Risk factors analysis on failure of maze procedure: mid-term results

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Abstract

Objective: Since the late 1980s, surgical ablation of atrial fibrillation (AF) has been one of the most effective means of curing this arrhythmia. However, about 20% of patients who underwent maze procedures have shown recurrence of AF during the follow-up periods. The aim of this study is to evaluate our result of maze procedures in last decade and to analyze the risk factors of maze failure.

Methods: Between July 1997 and July 2007, 560 consecutive patients underwent maze procedures for AF by a single surgeon. Demographics showed that average age of the patients is 51.3 years, with a slight female predominance (M:F = 248:312). Most of the maze procedures had been performed in conjunction with mitral valve (n = 494, 88.6%), while only six cases (1.1%) were performed with isolated maze procedure. The maze failure was defined as showing any rhythm besides normal sinus rhythm at the last follow-up. Univariate and multivariate analysis for the risk factors of maze failure were identified. The survival impact of maze failure was also evaluated.

Results: The in-hospital mortality (1.6%) was acceptable. During the 29.7 months of median follow-up period, the late mortality rate was 3.8% and permanent pacemaker insertion was necessary in 2.3% (n = 13) of the patients. The success rate of maze was 84.1% (471/560) and effective left atrial contraction was identified in 97.2% (458/471) of these patients. In multivariate analysis, the size of left atrium larger than 60 mm, cardiothoracic ratio over 60%, fine AF wave in preoperative ECG, no early normal sinus restoration and simplified surgical ablation were found as an independent predictor of maze failure. Furthermore, the patients with successful maze showed better long-term survival rates.

Conclusions: The results of our maze procedure during the last decade showed an acceptable success rate and the patients who were restored to sinus rhythm after maze procedures showed better long-term survival rates. For the patients who have independent biological risk factors, more thorough ablation lesion set is recommended for better long-term results.

Keywords: Atrial fibrillation; Maze; Risk factor analysis

1. Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia that increases morbidity and mortality [1], and presents in up to 60–80% of patients undergoing surgery for mitral valve disease [2]. Since Cox Maze procedure was introduced by James L. Cox in 1987, surgical ablation of AF has been one of the most effective means of curing this arrhythmia. The advantage of maze procedure has been reported that it shows a better survival rate and lower stroke incidence after combining with mitral valve surgery [3,4].

Because of a complexity of the classical cut and sew maze procedure, lots of modifications with various energy sources have been invented to perform maze procedures more rapidly and safely [5–9]. However, about 20–30% of the patients who underwent maze procedures have shown recurrence of AF during the follow-up periods [10], and there are few reports showing mid- to long-term results and reporting predictors of the maze failure [11–13].

The aim of this study is to evaluate results of 560 consecutive cases of maze procedure in the last decade and to identify the risk factors of the failed maze procedures.

2. Materials and methods

2.1. Patients and definitions

We analyzed 560 consecutive patients (248 male and 312 female patients, the mean age was 51.3 ± 13.1 years) who underwent maze procedures for AF by a single surgeon between July 1997 and July 2007. As the goal of maze procedure is the restoration to normal sinus rhythm (NSR), the success of maze procedure was exclusively defined as the
sinus restoration after the maze procedures in this study. Therefore, all patients with recurring atrial tachyarrhythmia (such as AF, atrial flutter), junctional rhythm and cardiac rhythm of permanent pacemaker were categorized into the failed maze group (Fig. 1).

The fine AF wave was defined when the voltage of f-wave in V1 lead is lesser than 0.1 mV in preoperative ECG. The size of the left atrium (LA) was measured preoperatively by parasternal long axis view of transthoracic echocardiography. As the method to determine the size of the LA in this study was restricted to only the antero-posterior diameter of LA, the cardiothoracic ratio was assessed for better evaluation lateral enlargement of the LA. Sustained AF was defined as AF that does not self terminate and paroxysmal AF was defined as intermittent or recurrent AF. After maze procedure, the day of sinus restoration was recorded for every patient. The early NSR return was defined as sinus restoration within the day of operation. To evaluate the changes of the success rate during follow-up period, the day of AF recurrence was documented by various methods, such as ECG, echocardiography or Holter monitoring. All data were collected prospectively and stored in a specially designed and regimented database for uniformity, accuracy, and objectivity of the generated data by using Access 2000 (Microsoft Inc.) program for later assessment.

This study was approved by our institution’s ethical committee/institutional review board. The informed consent was waived by our institution’s ethical committee/institutional review board owing to the retrospective nature of our study.

2.2. Surgical procedures

During the last decade, three different types of maze procedures have been performed. Before January 1999, the conventional Cox Maze III procedure was performed on 30 patients. Between January 1999 and July 2001, 136 patients had received maze operations according to the modification devised by Lee and associates. Detailed surgical techniques of Cox Maze III and modified maze by Lee have been reported previously [5]. Since July 2001, 394 patients have undergone simplified surgical ablation (SSA) with various energy sources (cryothermy, microwave and radiofrequency). Compared to the original Cox Maze III procedure, the resection of right atrium auricle and incision from auricle to tricuspid valve were omitted, and most of the cut and sew lesions in the right atrium were changed to ablation lines except the long oblique incision to enter the right atrium. Three ablation lines for the right atrium were proceeded on intercaval, carvo-tricuspid and free wall of right atrium.

The lesion sets of the LA consisted of inferior extension of left atriotomy to orifice of left inferior pulmonary vein and four ablation lines; inferior and superior ablation lines for pulmonary vein isolation, endocardial LA isthmus ablation, and epicardial coronary sinus ablation. Resection of inferior wall of LA was performed as much as possible, whenever the size of the LA was larger than 60 mm by the preoperative echocardiogram or its enlargement was definite in operative findings. The area of resection depended on the size of the LA.

The surgical ablation procedures have been performed in conjunction with mitral valve (88.2%), tricuspid valve (3.4%), aortic valve surgery (3.0%), and CABG (3.4%), while only six cases (1.1%) of isolated maze procedures were conducted.

2.3. Clinical follow-up

Preoperative and intraoperative data were prospectively collected and patients were followed up at regular intervals by cardiologists of our institute or referring physicians. Postoperative rhythms were checked daily during their postoperative hospitalization by using standard 12-channel surface ECG and electroatriogram atrial pacing wire, which were routinely applied after the maze procedure in our institute. Follow-up ECGs of the outpatient clinic were checked postoperatively at 3 months, 6 months, and then annually in all patients. The basic rhythms were classified into sinus rhythm, junctional rhythm, AF, atrial flutter and pacing rhythm. To evaluate the restoration of mechanical function in LA, an assessment of transmitral A-wave with transthoracic echocardiography was conducted during the week after surgery, at postoperative 6 months, and then annually during the follow-up. Whenever a patient complained of intermittent palpitation, a Holter monitoring was recommended to disclose the paroxysmal AF.

For the patients who showed sinus rhythm on ECG and transmitral A-wave was documented with postoperative echocardiography, no preemptive antiarrhythmic medication was prescribed at the time of discharge. If postoperative AF or atrial flutter was noted before discharge, intravenous administration of amiodarone with a loading dosage (up to 1350 mg/day) was initiated and 400 mg of amiodarone was given every 12 h. If a patient failed to restore sinus rhythm with medications, an electrical cardioversion was aggressively attempted.

In cases of recurrent atrial arrhythmia under amiodarone administration, we changed antiarrhythmic drug regimens to sotalol or flecainide and attempted electrical cardioversion. We attempted rate control on all of our patients who did not maintain sinus rhythm with the use of beta- and calcium channel blockers.

2.4. Statistical analysis

Continuous variables were presented as mean ± SD, and categorical variables as percentages or numbers. For univariate analyses, preoperative and operative variables were analyzed using Kaplan–Meier method or Cox regression
model to investigate the influences of these variables on the maze failures during follow-up period. Independent predictors were determined by using the Cox multivariable analysis involving a backward elimination procedure. The proportional hazards assumption was confirmed by examining the log(−log[survival]) curves and testing partial (Schoenfeld) residuals [14], and no relevant violations were found. Kaplan–Meier survival curve with log-rank test was conducted to evaluate the survival benefit of patients who had sinus restoration.

All p values were two-sided and a probability value of p < 0.05 was considered to indicate a significant difference. Statistical analysis was performed by using SPSS version 12.0 for Windows (SPSS Inc, Chicago, IL).

3. Results

3.1. Perioperative demographics

In these patients, 55.7% of the cases (n = 312) were female and sustained AF were 86.6% (n = 485). The mean duration of AF was 5.4 ± 6.6 years, mean LA size was 58.4 ± 10.3 mm, and mean CTR was 59.4 ± 7.8%. Mitral valve repair was performed in 52.8% of mitral valve surgery and rheumatic mitral valve disease was the most common (68.6%) cause of mitral pathology. Our study populations consisted of 166 cases (29.6%) of cut and sew mazes and 394 cases (70.4%) of SSA, which included 79 cases (14.1%) of right minithoracotomy approaches. The mean aortic cross-clamp time was 111.4 ± 38.2 min, and the mean cardiopulmonary bypass time was 160.8 ± 51.3 min. The common energy sources of ablations were cryothermy (76.3%) and microwave (22.7%).

Table 1

|                      | Overall (n = 560) | NSR (n = 471, 84.1%) | AF (n = 89, 15.9%) | p value |
|----------------------|------------------|---------------------|-------------------|---------|
| Follow-up duration   | 37.6 ± 30.8 (29.7)* | 37.6 ± 31.0 (29.2)* | 37.6 ± 30.3 (33.0)* | 0.989   |
| Female               | 55.7% (312)      | 56.3% (265)         | 52.8% (47)        | 0.547   |
| Preoperative EF (%)  | 55.2 ± 10.2      | 55.2 ± 10.2         | 55.0 ± 9.7        | 0.803   |
| Paroxysmal AF        | 13.4% (75)       | 14.4% (68)          | 7.9% (7)          | 0.095   |
| Rheumatic MV ds.     | 68.6% (319/465)  | 66.8% (264/395)     | 78.6% (55/70)     | 0.051   |
| MV repair            | 52.8% (261/494)  | 53.7% (224/417)     | 48.1% (37/77)     | 0.572   |
| Age (year)           | 51.4 ± 13.1      | 50.2 ± 12.8         | 57.7 ± 12.7       | <0.001  |
| AF duration          | 5.4 ± 6.6        | 4.8 ± 5.9           | 8.6 ± 8.8         | <0.001  |
| Preoperative LAS (mm)| 58.4 ± 10.3      | 57.6 ± 9.6          | 62.8 ± 12.7       | <0.001  |
| CTR (%)              | 59.4 ± 7.8       | 58.6 ± 7.5          | 63.7 ± 7.7        | <0.001  |
| Fine AF              | 44.1% (239/542)  | 38.7% (176/455)     | 72.4% (63/87)     | <0.001  |
| Cut and sew maze     | 29.6% (166)      | 30.4% (143)         | 25.8% (23)        | 0.392   |
| SSA                  | 70.4% (394)      | 69.6% (328)         | 74.2% (66)        | 0.392   |
| MICS                 | 14.1% (79)       | 15.9% (75)          | 4.5% (4)          | <0.001  |
| CPB time (min)       | 160.8 ± 51.3     | 159.0 ± 48.4        | 170.0 ± 64.0      | 0.063   |
| ACC time (min)       | 111.4 ± 38.2     | 110.4 ± 36.9        | 116.5 ± 44.8      | 0.178   |
| Reoperation          | 5.9% (33)        | 6.2% (29)           | 4.5% (4)          | 0.541   |
| Cryothermy           | 76.3% (427)      | 76.4% (360)         | 75.31% (67)       | 0.973   |
| Microwave            | 22.7% (127)      | 22.5% (106)         | 23.6% (21)        | 0.822   |
| Early NSR return     | 83.2% (466)      | 87.7% (413)         | 59.6% (53)        | <0.001  |
| ICU stay (day)       | 3.7 ± 17.7       | 3.6 ± 19.1          | 4.2 ± 6.0         | 0.770   |
| Hospital stay (day)  | 15.4 ± 20.0      | 14.6 ± 20.8         | 19.6 ± 14.1       | 0.030   |
| Concomitant TAP      | 47.0% (263)      | 45.4% (214)         | 55.1% (49)        | 0.095   |
| Concomitant CAGB     | 9.1% (51)        | 7.4% (35)           | 18.0% (16)        | 0.005   |

NSR, normal sinus rhythm; AF, atrial fibrillation; EF, ejection fraction; LAS, left atrium size; CTR, cardiothoracic ratio; SSA, simplified surgical ablation; MICS, minimally invasive cardiac surgery; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; ICU, intensive care unit; TAP, tricuspid annuloplasty; CAGB, coronary artery bypass graft.

* Median value.

To analyze the preoperative risk factors for maze failures, the patients were divided into two groups; patients with sinus rhythm restored (group S: 84.1%, n = 471) and failed maze (group F: 15.9%, n = 89), according to the documented rhythm at the last follow-up. Preoperative and operative characteristics of the patient are summarized in Table 1. In the present study, 99.8% of the preoperative size of the LA, 99.8% of AF duration, 96.8% of AF wave pattern and 96.4% of CTR were recorded. There were no significant differences between the successful and failed maze groups in terms of follow-up duration, female predominance, preoperative left ventricular ejection fraction, cardiopulmonary bypass time, aortic cross-clamping time, incidence of paroxysmal AF, rheumatic etiology of MV disease, choice of energy sources, prevalence of mitral valve repair and concomitant tricuspid annuloplasty. Patients in the failed group showed older age, longer history of AF, larger LA, bigger cardiothoracic ratio and more incidence of fine AF (p < 0.001).

3.2. Operative results

Despite 98.9% of the maze procedures being combined with cardiac surgery, the early mortality happened in only 9 (1.6%) patients. Causes of the early mortality included low output syndromes with multiple organ failure (n = 4), sudden death after discharge with unknown etiology within 30 days (n = 2), left ventricular rupture after mitral valve replacement (n = 2), stroke and esophageal bleeding (n = 1).

Postoperative complications included 13 cases (2.3%) of pacemaker implantation after the maze procedure, 4 cases of mild reversible cerebral accident, 5 cases of tracheostomy.
for prolonged ventilation, 8 cases of acute renal failure required dialysis, and 31 (5.5%) cases of re-exploration for bleeding.

3.3. Late outcome

The late mortality happened in 21 (3.8%) patients during the mean follow-up period of 37.2 \pm 30.8 months (median: 29.7 months; IQR: 10.5–60.7 months). Causes of the late mortality included respiratory failure (n = 4), cardiac death (n = 4), malignancy (n = 3), cerebral vascular accident (n = 3), sepsis (n = 2), and death of unknown etiology (n = 5).

At the last follow-up, sinus restoration was shown in 84.1% (471/560) of our patients and effective left atrial contraction was identified in 97.2% (458/471) of these patients. At the time of hospital discharge, 76.4% (n = 428) of patients showed NSR and 7.7% (n = 33) of those patients were reverted to AF at their last follow-up. Among 23.6% (n = 132) of patients who showed any rhythm besides NSR at the time of discharge, 57.6% (n = 76) were restored NSR at the last examination and most of them showed junctional rhythm at the time of discharge. In the present study, cumulative maze success rates in all patients were 82.2% at 5 years and 69.8% at 9 years (Fig. 2A).

The overall survival rates after the operation at 3, 5, and 9 years were 95.8%, 94.1%, and 88.9% respectively. Actuarial survival curves showed significant better long-term survival in successful maze group (Fig. 2B).

3.4. Risk factor analysis of maze failure

According to the definition of this study, 89 patients (15.9%) were defined as maze failures, which included recurred AF (n = 64), atrial flutter (n = 5), sustained junctional rhythm (n = 7), and permanent pacemaker rhythm (n = 13).

The univariate analysis of the maze failure in terms of preoperative and operative variables is shown in Table 2. The

Table 2

Univariate analysis for the maze failure.

| Variable                  | NSR (n = 471, 84.1%) | AF (n = 89, 15.9%) | HR       | p value |
|---------------------------|----------------------|--------------------|----------|---------|
| Age (year)                | 50.2 ± 12.8          | 57.7 ± 12.7        | 1.050    | <0.001  |
| AF duration (year)        | 4.8 ± 5.9            | 8.6 ± 8.8          | 1.059    | <0.001  |
| Preoperative LAS (mm)     | 57.6 ± 9.6           | 62.8 ± 12.7        | 1.040    | <0.001  |
| Preoperative LVEF (%)     | 55.2 ± 10.2          | 55.0 ± 9.7         | —        | 0.791   |
| CTR (%)                   | 58.6 ± 7.5           | 63.7 ± 7.7         | 1.080    | <0.001  |
| CPB time (min)            | 159.0 ± 48.4         | 170.3 ± 64.0       | —        | 0.115   |
| ACC time (min)            | 110.4 ± 36.9         | 116.5 ± 44.8       | —        | 0.603   |
| NSR return (day)          | 1.1 ± 0.33           | 1.4 ± 0.49         | 1.010    | <0.001  |
| ICU stay (day)            | 3.6 ± 19.1           | 4.2 ± 6.0          | —        | 0.719   |
| Sustained AF              | 85.6%                | 92.1%              | 0.126    |         |
| Cryothermy                | 76.4%                | 75.3%              | 0.237    |         |
| Reoperation               | 6.2%                 | 4.5%               | 0.350    |         |
| MICS                      | 15.9%                | 4.5%               | 0.066    |         |
| Concomitant TAP           | 45.4%                | 55.1%              | 0.078    |         |
| Fine AF                   | 38.7%                | 72.4%              | <0.001   |         |
| Cut and sew maze          | 30.4% (143)          | 25.8% (23)         | <0.001   |         |
| SSA                       | 69.6% (328)          | 74.2% (66)         |          |         |

NSR, normal sinus rhythm; AF, atrial fibrillation; HR, hazard ratio; LAS, left atrium size; LVEF, left ventricular ejection fraction; CTR, cardiothoracic ratio; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; ICU, intensive care unit; MICS, minimally invasive cardiac surgery; TAP, tricuspid annuloplasty; SSA, simplified surgical ablation.

Kaplan–Meier curves with log-rank test showed significant difference on freedom from maze failure rate following dichotomous variables (Fig. 3).

Although the rate of sinus restoration at last follow-up was similar according to the modifications of surgical technique, the Kaplan–Meier curves with log-rank test revealed a significant difference of success rate between cut and sew maze and SSA (Fig. 3F).

In multivariate analysis, preoperative size of the LA larger than 60 mm, cardiothoracic ratio over 60%, fine AF wave in preoperative ECG, no early sinus restoration and SSA were found as independent predictors of maze failure in mid-term follow-up period (Table 3).

Table 3

Multivariate analysis for the independent predictors of maze failure.

| Variable                  | p value | AHR     | 95% CI  |
|---------------------------|---------|---------|---------|
| Pre LA >60 mm             | 0.031   | 1.72    | 1.05–2.81 |
| CTR >60%                  | 0.001   | 2.56    | 1.48–4.44 |
| Fine AF                   | <0.001  | 2.64    | 1.56–4.47 |
| No early NSR return       | <0.001  | 3.02    | 1.87–4.89 |
| SSA maze                  | <0.001  | 3.50    | 1.92–6.36 |

AHR, adjusted hazard ratio; CI, confidence interval; LA, left atrium; CTR, cardiothoracic ratio; AF, atrial fibrillation; NSR, normal sinus rhythm; SSA, simplified surgical ablation.
3.5. Impact of the simplified surgical ablation comparing the cut and sew maze

As the significant difference of the sinus restoration during follow-up period was disclosed, the comparison between simplified surgical ablation and cut and sew maze (Cox Maze III and Lee’s modified surgical maze) was conducted (Table 4). Although most of the preoperative variables were comparable between groups, the patients in SSA group show significantly earlier sinus restoration. The shorter bypass time and aortic cross-clamping time was due to the simplicity of SSA, and the earlier sinus restoration resulted in the shorter postoperative ICU and hospital stay.

4. Discussion

Since the Cox Maze procedure was innovated as a surgical therapy for AF by Cox[15], the basic concept has been widely adopted by many surgeons and at the same time, various modifications over the past decade have been produced to simplify and easily perform the maze procedures [5—9]. This has enabled a wide acceptance among surgeons all around the world. However, there are few reports of intermediate or long-term results of modified maze procedure comparing to the original cut and sew maze procedures [13,16]. This study demonstrates well observed mid-term follow-up data of a considerable number of patients. With a single surgeon experience, a consistent surgical indication of maze

Table 4
Comparison between simplified surgical ablation and cut and sew maze.

|                      | Cut and sew maze (n = 166, 29.6%) | SSA (n = 394, 70.4%) | p value |
|----------------------|----------------------------------|----------------------|---------|
| Follow-up duration (month) | 67.6 ± 30.8 (74.7)*               | 25.0 ± 20.4 (19.1)*  | <0.001  |
| Age (year)            | 47.9 ± 12.6                      | 52.9 ± 13.0          | <0.001  |
| AF duration           | 5.2 ± 5.9                        | 5.5 ± 6.9            | 0.617   |
| Preoperative EF (%)   | 55.0 ± 10.8                      | 55.2 ± 9.9           | 0.869   |
| Preoperative LAS (mm) | 60.4 ± 9.7                       | 57.6 ± 10.4          | 0.002   |
| CTR (%)               | 60.2 ± 7.3                       | 59.1 ± 8.0           | 0.120   |
| Fine AF               | 49.4% (82/166)                   | 41.8% (157/376)      | 0.099   |
| CPB time (min)        | 167.8 ± 49.6                     | 157.8 ± 51.8         | 0.036   |
| ACC time (min)        | 126.2 ± 34.2                     | 105.0 ± 38.1         | <0.001  |
| MV repair             | 63.9% (106)                      | 39.3% (155)          | <0.001  |
| Concomitant TAP       | 37.3% (62)                       | 51.0% (201)          | 0.003   |
| Concomitant CABG      | 6.6% (11)                        | 10.2% (40)           | 0.185   |
| NSR restoration (day) | 2.4 ± 8.8                        | 0.4 ± 1.8            | <0.001  |
| ICU stay (day)        | 3.5 ± 3.7                        | 2.8 ± 3.5            | 0.037   |
| Hospital stay (day)   | 20.2 ± 11.7                      | 13.4 ± 22.3          | <0.001  |

SSA, simplified surgical ablation; AF, atrial fibrillation; EF, ejection fraction; LAS, left atrium size; CTR, cardiothoracic ratio; CPB, cardiopulmonary bypass; ACC, aortic cross-clamp; NSR, normal sinus rhythm; ICU, intensive care unit.

* Median value.
procedure and uniform surgical technique during the study period may increase the reliability of the presenting data.

As various methods and different definitions of reporting the success of the maze procedures have been made, to evaluate the outcomes of maze procedure is difficult. Outcomes of the maze procedure are influenced by a thoroughness of follow-up as well as the method of a rhythm assessment. Considering the method of a rhythm assessment, ‘last follow-up rhythm’ may underestimate the recurrence rate of AF, which then overestimates the success rate of the procedure. Conversely, actuarial methods used to delineate time-related events, ‘AF recurrence-free rate’ define any recurrent AF as a failure of the procedure, which may underestimate the actual clinical success rate. Since the most favorable method of the reporting the success rate is ‘rhythm at last follow-up’ [17—19], the method was adopted to evaluate the success and failure of maze procedures in this study. Looking at the definition of maze success, the reported clinical results of maze procedures were variously expressed, such as ‘freedom from AF recurrence’, and ‘normal sinus rhythm restoration rate’. In this study, the success of the maze procedure was exclusively defined as the sinus restoration after the maze procedure, On the other hand patients with recurring atrial tachyarrhythmia, junctional rhythm and cardiac rhythm of permanent pacemaker were categorized into the failed maze group.

Regarding to the long-term results of the maze procedure, Prasad and associates demonstrated that overall freedom from AF at 14 years is 92% and the freedom from AF rate was well maintained during long-term follow-up period [17]. On the contrary, many other long-term results of the maze procedure showed a gradual attrition rate of freedom from AF during the follow-up period [13,18,20]. This study also showed a progressively decreased maze success rate at 3, 5, 7, and 9 years after operation; 86.5%, 82.2%, 75.4%, and 69.8% respectively. Although the differences of the long-term success rate could be influenced by the differences among intraoperative variables, the long-term success rate of maze mostly varied from preoperative variables, such as the concomitant valvar surgical and rheumatic valvar heart disease. In this study, only 1.1% of the isolated maze procedure and 68.6% of the rheumatic mitral valve disease could be a possible explanation of relatively low maze success rate in a long-term follow-up period.

The well-known risk factors of maze failure in previous publications have included old age, larger LA diameter, longer history of AF, lower amplitude f-wave, having a rheumatic mitral valve disease, permanent AF, and lesion sets of maze procedures [11—13,21,22]. In this study, an LA size, a CTR, a fine AF, no early NSR return, and SSA maze procedure were identified as independent predictors of maze failure. The clinical applications of this study are as follows: first, we need to change our surgical approach from the right mini-thoracotomy to the median sternotomy for the patients who have three biological risk factors (LA size >60 mm, CTR >60%, fine AF). The sternotomy enables us to resect the LA auricle and to ensure the transmurality of ablation line. Second, close observation is necessary for the patients who returned to NSR after the day of operation.

There are still controversies whether the success rate of cut and sew maze is superior to other surgical modifications and ablations using alternative energy sources [23]. Some authors insist that more extensive lesion sets were not shown to improve outcomes of the surgery and rather biology of patients might be a major determinant of surgical AF ablation success [7,22]. However, others argued that more extensive lesion sets were associated with a greater success rate in their study population [10,24]. In this study the ablation line of the SSA reproduced most lesion sets of the Cox Maze III procedure except the resection of a right atrium auricle and an incision between right atrium auricle and tricuspid annulus. Although the SSA enabled earlier sinus restoration and shorter hospital stay, the mid-term success rate of the SSA was significantly lower than cut and sew maze. Furthermore nontransmural lesions of SSA associated with various condition could be a possible explanation of these difference.

This study has several limitations. First, this study was subjected to limitations inherent to a nonrandomized, retrospective, and observational data. As a result, operative techniques and energy sources were decided by surgeon’s preference. As the present study was based on a single surgeon’s experience, however, such bias might be minimized. Second, although close follow-up was maintained on most of the patients, none of the patients had continuous cardiac monitoring such as transtelaphonic ECG devices. As the symptomatic patients seem to have better follow-up with intermittent 12-lead ECG, the overestimation of AF at the long-term observation might be possible. On the contrary, underestimation of postoperative AF by missing the paroxysmal AF could also be possible. Third, the significant difference of follow-up duration between cut and sew maze and SSA was a major limitation on comparison of these two techniques. Therefore, longer duration of observation is needed. Fourth, as the two groups were divided according to the rhythm of the latest follow-up, these groups do not actually exist and patients in both groups can be altered in the next follow-up. This limitation weakened the statistical credibility of this study.

In conclusion, our maze procedure during last decade showed an acceptable success rate and the patients with sinus restoration after maze procedure showed better long-term survival rates. The close observation is necessary for the patients who returned to NSR after the day of operation. Although the SSA showed favorable early results, the long-term success rate needs to be observed precisely. For the patients who have independent biological risk factors such as LA size larger than 60 mm, CTR over 60% and fine AF, more thorough ablation lesion set is recommended for better long-term results.

Conflict of interest

None of authors have any conflict of interest.

Disclosure: None.

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**Appendix A. Conference discussion**

**Dr R. Klautz (Leiden, Netherlands):** It’s a very impressive series of over 500 patients with mainly concomitant atrial fibrillation with 3 different techniques and 3 different energy sources used.

In the follow-up, you used EKG and echos in the standard fashion, but Holter examinations were only done on indication. You have a very good success rate of over 80% at 5 years in this group that had a sustained atrial fibrillation rate of almost 90% and a very low incidence of pacemakers.

I think part of the success rate is that you have a different population than in the rest of Europe where we don’t see that many rheumatic valve disease.

You didn’t find any difference in energy source or a difference between paroxysmal and continuous atrial fibrillation, but you did find risk factors for failure very well known for failure in maze procedures.

You also found that a simplified maze was a risk factor for failure. I think it’s very difficult to draw conclusions from survival because risk factors for failure are also indicators for more advanced disease.

I have two questions for you. If patients convert to sinus rhythm, do you stop antiarrhythmic drugs and antiocoagulation therapy or what’s your policy in that respect?

**Dr Je:** Our policy on anti-arythmic medication was when the patient showed normal sinus rhythm on ECG and transmitral A wave was defined in the echocardiogram during hospitalization, we discontinued the anti-arrhythmic drugs at the time of discharge.

**Dr Klautz:** If they converted to sinus rhythm later after discharge in the follow-up, did you discontinue anticoagulation and anti-arrhythmic drugs?

**Dr Je:** Yes. If the patients showed the transmitral A wave in the echocardiogram.

**Dr Klautz:** Okay. Based on your risk factors, are there patients in which you decide not to ablate at all or where you do any other procedure like you going back to a cut-and-sew maze procedure as you had much better results in those procedures than any of the other techniques?

**Dr Je:** I’m sorry, I didn’t follow your question.

**Dr Klautz:** You show so much better results in your cut-and-sew maze procedures.

**Dr Je:** Yes.

**Dr Klautz:** Now, based on those risk factors, are you going back to cut-and-sew maze in high-risk patients?

**Dr Je:** Oh, I see, I get it.

After this study, we compared our cut-and-sew maze procedure and simplified surgical ablation technique. As you can see in this graph, the maze success rate is quite low for the surgical ablation group. However, it has several advantages such as early sinus restoration and less hospitalization and less ICU stay.

And we think that the simplified ablation technique itself is not a risk factor and a lot of factors might influence during the ablation procedure.

Because we have performed a lot of minimally invasive approaches for the maze procedure, we cannot fully guarantee the transorality during the ablation lesion of the past.

So after that, we changed our policy. If the patient was a high-risk group, we routinely performed the sternotomy and resected the left atrium, left atrial auricle, and then the ablation line was connected to the resected LA auricle margin.

We tried to make perfect and guaranteed transmural ablation line for box lesion. That’s our change. We do not want to go back to the cut-and-sew maze.

**Dr Klautz:** So you’re convinced that your simplified technique, as you’re using it now, is as good as cut-and-sew maze?
Dr Je: Yes. Now we are prospectively collecting our data of sternotomy maze for high risk group and will compare to the previous simplified surgical ablation. We already collected 20 to 30 patients, and we will analyze and report in the near future.

Dr Klautz: Okay.

Dr S. Benussi (Milan, Italy): This is a very impressive experience. I would just like to stimulate your comment on a practical point.

What would be, practically speaking, the take-home message from your series? Do you suggest that since patients with a larger left atrium, older age and other risk factors have a high relapsing rate at follow-up, they should not be given ablation at all? Or would you rather agree that, being modern ablation techniques virtually devoid of complications, indication to concomitant ablation should be expanded to include even patients with a predicted low success rate, maybe even accept a 50% success rate, based on the fact that you are not significantly adding to the operative risk?

Dr Je: I would like to show you this graph.

Yes, the patient has a lot of risk factors, but they are advantaged after our maze procedure because we aggressively resected the left atrium. And as you can see in this graph, the average of left atrial size is much decreased after the operation. And it can be very helpful to prevent thromboembolic event even though the patient recurred the atrial fibrillation.

And now we educate our patient like this; Yes, you have risk factors. So we will do a more thorough ablation lesion set to you via sternotomy approach, but we cannot guarantee 100% of your sinus restoration, but we will do our best.

Dr M. Jahangiri (London, UK): I have a quick question. Were your patients all chronic persistent AF, or did you have some paroxysmal AF because you didn’t really define what is this population of patient you started with.

Dr Je: You mean the paroxysmal and persistent?

Dr Jahangiri: Yes. Did you have any paroxysmal in this group?

Dr Je: Oh, yes. I show you in this graph, and in our study, 13.4% of patients were paroxysmal atrial fibrillation.

Dr Jahangiri: Because you know the results in surgery are significantly better in patients with paroxysmal atrial fibrillation.

Dr Je: Yes, yes.

Dr R. Chitwood (Greenville, N. Carolina): One quick question. How long did you freeze? In your simple mazes and your CryoMazes, how long did you freeze?

Dr Je: For the left side, two-minute ablation. For the right side, two minutes for the carvo-tricuspid lesion and the other side one minute.

Dr Chitwood: The CryoProbe minus-150, not the old Frigitronics device?

Dr Je: Yes.

Dr Chitwood: The new one.