Preoperative Left Atrial Emptying Fraction is a Powerful Predictor of Successful Maze Procedure

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Background The maze procedure for the treatment of atrial fibrillation (AF) is a widely used adjunctive therapy. It is necessary to define the precise indications for the procedure based on preoperative factors, but definitive parameters in terms of atrial function have not been well determined.

Methods and Results In the present study, 55 consecutive patients undergoing the maze procedure for persistent AF in combination with operations for organic heart diseases were evaluated. After dividing the patients into successful (n=41) and unsuccessful procedure (n=14) groups, based on the postoperative rhythm, the preoperative left atrial (LA) emptying fraction measured by transthoracic 2-dimensional echocardiogram was compared between groups. The LA emptying fraction was calculated as [(LA maximum volume–LA minimum volume)/LA maximum volume]×100. The preoperative LA emptying fraction was higher in the successful procedure group than in the unsuccessful procedure group (31.2±8.5 vs 21.4±10.9%, $P=0.0011$). Based on receiver-perating characteristic curve analyses, LA emptying fraction >26% predicted successful maze procedure with 70.7% sensitivity and 78.6% specificity.

Conclusions LA emptying fraction should be considered in the precise indications of the maze procedure as adjunctive therapy. (Circ J 2009; 73: 269–273)

Key Words: Atrial fibrillation; Left atrial emptying fraction; Maze

The deleterious effects of atrial fibrillation (AF) include loss of effective atrial contraction and atrio-ventricular synchrony, which may compromise hemodynamic performance and cause stasis of blood flow within the atrium that lead thrombus formation and systemic thromboembolic complications. In addition, a persistently elevated ventricular rate during AF may produce dilated ventricular cardiomyopathy (tachycardia-induced cardiomyopathy).^{1,2}

The maze procedure for the treatment of AF is widely performed as adjunctive therapy in patients undergoing operations for organic heart diseases.³ However, from a surgical point of view, it is a demanding procedure that prolongs the aortic cross-clamp and operating times. Therefore, it is necessary to define the precise indications of the maze procedure based on preoperative factors.

The duration of AF and the left atrial (LA) size have been reported as predictors of successful maze procedure^{4–8} as has the AF wave voltage on electrocardiography (ECG);^{4,5,7} however, definitive parameters in terms of atrial function for the maze procedure have not been well determined.

The LA emptying fraction has been widely used as an index of LA function⁹ so the goal of this study was to de-

termine whether it predicts successful maze procedure.

Methods

Study Population

Between March 2004 and February 2007, we evaluated 55 consecutive patients (42 men; aged 62±10 years; range, 37–78 years) who underwent the maze procedure for persistent AF in conjunction with other operations for organic heart diseases at Sakakibara Heart Institute. Persistent AF was defined as a state of continuous AF.¹⁰ The mean duration of AF before operation was 4.3±5.1 years (range, 0.2–26 years). The mean preoperative resting heart rate was 62 beats/min (range, 47–94 beats/min). The mean left ventricular (LV) ejection fraction was 59±10% (range, 29–75%).

The maze procedure is fundamentally the same as that initially described by Cox.^{8,10} A maze-like series of incisions is created in the left and right atria. During the operation, the pulmonary veins are completely isolated, and the LA and right atrial appendages are removed. In the present study, the most common concomitant cardiac procedure was mitral valve plasty for mitral regurgitation (Table 1).

Study Design

We retrospectively reviewed the data from operative notes, clinical case histories, and laboratory investigations, including ECGs and echocardiograms. Follow-up data were collected from the outpatient records of Sakakibara Heart Institute and correspondence with the physicians to whom the patients were referred. After hospital discharge, patients were followed up monthly for adjustment of medication and

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Table 1 Concomitant Cardiac Procedures

	Successful procedure (n=41)	Unsuccessful procedure (n=14)
MVP for MR, n (%)	12 (29.3)	3 (21.4)
MVP for MR+ASD closure + TAP for TR, n (%)	2 (4.9)	1 (7.1)
MVP for MR+CABG, n (%)	2 (4.9)	1 (7.1)
MVP for MR+LVP, n (%)	0 (0)	1 (7.1)
MVP for MR+TAP for TR, n (%)	4 (9.8)	1 (7.1)
MVR for MR, n (%)	2 (4.9)	0 (0)
MVR for MR+TAP for TR, n (%)	2 (4.9)	1 (7.1)
MVR for MS+TAP for TR, n (%)	1 (2.4)	1 (7.1)
MVR for MSR, n (%)	0 (0)	4 (28.6)
MVR for MSR+AVR for AS, n (%)	1 (2.4)	0 (0)
MVR for MSR+AVR for ASR, n (%)	1 (2.4)	0 (0)
MVR for MSR+TAP for TR, n (%)	3 (7.3)	0 (0)
AVR for AR, n (%)	3 (7.3)	0 (0)
AVR for AS, n (%)	2 (4.9)	0 (0)
AVR for AR+VSD closure+CABG, n (%)	1 (2.4)	0 (0)
ASD closure+TAP for TR, n (%)	4 (9.8)	1 (7.1)
CABG, n (%)	1 (2.4)	0 (0)

MVP, mitral valve plasty; MR, mitral regurgitation; ASD, atrial septal defect; TAP, tricuspid annuloplasty; TR, tricuspid regurgitation; CABG, coronary artery bypass grafting; LVP, left ventricle plasty; MVR, mitral valve replacement; MS, mitral stenosis; MSR, mitral stenosis and regurgitation; AVR, aortic valve replacement; AS, aortic stenosis; ASR, aortic stenosis and regurgitation; AR, aortic regurgitation; VSD, ventricular septal defect.

Fig 1. Measurement of LA volumes in the apical 4-chamber view immediately before mitral valve opening (LA maximum volume, Left) and at mitral valve closure (LA minimum volume, Right) according to the method of discs. LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

evaluation of cardiac rhythm. The recommended interval of 12-lead ECG follow-up was 3 months. Holter ECGs were performed at the discretion of the attending physicians.

An unsuccessful maze procedure was defined as the occurrence of any ECG-documented AF or atrial flutter, including transient events, more than 3 months after the operation. After dividing the patients into a successful procedure group and an unsuccessful procedure group based on the postoperative rhythm, we compared various parameters between the 2 groups.^{7,11}

All patients provided written informed consent before participating in the study, which was approved by the Sakakibara Heart Institute Ethics Committee.

Echocardiography

Comprehensive 2-dimensional echocardiographic views were recorded before operation with a Sonos 7500 (Philips Medical Systems, Andover, MA, USA) with an S3 transducer. All off-line analyses were performed with Xcelera (Philips Medical Systems) and all analyses were based on the average values obtained from measurements of more than 6 beats.^{12–15}

The LA dimension was obtained from M-mode echocardiography in the parasternal long-axis view according to the guideline of the American Society of Echocardiography.^{16,17} The volumes of the LA and LV were measured by manually drawing the endocardial boundaries of the cavities

Table 2 Clinical Characteristics

	Successful procedure (n=41)	Unsuccessful procedure (n=14)	P value
Age, years	60±11	67±7	0.0323
Male, n (%)	33 (80.5)	9 (64.3)	0.3819
Duration of AF, years	4.3±5.3	4.2±4.6	0.9356
Heart rate, beats/min	77±16	81±12	0.3117
Hypertension, n (%)	13 (31.7)	2 (14.3)	0.3563
Diabetes, n (%)	3 (7.3)	0 (0)	0.7991
Renal insufficiency (Cr>2.0mg/dl), n (%)	0 (0)	2 (14.3)	0.0982
BNP, pg/ml	308±247	282±169	0.7138
NYHA functional class			0.8841
I, n (%)	9 (22.0)	4 (28.6)	
II, n (%)	17 (41.5)	5 (35.7)	
III, n (%)	14 (34.1)	4 (28.6)	
IV, n (%)	1 (2.4)	1 (7.1)	

AF, atrial fibrillation; Cr, creatinine; BNP, brain natriuretic peptide; NYHA, New York Heart Association.

Table 3 Echocardiographic Parameters

	Successful procedure (n=41)	Unsuccessful procedure (n=14)	P value
LA dimension, mm	54.6±9.3	53.4±6.9	0.6749
LA maximum volume index, ml/m ²	91.4±37.6	92.0±37.5	0.9603
LA minimum volume index, ml/m ²	63.1±27.4	71.9±29.0	0.3151
LA emptying fraction, %	31.2±8.5	21.4±10.9	0.0011
LV end-diastolic volume index, ml/m ²	80.9±32.1	79.9±40.1	0.9202
LV end-systolic volume index, ml/m ²	33.0±17.3	34.3±18.4	0.8097
LV ejection fraction, %	60.2±10.0	57.4±9.0	0.3574
LV mean wall thickness, mm	10.4±1.2	9.9±0.8	0.1214

LA, left atrium; LV, left ventricle.

according to the method of discs in the apical 4-chamber view, and were corrected by body surface area.^{17,18}

LA volume was measured immediately before mitral valve opening (LA maximum volume) and at mitral valve closure (LA minimum volume).^{17,19} The pulmonary veins and LA appendage, when visualized, were excluded from the outlines (**Fig 1**).^{17,20} To evaluate LA function, the LA emptying fraction was calculated as [(LA maximum volume–LA minimum volume)/LA maximum volume]×100%.

The LV end-diastolic volume, LV end-systolic volume, and LV ejection fraction were obtained according to the guideline of the American Society of Echocardiography.¹⁸ LV mean wall thickness was determined as the average of the posterior and septal wall thicknesses measured from the parasternal long-axis view.

Re-analysis of the LA maximum volume, LA minimum volume, and LA emptying fraction was performed in 15 randomly selected participants by the same observer and also by a second observer on separate occasions but using the same recordings. Intra- and interobserver variabilities were assessed as mean percent error (absolute difference divided by the average of the 2 observations).

ECG

Standard 12-lead ECG was performed in each patient before operation. All ECGs were standardized to normal speed (25 mm/min) and sensitivity (1 mV input produced a 10-mm deflection). The AF wave with the greatest size was measured in lead V₁ for at least 6 cardiac cycles. It was measured from the upper edge of the peak to the upper edge of the trough.²¹

Statistical Analysis

Continuous variables are reported as mean±standard deviation, and categorical variables are reported as number and percentages. Comparisons between groups were made with the chi-square test or Fisher's exact test for categorical variables and Student's t-test for continuous variables. The significance of multiple variables found significant in the univariate analysis was determined using multiple logistic regression analysis. The optimal cut-off points were determined by receiver-operating characteristic curves analysis. A P-value less than 0.05 was considered to be significant. All statistical analyses were performed with SPSS software version 11.0 (SPSS Inc, Chicago, IL, USA).

Results

Clinical Follow-up

Clinical follow-up was achieved in all patients (mean duration, 14.7±8.0 months). No deaths occurred during the follow-up period. One (2%) patient had a pacemaker implanted for sick sinus syndrome at 3 months after the operation.

At 3 months after operation, 46 (84%) patients were free from AF and atrial flutter. At the last follow-up, 41 (75%) patients remained free from AF and atrial flutter (successful procedure group) and 14 (25%) patients continued to have AF or atrial flutter (unsuccessful procedure group).

In the successful procedure group, 4 (10%) patients were on cibenzoline, 1 (2%) was on pilsicainide, 2 (5%) were on amiodarone, 20 (49%) were on β -blockers, 16 (39%) were on angiotensin-receptor blockers and/or angiotensin-converting enzyme inhibitors, 10 (24%) were on calcium channel

Fig2. Receiver-operating characteristic curve of the LA emptying fraction for the prediction of successful maze procedure as an adjunctive therapy for persistent atrial fibrillation. Area under the curve was 0.769 (95% confidence interval, 0.616–0.922) and the optimal cut-off value for successful maze procedure was 26%. LA, left atrium.

blockers, and 5 (12%) was on digitalis.

Clinical Characteristics

The successful procedure group was younger than the unsuccessful procedure group (60 ± 11 vs 67 ± 7 years, $P=0.0323$) (**Table 2**). There were no statistically significant differences between the 2 groups regarding sex, duration of AF, heart rate, the prevalence of hypertension, diabetes, renal insufficiency (creatinine >2.0 mg/dl), plasma brain natriuretic peptide level, or New York Heart Association functional class.

Echocardiography

The LA emptying fraction was higher in the successful procedure group than in the unsuccessful procedure group (31.2 ± 8.5 vs $21.4 \pm 10.9\%$, $P=0.0011$) (**Table 3**). The remaining echocardiographic parameters of LA dimension, LA maximum volume index, LA minimum volume index, LV end-diastolic volume index, LV end-systolic volume index, LV ejection fraction and LV mean wall thickness did not differ between the 2 groups.

Intraobserver variabilities for LA maximum volume index, LA minimum volume index and LA emptying fraction were $5.7 \pm 4.2\%$, $7.1 \pm 5.9\%$ and $10.3 \pm 8.3\%$, respectively, and the interobserver variabilities were $6.8 \pm 5.2\%$, $7.6 \pm 6.0\%$ and $13.6 \pm 11.1\%$, respectively.

ECG

There was no statistically significant difference between the 2 groups in the AF wave voltage in lead V₁ (0.16 ± 0.10 mV vs 0.18 ± 0.11 mV, $P=0.4196$).

Predictor of Successful Maze Procedure

According to multiple logistic regression analysis, the preoperative LA emptying fraction was related to successful maze procedure ($P=0.0024$) and age was unrelated to successful maze procedure ($P=0.0722$).

Using receiver-operating characteristic curve analyses, a preoperative LA emptying fraction $>26\%$ predicted successful maze procedure with 70.7% sensitivity and 78.6% specificity (area under curve=0.769, 95% confidence interval 0.616–0.922) (**Fig 2**).

Discussion

We evaluated 55 consecutive patients to define the precise indications of the maze procedure as an adjunctive therapy. During an average follow-up of 15 months, 41 (75%) patients remained free from AF and atrial flutter. Only the preoperative LA emptying fraction significantly influenced the success of the maze procedure. LA emptying fraction greater than 26% predicted successful maze procedure with 70.7% sensitivity and 78.6% specificity. To our knowledge, this is the first study suggesting that the preoperative LA emptying fraction is a useful and powerful predictor of a successful maze procedure.

Prolonged AF results in loss of atrial muscle mass and fibrotic changes within the atrial myocardium^{22–25}. The combination of mitral valve disease and atrial inflammation secondary to rheumatic carditis causes fibrosis of the atrial wall and disorganization of the atrial muscle bundles^{6,26}. Patients who have mild fibrosis respond more successfully to cardioversion than those with severe fibrosis²⁷ so we assume that the LA emptying fraction mirrors the degree of structural change in the LA.

Low AF wave voltage in the V₁ lead has been reported as a predictor of unsuccessful maze procedure^{4,5,7} but its predictive value was not documented in our study. A decrease in the voltage of AF waves on the 12-lead ECG correlates with the extent of atrial fibrosis²⁸; however, the voltage on the 12-lead ECG is influenced by physiological conditions such as subcutaneous fat and the presence of fluid and gas in the thoracic cavity. Thus, a more precise and robust determinant that represents atrial function is needed.

The LA emptying fraction has been widely used as an index of LA mechanical function⁹ and in this study, the preoperative LA emptying fraction measured by transthoracic 2-dimensional echocardiography was demonstrated to be a powerful predictor of a successful maze procedure and can easily be used as a predictor to decide the indication of the maze procedure as an adjunctive therapy for persistent AF.

Study Limitations

First, patients with longstanding AF and those with extremely enlarged LA were excluded from our retrospective study according to the surgeon's decision. We expect that the duration of AF and the LA size could be predictors of successful maze procedure if these patients had not been excluded from the study. The mean duration of AF was 4.3 years (range, 0.2–26 years) in patients with successful maze procedure and 4.2 years (range, 0.3–17 years) in patients with unsuccessful maze procedure, which was relatively shorter than previous studies^{5–8}. At the same time, the mean LA dimension was 55 mm (range, 35–74 mm) in patients with successful maze procedure and 53 mm (range, 42–68 mm) in patients with unsuccessful maze procedure and these measurements were smaller than in previous studies^{4–7}.

Second, the efficacy of the maze procedure was only 75% in the present study. Other investigators report long-term success rates of maze procedure in excess of 90%^{4–6,8,10}. The explanation for this discrepancy may be related to the

differences in the study population and perioperative strategy. Although most previous studies investigated patient groups with both persistent and paroxysmal AF, the present study investigated only patients with persistent AF.

Third, the functional effect of the maze procedure was not evaluated by the LA emptying fraction after operation. The time course of the LA emptying fraction must have some influence on the occurrence of AF or atrial flutter after the operation. Further study is needed to clarify this and its relationship to the occurrence of AF or atrial flutter after operation during the follow-up period.

Conclusions

The preoperative LA emptying fraction was significantly related to the success of the maze procedure in the present study. Preoperative LA emptying fraction greater than 26% predicted successful maze procedure with 70.7% sensitivity and 78.6% specificity, so it should be taken into consideration in defining the precise indications of the maze procedure as an adjunctive therapy for persistent AF.

Disclosures

None.

Statement of Responsibility

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.

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