synchrony can improve diastolic function, resulting in increased cardiac output up to 15%.26 Because AF can also lead to tachycardia-induced cardiomyopathy, elimination of AF can restore LV function by blocking this pathological process.27–30 Tachycardia-induced cardiomyopathy is commonly thought to be associated with chronic arrhythmias having ventricular rates >100 to 120 bpm. Even when the ventricular rate is regarded as being under adequate control with medications, the resting heart rate may not truly reflect the overall heart rate in patients with AF. Even in patients with well-controlled resting heart rates, a rapid ventricular rate can frequently be induced by minimal activity, which can be associated with the development of tachycardia-induced cardiomyopathy.31

Because AF can contribute to the development and aggravation of functional TR, the concomitant maze procedure may prevent late functional TR progression in patients with AF undergoing left-sided valve surgery, with 1 study showing that performance of the maze procedure was the most important predictor of TR aggravation after MV surgery.34 In that study, the maze procedure more strongly protected against TR progression than tricuspid valve repair did. We found that the maze procedure may benefit patients by preventing late TR, reinforcing previous results. This effect was consistent throughout the subgroups of patients who underwent concomitant tricuspid valve repair and those who did not.

Although functional status tended to be better in the maze than in the control group, the benefits were modest (\( P = 0.098 \)). Furthermore, the rates of readmission for CHF were similar in the 2 groups. This may be attributable to the small number of patients in each group who had experienced symptoms of advanced heart failure late after surgery. Studies in a larger population may be needed to differentiate, with reasonable statistical power, the effects of these 2 surgical strategies on functional status.

**Study Limitations**

This study is subject to the limitations inherent to a retrospective analysis of observational data. The decision to perform concomitant maze procedure was affected by patients’ preoperative conditions, and the maze group patients tended to have better clinical conditions (younger, better New York Heart Association functional class, smaller LA size) than the control group patients. Although we used propensity score analysis to adjust for this selection bias, unmeasured confounders, procedure bias, or detection bias may have affected our results. The number of events in each EuroSCORE subgroup was relatively small for differentiating the clinical effects of maze procedure, especially on thromboembolic events, between the 2 subgroups.

**Conclusions**

Compared with valve replacement alone, the addition of the maze procedure was associated with a reduction in
thromboembolic complications but not with notable survival benefits in patients undergoing mechanical valve replacement, particularly in those at low risk from surgery. The concomitant maze procedure was associated with improved LV function, prevention of late TR, and modest survival benefits in patients undergoing mechanical valve replacement, particularly in those at low risk from surgery. The approach for individual patients should be tailored according to their projected risks of surgical mortality/morbidity. Conclusions from a comparison of valve replacement alone and valve replacement plus the maze procedure in these patients await the results of prospective randomized trials.

Disclosures

None.

References


2. Cohn LH, Couper GS, Aranki SF, Rizzo RJ, Kinchla NM, Collins JJ. Long-term results of mitral valve replacement for regurgitation developed in partnership with the European Heart Rhythm Association (EHRA) and the European Cardiac Arrhythmia Society (ECAS); in collaboration with the American College of Cardiology (ACC), American Heart Association (AHA), and the Society of Thoracic Surgeons (STS). Endorsed and approved by the governing bodies of the American College of Cardiology, the American Heart Association, the European Cardiac Arrhythmia Society, the European Heart Rhythm Association, the Society of Thoracic Surgeons, and the Heart Rhythm Society. Europace. 2007;9:335–379.


It has remained controversial whether the concomitant maze procedure may improve long-term clinical outcomes in chronic atrial fibrillation patients who undergo mechanical heart valve replacement. In the present study, a retrospective analysis was carried out on 569 consecutive patients with atrial fibrillation–associated valvular heart disease who underwent mechanical valve replacement. Of them, 317 patients concomitantly underwent the maze procedure and 252 underwent mechanical valve replacement alone. After adjustment for differences in baseline risk profiles between the 2 groups of patients, patients who had undergone the maze procedure were at similar risks of death (hazard ratio, 1.15; 95% confidence interval, 0.65–2.03; \( P = 0.63 \)) but were at a significantly lower risk of thromboembolic events (hazard ratio, 0.29; 95% confidence interval, 0.12–0.73; \( P = 0.008 \)) compared with those who underwent valve replacement alone at a median follow-up of 63.6 months (range, 0.2–149.9 months). The effect of superior event-free survival by the concomitant maze procedure was notable in a low-risk EuroSCORE (0–3) subgroup (\( P = 0.049 \)), but it was insignificant in a high-risk EuroSCORE (\( \geq 4 \)) subgroup (\( P = 0.65 \)). Furthermore, the combination of the maze procedure resulted in superior left ventricular (\( P < 0.001 \)) and tricuspid valvular functions (\( P < 0.001 \)) compared with valve replacement alone on echocardiographic assessments performed at a median of 52.7 months (range, 6.0–146.8 months) after surgery. These findings suggest that the combination of the maze procedure is a reasonable option for this population, especially for those with low risks of surgery. Further prospective, randomized studies are needed to confirm the findings of this study.

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Long-Term Outcomes of Mechanical Valve Replacement in Patients With Atrial Fibrillation: Impact of the Maze Procedure
Joon Bum Kim, Joon Suk Moon, Sung-Cheol Yun, Wan Kee Kim, Sung-Ho Jung, Suk Jung Choo, Hyun Song, Cheol Hyun Chung and Jae Won Lee

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판막 치환술을 받는 만성 심방세동 환자들은 maze 술식을 함께 해주는 것이 유리할 수 있다

오 세일 교수 서울대학교병원 순환기내과

Summary

배경
기계식 판막치환술을 받는 만성 심방세동 환자들은 이 미 평생 항응고 요법을 받고 있는데, 이들에서 maze 술식의 장기적인 이득은 불분명하다.

방법 및 결과
연구자들은 1999-2010년에 기계식 판막치환술을 받으면서 maze 수술을 함께 받거나(317명) 혹은 받지 않은(252명) 총 569명의 판막질환과 연관된 심방세동 환자들을 대상으로 사망, 혈전색전 사건, 사망-심부전-판막과 연관된 합병증들의 복합적인 성적을 평가하였다.
기초 위험인자들의 차이에 대해서 보정했을 때, 중앙값 63.6개월(범위 0.2-149.9개월)의 추적 관찰기간 중 maze 수술을 함께 받은 환자들은 그렇지 않은 환자군에 비해 사망(HR, 1.15; 95% CI, 0.65-2.03; P=0.63), 복합 성적(HR, 0.82; 95% CI, 0.50-1.34; P=0.42)은 유사하였으나, 혈전색전 사건의 위험은 유의하게 낮았다(HR, 0.29; 95% CI, 0.12-0.73; P=0.008).

판막치환술과 동시에 시행한 maze 수술의 무사건 생존에 대한 우수한 효과는 저위험 EuroSCORE군(0-3)에서 두었으나(적=0.049), 고위험 EuroSCORE군(≥4)에서는 유의하지 않았다(P=0.65). 또한, maze 수술을 동시에 받은 환자군은 그렇지 않은 군에 비해 수술 후 중앙값 52.7개월(범위 6.0-146.8개월)에 시행한 심초음파에서 좌심실 기능(P<0.001)과 삼첨판막 기능(P<0.001)이 우수하였다.

결론
판막치환술만 단독으로 시행하는 경우와 비교하였을 때 maze 술식의 추가는 혈전색전 합병증 감소 및 혈역학적 기능 향상과 연관이 있었으며, 이는 특히 수술 위험도가 낮은 환자들에서 두었으나.
정상 동리듬으로 유지하는 것이 심방세동의 상태로 있는 것에 비해 각종 유병률과 사망률에서 유리하다는 것은 잘 알려진 사실이다. 심방세동 환자에서 동리듬을 유지하기 위한 비약물적 치료 방법 중 하나가 maze 수술이다. 원래 Cox 등이 보고한 술식은 심방 내의 여러 부위를 절개 후 다시 봉합하는 방식으로 이루어지므로 수술 시간이 상당히 걸어지는 문제가 있기 때문에, 최근에는 이를 개량하여 절개/봉합 외에 냉동 절개나 단파를 이용한 절개를 함께 이용하는 방식이 이용된다. 그렇다 하더라도 추가 수술 시간이 필요하므로 판막 수술을 시행하는 외과의에게는 다소 부담이 될 수 있다. 이런 연구로 아직은 장기 성적에 대한 믿을만한 절단 연구가 제대로 수행되지 않았고, maze 술식의 추가가 어떤 이득이 있을지에 대해 잘 모르는 상태이다.

연구자들은 본 논문에서 후향적 분석을 통해 판막치환술을 받는 환자에게 maze 술식을 추가하게 되면 혈전색전증의 감소와 혈액질환 기능의 향상되며, 이는 특히 수술 위험도가 낮은 환자들에서 두고하였다고 보고하고 있다. 즉, EuroSCORE로 평가한 수술 위험도가 낮은 판막 치환술을 수행할 때에는 maze 수술을 함께 시행하는 것을 고려하는 의미로 받아들일 수 있었다. 하지만 본 연구의 결과를 해석할 때 주의해야 할 부분들이 있다. 첫째, 연구자들도 제한적으로 밝힌 바와 같이 후향적인 연구라는 점이다. 양군의 특성이 다른데, maze군이 대조군에 비해 나이가 유의하게 젊고 NYHA 기능 등급도 유의하게 좋다. 즉, 상태가 더 좋은 환자에서만 maze 수술을 추가로 적용했을 수 있으며, 이는 수술 성적에 영향을 미칠 수 있다. 물론 연구자들은 통계적인 보정을 했지만, 중요한 제한점을 남는다. 둘째, 좌심방이(left atrial appendage)에 대한 시술 정보가 없다. 판막성 심방세동의 경우 그 중요성이 떨어지기도 하지만, 혈전색전증에서 중요한 부위는 좌심방이다. 하지만 본 연구에는 이에 대한 언급이 부족하다. 본 논문의 연구방법에 기술된 바로는 maze 수술을 함께 받은 군은 317명인데 maze 수술을 하면서 좌심방을 절제한 환자는 201명, 남겨둔 환자는 88명이라고 한다(maze군의 전체 환자 수와 28명이 차이가 남). 판막치환술만을 단독으로 시행할 때에도 심방세동이 있는 환자에게는 좌심방이 절제하는 경우가 있는데, 본 연구의 대조군에는 좌심방이에 대한 기술이 빠져있었다. 즉, 양군 간의 좌심방이 절제 또는 폐쇄에 대한 차이를 알 수 있는 정보가 없다.

셋째, 심방 기능에 대한 정보가 없다. 기존 보고에 의하면 maze 수술 후 심전도는 동리듬이지만 좌심방의 기능이 없는 경우는 37%이며, 좌심방의 기능이 돌아왔다는 점으로 정상보다는 심방의 기능이 낮은 것으로 알려져 있다. 따라서 이에 관한 기술과 분석이 있어야지 다만 단지 maze 술식만 추가하면 좋은 것인지, 동리듬으로 유지되는 환자들만 이득을 볼 수 있는 것인지, 아니면 좌심방의 기능까지 정상으로 돌아올 경우에만 이득이 있는 것인지 알 수 있을 것이다.

**Reference**

Long-Term Outcomes of Mechanical Valve Replacement in Patients With Atrial Fibrillation: Impact of the Maze Procedure
Joon Bum Kim, MD; Joon Suk Moon; Sung-Cheol Yun, PhD; Wan Kee Kim, MD; Sung-Ho Jung, MD; Suk Jung Choo, MD, PhD; Hyun Song, MD, PhD; Cheol Hyun Chung, MD, PhD; Jae Won Lee, MD, PhD

Background—The long-term benefits of the maze procedure in patients with chronic atrial fibrillation undergoing mechanical valve replacement who already require lifelong anticoagulation remain unclear.

Methods and Results—We evaluated adverse outcomes (death; thromboembolic events; composite of death, heart failure, or valve-related complications) in 569 patients with atrial fibrillation–associated valvular heart disease who underwent mechanical valve replacement with (n = 317) or without (n = 252) a concomitant maze procedure between 1999 and 2010. After adjustment for differences in baseline risk profiles, patients who had undergone the maze procedure were at similar risks of death (hazard ratio, 1.15; 95% confidence interval, 0.65–2.03; P = 0.63) and the composite outcomes (hazard ratio, 0.82; 95% confidence interval, 0.50–1.34; P = 0.42) but a significantly lower risk of thromboembolic events (hazard ratio, 0.29; 95% confidence interval, 0.12–0.73; P = 0.008) compared with those who underwent valve replacement alone at a median follow-up of 63.6 months (range, 0.2–149.9 months). The effect of superior event-free survival by the concomitant maze procedure was notable in a low-risk EuroSCORE (0–3) subgroup (P = 0.049), but it was insignificant in a high-risk EuroSCORE (≥4) subgroup (P = 0.65). Furthermore, the combination of the maze procedure resulted in superior left ventricular (P < 0.001) and tricuspid valvular functions (P < 0.001) compared with valve replacement alone on echocardiographic assessments performed at a median of 52.7 months (range, 6.0–146.8 months) after surgery.

Conclusion—Compared with valve replacement alone, the addition of the maze procedure was associated with a reduction in thromboembolic complications and improvements in hemodynamic performance in patients undergoing mechanical valve replacement, particularly in those with low risk of surgery. (Circulation. 2012;125:2071-2080.)

Key Words: ablation ■ atrial fibrillation ■ heart valve prosthesis ■ heart valve prosthesis implantation ■ surgery ■ valve replacement

Since the recognition of the maze procedure as an effective method of restoring normal sinus rhythm in patients with atrial fibrillation (AF), it has gained popularity as a concomitant procedure during surgery for structural heart diseases.1–4 The maze procedure has been found to result in symptom improvement, improved hemodynamics, a reduction in thromboembolic events, and even improved survival.5–8

Clinical Perspective on p 48

However, concerns still exist with regard to routinely combining the maze procedure with major cardiac surgery because it may increase surgical risks as a consequence of increased cardiac ischemic time and more extensive surgery.1,9 These arguments can be further justified when it comes to performing the maze procedure on patients undergoing mechanical heart valve replacement. Unlike patients undergoing valve repair or bioprosthetic valve replacement whose risks of thromboembolism or anticoagulation-related hemorrhage can be minimized by restoration of sinus rhythm, the benefits of the maze procedure may be limited to theoretical advantages of hemodynamic improvements in patients receiving mechanical valve replacement.1 In this regard, an evaluation of clinical results after mechanical valve replacement combined with the maze procedure compared with valve replacement is available for this article. Go to http://cme.ahajournals.org to take the quiz.

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replacement alone in a reasonably sized cohort of patients with valvular AF is clinically important. We therefore evaluated the long-term clinical outcomes of patients with valvular AF who underwent mechanical valve replacement with or without a concomitant maze procedure. For further measures, we compared functional status and echocardiographic parameters of left ventricular (LV) function and tricuspid regurgitation (TR) in these 2 groups of patients.

Methods

Patients

All patients undergoing major cardiac surgery are prospectively registered in the database at our institution, which records baseline patient characteristics, results of cardiac evaluations, detailed information on surgery, and perioperative complications. We screened this registry to identify patients with AF associated with left-side valvular heart disease who underwent mechanical valve replacement between January 1999 and January 2010. To form a homogeneous study population, we excluded patients diagnosed with symptomatic coronary disease or infective endocarditis and those who underwent concomitant cardiac surgery for correction of congenital heart defects, aortic replacement, or tricuspid/pulmonic valve replacement. However, patients found to have incidental coronary lesions during preoperative screening, including the need for coronary artery bypassing, were not excluded. Finally, we identified 559 patients who met the enrollment criteria and formed the study population; of these, 317 patients concomitantly underwent the maze procedure (maze group) and 242 underwent mechanical valve replacement alone (control group). Some of these patients had been included in previous reports on surgical ablation of AF in patients undergoing mitral valve (MV) surgery.10,11 The decision to perform the maze procedure was influenced by several demographic (age), clinical (severity of symptoms, left atrium [LA] size), and procedural (replaced valve position) factors but was at the discretion of the attending surgeon; we had different attitudes regarding the performance of the maze procedure in patients undergoing mechanical valve replacement.

This study was approved by our institutional Ethics Committee/Review Board, which waived the requirement for informed patient consent because of the retrospective nature of the study.

Surgeon Procedures

In the maze group, 285 underwent cryoablation and 32 underwent microwave ablation via an endocardial approach. The lesion sets for the maze procedure have been described previously.8,12 Briefly, LA ablation started with a longitudinal right-sided left atriotomy. Left-side ablation included separate left and right isolation lesions in 232 patients and a single box lesion in 85 patients to isolate pulmonary veins, with 2 connecting lines from the pulmonary isolation lesion to the LA appendage and the MV annulus, respectively. Additional epicardial coronary sinus ablation was performed on the opposite side of the MV annular lesion. LA size was reduced by resection of redundant atrial tissue between the inferior pulmonary veins and posterior mitral annulus. The LA appendage was amputated in 201 patients as part of the maze procedure and preserved in 88. Right-side ablation was followed by an oblique right atriotomy involving a cavo-tricuspid isthmus isolation lesion and a line from the isthmus lesion to the superior vena cava. During MV replacement, the surgeons attempted to retain as much subvalvular tissue as possible in a chordae-sparing manner.

Postoperative Management and Rhythm Assessments

Anticoagulation therapy was adjusted during outpatient visits at 3-month intervals to achieve a target international normalized ratio of 2.0 to 3.0, regardless of cardiac rhythm. Patients with inadequate international normalized ratio values were followed up weekly or monthly until the target international normalized ratio value was achieved.

Generally, follow-up electrocardiography assessments were performed at 3, 6, 12, 18, and 24 months after surgery and every year thereafter. For patients considered to have restored sinus rhythm, 24-hour Holter monitoring was done to validate that they were free of AF in the presence of symptoms suggestive of arrhythmia. Any 1 of the following 3 rhythms was considered postoperative AF if it had a duration of ≥30 seconds by the monitoring: AF, atrial flutter, or atrial tachycardia.1

Overall, 5274 ECGs (12 lead; 3233 [10.2 per patient] in the maze group and 2041 [8.1 per patient] in the control group) and 419 sets of 24-hour Holter monitoring data (398 in the maze group and 21 in the control group) were retrieved, and every patient had at least 1 record available. Among 1-year surviving patients (n=550), 494 (89.8%) had an ECG ≥1 year after the operation (median, 4.7 years; range, 1.0–11.4 years).

Patients in the maze group with postoperatively detected AF, atrial flutter, or paroxysmal atrial tachycardia were managed with the rhythm control strategy involving class I or III antiarrhythmic medications (amiodarone, sotalol, flecainide, or propafenone). Patients who failed to achieve freedom from AF after treatment with class I or III antiarrhythmic medications for a sufficient period of time were discontinued from those drugs and switched to the rate control strategy involving digitalis, β-blockers, or calcium channel blockers to control ventricular rate. Patients who did not undergo the maze procedure were managed with the rate control strategy.

Definitions and Data Collection

The primary end points were all-cause death and thromboembolic events. All-cause death rather than cardiac death was chosen as one of the primary end points because it is the most robust and unbiased index, requiring no adjudication to avoid inaccurate or biased documentation and clinical assessments.13 Thromboembolic events were clinically diagnosed, which may be manifested by a neurological event (stroke or transient ischemic attack) or a noncerebral (peripheral) embolic event. Peripheral embolism should have produced signs or symptoms attributable to complete or partial obstruction of a peripheral artery.14

Secondary end points were the composite of death, congestive heart failure (CHF) requiring hospitalization, and valve-related complications—including thromboembolic events, infective endocarditis, and bleeding complications secondary to anticoagulation or a requirement for reoperation. A CHF hospitalization was defined as an unplanned, urgent admission for management of CHF. Any patient admitted for CHF had to show resting dyspnea or radiological signs of pulmonary edema and had to require intravenous diuretics. Bleeding secondary to anticoagulation was defined as any requirement for transfusion, unplanned hospital admission, or a hemothoracic intervention.

Clinical follow-up was performed via outpatient clinic visits every 3 months (n=505). For those who were followed up at other hospitals (n=64), clinical information was obtained from telephone contacts. For validation of complete follow-up, information on mortality, data on vital status, and dates and causes of death were obtained through August 31, 2011, from the Korean National Registry of Vital Statistics. All deaths were considered of cardiac origin unless a noncardiac origin was established clinically or was determined at autopsy.

Statistical Analysis

Categorical variables, presented as frequencies and percentages, were compared by use of the χ² test or Fisher exact test. Continuous variables, expressed as mean±SD or median with range, were compared by use of the Student unpaired t test or the Mann-Whitney U test as appropriate. Cumulative incidence rates of individual and composite outcomes were estimated by the Kaplan-Meier method and compared by use of the log-rank test.
To reduce the effect of treatment selection bias and potential confounding, we adjusted for differences in baseline characteristics by weighted Cox proportional-hazards regression models and inverse probability of treatment weighting. With that technique, weights for patients receiving valve replacement alone were the inverse of 1—propensity score, and weights for patients receiving valve replacement plus the maze procedure were the inverse of the propensity score. Propensity scores were estimated without regard to outcome variables with the use of multiple logistic regression analysis. Prespecified covariates listed in Table 1 were included in the full nonparsimonious models for valve replacement plus the maze procedure versus valve replacement alone. The discrimination and calibration abilities of the propensity score model were assessed by means of C statistics and the Hosmer-Lemeshow test. The model had a C statistic of 0.95 from AF compared with those who did not (Figure 1).

Table 1. Baseline Characteristics of All Patients

<table>
<thead>
<tr>
<th></th>
<th>Maze Group</th>
<th>Control Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n</td>
<td>317</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>51.1±10.2</td>
<td>53.1±10.3</td>
<td>0.021</td>
</tr>
<tr>
<td>Male sex, n (%)</td>
<td>125 (39.4)</td>
<td>97 (38.5)</td>
<td>0.82</td>
</tr>
<tr>
<td>NYHA functional class, n (%)</td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>I</td>
<td>83 (26.2)</td>
<td>39 (15.5)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>138 (43.5)</td>
<td>104 (41.3)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>83 (26.2)</td>
<td>87 (34.5)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>13 (4.1)</td>
<td>22 (8.7)</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td></td>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>33 (10.4)</td>
<td>20 (7.9)</td>
<td>0.31</td>
</tr>
<tr>
<td>Incidental coronary disease, n (%)</td>
<td></td>
<td></td>
<td>0.075</td>
</tr>
<tr>
<td>History of thromboembolism, n (%)</td>
<td>39 (12.3)</td>
<td>32 (12.7)</td>
<td>0.89</td>
</tr>
<tr>
<td>Previous cardiac surgery, n (%)</td>
<td>12 (3.8)</td>
<td>1 (0.4)</td>
<td>0.008</td>
</tr>
<tr>
<td>CHAD2 score, n (%)</td>
<td>168 (53.0)</td>
<td>112 (44.4)</td>
<td></td>
</tr>
<tr>
<td>Paroxysmal</td>
<td>16 (5.0)</td>
<td>9 (3.6)</td>
<td></td>
</tr>
<tr>
<td>Persistent (&lt;1 y)</td>
<td>85 (26.8)</td>
<td>66 (26.2)</td>
<td></td>
</tr>
<tr>
<td>Longstanding (&gt;1 y) persistent</td>
<td>216 (68.1)</td>
<td>177 (70.2)</td>
<td></td>
</tr>
<tr>
<td>LV ejection fraction, %</td>
<td>53.6±9.0</td>
<td>54.7±8.8</td>
<td>0.16</td>
</tr>
<tr>
<td>LV end-systolic dimension, mm</td>
<td>36.4±7.9</td>
<td>37.3±7.5</td>
<td>0.079</td>
</tr>
<tr>
<td>LV end-diastolic dimension, mm</td>
<td>55.0±8.7</td>
<td>53.4±9.0</td>
<td>0.042</td>
</tr>
<tr>
<td>Left atrial diameter, mm</td>
<td>57.7±9.0</td>
<td>61.0±10.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LV mass</td>
<td>212.1±92.0</td>
<td>217.1±104.1</td>
<td>0.54</td>
</tr>
<tr>
<td>RV systolic pressure, mm Hg</td>
<td>35.6±11.8</td>
<td>37.5±15.9</td>
<td>0.13</td>
</tr>
<tr>
<td>Tricuspid regurgitation grade, n (%)</td>
<td>22 (6.9)</td>
<td>6 (2.4)</td>
<td>0.054</td>
</tr>
<tr>
<td>Operation type, n (%)</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AV replacement</td>
<td>14 (4.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>MV replacement</td>
<td>181 (57.1)</td>
<td>175 (69.4)</td>
<td></td>
</tr>
<tr>
<td>AV and MV replacement</td>
<td>109 (34.4)</td>
<td>77 (30.6)</td>
<td></td>
</tr>
<tr>
<td>AV replacement plus MV repair</td>
<td>12 (3.8)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Concomitant tricuspid repair</td>
<td>134 (42.3)</td>
<td>88 (34.8)</td>
<td>0.074</td>
</tr>
<tr>
<td>EuroSCORE, median (range)</td>
<td>4 (2–10)</td>
<td>3 (2–11)</td>
<td>0.38</td>
</tr>
<tr>
<td>Low (0–2), n (%)</td>
<td>47 (14.8)</td>
<td>30 (11.9)</td>
<td></td>
</tr>
<tr>
<td>Medium (3–5), n (%)</td>
<td>222 (70.0)</td>
<td>175 (69.4)</td>
<td></td>
</tr>
<tr>
<td>High (≥6), n (%)</td>
<td>48 (15.1)</td>
<td>47 (18.7)</td>
<td></td>
</tr>
<tr>
<td>Logistic EuroSCORE, %</td>
<td>3.24±2.33</td>
<td>3.48±2.68</td>
<td>0.26</td>
</tr>
</tbody>
</table>

NYHA indicates New York Heart Association; LV, left ventricle; RV, right ventricle; AV, aortic valve; and MV, mitral valve.
Freedom from AF off class I/III antiarrhythmic medications during each postoperative year ranged from 70.0% to 91.2% in the maze group and from 16.7% to 27.2% in the control group (P < 0.001 for all postoperative time points).

Overall Clinical Outcomes
Median follow-up duration was 63.6 months (range, 0.2–149.9 months [3224.9 patient-years]). During the entire study period, 55 patients (9.7%) died and 23 (4.0%) experienced thromboembolic events, including nonhemorragic stroke in 20, transient ischemic attack in 2, and embolic renal infarction in 1. Other major adverse outcomes included readmission because of CHF in 16 patients (2.8%), anticoagulation-related hemorrhage in 60 (10.5%), heart valve reoperation in 13 (2.3%), and infective endocarditis in 2 (0.4%; Table 2). Figure 2 depicts the unadjusted overall survival, freedom from thromboembolism, thromboembolism-free survival, and major event-free survival in the 2 groups. The linearized rates of death, thromboembolic events, and the composite outcome were 1.9%, 0.4%, and 4.1% per patient-year, respectively, in the maze group and 1.5%, 0.9%, and 4.6% per patient-year, respectively, in the control group (P = 0.73, P = 0.059, and P = 0.27, respectively).

Figure 3 shows treatment-related clinical outcomes in patients at low to medium (0–3; n = 268) and medium to high (>3; n = 301) risk as determined by EuroSCORE. In this subgroup analysis, the addition of the maze procedure had no significant effects on the risks of death in the low- (P = 0.92) and high- (P = 0.39) EuroSCORE groups. In the low-EuroSCORE group, however, the addition of the maze procedure significantly reduced the risks of thromboembolism (P = 0.040) and the composite outcome (P = 0.049), but these benefits were not observed in the high-EuroSCORE group.

Table 3 summarizes the adjusted hazard ratios for clinical end points in the maze group compared with the control group. Patients undergoing the concomitant maze procedure were at a significantly lower risk of thromboembolic events and showed comparable risks of death and the composite outcome.

Table 2. Operative Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Maze Group (n=317)</th>
<th>Control Group (n=252)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early (within 30 d) death, n (%)</td>
<td>5 (1.6)</td>
<td>2 (0.8)</td>
<td>0.47</td>
</tr>
<tr>
<td>Patients with early major morbidity, n (%)</td>
<td>44 (13.9)</td>
<td>39 (15.5)</td>
<td>0.59</td>
</tr>
<tr>
<td>Low cardiac output syndrome</td>
<td>4 (1.3)</td>
<td>2 (0.8)</td>
<td>0.59</td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (0.3)</td>
<td>0</td>
<td>0.37</td>
</tr>
<tr>
<td>Ventricular tachycardia/fibrillation</td>
<td>2 (0.6)</td>
<td>0</td>
<td>0.21</td>
</tr>
<tr>
<td>Requirement for new dialysis</td>
<td>6 (1.9)</td>
<td>5 (2.0)</td>
<td>0.94</td>
</tr>
<tr>
<td>Surgical bleeding requiring re-exploration</td>
<td>16 (5.0)</td>
<td>16 (6.3)</td>
<td>0.50</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>18 (5.7)</td>
<td>14 (5.6)</td>
<td>0.95</td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>0</td>
<td>1 (0.4)</td>
<td>0.26</td>
</tr>
<tr>
<td>Surgical-site wound problem</td>
<td>7 (2.2)</td>
<td>5 (2.0)</td>
<td>0.85</td>
</tr>
<tr>
<td>Permanent pacemaker implantation</td>
<td>8 (2.5)</td>
<td>3 (1.2)</td>
<td>0.25</td>
</tr>
<tr>
<td>Primary outcomes, n (%)</td>
<td>32 (10.1)</td>
<td>44 (17.5)</td>
<td>0.010</td>
</tr>
<tr>
<td>Death</td>
<td>25 (7.9)</td>
<td>30 (11.9)</td>
<td>0.11</td>
</tr>
<tr>
<td>Thromboembolic events</td>
<td>7 (2.2)</td>
<td>16 (6.3)</td>
<td>0.013</td>
</tr>
<tr>
<td>Secondary outcomes, n (%)</td>
<td>64 (20.2)</td>
<td>76 (30.2)</td>
<td>0.006</td>
</tr>
<tr>
<td>Admission for CHF</td>
<td>6 (1.9)</td>
<td>10 (4.0)</td>
<td>0.14</td>
</tr>
<tr>
<td>Anticoagulation-related bleeding</td>
<td>27 (8.5)</td>
<td>33 (13.1)</td>
<td>0.077</td>
</tr>
<tr>
<td>Cardiac reoperation</td>
<td>2 (0.6)</td>
<td>11 (4.4)</td>
<td>0.004</td>
</tr>
<tr>
<td>Infective endocarditis</td>
<td>1 (0.3)</td>
<td>1 (0.4)</td>
<td>&gt;0.99</td>
</tr>
</tbody>
</table>

CHF indicates congestive heart failure.

Table 2. Operative Outcomes

Maze Group  Control Group  P
---  ---  ---
Early (within 30 d) death, n (%) 5 (1.6) 2 (0.8) 0.47
Patients with early major morbidity, n (%) 44 (13.9) 39 (15.5) 0.59
Low cardiac output syndrome 4 (1.3) 2 (0.8) 0.59
Stroke 1 (0.3) 0 0.37
Ventricular tachycardia/fibrillation 2 (0.6) 0 0.21
Requirement for new dialysis 6 (1.9) 5 (2.0) 0.94
Surgical bleeding requiring re-exploration 16 (5.0) 16 (6.3) 0.50
Pericardial effusion 18 (5.7) 14 (5.6) 0.95
Mediastinitis 0 1 (0.4) 0.26
Surgical-site wound problem 7 (2.2) 5 (2.0) 0.85
Permanent pacemaker implantation 8 (2.5) 3 (1.2) 0.25
Primary outcomes, n (%) 32 (10.1) 44 (17.5) 0.010
Death 25 (7.9) 30 (11.9) 0.11
Thromboembolic events 7 (2.2) 16 (6.3) 0.013
Secondary outcomes, n (%) Admission for CHF 6 (1.9) 10 (4.0) 0.14
Anticoagulation-related bleeding 27 (8.5) 33 (13.1) 0.077
Cardiac reoperation 2 (0.6) 11 (4.4) 0.004
Infective endocarditis 1 (0.3) 1 (0.4) >0.99
All clinical endpoints, n (%) 64 (20.2) 76 (30.2) 0.006

Figure 1. Freedom from postoperative atrial fibrillation (AF) at each postoperative period. AAD indicates antiarrhythmia drugs.
Echocardiographic and Functional Parameters at Late Follow-Up (>6 months)

Echocardiographic data >6 months after surgery were available for 459 of the 557 patients (82.4%) who survived >6 months. The median echocardiographic follow-up period was 52.7 months (range, 6.0–146.8 months). Among these patients, 103 pairs of patients could be yielded by propensity score matching for the comparisons of echocardiographic and functional parameters at late follow-up (55.4±35.6 months); there were no significant differences in baseline profiles between the 2 groups, including the echocardiographic follow-up duration (53.5±32.8 and 57.3±34.4 months in the maze and control groups, respectively; \( P=0.23 \)).

Figure 4 shows comparisons of preoperative and last follow-up (>6 months) echocardiographic parameters in the maze and control groups. Compared with preoperative findings, both groups showed significant reductions in LV systolic/diastolic dimensions and LA dimension, although a significant improvement in LV ejection was observed only in the maze group. At the last follow-up, patients in the maze group had significantly higher LV ejection fraction and significantly smaller LV and LA dimensions than patients in the control group.

Figure 5 shows the postsurgical changes in TR in both groups. In the entire propensity-matched cohort (n=206), the degree of TR was significantly lower in the maze group.
than in the control group ($P<0.001$). These differences were also observed in the 31 pairs of patients who underwent concomitant tricuspid valve repair ($P=0.092$) and in the 72 pairs who did not ($P=0.001$).

Although both groups showed significant improvements in New York Heart Association functional class after surgery ($P<0.001$), patients in the maze group tended to have better functional status than those in the control group ($P=0.098$; Figure 6).

**Figure 3.** Adjusted hazard ratios (HRs) for clinical end points in low to medium (0–3) and medium to high (≥4) EuroSCORE groups. Hazard ratios were adjusted by weighted Cox proportional-hazards regression models and inverse probability of treatment weighting. CI indicates confidence interval.

**Figure 4.** Echocardiographic results in the propensity score–matched groups before surgery and at last-follow-up (>6 months). A, Left ventricular (LV) ejection fraction (LVEF). B, LV end-systolic dimension (LVIDs). C, LV end-diastolic dimension (LVIDd). D, Left atrial (LA) diameter.
Discussion

Despite anticoagulation therapy, the rate of major systemic embolism after mechanical valve replacement remains 0.8%/y to 3%/y. This thromboembolic risk is enhanced by several risk factors such as advanced age, history of stroke, and the presence of chronic AF, with chronic AF regarded as the most significant but only correctable factor. In an effort to reduce this serious complication after mechanical valve replacement, several groups advocated combining the maze procedure to eliminate AF. Additional potential benefits of the concomitant maze procedure include better hemodynamic results by incorporating atrial kicking into the generation of cardiac output, elimination of palpitation symptoms, and consequent improvements in overall functional outcomes.

In contrast, combining the maze procedure with mechanical replacement has been criticized because (1) further reductions in thromboembolic risk are doubtful compared...
with anticoagulation therapy alone, (2) the increased cardiac ischemic and cardiopulmonary bypass times needed for the maze procedure may hamper early postoperative recovery, and (3) more troublesome bradycardia may occur more frequently.1–9 To address these possible drawbacks, several studies have assessed the effect of the maze procedure on long-term clinical outcomes in patients with valvular AF patients,5,10,20 a review of 5466 patients followed up for a mean 6.6 years found that conversion to sinus rhythm did not improve long-term survival or reduce the incidence of embolic complications after valve surgery.9 Although patients with preoperative AF had poorer survival than patients without preoperative AF in the cited study, the authors concluded that AF may be a marker of advanced disease in these patients rather than a cause of poor outcomes.

Our data suggest that the risk of thromboembolic complications can be reduced by the concomitant maze procedure. In contrast, the survival and overall event-free survival rates were not affected by the maze procedure, indicating that the decreased incidence of thromboembolic events and improvements in hemodynamic profiles may not directly translate into improved survival or decreased incidence of overall adverse events.

It remains unclear whether the maze procedure should be combined with major cardiac surgery in high-risk patients. High-risk patients such as elderly patients and those with advanced heart failure or low LV ejection fraction may benefit more from restoration of sinus rhythm than low- or average-risk patients. At the same time, however, these vulnerable patients may have more difficulties in overcoming the early perioperative risks associated with increased procedural extent and prolonged cardiopulmonary bypass and aortic cross-clamping times. It remains unclear whether the benefits of the maze procedure can offset the risks added by this procedure. In this study, we found that the addition of the maze procedure in patients with low to intermediate EuroSCOREs (0–3) significantly reduced thromboembolic risks (hazard ratio, 0.18; \( P = 0.040 \)) and enhanced overall event-free survival (hazard ratio, 0.48; \( P = 0.049 \)), whereas these benefits were not observed in patients with intermediate to high EuroSCOREs. Further studies, including detailed analyses of early and late clinical outcomes, are needed to confirm our findings and to test the risk-benefit effects of the maze procedure in high-risk populations.

In agreement with previous reports, we observed that the addition of the maze procedure significantly improved LV function. For example, Stulak et al25 reported that surgical AF ablation in patients with lone AF improved LV ejection and reduced LV end-diastolic diameter significantly. In that study, the improvement in LV function appeared during the immediate postoperative period and was maintained for a median of 48 months. Several underlying mechanisms may explain this phenomenon. First, restoration of atrioventricular synchrony can improve diastolic function, resulting in increased cardiac output up to 15%.26 Because AF can also lead to tachycardia-induced cardiomyopathy, elimination of AF can restore LV function by blocking this pathological process.27–30 Tachycardia-induced cardiomyopathy is commonly thought to be associated with chronic arrhythmias having ventricular rates >100 to 120 bpm. Even when the ventricular rate is regarded as being under adequate control with medications, the resting heart rate may not truly reflect the overall heart rate in patients with AF. Even in patients with well-controlled resting heart rates, a rapid ventricular rate can frequently be induced by minimal activity, which can be associated with the development of tachycardia-induced cardiomyopathy.31

Because AF can contribute to the development and aggravation of functional TR, the concomitant maze procedure may prevent late functional TR progression in patients with AF undergoing left-sided valve surgery.32–34 With 1 study showing that performance of the maze procedure was the most important predictor of TR aggravation after MV surgery.34 In that study, the maze procedure more strongly protected against TR progression than tricuspid valve repair did. We found that the maze procedure may benefit patients by preventing late TR, reinforcing previous results. This effect was consistent throughout the subgroups of patients who underwent concomitant tricuspid valve repair and those who did not.

Although functional status tended to be better in the maze than in the control group, the benefits were modest (\( P = 0.098 \)). Furthermore, the rates of readmission for CHF were similar in the 2 groups. This may be attributable to the small number of patients in each group who had experienced symptoms of advanced heart failure late after surgery. Studies in a larger population may be needed to differentiate, with reasonable statistical power, the effects of these 2 surgical strategies on functional status.

Study Limitations

This study is subject to the limitations inherent to a retrospective analysis of observational data. The decision to perform concomitant maze procedure was affected by patients’ preoperative conditions, and the maze group patients tended to have better clinical conditions (younger, better New York Heart Association functional class, smaller LA size) than the control group patients. Although we used propensity score analysis to adjust for this selection bias, unmeasured confounders, procedure bias, or detection bias may have affected our results. The number of events in each EuroSCORE subgroup was relatively small for differentiating the clinical effects of maze procedure, especially on thromboembolic events, between the 2 subgroups.

Conclusions

Compared with valve replacement alone, the addition of the maze procedure was associated with a reduction in
thromboembolic complications but not with notable survival benefits in patients undergoing mechanical valve replacement, particularly in those at low risk from surgery. The concomitant maze procedure was associated with improved LV function, prevention of late TR, and modest benefit in functional status. These findings suggest that the approach for individual patients should be tailored according to their projected risks of surgical mortality/morbidity. Conclusions from a comparison of valve replacement alone and valve replacement plus the maze procedure in these patients await the results of prospective randomized trials.

Disclosures

None.

References


It has remained controversial whether the concomitant maze procedure may improve long-term clinical outcomes in chronic atrial fibrillation patients who undergo mechanical heart valve replacement. In the present study, a retrospective analysis was carried out on 569 consecutive patients with atrial fibrillation–associated valvular heart disease who underwent mechanical valve replacement. Of them, 317 patients concomitantly underwent the maze procedure and 252 underwent mechanical valve replacement alone. After adjustment for differences in baseline risk profiles between the 2 groups of patients, patients who had undergone the maze procedure were at similar risks of death (hazard ratio, 1.15; 95% confidence interval, 0.65–2.03; $P=0.63$) but were at a significantly lower risk of thromboembolic events (hazard ratio, 0.29; 95% confidence interval, 0.12–0.73; $P=0.008$) compared with those who underwent valve replacement alone at a median follow-up of 63.6 months (range, 0.2–149.9 months). The effect of superior event-free survival by the concomitant maze procedure was notable in a low-risk EuroSCORE (0–3) subgroup ($P=0.049$), but it was insignificant in a high-risk EuroSCORE ($\geq 4$) subgroup ($P=0.65$). Furthermore, the combination of the maze procedure resulted in superior left ventricular ($P<0.001$) and tricuspid valvular functions ($P<0.001$) compared with valve replacement alone on echocardiographic assessments performed at a median of 52.7 months (range, 6.0–146.8 months) after surgery. These findings suggest that the combination of the maze procedure is a reasonable option for this population, especially for those with low risks of surgery. Further prospective, randomized studies are needed to confirm the findings of this study.