



Surgical outcomes of modified-maze procedures in adults with atrial septal defect

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Abstract

Purpose We examined the outcome of modified-maze procedures reflecting a single-center strategy in the treatment of atrial fibrillation (AF) associated with atrial septal defect (ASD) in adults.

Methods A retrospective chart review was performed for 29 patients who underwent surgical ASD closure and 2 types of maze procedures (full and simplified maze procedures) for AF. The outcome related to the each procedure was examined. A Cox proportional hazards analysis was performed to assess the independent predictors of AF and atrial tachycardia (AT) recurrence.

Results The rates of freedom from AF and AT recurrence at 1 and 4 years were 86.6% and 72.2% in the full maze group and 78.5% and 62.8% in the simplified maze group, respectively ($p=0.70$). The only risk factor for recurrence was the age at the time of surgery. A receiver operating characteristic curve analysis gave an optimum cut-off value of 58 years of age for predicting recurrence within 2 years (58.4% for ≥ 58 years versus 5.9% for < 58 years, $p=0.003$).

Conclusions Simplification of the maze procedure was not associated with AF or AT recurrence. The age at the time of surgery might be a clinical predictor of success or failure in adult patients.

Keywords Maze procedure · Atrial septal defect · Radiofrequency ablation

Introduction

Adult patients with atrial septal defect (ASD) are frequently complicated by atrial fibrillation (AF) [1, 2]. Surgery for AF is an option during surgical treatment of ASD to provide a better quality of life in terms of the prevention of thromboembolism. In the era of catheter closure of ASD, surgical closure of ASD tends to use minimally invasive procedures [3–5]. However, AF surgery combined with ASD closure is invasive and creates many lesions in the full maze procedure, which can result in a prolonged aortic clamping time, increased risk of bleeding, and scar formation in the left atrium.

Recently, the development of surgical ablation devices has provided a replacement for the cut and sew technique in AF surgery [6–9]. The pulmonary vein was reliably isolated using epicardial ablation and a bipolar radiofrequency

clamp device. However, in the full maze procedure, a left atrial incision is still required to make a lesion between the pulmonary veins and a lesion toward the mitral valve [10].

The aim of this study was to examine the outcomes of two types of surgical procedures and the adequacy of omitting a left atrial incision using surgical ablation devices. In addition, we performed multivariate analysis to identify predictors of the recurrence of AF and atrial tachycardia (AT), regardless of the procedure employed.

Materials and methods

Patients

A retrospective chart review was performed for 29 patients who underwent surgical closure of ASD and 1 of 2 types of modified-maze procedures (full or simplified maze procedures) for AF between November 1993 and November 2014. This study was performed in accordance with the guidelines of the Declaration of Helsinki [11] and was approved by the

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Ethics Committee of the Nippon Medical School in Tokyo, Japan (reference number 29-01-888).

Nineteen (65.5%) patients were male. The mean average age at the time of operation was 54.6 ± 10.2 years. Seventeen patients were diagnosed with long-standing AF, 1 with

having persisting AF, and 11 with paroxysmal AF (PAF). Significant mitral valve and tricuspid valve regurgitation were present in 9 and 12 patients, respectively. A full maze procedure was performed in every case from 1993 to 2002. After radiofrequency ablation device was introduced in 2003, a full or simplified maze procedure was selected at the surgeon's discretion. In the patients with significant mitral valve regurgitation, a full maze procedure was selected. The preoperative patient characteristics in each procedure are presented in Table 1.

Table 1 Baseline characteristics of the patients

	Full maze (N=15)	Simplified maze (N=14)	<i>p</i>
Age, years	53.3 ± 9.9	56.1 ± 12.1	0.50
Female, %	20	50	0.12
Type of ASD			
Secundum, %	86	100	0.48
Type of AF, %			
Paroxysmal	27	50	0.36
Non-paroxysmal	73	50	0.36
NYHA (> II), %	87	85	1.0
LVEF, %	61.4 ± 9.0	67.5 ± 7.4	0.05
Left atrial dimension, mm	45.4 ± 7.8	40.4 ± 8.8	0.11
Mitral valve disease, %	46	0	
Tricuspid valve disease	40	42	0.82
CPB time, min	190.3 ± 62.8	116.0 ± 48.1	0.001
Aortic clamp time, min	138.0 ± 44.4	79.6 ± 36.0	<0.001
Radiofrequency ablation, %	53	100	0.006
Pacemaker implantation, %	26	14	1.0
Postoperative complication, %	6	7	1.0

AF atrial fibrillation, NYHA New York Heart Association, LVEF left ventricular ejection fraction, CPB cardiopulmonary bypass

Surgical technique

The chest was opened via median sternotomy. Cardiopulmonary bypass was established using aortic and bicaval cannulation. Cardiac arrest was induced and maintained using both antegrade and retrograde cold crystalloid cardioplegia. The full maze procedure involved the construct of eight lesions: right atrial incision, tricuspid lesion, pulmonary vein isolation, connecting lesion between both pulmonary veins, atrial septal ablation, mitral lesions, coronary sinus ablation, and resection of the left atrial appendage (Fig. 1). In the patients with a large left atrium (> 6 cm in diameter), the posterior wall of the left atrium was isolated. The cut and sew technique with cryoablation was performed in seven patients. After 2003, bilateral pulmonary vein isolation was performed using a bipolar radiofrequency ablation device on a beating heart. An electrical conduction block between the pulmonary vein and left atrium was confirmed by the pacing of each pulmonary vein [12]. The simplified maze procedure involved the isolation of the right atrial lesion, septal lesion, and both pulmonary veins (Fig. 1). The left atrial appendage was resected in seven patients.

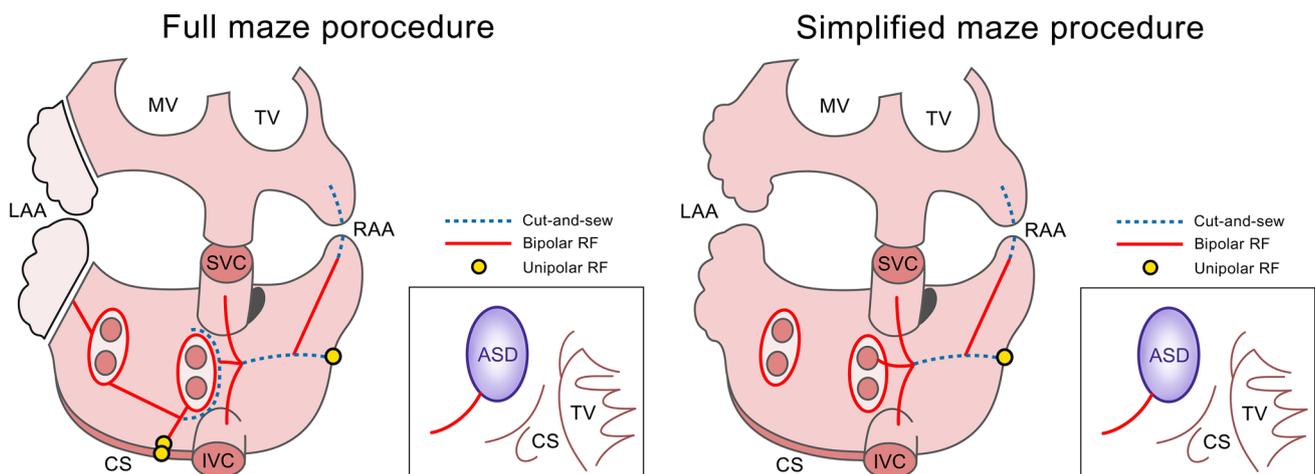


Fig. 1 LAA left atrial appendage, MV mitral valve, TV tricuspid valve, RAA right atrial appendage, SVC superior vena cava, IVC inferior vena cava, CS coronary sinus, ASD atrial septal defect, RF radiofrequency

The ostium secundum ASD was closed using direct or pericardial patch sutures. The ostium primum ASD was closed using a pericardial patch suture.

Postoperative management and follow-up

This study did not follow the protocol of postoperative electrocardiography (ECG) monitoring recommended in the HRS/EHRA/ECAS expert consensus statement [13] because 50% of the patients in this study had undergone surgery before the initial statement. The patients were followed up with scheduled visits at 1 month and then visits every 3 months for the first year to check the heart rhythm using ECG. Whenever arrhythmic symptoms were reported by the patients, 24-h ECG Holter monitoring was repeated. Antiarrhythmic drugs were discontinued within 3 months after surgery, regardless of AF or AT recurrence. The patients were followed up by cardiologists and cardiac surgeons thereafter. Their medical records were reviewed to determine the postoperative cardiac rhythm and any morbidities or mortalities. The cardiac rhythm was examined by ECG and 24-h ECG Holter monitoring. Recurrence of AF or AT was defined as the existence of AF or AT lasting for > 30 s except for AT occurring within 3 months of the blanking period postoperatively.

Statistical analyses

Preoperative characteristics and intraoperative and postoperative data were statistically compared between the full and simplified maze groups. The primary endpoint of the study was recurrence of AF and AT, including atrial flutter. A Kaplan–Meier analysis and the log-rank test were used to determine the probability of freedom from recurrence of AF and AT. A Cox proportional hazards regression analysis using the significant covariates ($p < 0.1$) and the occurrence of AF or AT as a dependent variable was performed by selecting backwards elimination with likelihood estimates and default criteria. A p value of < 0.05 was considered to indicate statistical significance. All statistical procedures were performed using the SPSS 22 statistical package (SPSS Inc., Chicago, IL, USA). The optimum cut-off value for the age at the operation to predict AF recurrence within 2 years after surgery was determined by a receiver operating characteristic (ROC) curve analysis. The optimum cut-off value was defined as the age providing the greatest accuracy in distinguishing between patients with and without AF and AT recurrence.

Results

Baseline characteristics

The baseline characteristics of each group are shown in Table 1. There were no significant differences in the age, type of AF, grade of NYHA, left ventricular ejection fraction, or left atrial dimension. A concomitant procedure for mitral valve disease was performed only in the full maze group. The aortic clamp time and cardiopulmonary bypass time were significantly longer in the full maze group than in the simplified maze group. The maze procedure without using a radiofrequency ablation device was performed only in the full maze group.

Clinical outcomes

There were no surgical mortalities. During the median follow-up time of 84 (20–263) months, one patient developed congestive heart failure as an early postoperative complication in each group. One patient died of pneumonia at 20 months postoperatively in the simplified maze group. The freedom of recurrence rates of AF or AT at 1, 4, and 8 years were 86.6%, 72.2%, and 63.1% in the full maze group and 78.5%, 62.8%, and 52.3% in the simplified maze group, respectively ($p = 0.70$, Fig. 2) Pacemaker implantation was required in six patients (four patients in the full maze group and two patients in the simplified maze group, $p = 1.0$).

Predictors of recurrence of AF and AT

A univariate analysis identified age ($p = 0.03$), type of AF ($p = 0.07$), and left atrial dimension ($p = 0.05$) as risk factors for recurrence of AF or AT. In the multivariate analysis, the only risk factor for AF or AT recurrence was the age at the time of surgery (hazard ratio, 1.067; 95% confidence interval, 1.001–1.137; $p = 0.04$) (Table 2). An ROC curve analysis showed that the optimum cut-off value for the age was 58 years to predict sinus rhythm maintenance within 2 years, which resulted in a sensitivity of 87.5%, a specificity of 81.0%, and an area under the curve of 0.839 (Fig. 3). The sinus restoration rate at 2 years was significantly higher in the patients ≥ 58 years of age (94.1%) than in those < 58 years of age (41.6%) ($p = 0.003$).

Fig. 2 Freedom from recurrence of atrial fibrillation or atrial tachycardia. *AF* atrial fibrillation, and *AT* atrial tachycardia

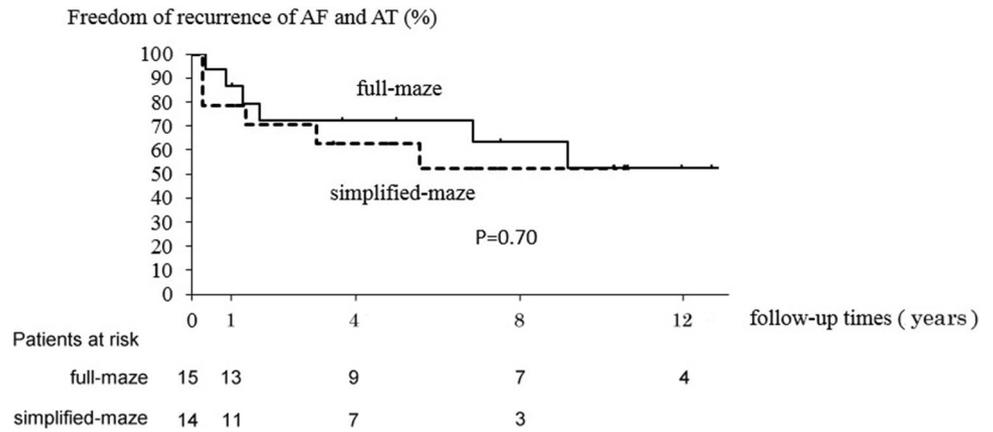


Table 2 Risk factors for recurrence of AF and AT

	Uni-variate <i>p</i> value	Multivariate		
		Hazard ratio	95% CI	<i>p</i>
Age, years	0.03	1.067	1.001–1.137	0.04
Female, %	0.84			
Non-PAF, %	0.07			
LVEF, %	0.68			
Left atrial dimension, mm	0.05	1.072	0.989–1.162	0.09
Mitral value disease, %	0.89			
Tricuspid value disease, %	0.75			
Aortic clamp time, min	0.23			
Radiofrequency ablation, %	0.32			

PAF paroxysmal atrial fibrillation, LVEF left ventricular ejection fraction

Discussion

Adequacy of lesion sets

The most important finding of this study was that simplification of the maze procedure, which omits the incision and/or RF ablation in the posterior wall, was not associated with recurrence of AF or AT. Although the Cox maze procedure has been performed over the past three decades via modification of the lesion set, there have been several reports of modification involving omission of the left-sided procedure for AF surgery in ASD. Kobayashi et al. reported three cases of a right-sided maze procedure in a combined AF and ASD surgery series. All of the cases had a recurrence of AF postoperatively, and there was speculation about the remaining mechanism of AF that might have

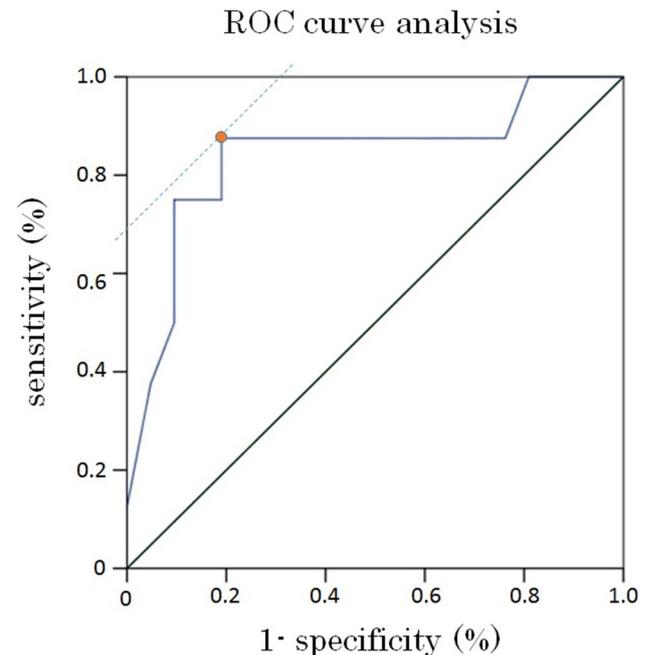


Fig. 3 Receiver operating characteristics (ROC) curve showing an optimum cut-off value of 58 years for the age at the time of operation to predict sinus rhythm restoration within 2 years. The red point indicates the optimum cut-off value

been eliminated by the left-sided procedure in the area of left atrial enlargement [14].

More recently, a retrospective study that compared right-sided lesion and bilateral lesion groups in ASD found that the bilateral lesion group had a better outcome than the right-sided lesion group in the treatment of AF [15, 16]. Our intraoperative cardiac mapping study for AF-associated ASD detected combined focal and reentrant activation in the left atrium in > 80% of the patients with persistent and long-standing AF [17]. In these patients, the right atrium was passively activated with fibrillatory conduction via the interatrial conduction pathway. This finding supported the

adequacy of the bilateral lesion set, especially for isolating the pulmonary vein, around which 83% of the foci sites existed. In the present study, isolation of both pulmonary veins was performed in the simplified maze group because it was expected to eliminate focal activation in the left atrium. However, our mapping data also revealed that the macro-reentrant circuit or focal activation in the right atrium was the main mechanism underlying the paroxysmal AF associated with ASD. This finding suggested that the right atrial lesion set with or without pulmonary vein isolation was an effective treatment for PAF. However, in our study population, there were five recurrences of AF or AT in the PAF cases during the follow-up period, which suggested that the surgical strategy for type of AF had nothing to do with the outcome in the ASD patients.

Atrial remodeling in ASD patients

Volume overload due to left-to-right shunt in ASD leads to enlargement of the right atrium accompanying electrophysiological remodeling as a substrate of AF [18]. Conduction disturbance and dispersion of atrial refractory period in the right atrium may develop long-term atrial arrhythmias. ASD also contributes to left atrial stretching and electrical remodeling due to left atrial enlargement, loss of myocardium, and electrical scarring [19]. Surgical or catheter closure of ASD is expected to provide reverse atrial remodeling and the new onset of atrial arrhythmias. However, age was a predictor of the early onset of atrial arrhythmias, and there is a likelihood of remaining atrial remodeling even after ASD closure [20, 21]. This finding is consistent with our data showing that recurrence after AF surgery in ASD increases with age, which suggests that right and left atrial remodeling over the long term leads to various substrates of AF in which full maze lesions are unable to be eliminated completely.

In our series, the overall pacemaker implantation rate was 20.6% postoperatively. This rate is higher than that in AF surgery for other structural heart diseases, where the rate ranges between 5% and 13% [22–24]. Sinus node dysfunction due to right atrial remodeling is also an underlying electrophysiological property that hampers the restoration of sinus rhythm postoperatively [18].

Clinical implications

According to the guidelines of the Society of Thoracic Surgery, surgery for AF can be performed without any additional risk in surgeries for structural heart disease [25]. In our ASD series, no patients suffered any severe complications during surgery. AF surgery is acceptable as a combined surgery with ASD closure from a risk assessment perspective. However, the analysis of our data showed an unclear expectation of a surgical benefit for older patients.

The cumulative freedom from recurrence rate of ATs within 10 years was approximately 50% for both the full and simplified maze groups. More than half of the patients ≥ 58 years of age experienced recurrence of AF or AT within 2 years. In this study, only seven patients had their left atrial appendage removed in the simplified maze group. Recently, the use of surgical devices to occlude the left atrial appendage is prevailing as a safe and reliable technique [26]. Left atrial appendage occlusion should be considered essential in consideration of the risk of recurrence with the simplification of maze procedure.

Limitations

Several limitations associated with the present study warrant mention. This was not a randomized study, so it is possible that there was bias in the selection of the type of AF surgery. In the cases of mitral valve disease, the full maze procedure was selected because a left atrial incision was required. A multivariate analysis revealed that mitral valve disease was not a predictor of recurrence of ATs; however, AF associated with both ASD and mitral valve disease not only arises from the left-to-right shunt in ASD but also from volume overload due to mitral valve insufficiency that may facilitate left atrial remodeling. Furthermore, in this study, no degenerative changes in the mitral leaflet were observed in the mitral valve cases, suggesting that mitral valve regurgitation may arise from isolated annular dilatation secondary to AF [27].

Conclusion

Omission of the left posterior lesion in the maze procedure was not associated with AF or AT recurrence. However, the age at the time of surgery might be a clinical predictor of success or failure in adult patients.

Compliance with ethical standards

Conflict of interest Shun-ichiro Sakamoto and the other co-authors have no conflicts of interest.

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