Multislice Computed Tomography Accurately Quantifies Left Atrial Size and Function After the MAZE Procedure

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Background—Although the MAZE procedure allows for the recovery of sinus rhythm and left atrial (LA) mechanical function in the great majority of patients with chronic atrial fibrillation (AF), the effects of MAZE on the precise LA geometry and wall motion remain to be elucidated. We hypothesized that LA size and mechanical function in patients with chronic AF and mitral valvar disease are well restored after MAZE.

Methods and Results—We studied 14 patients (MAZE group: mean±SD age, 63.9±8.6 years; 8 men and 6 women) who underwent MAZE for chronic AF and mitral valve surgery and 10 patients with sinus rhythm (coronary artery bypass graft [CABG] group: age, 70.0±7.9 years; 5 men and 5 women) who underwent CABG at Takeda Hospital between February 2002 and September 2005. MAZE was conducted by the endocardial application of radiofrequency ablation with a temperature-controlled multipolar radiofrequency catheter. LA volume and booster function were quantitatively evaluated by multislice computed tomography at 17.9±10.0 months (MAZE group) and 15.3±13.6 months (CABG group) postoperatively. All patients with MAZE were free of AF and other atrial arrhythmias during the follow-up period. In the CABG group, LA maximal and minimal volumes and ejection fraction were 109±12 mL, 82±11 mL, and 26±10%, respectively. In the MAZE group, LA maximal volume was 139±17 mL (P=0.187 versus CABG), and LA minimal volume was 121±16 mL (P=0.082 versus CABG), with an ejection fraction of 15±7% (P=0.004 versus CABG). In both groups, all parts of the LA wall contracted toward the geometric center of the LA. The extent of wall motion was significantly worse in the MAZE group compared with the CABG group. In both groups, LA booster function was inversely correlated with LA maximal volume.

Conclusions—MAZE with radiofrequency ablation is safe and effective for the restoration of sinus rhythm in patients with chronic AF and mitral valve disease. However, chronic AF associated with mitral valve disease deteriorates LA mechanical function diffusely throughout the LA wall. Further studies with the use of multislice computed tomography are needed to sequentially evaluate LA function after MAZE in patients with and without mitral valve surgery.

Key Words: ablation ■ atrium ■ fibrillation ■ mitral valve ■ tomography

Atrial fibrillation (AF) has been recognized as 1 of the most common tachyarrhythmias, and it is responsible for the increased morbidity and mortality accompanying thromboembolism or heart failure.1 Because drug treatment to restore and maintain sinus rhythm is unsuccessful in a considerable number of patients, surgical approaches have been developed. In 1987, Cox et al 2 proposed the MAZE procedure to restore sinus rhythm and left atrial (LA) booster function in patients with AF. Because the effectiveness and safety of MAZE have been well accepted,3–5 it has been widely performed in combination with left-sided valve surgery. Recently, the initial surgical technique has been modified with the use of radiofrequency ablation.6–7 Although MAZE offers successful long-term elimination of AF, the precise effects on LA size and mechanical function remain unclear. This is attributed mainly to the limited methodological means to accurately evaluate LA geometry and wall motion.8–11 Two-dimensional echocardiographic assessment of LA volume may be inaccurate because of the complexity of the LA shape.11 Furthermore, diastolic inflow measurements such as the E/A ratio of the mitral valve are largely influenced by many factors other than LA function,8–10 so the assessment by Doppler echocardiography may have an intrinsic limitation in evaluating LA booster function. Therefore, we have used for the first time multislice computed tomography (MSCT) to accurately assess postoperative...
LA geometry and mechanical function in patients undergoing MAZE and left-sided heart surgery for chronic AF and mitral valve disease. In the present study, we used coronary artery bypass grafting surgery (CABG) patients as the control group, with the rationale that open-heart surgery with extracorporeal circulation may affect LA function. As a result, it would be possible to elucidate the effects of chronic AF, long-standing hemodynamic overload due to mitral valve disease, and MAZE on LA function. Thus, the purpose of this study was to accurately evaluate LA volume and wall motion in patients with AF who underwent MAZE and mitral valve surgery with use of MSCT and to compare these parameters in patients undergoing CABG.

Methods

Study Population

Fourteen consecutive patients (63.9±8.6 years, 8 men and 6 women) who underwent mitral valve operation and MAZE in our hospital between February 2002 and October 2005 were studied (MAZE group). Ten patients (70.0±7.9 years, 5 men and 5 women) with sinus rhythm and well-preserved left ventricular function who underwent CABG served as the controls (CABG group).

Surgical Procedure and Postoperative Care

We performed a modified and simplified MAZE by endocardial application of radiofrequency ablation with use of a temperature-controlled multipolar radiofrequency catheter (Cobra RF System; Boston Scientific) without any complications.12,13 CarboMedicus valves or Cosgrove-Edwards rings were used for mitral valve replacement or valvuloplasty, respectively. In the CABG group, the left internal thoracic artery was routinely used to bypass the left anterior descending coronary artery. There were no perioperative deaths in both groups.

Postoperatively, sinus rhythm with a normal P-R interval was maintained in all patients with MAZE. For 5 of 14 patients, prophylactic antiarrhythmic drug therapy with cibenzoline succinate, was started soon after the operation and continued until hospital discharge. No patient required an antiarrhythmic drug treatment during hospitalization. In the CABG group, the MSCT study was performed 17.9±10.0 months postoperatively. All MSCT examinations were performed with a single breath-hold of 31 to 44 seconds’ (mean, 38.4 seconds) duration in the supine position. For enhancement of the cardiac cavity, 100 mL of nonionic contrast medium was injected at a flow-rate of 2.5 mL/s. Image reconstruction was performed with the cardiac image reconstruction algorithm provided with the CT scanner. The temporal resolution of this system was 50 to 100 ms.

Slices over the entire LA cavity were used for the subsequent quantitative assessment. The maximal and minimal LA volumes were calculated from manually drawn endocardial boundaries of the LA cavity according to Simpson’s method.14 Cine loops in the long axis were chosen to determine the horizontal slice for the LA wall motion analysis. As shown in Figure 1, a vertical line was drawn between the LV apex and the midpoint of the mitral valve area. Then, a horizontal line crossing at right angles to the vertical line was drawn at the junction between the left coronary sinus and the ascending aorta.

Statistical Analysis

All values are expressed as the mean±SE. Comparative analysis of the 2 groups was performed with the unpaired t test. Comparative analysis of the 8 segments was done with ANOVA and Sheffe’s post hoc test for continuous variables. Spearman’s correlation coefficients were used to evaluate the relation between LA size and ejection fraction. Statview for Windows, version 5.0 (SAS Institute Inc, Cary, NC), was used for the statistical analyses, and a probability value of <0.05 was considered statistically significant.

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

Results

General Features

The baseline characteristics of the study population are shown in the Table. There were no statistically significant differences in age, body surface area, or sex between the MAZE and CABG groups. The prevalence of diabetes mellitus was significantly higher in the CABG group.
Clinical and Preoperative Echocardiographic Parameters

<table>
<thead>
<tr>
<th></th>
<th>MAZE Group</th>
<th>CABG Group</th>
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<tbody>
<tr>
<td></td>
<td>(n=14)</td>
<td>(n=10)</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>63.9±8.6</td>
<td>70.0±7.9</td>
<td>0.092</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.53±0.17</td>
<td>1.61±0.31</td>
<td>0.429</td>
</tr>
<tr>
<td>Male:female</td>
<td>8:6</td>
<td>5:5</td>
<td>0.729</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>1 (7)</td>
<td>5 (50)</td>
<td>0.017</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>6 (43)</td>
<td>1 (10)</td>
<td>0.013</td>
</tr>
<tr>
<td>Smoker, n (%)</td>
<td>5 (36)</td>
<td>3 (30)</td>
<td>0.770</td>
</tr>
<tr>
<td>Previous myocardial infarction, n (%)</td>
<td>0 (0)</td>
<td>8 (80)</td>
<td>0.001</td>
</tr>
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</table>

Preoperative echocardiographic parameters

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<tr>
<td>LVEDD, mm</td>
<td>51.8±11.1</td>
<td>47.4±10.0</td>
<td>0.331</td>
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<tr>
<td>LVESD, mm</td>
<td>32.8±7.8</td>
<td>35.1±10.0</td>
<td>0.530</td>
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<tr>
<td>LVEF, %</td>
<td>67.5±8.6</td>
<td>54.8±16.7</td>
<td>0.041</td>
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<tr>
<td>LA size, mm</td>
<td>54.9±8.9</td>
<td>38.7±8.3</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Values are presented as the mean±SE.

BSA indicates body surface area; LV, left ventricle; EDD, end-diastolic diameter; ESD, end-systolic diameter; and EF, ejection fraction.

whereas that of hypertension was significantly higher in the MAZE group. The prevalence of current smokers was comparable between the 2 groups. Eight of 10 patients in the CABG group had previous myocardial infarction, whereas no patients in the MAZE group had a prior myocardial infarction. Preoperative echocardiographic left ventricular end-diastolic and end-systolic diameters were comparable in the 2 groups. However, left ventricular ejection fraction was significantly higher in the MAZE group. Preoperative LA size was significantly larger in the MAZE group than in the CABG group. In the MAZE group, 9 of the 14 patients had mitral valve replacement, 5 had mitral valvuloplasty, and 9 had tricuspid annuloplasty concomitantly. Most patients in the MAZE group had a history of chronic AF >5 years. In the CABG group, all grafts were patent, and sinus rhythm was maintained preoperatively and postoperatively.

Data on MSCT Study

MSCT examination was successfully completed in all patients without complications. Heart rates did not differ significantly between the MAZE and CABG groups (77.0±7.5 versus 83.4±12.7 bpm, *P=0.447*). Whereas LA maximal volume tended to be larger in the MAZE group (139±17 versus 109±12 mL, *P=0.187*), LA minimal volume was also larger in the MAZE group (121±16 versus 82±11 mL, *P=0.082*). As a result, LA stroke volume (18±7 versus 27±11 mL, *P=0.024*) and ejection fraction (15±7% versus 26±10%, *P=0.004*) were significantly smaller in the MAZE group. The LA maximal volume was inversely correlated with LA ejection fraction (n=24, r=−0.545, *P=0.006*).

Figure 3 shows LA regional wall motion as a fractional contraction of each segment over the entire LA wall. There were no significant differences in fractional contraction among the 8 segments in each group. However, in 5 segments, the fractional contraction was significantly worse in the MAZE group than in the CABG group.

Discussion

The principal findings of the present study were that (1) MSCT successfully quantified LA volume and regional wall motion in patients undergoing MAZE and mitral valve surgery and (2) chronic AF associated with mitral valve disease worsened LA mechanical function diffusely throughout the LA wall, despite the recovery and maintenance of sinus rhythm. To our knowledge, this is the first study that shows the usefulness of MSCT for the quantitative assessment of LA size and wall motion after MAZE combined with mitral valve surgery.

Factors Affecting MSCT Imaging

Rapid progress in noninvasive imaging with MSCT has resulted in wider clinical application for a variety of heart diseases, such as congenital heart disease, valvular heart disease and coronary artery disease. A new generation MSCT scanners can diagnose coronary artery narrowing with a high degree of certainty. In the present study, we used 16-slice scanners, which needed prolonged breath-holding of ~40 seconds. The patients complicated with chronic heart failure may be excluded from the MSCT study. The greater field coverage available with 64-slice MSCT allows a shorter scanning time so that a study can be completed in 10 to 12 seconds. The shorter scanning time reduces the likelihood of occurrence of ectopic beats and allows motion-free scanning in a larger proportion of patients.

LA Mechanical Function

In the present study, LA booster function was restored in all MAZE patients. However, the extent of LA wall motion in the MAZE group was significantly worse compared with that in the CABG group. These results are in agreement with findings from earlier Doppler echocardiographic studies. The Doppler echocardiographic approach enabled us to quantitatively assess LA booster function, ie, LA active contraction, as the mitral inflow velocity. The
measurement of peak velocities of the early filling wave (E wave) and the atrial contraction wave (A wave) provides the E/A ratio, which is a simple index of evaluating the LA contribution to ventricular filling. Kim et al\(^1\) have demonstrated that the peak A wave velocity in patients with MAZE was 0.46 m/seconds in the mean, being significantly lower than the 0.75 m/seconds in age- and sex-matched patients undergoing open heart surgery. Incomplete recovery of LA booster function in the MAZE group likely resulted from the greater progression of LA organic change due to mitral valve disease associated with chronic AF. However, it appears difficult to determine whether either long-standing hemodynamic overload due to mitral valve disease or chronic AF is responsible for the reduced recovery of LA booster function. Furthermore, MAZE itself may deteriorate LA function. In this regard, it is tempting to compare our results with those associated with catheter\(^{20,21}\) or thoracoscopic microwave\(^{22}\) ablation for isolated AF. These studies have demonstrated that LA mechanical function is well preserved despite the inherent damage of ablation to the LA.\(^{20-22}\) Thus, it is likely that MAZE by radiofrequency ablation only minimally deteriorates LA booster function, if at all.

**Limitations**

There are several limitations to the present study. First, in the present study we did not evaluate LA function immediately after MAZE and mitral valve operation.\(^9\) MSCT would have enabled us to elucidate the precise time course of LA functional recovery after surgery. Second, we adopted the patients with CABG as controls. Our CABG patients had significantly worse LV function than did the MAZE patients, which would likely have affected LA function. Accordingly, normal subjects may be more suitable as the reference population. However, there are problems with using subjects with no known heart disease for this study. Third, in the present study as shown in Figure 1, we used a horizontal slice at a relatively low LA level for the LA wall motion analysis. There are 3 reasons why we used that plane of the LA. It is easy to visually determine the junction between the left coronary sinus and the ascending aorta. This plane does not involve the left appendage and pulmonary vein orifices, which possibly affect LA wall motion. Because the LA wall in this plane had an endocardial application of radiofrequency ablation, it appears possible to assess the effect of ablation on LA function. However, further studies are needed to examine LA function and dimensions at other LA levels for clarification of the extent of LA function. Finally, although we quantitatively analyzed LA regional wall motion as a centripetal movement toward a geometric center of the boundary of the maximal LA area, there is no direct evidence indicating whether our method is the best way to evaluate LA regional wall motion, which is the case in assessing left ventricular wall motion by contrast left ventricular cineangiography.\(^{23-25}\) Despite these limitations, we believe that our data are important because they are novel findings concerning the quantitative assessment of LA volume and wall motion in patients undergoing MAZE associated with mitral valve surgery.

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**Disclosures**

None.

**References**


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