Left Atrial and Left Ventricular Diastolic Function After the Maze Procedure for Atrial Fibrillation in Mitral Valve Disease: Degenerative Versus Rheumatic

Hwan Wook Kim · Mi Hyoung Moon · Keon Hyun Jo · Hyun Song · Jae Won Lee

Received: 21 January 2012 / Accepted: 3 September 2012 / Published online: 14 September 2012
© Association of Surgeons of India 2012

Abstract The present study was aimed to compare the left atrial and left ventricular diastolic functions amongst the rheumatic and degenerative mitral valve disease patients in atrial fibrillation who reverted to normal sinus rhythm following Cox-maze procedure. We prospectively investigated the left atrial and left ventricular function with Doppler echocardiography, by dividing into the rheumatic ($N=105$) and the degenerative group ($N=47$). Over the follow-up period (mean: 4.4 ± 1.2 years in the rheumatic group, 4.8 ± 1.3 years in the degenerative group), the rheumatic group showed statistically significant decrease in A' velocity and E' velocity, on contrary to degenerative group (A' velocity: mean decrease of 0.43 ± 0.13 cm/s in the rheumatic group, mean increase of 0.57 ± 0.11 cm/s in the degenerative group, $p=0.029$, E' velocity: mean decrease of 0.23 ± 0.17 cm/s in the rheumatic group, mean increase of 0.21 ± 0.15 cm/s in the degenerative group, $p=0.031$). In addition, the rheumatic group showed statistically significant increase in E/E' ratio than the degenerative group (mean increase of 4.49 ± 1.98 in the rheumatic group, mean increase of 1.74 ± 1.52 in the degenerative group, $p=0.047$). Despite successful sinus rhythm restoration, the progressive loss of LA function as well as LV diastolic function is more prominent in the rheumatic group than the degenerative group. Therefore,

differentiated strategies for postoperative surveillance are needed according to the pathology of mitral valve disease.

Keywords Left atrial function · Left ventricular diastolic function · Maze · Degenerative · Rheumatic

Introduction

As atrial fibrillation is observed in 30 % to 50 % of patients who require operation for mitral valve disease [1], the Cox-maze procedure has been performed concomitantly with mitral valve surgery as a standard surgical treatment for atrial fibrillation. Although high efficiency of conversion into sinus rhythm has been demonstrated after the Cox-maze procedure, irrespective of the origin of valve pathology [2], the changes in size and function of left atrium (LA) have been poorly elucidated, especially in long-term periods.

In fact, in terms of sinus conversion rate and existence of LA electrical activity, some authors reported unsatisfactory results of the Cox-maze procedure in patients more with rheumatic disease than other causes. The left atrial contractility determined as the peak velocity of the atrial filling wave to peak velocity of early filling wave ratio for the LA in the rheumatic group was significantly reduced compared with that in the nonrheumatic group [3]. On the contrary, others including our group demonstrated equally effective results, even though those were short-term outcomes [4, 5].

Along with the sinus conversion rate and electrical activity, one of the issues of debate in the Cox-maze procedure is that whether the etiology of mitral valve disease has an effect on the change of LA function and left ventricular (LV) function over a long-term follow-up, in patients with restoration to normal sinus rhythm after surgery. Although some studies dealt with the improvement of LA and LV functions after the successful maze procedure, these were

H. W. Kim · M. H. Moon · K. H. Jo · H. Song
Department of Thoracic and Cardiovascular Surgery,
Seoul St. Mary's Hospital, School of Medicine,
The Catholic University of Korea,
505 Banpo-dong, Seocho-gu,
Seoul 137-701, Republic of Korea

J. W. Lee (✉)
Department of Thoracic and Cardiovascular Surgery, Seoul Asan
Hospital, School of Medicine, The University of Ulsan,
388-1 Pungnap-dong, Songpa-gu,
Seoul 138-736, Republic of Korea
e-mail: cardiol@naver.com

separately performed only according to the etiology of mitral valve diseases, having degenerative or rheumatic origins [6, 7], not for the comparison between the two etiologies. Furthermore, most of these studies focused predominantly on the LV dimension and systolic function (ejection fraction) [5–8], and no prospective studies have been performed, to our knowledge. In Korea, a significant number of patients with mitral valve disease accompanied by atrial fibrillation had rheumatic origin.

The objective of this study was to compare LA size and mechanical function, and LV diastolic function after the Cox-maze procedure for atrial fibrillation accompanied by rheumatic and degenerative mitral valve disease. We have performed the Cox-maze III procedure concomitantly with mitral valve operations since 1997, and we prospectively investigated serial changes in LA dimension, LA function, and LV diastolic function with Doppler echocardiography.

Materials and Method

Patients

Between July 1997 and July 2008, 647 consecutive patients underwent surgery for atrial fibrillation associated with mitral valve disease. The Cox-maze procedure and mitral valve operation were performed concomitantly, with or without other cardiac procedures. A total of 332 patients who had an operation within the last 3 years ($N=284$) or were lost during follow-up ($N=48$) were excluded. From the total of 315 patients with a follow-up period of more than 3 years, patients with intractable atrial fibrillation ($N=42$) were also excluded, as were patients who maintained normal sinus rhythm with intermittent antiarrhythmic medication or synchronized electrical cardioversion ($N=61$). During the follow-up, 60 patients were newly diagnosed with valvular regurgitation greater than grade II or mild grade valvular stenosis. Therefore, 152 patients that were able to be followed up more than 3 years after surgery had sustained normal sinus rhythm without antiarrhythmic medications and did not have valvular regurgitation greater than grade II or valvular stenosis more than mild grade were selected for evaluation. The patients were divided into the rheumatic group ($N=105$) and the degenerative group ($N=47$).

The clinical characteristics for each group were summarized in Table 1. Results showed that patients in both groups were similar in terms of age, sex, preoperative cardiothoracic ratio (CT ratio), and the nature of atrial fibrillation.

Rheumatic mitral valve disease was determined by preoperative echocardiography and gross findings of valve morphology, as previously reported [5]. In brief, irrespective of mitral stenosis or regurgitation, the lesions combined with immobility of the thickened leaflet, calcification of

subvalvular apparatus, commissural fusion, and contraction of the chordae tendineae were defined as rheumatic. In addition, all stenotic lesions of the mitral valve combined with aortic valve stenosis were considered rheumatic.

After the Cox-maze procedure, other cardiac procedures were performed with the mitral valve surgery. To access valve competence in mitral valvuloplasty, the entire coaptation line parallel to the mural part of the annulus was checked after saline injection forcibly through the valve to fill the left ventricle using a 20-Fr red rubber catheter attached to a bulb syringe. Once the heart was beating and the patient had been weaned from cardiopulmonary bypass, less than mild regurgitations were confirmed by intraoperative transesophageal echocardiography. The most common concomitant procedures were tricuspid annuloplasty ($N=54$). Other procedures included aortic valve replacement in 19 patients, coronary artery bypass grafting in 6 patients, atrial septal defect closure in 6 patients, ventricular septal defect closure in 1 patient, and ascending aortic graft replacement in 1 patient.

This cohort study was approved by the institutional review board and the ethics committee of our hospital. Informed consent forms were obtained.

Surgical Procedures

We modified the classic Cox-maze procedure to preserve and enhance the LA function. The details of our Cox-maze procedure have been reported previously in detail [5]. A standard LA incision was made and extended inferiorly to the orifice of the left inferior pulmonary vein. To reduce LA tissue inclusion on the pulmonary vein isolation, we tightly encircled the pulmonary vein orifices. To minimize the number of incisions, cut and sew lesions were replaced with either cryoablation ($N=36$) or microwave ablation ($N=116$). The lesion set of the LA side included a single box lesion for pulmonary vein isolation (two round lesions for the isolation of pulmonary veins in pairs, two parallel lesions for connecting between both the superior and inferior pulmonary veins) and two linear ablations from the pulmonary isolation lesion to the posterior mitral valve annulus and LA appendage, respectively, with additional epicardial coronary sinus ablation. To reduce the LA dimension, the parallel resection of LA wall to the posterior mitral annulus was performed after exclusion of the left atrial appendage from within, especially in all patients with LA size greater than 60 mm preoperatively. Our modification of the maze procedure was illustrated in Fig. 1. For cryoablation, the cryoprobe (Frigitronics Cardiac Cryosurgical System 200; Frigitronics, Inc, Coopersurgical, Shelton, Conn) was applied endocardially at -60°C . The duration of ablation varied depending on the thickness of the atrium, usually between 90 s and 2 min after ice crystals were observed transmurally. For microwave ablation, the FLEX microwave probe (Afx Inc, Fremont, Calif) was applied endocardially

Table 1 Preoperative and operative data of the patients

Characteristic	Degenerative group	Rheumatic group	<i>p</i> value
No	47	105	
Age (yr)	50.6±13.1	47.2±10.5	0.089
Male/Female	25/22	69/36	0.142
Mitral valve disease			
Stenosis/Regurgitation	1/45	64/33	< 0.001
Stenoregurgitation	1	9	
Af profile			
CT ratio (%)	58.7±7.6	58.7±10.5	0.132
Af duration (yr)	3.6±4.6	5.8±6.7	0.018
Paroxysmal/Continuous	12/35	5/100	< 0.001
Fine/Coarse	20/27	49/56	0.638
Myocardial function			
LVEF(%)	57.8±9.0	53.3±10.7	0.008
LA dimension (mm)	58.8±10.9	60.8±9.7	0.260
LVESD (mm)	41.5±7.9	40.3±7.7	0.390
LVEDD (mm)	62.3±11.2	56.7±9.0	< 0.001
Prev. Cardiac OP history	2 (4.3 %)	6 (5.7 %)	
Operative data			
CPB (min)	169±41	158±41	0.132
ACC (min)	125±35	115±32	0.090
Microwave/Cryo	31/16	85/20	0.118
MVR/MVP	6/41	62/43	< 0.001
LA volume reduction procedure	31	85	0.118
TAP	10	44	0.032
AVR	1	18	
CABG	0	6	
ASD or VSD	6	1	
Other	0	1	
Follow-up period (yr)	4.4±1.2	4.8±1.3	0.079

ACC aortic cross clamp, *Af* atrial fibrillation, *ASD* atrial septal defect, *AVR* aortic valve replacement, *CABG* coronary artery bypass graft, *CPB* cardiopulmonary bypass, *CT ratio* cardiothoracic ratio, *LA* left atrium, *LVEDD* left ventricular end diastolic dimension, *LVEF* left ventricular ejection fraction, *LVESD* left ventricular end systolic dimension, *MVP* mitral valvuloplasty, *MVR* mitral valve replacement, *TAP* tricuspid annuloplasty, *VSD* ventricular septal defect

with an energy level of 65 W for 2 min uniformly because of the lacking of transmural feedback sensor system. In addition, to prevent postoperative atrial flutter, the right atrial isthmus was isolated completely with cryoablation after two ablation

lines on the intercaval and free wall of right atrium. The end point of ablation was the conversion to regular atrial tachycardias or sinus rhythm during the weaning process of cardiopulmonary bypass.

Fig. 1 Schematic illustration of the modified maze procedure

Postoperative Follow-Up

To evaluate cardiac rhythm after surgery, standard 12-channel surface electrocardiography and 24-hour Holter monitoring were performed at 6 month intervals during the first 2 years and then repeated every year after.

To evaluate LA dimension, LA function, and mitral annulus movement postoperatively, transthoracic echocardiography with tissue Doppler imaging (Hewlett-Packard Sonos 2500 or 5500 imaging system with a 2.5-MHz transducer) were performed at 6-month intervals during the first 2 years and then repeated every year after. Echocardiographic variables on 1 year after surgery were regarded as the data of base line. Ejection fraction of the LV was calculated using the biplane Simpson method. The LV end diastolic and end systolic dimensions were measured from parasternal M-mode acquisitions. LA dimension was measured at end systole as the largest distance between the posterior aortic wall and the center of the line denoting the posterior LA wall. Using the sample volume on the tip of the mitral valve in an apical four chamber view, mean peak velocity of transmitral E wave and A wave was obtained. Particularly, E/A ratio was calculated by the mean values of five consecutive beats. Mean peak early (E') and late (A') diastolic annulus velocity and the ratio of early to late peak velocities (E'/A') were calculated with the sample volume located at the septal side of the mitral annulus. For later assessment, all data were collected prospectively and stored in a specially organized and controlled database.

For patients with early atrial fibrillation recurrences, amiodarone was prescribed at 1200 mg/d after the Cox-maze procedure and tapered after conversion into normal sinus rhythm. For patients with valve repair ($N=84$), or replacement with biological prosthesis ($N=13$), warfarin was prescribed for 6 months postoperatively with international normalized ratio (INR) of 1.5 to 2.0. For patients with mechanical valve replacement ($N=55$), warfarin was prescribed for life-long periods with INR of 2.0 to 3.0.

Statistics

All continuous variables were expressed as mean $\pm$ S.D and were tested using a student *t* test. For categorical variables, Chi-square statistics were used. For comparison of repeated data between two sets of data within a group at different time periods, the paired *t* test was used. A *p* value of 0.05 or less was considered statistically significant in all cases. The SPSS software package 14.0 (SPSS Inc, Chicago, IL) was used for statistical analysis.

Results

Preoperative echocardiographic findings of the degenerative and rheumatic groups are shown in Table 1. Mean LA

dimension did not significantly differ between the two groups. However, in the degenerative group, a preoperative mean duration of atrial fibrillation was longer ($p=0.018$), the continuous nature of atrial fibrillation was more often found ($p<0.001$), and the LV end diastolic dimension was larger ($p<0.001$). Compared to the rheumatic group, almost all patients in the degenerative group had mitral valve surgery for regurgitation ($p<0.001$).

Operative information is summarized in Table 1. Compared to the rheumatic group, a significantly greater number of patients in the degenerative group received mitral valvuloplasty, $p<0.001$. However, tricuspid annuloplasty was more often used in the rheumatic group than the degenerative group ($p=0.032$). Nevertheless, there was no difference in statistical results according to the cardiopulmonary bypass time, aortic cross clamp time, and energy source for the maze procedure between the two groups, respectively. In addition, postoperative follow-up periods were a little longer in the rheumatic group, but there was no significant difference ($p=0.079$).

Table 2 shows the LA function and mitral annulus movement in both groups on postoperative 1 year (base line). Compared to the degenerative group, patients in the rheumatic group showed a significantly larger LA dimension (43.6 ± 7.4 mm in the degenerative group, 46.8 ± 6.6 mm in the rheumatic group, $p=0.009$). There were, however, no significant differences in LV ejection fraction, LV end diastolic dimension, and LV end systolic dimension between the two groups. In addition, A wave velocity, E wave velocity, and E/A ratio were not statistically different between the two groups. Even though obvious LV diastolic dysfunction, the degree of E' velocity and E/E' ratio were similar in both

Table 2 Cardiac function on postoperative 1 years (Base line)

Variable	Degenerative group	Rheumatic group	<i>p</i> value
LVEF(%)	58.9 $\pm$ 7.5	59.2 $\pm$ 5.8	0.799
LA dimension (mm)	43.6 $\pm$ 7.4	46.8 $\pm$ 6.6	0.009
LVESD (mm)	33.5 $\pm$ 5.9	34.6 $\pm$ 5.2	0.767
LVEDD (mm)	50.6 $\pm$ 5.8	50.3 $\pm$ 5.2	0.254
E velocity (cm/s)	149.3 $\pm$ 32.1	150.0 $\pm$ 31.9	0.898
A velocity (cm/s)	71.8 $\pm$ 68.1	69.2 $\pm$ 28.0	0.411
E/A ratio	2.3 $\pm$ 0.9	2.5 $\pm$ 1.3	0.240
E' velocity (cm/s)	5.9 $\pm$ 1.8	5.8 $\pm$ 1.9	0.784
A' velocity (cm/s)	4.9 $\pm$ 1.6	4.6 $\pm$ 1.8	0.381
E'/A' ratio	1.3 $\pm$ 0.6	1.4 $\pm$ 0.5	0.715
E/E' ratio	29.5 $\pm$ 14.3	29.0 $\pm$ 11.8	0.859

A velocity mean peak late filling wave velocity due to atrial contraction, *A' velocity* mean peak late diastolic annulus velocity, *E velocity* mean peak early rapid filling wave velocity, *E' velocity* mean peak early diastolic annulus velocity, *LA* left atrium, *LVEDD* left ventricular end diastolic dimension, *LVEF* left ventricular ejection fraction, *LVESD* left ventricular end systolic dimension

groups (E' velocity: 5.9 ± 1.8 cm/s in the degenerative group, 5.8 ± 1.9 cm/s in the rheumatic group, $p=0.784$; E/E' : 29.5 ± 14.3 in the degenerative group, 29.0 ± 11.8 in the rheumatic group, $p=0.859$).

Table 3 shows the changes of LA dimension, LA function, and mitral annulus movement over the follow-up period. Compared to base line (1 year after surgery), LA dimension (from 45.84 ± 7.00 to 47.13 ± 7.26 mm, $p<0.001$) and E/A ratio (from 2.45 ± 1.18 to 2.97 ± 1.34 , $p<0.001$) were significantly increased. Furthermore, along with a significant increase of E wave velocity (from 149.78 ± 31.85 to 165.22 ± 38.02 cm/s, $p<0.001$) and A wave velocity (from 70.06 ± 27.78 to 63.65 ± 30.40 cm/s, $p<0.001$), the E/E' ratio was significantly increased from 29.44 ± 13.56 to 32.81 ± 12.71 , $p=0.028$. However, E' velocity and A' velocity were not changed significantly.

Figure 2 (the first row) shows the changes of the LA dimension and E/A ratio from the postoperative 1 year to the last follow-up years. Respectively, LA dimension (from 43.64 ± 5.41 to 45.62 ± 4.52 mm in the degenerative group, $p<0.001$; from 46.83 ± 4.01 to 47.81 ± 3.91 mm in the rheumatic group, $p=0.004$) and E/A ratio (from 2.31 ± 0.73 to 2.57 ± 1.12 in the degenerative group, $p=0.031$; from 2.51 ± 0.53 to 3.18 ± 0.91 in the rheumatic group, $p<0.001$) were significantly increased in both groups. Moreover, compared to the degenerative group, E/A ratio was more increased in the rheumatic group ($p=0.028$). However, there was no statistical difference in the change of LA dimension between the two groups ($p>0.1$).

Over the follow-up periods, the changes of A and E wave velocity are shown in Fig. 2 (the second row). Despite the significant increase of E wave velocity in both groups (from 149.28 ± 28.26 to 167.36 ± 29.12 cm/s in the degenerative group, $p=0.002$; from 150.00 ± 30.23 to 164.27 ± 31.12 cm/s in the rheumatic group, $p<0.001$), these changes did not statistically differ between the two groups ($p>0.1$). However, despite a statistically insignificant increase of A

wave velocity in the degenerative group, the rheumatic group showed a significant decrease of A wave velocity from 69.22 ± 11.19 to 58.39 ± 13.23 cm/s over the follow-up periods ($p<0.001$). Furthermore, this difference was statistically significant between the two groups ($p<0.001$).

Figure 2 (the third row) also shows the change of A' velocity over the follow-up periods. Despite a statistically insignificant increase of A' velocity in the degenerative group, the rheumatic group showed a significant decrease of A' velocity (mean increase of 0.57 ± 0.11 cm/s in the degenerative group, $p>0.1$; mean decrease of 0.43 ± 0.13 cm/s in the rheumatic group, $p=0.018$). Furthermore, this difference was statistically significant between the two groups ($p=0.029$).

Finally, Fig. 2 (the last row) shows the change of E' velocity and E/E' ratio. There was a statistically insignificant increase in E/E' ratio in the degenerative group. However, the significant increase of E/E' ratio was found in the rheumatic group ($p=0.043$). Moreover, these differences were statistically significant between the two groups (E/E' ratio: mean increase of 1.74 ± 1.52 in the degenerative group, mean increase of 4.49 ± 1.98 in the rheumatic group, $p=0.047$). In particular, despite a statistically insignificant increase of E' velocity in the degenerative group, the rheumatic group showed a significant decrease of E' velocity over the follow-up periods ($p=0.035$). Furthermore, this difference was statistically significant between the two groups (E' velocity: mean increase of 0.21 ± 0.15 cm/s in the degenerative group, mean decrease of 0.23 ± 0.17 cm/s in the rheumatic group, $p=0.031$).

Discussion

Main Findings

The present study revealed three important findings. First, the trend toward a gradual decline in the LA function along with a increase of LA dimension was found in patients with atrial fibrillation accompanied by mitral valve disease after the successful maze procedure and concomitant mitral valve surgery (E/A ratio: 2.45 ± 1.18 on postoperative 1 year vs. 2.97 ± 1.34 on the last follow-up, $p<0.001$; LA dimension: 45.84 ± 7.00 mm on postoperative 1 year vs. 47.13 ± 7.26 mm on the last follow-up, $p<0.001$). These results were in line with the previous report [9].

The difference in the change of late diastolic annulus velocity (A') was the second finding. A' velocity is a more sensitive marker of the LA booster function [10]. On contrary to the degenerative group, the rheumatic group showed statistically significant decrease in A' velocity ($p=0.018$). This finding means that the LA function is more deteriorating in the rheumatic group. With the progressive increase of LA dimension, the progressive increase in E/A ratio and the

Table 3 Overall change of LA & LV diastolic function

Variable	Base (Postoperative 1 years)	Follow-up period (mean $\pm$ SD: 4.67 $\pm$ 1.25 years)	<i>p</i> value
LA dimension (mm)	45.84 ± 7.00	47.13 ± 7.26	<0.001
E velocity (cm/s)	149.78 ± 31.85	165.22 ± 38.02	<0.001
A velocity (cm/s)	70.06 ± 27.78	63.65 ± 30.40	<0.001
E/A ratio	2.45 ± 1.18	2.97 ± 1.34	<0.001
E' velocity (cm/s)	5.77 ± 1.82	5.72 ± 3.77	0.617
A' velocity (cm/s)	4.76 ± 1.75	4.55 ± 2.15	0.319
E/E' ratio	29.44 ± 13.56	32.81 ± 12.71	0.028

A velocity mean peak late filling wave velocity due to atrial contraction, *A'* velocity mean peak late diastolic annulus velocity, *E* velocity mean peak early rapid filling wave velocity, *E'* velocity mean peak early diastolic annulus velocity, *LA* left atrium

Fig. 2 Change of LA dimension, E/A ratio, transmitral A wave velocity, transmitral E wave velocity, late diastolic annulus velocity (A'), early diastolic annulus velocity (E'), and E/E' ratio in both groups

progressive decrease in A' velocity raises have concerned about the effects of the Cox-maze procedure on the LA function, especially in the rheumatic group.

The last interesting finding was the difference in the change of the LV diastolic function, which was found by Doppler tissue imaging. At first, we found that despite a little decrease of E' velocity (5.77 ± 1.82 cm/s on postoperative 1 year vs. 5.72 ± 3.77 cm/s on the last follow-up, $p > 0.1$), E/E' ratio was significantly increased on the whole (29.44 ± 13.56 on postoperative 1 year vs. 32.81 ± 12.71 on the last follow-up, $p = 0.028$). In addition, after analyzing by

dividing into two groups, namely degenerative and rheumatic group, different patterns of the change of the LV diastolic function were revealed according to mitral valve pathology. On contrary to the degenerative group, the rheumatic group showed statistically significant decrease in E' velocity ($p = 0.031$). In addition, the rheumatic group showed statistically significant increase in E/E' ratio compared to the degenerative group ($p = 0.047$). This finding means that although the LV diastolic dysfunction is apparent in both groups, the LV diastolic function is more worsening in the rheumatic group than the degenerative group.

Clinical Implications

It is well known that mitral annulus velocity determined by Doppler tissue imaging is a relatively preload independent variable in evaluating the LV diastolic function [11]. In normal subjects, E' velocity increases as transmitral gradient increases with exertion or increased preload. However, E' velocity is reduced at baseline and does not increase with increased preload in patients with the LV diastolic dysfunction, as much as in normal subjects. Therefore, E' velocity increases with increasing transmitral gradient in healthy individuals, so that E/E' ratio is similar at rest and with exercise (usually <8) [12].

Decreased E' velocity is one of the earliest markers for LV diastolic dysfunction. As diastolic dysfunction progresses, E wave velocity increases and E' velocity remains reduced with higher filling pressure. Therefore, E/E' ratio correlates well with LV filling pressure or mean pulmonary capillary wedge pressure (PCWP), namely, mean PCWP is >20 mmHg if E/E' is >15 [13].

However, E/E' ratio is not reliable in predicting LV filling pressure in mitral valve disease, especially in patients with primary severe mitral regurgitation. Furthermore, E/E' ratio in patients with mitral valve replacement is often high, even in normal LV filling pressure [14]. These are the reasons why we did not regard the preoperative echocardiographic variables as baseline data. We focused on the change of cardiac function only after the successful Cox-maze procedure performed concomitantly with mitral valve surgery.

In this study, LV filling patterns of abnormal relaxation were found in all patients of both groups who underwent the Cox-maze procedure concomitantly with mitral valve operations. In addition, the significant increase of E/E' ratio and decrease of E' velocity were found in the rheumatic group, compared to the degenerative group. Furthermore, these differences were statistically significant between the two groups. These findings suggest that the LV diastolic function is more worsening in the rheumatic group than the degenerative group.

Despite the high rate of sinus rhythm conversion, some authors reported that the Cox-maze procedure was less satisfactory in rheumatic disease than nonrheumatic disease [3]. However, previously our groups demonstrated that the Cox-maze procedure was equally effective in treating atrial fibrillation in patients with either rheumatic or nonrheumatic mitral valve disease in terms of sinus conversion rate and LA function over short-term follow-up [5]. Nevertheless, as time went on, the rheumatic group showed a more progressive decline in the LA function and LV diastolic function than the degenerative group in this study. With degenerative change from aging process, the stiffness of heart chambers caused by persistent volume or pressure burden may be a

pivotal role of the functional deterioration of heart, irrespective of etiology of mitral valve disease. Rheumatic disease might be a chronic and ongoing cardiac remodeling process. However, unfortunately we were not able to find any specific histopathologic features of rheumatic heart disease in the surgically resected LA posterior wall, except for non-specific interstitial inflammation and fibrosis. Even after the recovery phase from rheumatic disease, these changes of heart function might be irreversible or progressive because of 'rheumatic myocarditis'. Consequently, these natures of rheumatic disease may be responsible to explain the changes in LA and LV diastolic functions, which are different from nonrheumatic disease [7].

LA size has been related with an increased risk of stroke in patients with atrial fibrillation [15] and was also an important predictor to achieve sinus rhythm after radiofrequency ablation [16]. For reduction of LA dimension in patients with LA size greater than 60 mm preoperatively, we routinely performed the resection of the posterior LA wall parallel to the mitral annulus. Therefore, compared to preoperative data (60.8 ± 10.1 mm), LA dimension was significantly decreased at discharge (45.1 ± 6.7 mm, $p < 0.01$). To exclude surgical effect on the change of LA dimension after the successful Cox-maze procedure, the data on post-operative 1 year was considered as baseline variables.

We measured LA dimension rather than LA volume and found a significant increase of LA dimension postoperatively in the present study. However, LA volume was well considered as a more accurate index of LA size than LA dimension [17]. Although that was a significant limitation, these changes of LA geometry were parallel with other studies [18]. LA dimension was significantly decreased just after sinus rhythm conversion and showed an increase during the follow-up period (54 ± 9 vs. 46 ± 5 vs. 48 ± 6 mm for before the maze procedure and in the early stages, mean: 3.1 months and late stages, mean: 2.2 years). Moreover, without performing LA volume reduction surgery, LA volume measured by magnetic resonance imaging did not decrease at a mean follow-up period of 13.8 months in patients with LA enlargement even after successful sinus rhythm recovery [19]. The LA size is known to be an important risk factor for failure of the maze procedure [20], and the long-term success rate of the maze procedure is dependent on the size of the LA [21]. Even though our cohort included the patients with regular sinus rhythm after the maze procedure throughout the follow-up period, these findings in this study add support to the view that the failure rate of the maze procedure and the recurrence rate of atrial fibrillation after successful sinus rhythm conversion might be higher in patients with the rheumatic mitral disease.

In addition, a decreased LA function might predispose to thrombus formation in the LA despite elimination of atrial fibrillation after the Cox-maze procedure [22]. These

findings mean that the possibility of thrombus formation within the LA was high in spite of the successful Cox-maze procedure, especially in the rheumatic mitral disease. Furthermore, the risk of thromboembolic events might also be a trend toward increase over the periods of follow-up in the rheumatic mitral disease compared to the degenerative mitral disease. Therefore, according to the pathology of mitral valve disease, different guidelines on anticoagulation management after the successful Cox-maze procedure deserve consideration, but further studies are necessary. In fact, we experienced two cases of minor intracerebral thromboembolic events in the rheumatic group during the follow-up periods, in spite of normal sinus rhythm.

This study has several limitations. First, the majority of patients in this study had abnormal LV diastolic function preoperatively. We do not guarantee the same results of the Cox-maze procedure in patients with a normal LV diastolic function. Second, like LA function, LV diastolic function usually depends on other factors such as the degree of residual valvular disease, volume status, and so on. Consequently, echocardiographic data may vary according to the status of patients just at that time. Third, the current study involved patients who received the Cox-maze procedure with concomitant mitral valve operation. Therefore, these changes are not interpreted as the effect of only the Cox-maze procedure on LA or LV diastolic functions. The change of myocardial function is usually an ongoing process despite mitral valve operations. Fourth, many patients had concomitant cardiac interventions (aortic valve replacement, tricuspid annuloplasty, coronary artery bypass grafting, or correction of congenital heart diseases) with the Cox-maze procedure, which may have influenced the cardiac diastolic functions. Another limitation was the nonhomogeneous pathology of mitral valve disease. Not only the etiology of mitral valve disease (rheumatic disease versus degenerative disease), but also the pathology of mitral valve disease (mitral regurgitation versus mitral stenosis) may be significant determinants of the outcome of the patients in this study. Finally, a relatively small sample size may affect the results of the Cox-maze procedure in patients with atrial fibrillation. Nevertheless, this study was encouraging because it showed distinct results in respect of etiology, differently from the other studies previously discussed.

In conclusion, there was a steady enlargement of the LA size and decrease of LA function during the follow-up period in patients sustaining normal sinus rhythm conversion after the Maze procedure with mitral valve operation. Particularly, the progressive loss of the LA function as well as LV diastolic function was more prominent in the rheumatic group than the degenerative group. Therefore, differentiated strategies for postoperative follow-up and anticoagulation treatment are needed according to the pathology of mitral valve disease.

References

1. Brodell GK, Cosgrove D, Schiavone W, Underwood DA, Loop FD (1991) Cardiac rhythm and conduction disturbances in patients undergoing mitral valve surgery. *Cleve Clin J Med* 58:397–9
2. Cox JL, Schuessler RB, D'Agostino JH Jr et al (1991) The surgical treatment of atrial fibrillation. III. Development of a definitive surgical procedure. *J Thorac Cardiovasc Surg* 101:569–83
3. Fukada J, Morishita K, Komatsu K et al (1998) Is atrial fibrillation resulting from rheumatic valve disease a proper indication for the maze procedure? *Ann Thorac Surg* 65:1566–9
4. Jatene MB, Marcial MB, Tarasoutchi F, Cardoso RA, Pomerantzeff P, Jatene AD (2000) Influence of the maze procedure on the treatment of rheumatic atrial fibrillation evaluation of rhythm control and clinical outcome in a comparative study. *Eur J Cardiothorac Surg* 17:117–24
5. Lee JW, Park NH, Choo SJ, Jo MS, Song H, Song MG (2003) Surgical outcome of the maze procedure for atrial fibrillation in mitral valve disease: rheumatic versus degenerative. *Ann Thorac Surg* 75:57–61
6. Fujita T, Kobayashi J, Toda K et al (2010) Long-term outcome of combined valve repair and maze procedure for nonrheumatic mitral regurgitation. *J Thorac Cardiovasc Surg* 140:1332–7
7. Kim KC, Cho KR, Kim YJ, Sohn DW, Kim KB (2007) Long-term results of the Cox-Maze III procedure for persistent atrial fibrillation associated with rheumatic mitral valve disease: 10-year experience. *Eur J Cardiothorac Surg* 31:261–6
8. Kobayashi J, Sasako Y, Bando K et al (2002) Eight-year experience of combined valve repair for mitral regurgitation and maze procedure. *J Heart Valve Dis* 11:165–72
9. Lönnerholm S, Blomström P, Nilsson L, Blomström-Lundqvist C (2008) Long-term effects of the maze procedure on atrial size and mechanical function. *Ann Thorac Surg* 85:916–20
10. Hesse B, Schuele SU, Thamilarasan M, Thomas J, Rodriguez L (2004) A rapid method to quantify left atrial contractile function: Doppler tissue imaging of the mitral annulus during atrial systole. *Eur J Echocardiogr* 5:86–92
11. Sohn DW, Chai IH, Lee DJ et al (1997) Assessment of mitral annulus velocity by Doppler tissue imaging in the evaluation of left ventricular diastolic function. *J Am Coll Cardiol* 30:474–80
12. Yu CM, Sanderson JE, Marwick TH, Oh JK (2007) Tissue Doppler imaging a new prognosticator for cardiovascular disease. *J Am Coll Cardiol* 49:1903–14
13. Ommen SR, Nishimura RA, Appleton CP et al (2000) Clinical utility of Doppler echocardiography and tissue Doppler imaging in the estimation of left ventricular filling pressure: a comparative simultaneous Doppler-catheterization study. *Circulation* 102:1788–94
14. Bruch C, Stypmann J, Gradaus R, Breithardt G, Wichter T (2004) Usefulness of tissue Doppler imaging for estimation of filling pressures in patients with primary or secondary pure mitral regurgitation. *Am J Cardiol* 93:324–8
15. Dittrich HC, Pearce LA, Asinger RW et al (1999) LA diameter in nonvalvular AF: an echocardiographic study. *Am Heart J* 137:494–9
16. Chen MC, Chang JP, Guo GB, Chang HW (2001) Atrial size reduction as a predictor of the success of radiofrequency maze procedure for chronic atrial fibrillation in patients undergoing concomitant valvular surgery. *J Cardiovasc Electrophysiol* 12:867–74
17. Tsang TS, Abhayaratna WP, Barnes ME et al (2006) Prediction of cardiovascular outcomes with left atrial size; is volume superior to area or diameter? *J Am Coll Cardiol* 47:1018–23

18. Yuda S, Nakatani S, Kosakai Y, Yamagishi M, Miyatake K (2001) Long-term follow-up of atrial contraction after the maze procedure in patients with mitral valve disease. *J Am Coll Cardiol* 37:1622–7
19. Marui A, Nishina T, Tadamura E et al (2008) Impact of left atrial volume reduction concomitant with atrial fibrillation surgery on left atrial geometry and mechanical function. *J Thorac Cardiovasc Surg* 135:1297–305
20. Kamata J, Kawazoe K, Izumoto H et al (1997) Predictors of sinus rhythm restoration after Cox maze procedure concomitant with other cardiac operations. *Ann Thorac Surg* 64:394–8
21. Schuessler R (2001) Does size matter? *J Cardiovasc Electrophysiol* 12:875–6
22. Lemola K, Desjardins B, Sneider M et al (2005) Effect of left atrial circumferential ablation for atrial fibrillation on left atrial transport function. *Heart Rhythm* 2:923–8