

Long-term results of the maze procedure on left ventricular function for persistent atrial fibrillation associated with mitral valve disease

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Abstract Although the maze procedure is often performed as a surgical treatment for atrial fibrillation (AF) combined with mitral valve surgery, the long-term efficacy of the maze procedure concerning cardiac function has not been determined. The aim of this study was to assess long-term results of the maze procedure for left ventricular function in patients with persistent AF associated with mitral valve disease. We analyzed 38 patients who underwent the maze procedure for persistent AF and mitral valve surgery. The cardiothoracic ratio on chest X-ray and the left atrial dimension, left ventricular end-diastolic dimension, left ventricular end-systolic dimension and left ventricular ejection fraction on transthoracic echocardiography were evaluated before and 6 years after the maze procedure. Twenty-two patients maintained sinus rhythm (SR group) and 16 patients had recurrence of permanent AF (AF group) after the maze procedure. Preoperative cardiac function and the methods of mitral surgery were similar between the two groups. At the latest follow-up, left ventricular function tended to be better in the SR group than in the AF group. Cardiovascular events occurred more often in the AF group during follow-up (50 vs. 18%, $p < 0.05$). This retrospective study revealed that maintaining the sinus rhythm after the maze procedure for patients who underwent mitral valve surgery might be important for preserving better long-term left ventricular function and result in fewer cardiovascular events.

Keywords Atrial fibrillation ·
Left ventricular function · Maze procedure ·
Mitral valve disease · Mitral valve surgery

Introduction

Atrial fibrillation (AF) is the most common arrhythmia in patients with mitral valve disease [1–3] and is associated with high risks of cardiac death, heart failure and stroke [4–7]. The maze procedure developed by Cox and colleagues has been considered the most effective surgical treatment of AF. The Cox maze procedure was designed to interrupt all possible macro-reentrant circuits in the atria, thereby precluding the ability of the atria to fibrillate, and restoration of sinus rhythm has been reported to be successful in 75–95% of patients [8, 9]. Therefore, the maze procedure has been performed frequently for AF during mitral valve surgery. Reports on the maze procedure have mainly focused on freedom from the recurrence of AF, cardiac events and stroke. The maze procedure has resulted in greater freedom from the recurrence of AF and in fewer cardiac events and strokes [8, 9]. However, the long-term efficacy concerning cardiac function has not been well studied. The purpose of this study was to evaluate the long-term efficacy of the maze procedure for persistent AF on left ventricular function in patients who underwent concomitant mitral valve surgery.

Methods

Study patients

From 1995 to 2006, 545 patients with mitral valve disease were admitted to our cardiovascular department and

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evaluated for mitral valve surgery and/or the maze procedure. Of them, 329 patients underwent the operations. After operation, most of them (267 patients) were re-admitted to our department for rehabilitation. Among them, patients with severe heart failure, severe renal or hepatic disease and who did not give informed consent were excluded. A total of 38 patients who underwent both the maze procedure for persistent AF and mitral valve surgery were enrolled in this study. A standard Cox maze procedure was carried out as described by Cox and colleagues [10]. In the Kosakai maze procedure, incision and cryoablation lines were made according to Kosakai's modification [11]. Briefly, cryoablation was used instead of atriotomy and re-anastomosis to preserve the sinus node artery and to simplify the procedure. Atria that had dilated excessively were trimmed to approximately 4 cm at the circumferential left atriotomy around the pulmonary veins. All of the right atrial appendage and a part of the left atrial appendage were preserved. All data were retrospectively analyzed from the medical records, including the operative records, clinical histories, chest X-rays, standard 12-lead electrocardiograms (ECG), echocardiograms and cardiac catheterization data. Transthoracic echocardiography was performed with the parasternal view. The left atrial dimension (LAD), left ventricular end-diastolic dimension (LVEDd), left ventricular end-systolic dimension (LVESd) and left ventricular ejection fraction (LVEF) were measured by the mean value averaging ten heart beats. All patients had been hospitalized more than 1 month in our department before surgery, and persistent AF was confirmed by repetitive standard 12-lead ECG and 24-h ambulatory ECG recordings. The patients were divided into the two groups based on cardiac rhythm at the latest follow-up. The AF group was defined as those patients with recurrence of permanent AF that was sustained for more than 6 months. The SR group was defined as those with absences of permanent AF and other atrial arrhythmias.

Postoperative follow-up

After the operation the patients visited our clinic every 1 month for check-ups and standard 12-lead ECGs, and echocardiographies and chest X-rays were obtained every 6 months. For the patients who developed recurrence of AF soon after the operation, antiarrhythmic drugs and/or cardioversion were tried once to restore the sinus rhythm. When the sinus rhythm could be effectively maintained, some of the patients were put on antiarrhythmic drugs thereafter. The patients who developed recurrent AF were treated with rate control agents such as β -blockers, non-dihydropyridine calcium channel blockers and/or digoxin. All patients were put on Coumadin to keep the international normalized ratio (INR) around 2.0.

Statistical analysis

All values were expressed as mean \pm standard deviation or percentages. A p value of <0.05 was considered statistically significant. The Student's t test was used in case of normally distributed variables. The difference in cardiovascular events between the groups was assessed by the chi-square test and Fisher's exact test for categorical variables.

Results

Twenty-two patients maintained the sinus rhythm (SR group), and 16 patients had recurrence of permanent AF (AF group) during follow-up after the maze procedure (mean follow-up periods 79 ± 44 months for the SR group vs. 66 ± 37 months for the AF group, $p = 0.36$). Because this was a retrospective study, there was a difference in follow-up periods. The clinical characteristics are shown in Table 1. The AF group was significantly older (age

Table 1 Clinical characteristics

	AF group ($n = 16$)	SR group ($n = 22$)	p value
Male/female	10/6	8/14	0.11
Age (years)	64 ± 6	56 ± 9	<0.01
MR/MS	12/4	15/7	0.92
RHD/nonRHD	6/10	12/10	0.29
Hypertension	6 (37%)	3 (13%)	0.08
CAD	1 (6%)	1 (4%)	0.81
Cardiomyopathy	1 (6%)	0 (0%)	0.23
Drugs at the last follow-up			
Antiarrhythmic drug	1 (6%)	8 (36%)	<0.05
β -blocker	6 (37%)	1 (4%)	<0.01
Digoxin	9 (56%)	12 (54%)	0.91
Diuretic	10 (62%)	14 (63%)	0.94
ACE	7 (43%)	10 (45%)	0.91
Maze procedures			
Cox maze	4 (25%)	7 (31%)	0.64
Kosakai maze	12 (75%)	15 (68%)	
Concomitant mitral surgery			
MVP	2	3	0.91
MVR	3	9	0.14
MVP + TAP	4	1	0.06
MVR + TAP	4	7	0.64
DVR	2	1	0.36
DVR + TAP	1	1	0.81

MR mitral regurgitation, MS mitral stenosis, RHD rheumatic heart disease, CAD coronary artery disease, ACE angiotensin-converting enzyme inhibitor, MVP mitral valve plasty, MVR mitral valve replacement, TAP tricuspid valve plasty, DVR aortic and mitral valve replacement

64 ± 6 years in the AF group vs. 56 ± 9 years in the SR group; $p < 0.01$). The etiology of mitral valve disease, frequency of other diseases, method of maze procedure and concomitant mitral surgery were similar in both groups. At the latest follow-up, anti-arrhythmic drugs were more frequently used in the SR group ($p < 0.05$), and the rate of control agents used was more in the AF group than in the SR group ($p < 0.01$). Most of the maze procedures (97%) were done by the Kosakai maze method, and the prevalence of the Kosakai maze method was similar between the groups. The preoperative cardiac function is shown in Table 2. The systolic blood pressure in the AF group was significantly higher than in the SR group (systolic blood pressure 127 ± 13 mmHg in the AF group vs. 116 ± 13 mmHg in the SR group; $p < 0.05$). Otherwise, there were no significant differences between the groups in regard to the cardiothoracic ratio (CTR) on chest X-ray or the echocardiographic parameters. Cardiac catheterization was performed in 15 patients in the AF group and 19

patients in the SR group before surgery. There were no significant differences in hemodynamic parameters between the groups.

Early postoperative cardiac function

Early postoperative evaluations were performed at a postoperative mean of 18 ± 6 days in the AF group and 23 ± 16 days in the SR group ($p = 0.23$). Cardiac function soon after cardiac surgery was similar between the groups (Table 3).

Long-term follow-up

In the AF group, 11 patients initially had sinus rhythm after the maze procedure but had recurrence of AF at 44 ± 33 months (range 2–112 months). The SR group maintained sinus rhythm throughout the follow-up period. Left ventricular function tended to be better in the SR group (CTR: 56 ± 7% in the AF group vs. 52 ± 5% in the SR group, $p = 0.08$; LAD: 49 ± 5 mm in the AF group vs. 45 ± 7 mm in the SR group, $p = 0.05$; LVEF: 60 ± 12% in the AF group vs. 64 ± 8% in the SR group, $p = 0.20$; LVEDd: 51 ± 8 mm in the AF group vs. 47 ± 5 mm in the SR group, $p = 0.06$; LVESd: 34 ± 9 mm in the AF group vs. 31 ± 5 mm in the SR group, $p = 0.14$; BNP: 73.8 ± 45.0 pg/ml in the AF group vs. 57.4 ± 29.5 pg/ml in the SR group, $p = 0.27$), though not statistically significantly (Fig. 1).

There was no reoperation or death during follow-up. The postoperative cardiovascular events are shown in Table 4. Permanent pacemakers were implanted in four patients (25%) in the AF group because of tachycardia-bradycardia syndrome ($n = 2$) and brady AF ($n = 2$), and in the SR group two patients (9%) because of sinus arrest or complete atrial ventricular block. One patient in the AF group had both pacemaker implantation and stroke, and one patient in the SR group had both pacemaker implantation

Table 2 Preoperative cardiac function

	AF group ($n = 16$)	SR group ($n = 22$)	p value
Blood pressure (mmHg)			
Systolic pressure	127 ± 13	116 ± 13	<0.05
Diastolic pressure	77 ± 10	72 ± 7	0.06
Chest X-ray			
CTR (%)	57.4 ± 6.0	58.0 ± 7.3	0.77
Echocardiography			
LAD (mm)	54 ± 9	57 ± 8	0.27
LVEDd (mm)	55 ± 12	55 ± 10	0.88
LVESd (mm)	37 ± 12	37 ± 8	0.89
LVEF (%)	61 ± 12	64 ± 11	0.43
	AF group ($n = 15$)	SR group ($n = 19$)	p value
Cardiac catheter examination			
Mean RA (mmHg)	4.6 ± 2.6	4.7 ± 3.1	0.90
Mean PA (mmHg)	19.3 ± 4.9	20.5 ± 8.7	0.64
RVs (mmHg)	30.2 ± 7.4	29.4 ± 7.9	0.78
Mean PCWP (mmHg)	11.9 ± 4.3	12.9 ± 6.0	0.59
LVSP (mmHg)	124.4 ± 19.0	122.2 ± 19.6	0.75
LVEDP (mmHg)	8.2 ± 3.5	9.3 ± 3.7	0.40
Mean Ao (mmHg)	90.0 ± 9.4	87.1 ± 8.4	0.35
CI (l/min/m ²)	2.24 ± 0.89	2.05 ± 0.61	0.48

CTR cardiothoracic ratio, LAD left atrial dimension, LVEDd left ventricular end diastolic dimension, LVESd left ventricular end systolic dimension, LVEF left ventricular ejection fraction, RA right atrial pressure, PA pulmonary artery pressure, RVs systolic right ventricular pressure, PCWP pulmonary capillary wedge pressure, LVSP left ventricular systolic pressure, LVEDP left ventricular end-diastolic pressure, Ao aortic pressure, CI cardiac index

Table 3 Early postoperative cardiac function

	AF group ($n = 16$)	SR group ($n = 22$)	p value
Chest X-ray			
CTR (%)	56 ± 4	53 ± 5	0.06
Echocardiography			
LAD (mm)	46 ± 5	42 ± 7	0.07
LVEDd (mm)	49 ± 9	49 ± 5	0.79
LVESd (mm)	35 ± 9	35 ± 5	0.98
LVEF (%)	61 ± 10	59 ± 9	0.67

CTR cardiothoracic ratio, LAD left atrial dimension, LVEDd left ventricular end diastolic dimension, LVESd left ventricular end systolic dimension, LVEF left ventricular ejection fraction

Fig. 1 Cardiac function was similar between the AF and SR groups at the last follow-up. *CTR* cardiothoracic ratio, *LAD* left atrial dimension, *LVEF* left ventricular ejection fraction, *LVEDd* left ventricular end diastolic dimension, *LVESd* left ventricular end systolic dimension, *BNP* brain natriuretic peptide. AF group indicates persistent atrial fibrillation after the maze procedure, and SR group indicates sinus rhythm after maze procedure

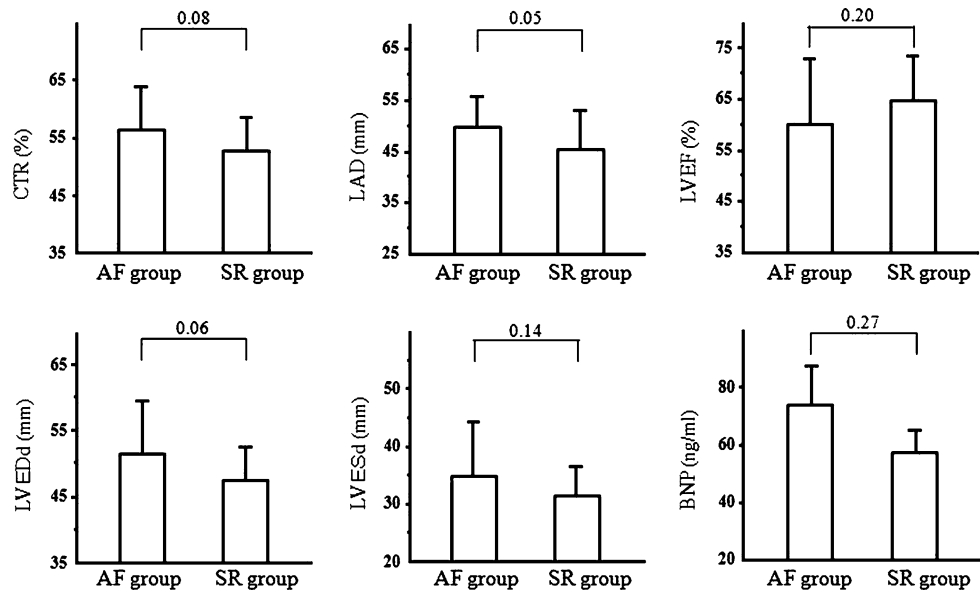


Table 4 Postoperative cardiovascular events

	AF group (n = 16)	SR group (n = 22)	p value
Pacemaker implantation	4	2	0.38
Congestive heart failure	3	2	0.70
Stroke	1	0	0.87
Total number of events	8	4	<0.05
Total number of patients	7	3	<0.05

and congestive heart failure. The total number of events or patients with cardiovascular events was greater in the AF group.

Discussion

In this study, we retrospectively evaluated the long-term efficacy of the maze procedure on left ventricular function for patients with persistent AF who underwent mitral valve surgery. One half of the patients had recurrence of AF. Long-term left ventricular function tended to be better in the SR group. Cardiovascular events occurred more often in the AF group.

Cardiac function after the maze procedure

AF can be considered to cause a deterioration of cardiac function. Atrial kick contributes importantly to left ventricular function, and thus loss of atrial kick deteriorates left ventricular function [12–14]. In fact, Daud et al. [15] demonstrated that irregular ventricular rhythm results in an approximately 12% decrease in cardiac output compared to

regular ventricular rhythm. There has been little information on the effects of the maze procedure on cardiac function. As far as we know, there have been only two reports. Kobayashi et al. [16] reported the mid-term results of the maze procedure for chronic and paroxysmal AF associated with mitral regurgitation. In their study, LAD, LVEDd and LVESd in patients who had restored sinus rhythm were smaller than in patients who did not have restored sinus rhythm. Kim et al. [17] reported the long-term results of the Cox maze III procedure on cardiac function for persistent AF associated with rheumatic mitral valve disease. In their study LVEF in patients who maintained their sinus rhythm was higher than that in patients who had recurrence of persistent AF. Kim et al. [17] evaluated only rheumatic mitral valve disease. We evaluated effects of the maze procedure in patients with non-rheumatic heart disease. Our study indicated that left ventricular function tended to be better in the group maintaining SR after the maze procedure. Although we tried to have comparable backgrounds, age was younger, the prevalence of hypertension was less and preoperative blood pressure was lower in the SR group. Age and blood pressure are very important determinants of left ventricular function. Thus, the better left ventricular function in the SR group may well be related to younger age and lower preoperative blood pressure.

Postoperative complications with the maze procedure

As in previous reports [8, 9], in this study, after the maze procedure and mitral valve surgery, the patients had a good prognosis and low incidence of stroke; there were no deaths and only one stroke. Itoh et al. [9] reported that the freedom from stroke after 5 and 10 years was 97.9 and 92.4% in patients with successful maze procedures, and 84.4 and 76.6% in those with failed maze procedures.

Unfortunately, the cause of stroke in our case was unknown. Non-cardio-embolic stroke might have been most likely because INR was maintained in the therapeutic range by Coumadin in all patients. Five patients had hospitalization for congestive heart failure in this study. Three patients with congestive heart failure in the AF group had rapid ventricular responses, which possibly contributed to the development of heart failure. Two patients in sinus rhythm developed heart failure. One had constrictive pericarditis and renal failure, and the other had complete atrial ventricular block. Cox [18] and others [19] reported that the risk of permanent pacemaker implantation after the maze procedure was 10–15%. In this study it was 16%, compatible with previous reports and not different between the AF and SR group. Finally, although the total number of postoperative cardiovascular events was higher in the AF group, we cannot say that AF caused the adverse events, and it could rather be the other way round.

Study limitations

This study has several limitations. All patients visited our clinic every 1 month after discharge, and standard 12-lead ECGs were obtained. Thus, we were almost certain about their rhythm, but some patients in the SR group might have had paroxysmal AF without symptoms. Cardiac function is influenced by many factors. In fact, various etiologies of valvular heart disease may also have influenced the preoperative cardiac function. Moreover, age, preoperative blood pressure and the use of antiarrhythmic drugs were different between the groups. The number of patients was relatively small. It would be expected that a large number of patients would produce results showing more favorable effects of the maze procedure on left ventricular function. Finally, this study was retrospective. A prospective study with a large number of patients is necessary to confirm the findings of our study.

Conclusion

This retrospective study revealed that long-term left ventricular function tended to be better in sinus rhythm than in AF after the maze procedure for patients who underwent mitral valve surgery. Cardiovascular events occurred less often in sinus rhythm. Our results suggest that it may be better to maintain sinus rhythm after the maze procedure.

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