Modified Maze Procedure for Atrial Fibrillation

as an Adjunct to Elective Cardiac Surgery: Predictors of
Mid-Term Recurrence and Echocardiographic Follow-Up

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The radiofrequency maze procedure achieves sinus rhythm in 45%–95% of patients treated for atrial fibrillation. This retrospective study evaluates mid-term results of the radiofrequency maze—performed concomitant to elective cardiac surgery—to determine sinus-rhythm predictive factors, and describes the evolution of patients' echocardiographic variables.

From 2003 through 2011, 247 patients (mean age, 64 ± 9.5 yr) with structural heart disease (79.3% mitral disease) and atrial fibrillation underwent a concomitant radiofrequency modified maze procedure. Patients were monitored by 24-hour Holter at 3, 6, 12, and 24 months, then annually. Eighty-four mitral-valve patients underwent regular echocardiographic follow-up. Univariate and multivariate analysis for risk factors of maze failure were identified.

The in-hospital mortality rate was 1.2%. During a median follow-up of 39.4 months, the late mortality rate was 3.6%, and pacemaker insertion was necessary in 26 patients (9.4%). Sinus rhythm was present in 63% of patients at the latest follow-up. Predictive factors for atrial fibrillation recurrence were arrhythmia duration (hazard ratio [HR]=1.296, $P=0.045$) and atrial fibrillation at hospital discharge (HR=2.03, $P=0.019$). The monopolar device favored maze success (HR=0.191, $P<0.0001$). Left atrial area and indexed left ventricular end-diastolic volume showed significant decrease both in sinus rhythm and atrial fibrillation patients. Early sinus rhythm conversion was associated with improved left ventricular ejection fraction.

Concomitant radiofrequency maze procedure provided remarkable outcomes. Shorter preoperative atrial fibrillation duration, monopolar device use, and prompt treatment of arrhythmia recurrences increase the midterm success rate. Early sinus rhythm restoration seems to result in better left ventricular ejection fraction recovery. (*Tex Heart Inst J* 2015;42(4):341-7)

Key words: Atrial fibrillation/surgery/therapy; echocardiography; radiofrequency maze; risk factors/analysis

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Atrial fibrillation (AF), the most common cardiac arrhythmia, increases morbidity and mortality rates in adults after cardiac surgery,¹ reaching a peak incidence in mitral-valve patients of 60% to 80%.² According to several different clinical trials,³⁻⁶ maze surgery by the cut-and-sew technique—or by alternative means of electrical blockage through the creation of linear lesions—results in sinus rhythm in 44% to 95% of patients. Its advantages consist of better survival rate and quality of life.^{7,8} Although the maze procedure and its modifications have been performed since 1987, some issues remain unsolved. For example, it is uncertain how to identify features that can help in detecting patients who can truly benefit from this procedure as an adjunct to elective cardiac surgery. Moreover, whether its clinical gain is secondary, at least in part, to a favorable evolution of the dimensions and function of the cardiac chambers is still to be determined.

This report of midterm follow-up of the radiofrequency maze procedure performed concomitant to elective cardiac surgery focuses upon the negative predictive role on arrhythmia recurrence played by the presence of AF at hospital discharge and, more unexpectedly, upon the positive effect of monopolar device use. It also describes the progression of patients' echocardiographic values.

Patients and Methods

We retrospectively analyzed 247 consecutive patients with structural heart disease and atrial fibrillation who were scheduled for cardiac surgery and a concomitant modi-

fied radiofrequency maze procedure at our center from January 2003 through June 2011 (Table I). There were 121 men and 126 women, with a mean age of 64 ± 9.5 years (range, 24–80 yr). More than half (67.6%) of the patients had permanent or persistent AF (arrhythmia definitions were in accordance with the 2011 American College of Cardiology/American Heart Association guidelines).⁹ Our patient population's mean preoperative arrhythmia duration (including both chronic and paroxysmal AF) was 29.9 months (range, 1–240 mo).

The 247 patients were categorized into 2 groups: 196 mitral-valve patients who needed valve surgery with or without additional surgical procedures and 51 “non-mitral” patients (29 with aortic valve diseases, 4 with isolated tricuspid regurgitation, 15 with coronary-artery disease, and 3 with congenital defects). The mean preoperative left atrial dimensions were 54 ± 9 mm and 33 ± 8 cm². Basal preoperative clinical and echocar-

diographic variables are shown in Table I. This study was approved by our institution's ethical committee/institutional review board.

Modified Radiofrequency Maze Procedures. Radiofrequency energy was used to create continuous endocardial and epicardial lesions that mimicked most of the set of left atrial incisions as described in the Cox maze III procedure.¹⁰ In the first 92 patients (37%, 2003–2006), the irrigated monopolar Cardioblate® Surgical Ablation Pen (Medtronic, Inc.; Minneapolis, Minn) was used. In the 155 more recent patients (63%), a bipolar irrigated device was used, involving the Cardioblate® BP2 Irrigated RF Surgical Ablation System (Medtronic).

In nonmitral patients, only isolation of both pulmonary veins and of the left atrial appendage was performed—epicardial isolation in cases of bipolar device use (34 patients, 67%); or endocardial isolation with the monopolar pen after specific dedicated left atriotomy (17 patients, 33%).

In mitral-valve patients, we performed additional left atrial radiofrequency ablation: a double-union line between the left and right pulmonary islands and a lesion connecting the right pulmonary island to the posterior annulus of the mitral valve at the P2 or P3 segment (according to the left circumflex coronary artery anatomy); a bipolar device was used in 121 mitral patients (62%), and the remaining 75 (38%) underwent the ablation procedure with the monopolar pen. After ablation, the main surgical procedure was performed (Table II).

Clinical Follow-Up. Early postoperative rhythms were checked daily by standard 12-channel surface electrocardiography. Follow-up 24-hour Holter monitoring was checked postoperatively at 3, 6, 12, and 24 months

TABLE I. Patients' Preoperative and Operative Characteristics at Baseline

Variable	Overall (N=247)	Mitral-Valve (isolated or concomitant) (n=196)
Male/female	121/126	109/87
Age (yr)	64 ± 9.5	63 ± 9
Chronic atrial fibrillation	167 (67.6)	140 (71.4)
Paroxysmal atrial fibrillation	80 (32.4)	56 (28.6)
AF duration (mo)	29 (1–240)	28.5 (1–240)
Left atrial diameter (mm)	54 ± 9	52 ± 8
Left atrial area (cm ²)	33 ± 8	35 ± 8
LVEDD (mm)	54 ± 9	54 ± 9
LVESD (mm)	34 ± 8	34 ± 8
LVEF	0.58 ± 0.08	0.58 ± 0.08
Mitral disease (isolated or concomitant)	196	—
Aortic disease (isolated or concomitant)	29	—
Isolated tricuspid disease	4	—
Isolated coronary disease	15	—
Congenital defects	3	—
Mitral stenosis	—	75 (38.2)
Mitral regurgitation	—	121 (61.8)

AF = atrial fibrillation; LVEDD = left ventricular end-diastolic diameter; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic diameter

Data are presented as mean $\pm$ SD, as a number, as number and range, or as number and percentage.

TABLE II. Main Cardiac Procedures Performed after Radiofrequency Maze

Procedure	Overall (N=247)
Mitral valve replacement	60 (24.3)
Mitral valve repair	73 (29.6)
Mitral valve surgery + tricuspid repair	63 (25.6)
Aortic valve replacement	24 (9.7)
Aortic valve replacement + tricuspid repair	2 (0.8)
Aortic valve replacement + CABG	3 (1.2)
CABG	15 (6)
Tricuspid valve repair	4 (1.6)
Interatrial defect closure	3 (1.3)

CABG = coronary artery bypass grafting

Data are presented as number and percentage.

after the intervention, and then annually. Follow-up lasted through June 2011.

Echocardiographic Follow-Up. A subgroup of 84 mitral patients who underwent a full, successful mitral valve repair was evaluated with use of 2-dimensional transthoracic echocardiography (TTE) at 3, 6, 12, and 24 months, in order to monitor the evolution of cardiac-chamber dimensions and systolic performance.

Statistical Analysis

Data were analyzed with use of SPSS 12.0 software (IBM Corporation; Armonk, NY). Continuous variables were presented as mean $\pm$ SD and categorical variables as percentages or numbers. Seventeen variables were evaluated univariately to identify predictors of arrhythmia recurrence. Univariate analyses were performed for all relevant categorical variables by means of χ^2 analysis, and by Student *t* tests when indicated. A Cox proportional hazard model was used to determine the independent predictors of late-arrhythmia recurrence. A multiple-events Cox model was also applied in the analysis, to account for the chance of multiple arrhythmia reappearances. Kaplan-Meier survival analysis was used to estimate freedom from recurrent AF. A *P* value of less than 0.05 was considered statistically significant.

Results

Early Postoperative Data. Three patients (1.2%) died of refractory cardiac failure in the intensive care unit. Other postoperative sequelae included major cerebrovascular events (2.4%, 6/247), cardiac tamponade (1.2%, 3/247), transient acute renal failure (6.4%, 16/247), and reoperation for bleeding unrelated to the maze lesions (3.6%, 9/247).

One hundred fifty-one patients (62%) were discharged from the hospital in sinus rhythm; of those, 52 (21%) had stable atrial fibrillation, 7 (3%) had atrial flutter, and 11 (4.5%) had a well-tolerated atrial ectopic rhythm.

Twenty-three bicameral pacemakers were implanted (in 9% of patients) for advanced atrioventricular blocks or for atrial ectopic rhythm accompanied by a heart rate that was too low.

Late Follow-Up. Late follow-up was achieved in 90% of the patients, with a mean follow-up duration of 1,184 days (range, 2–2,939 d). There were 9 late deaths (3.6%) (4 of progressive congestive heart failure and 5 of extracardiac causes).

At the last follow-up evaluation, stable sinus rhythm had been achieved in 63% (155/247) of patients, 24% (60/247) experienced recurrent AF, and 1 had a refractory post-incisional tachycardia. In the whole study population, 26 patients underwent permanent pacemaker implantation: of these, 13 patients had devices that were completely silent secondary to the late emergence of

sinus rhythm, 10 patients had an underlying AF (such rhythm categories are included in both sinus rhythm and AF classes), and 3 showed a pacemaker-dependent rhythm.

Cumulative radiofrequency maze success rates in all patients were 77.9% at 1 year, 75.4% at 2 years, and 65.4% at 5 years (Fig. 1).

Risk-Factor Analysis of Maze Failure. The univariate analysis of the predictive factors of freedom from recurrent AF at last follow-up is shown in Table III and identifies (as significant protective variables) monopolar device use, a preoperative arrhythmia duration of less than 36 months, sinus rhythm at hospital discharge, and a longer cross-clamp time. Multivariate analysis confirmed the favorable role of these factors (arrhythmia duration: hazard ratio [HR] = 1.296, *P*=0.045; atrial fibrillation presence at hospital discharge: HR=2.03, *P*=0.019; and monopolar device use: HR=0.0191, *P*<0.0001), with the exception of longer cross-clamp time (Table III). The same analysis, repeated exclusively in the mitral group, retrieved similar results: only sinus rhythm at hospital discharge lost significance.

In order to better evaluate the theoretical possibility of multiple recurrent AF, we applied a multiple-events Cox model, again revealing the protective role played by shorter preoperative arrhythmia duration and by restoration of pre-discharge sinus rhythm. However, with this model the monopolar device lost statistical significance.

Echocardiographic Follow-Up. In the 84 mitral-valve patients who underwent specific TTE follow-up, we observed that left atrial area (Fig. 2) and indexed left ventricular (LV) end-diastolic volume showed a significant progressive decrease, whereas indexed LV end-systolic volume increased 3 months after surgery and then

Fig. 1 Kaplan-Meier curve shows the cumulative radiofrequency maze success rates in all patients: 77.9% at 1 year, 75.4% at 2 years, and 65.4% at 5 years.

AF = atrial fibrillation; Pts = patients at risk

TABLE III. Univariate and Multivariate Analyses for Freedom from Recurrent AF at Last Follow-Up Evaluation

Factor	Univariate <i>P</i> Value	Multivariate Analysis*		
		Hazard Ratio	95% CI	<i>P</i> Value
Monopolar device	0.0002	0.191	0.09–0.41	<0.0001
Duration of AF (>36 mo)	<0.0001	1.296	1.01–1.67	0.045
AF at hospital discharge	<0.0001	2.03	1.12–3.69	0.019
Cross-clamp time	0.0002	0.684	0.38–1.24	0.208
Age	0.1852	—	—	—
Rheumatic disease	0.09	—	—	—
Sex	0.066	—	—	—
Permanent/persistent AF	0.1385	—	—	—
“Mitral” patients**	0.31	—	—	—
Postoperative bleeding	0.33	—	—	—
CPB time	0.28	—	—	—
Assisted ventilation time	0.21	—	—	—
Left atrial diameter	0.3681	—	—	—
Left atrial area	0.1419	—	—	—
LVEDS	0.2345	—	—	—
LVEDD	0.6832	—	—	—
LVEF	0.52	—	—	—

AF = atrial fibrillation; CI = confidence interval; CPB = cardiopulmonary bypass; LVEDD = left ventricular end-diastolic diameter; LVEF = left ventricular ejection fraction; LVEDS = left ventricular end-systolic diameter

*Not all factors were entered into the multivariate model.

**The variable “mitral” patients corresponds, in our protocol, to patients who underwent complete intra-atrial ablation set lesions, whereas “nonmitral” patients underwent pulmonary-vein encircling without left atrial opening.

P < 0.05 was considered statistically significant.

Fig. 2 Graph shows a progressive significant decrease in the evolution of postoperative left atrial area. Vertical bars denote 95% confidence intervals. *P* < 0.05 was considered statistically significant.

**P* < 0.05 versus baseline.

***P* < 0.05 versus 3 postoperative months.

gradually decreased. Nevertheless, LV ejection fraction (LVEF) showed an early (and expected) postoperative fall, then returned toward its baseline levels (Fig. 3).

This phenomenon occurred regardless of the patients' actual underlying rhythm and, consequently, regardless of maze-procedure success, because it was similar both in sinus-rhythm and AF patients. In addition, patients who were in sinus rhythm 3 months after surgery showed a statistically significant improvement in LVEF (*P* = 0.04) at 12 months (Fig. 4).

Discussion

Since the Cox maze procedure was introduced as AF surgical therapy,¹⁰ various modifications (in terms of set lesions and of alternative energy sources) have been introduced in order to diminish its original high rate of complications while preserving its success rate.^{11–13} Currently available ablation devices achieve an acceptable degree of sinus-rhythm conversion (45% to 95%)

Fig. 3 Graph shows trends for indexed left ventricular end-diastolic volume (Ind LVEDV), indexed left ventricular end-systolic volume (Ind LVESV), and left ventricular ejection fraction (LVEF). Indexed LVEDV showed a progressive significant decrease; indexed LVESV increased 3 months after surgery and then decreased; and LVEF showed a postoperative fall and then returned toward its baseline levels. Vertical lines denote 95% confidence intervals. $P < 0.05$ was considered statistically significant.

* $P < 0.05$ versus baseline

Fig. 4 At 12 months after the maze procedure, the left ventricular ejection fraction (LVEF) was significantly improved in patients who had experienced early sinus rhythm conversion at 3 months after operation, when compared with those in atrial fibrillation at that time. Vertical bars denote 95% confidence intervals. $P < 0.05$ was considered statistically significant.

at mid- to long-term follow-up,¹⁴⁻¹⁶ although this success range remains inferior to the results of the surgical maze.

The present study provides midterm follow-up data pertaining to a considerable number of patients (mostly mitral-valve) who underwent radiofrequency maze ablation concomitant to their main surgical procedures. The population study failed to be homogeneous in terms of arrhythmia type and of operative device (because of the late appearance of bipolar devices), but most patients

had basal mildly dilated LVs with good contractile performance. Immediate and midterm maze success rates (62% and 63%, respectively), as well as overall survival rates and the incidence of major sequelae, were similar to those previously reported.¹⁷

Regarding maze surgery, a question that was not fully answered concerns the possible preoperative identification of features that might discourage ablation because of their strong association with failure to terminate arrhythmia. Earlier studies have detected various such factors, including old age, larger left atrial diameter, a long preoperative history of arrhythmia, lower amplitude of F wave, rheumatic mitral valve disease, permanent AF, and maze-lesion sets.¹⁸⁻²² In our study, only arrhythmia duration longer than 36 months was confirmed as an adverse variable; other issues emerged unexpectedly, and their significant role was corroborated by multiple statistical tools that we also used to evaluate the intrinsic nature of the arrhythmia (that is, its chance of recurring several times).¹⁷

First, we confirmed the importance of discharge rhythm, as was pointed out by Lazopoulos and colleagues¹⁵; the consequent clinical application consists in prompt cardioversion of every tachyarrhythmia.

The second undeclared protective factor, which perhaps could be called a “before-was-better” theory, is represented by the radiofrequency monopolar device, which theoretically is characterized by its absence of transmural and by its danger of fatal esophageal damage.²³ In order to prevent possible adverse sequelae, we decided to place an ice-cold lint (surgical dressing) behind the left atrium, to pull back the transesophageal echocardiography probe and to administer cold-blood cardioplegic solution continuously via the coronary sinus during the entirety of the ablation time, thereby increasing the distance between the atrial wall and the esophagus and avoiding excessive myocardial warming.

In our judgment, such probable superiority of the monopolar device needs confirmation, because it could in part be related to surgical accuracy during the patient’s first procedure, as supported by the significant positive prognostic contribution played by longer cross-clamp times.

Nevertheless, if confirmed, this finding could lead to a veritable change in patterns of thought and practical conduct, also involving a reconsideration of AF pathophysiology.

With regard to the lack of a significant correlation between left atrial dimensions and the failure of maze procedures, we must remember that our mean preoperative left atrial diameter was quite low (other trials have established a cutoff at 60 mm).^{15,24}

Our series included a large number of pacemaker implantations, considerably more than reported elsewhere in the medical literature.²⁴ We should note that, at last follow-up, several of these pacemakers had fallen

silent in the presence of patients' spontaneous sinus rhythm. This suggests to us the value of a more conservative approach to pacemaker implantation: some early postoperative slow rhythms vanish after the resolution of tissue inflammation.

The second important issue highlighted by the present study is the identification of an effect of maze on the improvement of cardiac diameters and function. In fact, even if the mortality-and-stroke-rate benefit of maze over non-maze has not yet been proved,^{25,26} it is reasonable to assume that the restoration of sinus rhythm improves the quality of life and perhaps survival prospects.^{15,27} In our judgment, such a gain could be related to the progressive improvement of heart-chamber size and contractile performance. Indeed, our subgroup of 84 mitral patients showed a significant midterm persistence of left atrial area and of indexed LV end-diastolic volume improvement, an entity superior to that previously reported even in cases of optimal mitral valve repair.^{28,29} This suggests that a substantial role is being played by the success of the maze procedure. In addition, such a result is much more worthy of interest in view of our patients' preoperative presentation with mild LV dilation, quite normal LVEFs, and left atrial volumes that were far from enormous. We could object that the same enhancing trend was observed in all patients (independently of maze success evaluated at different follow-up times), but in the considered sample, the percentages of AF patients were very small, especially at 12 and 24 months' follow-up time. Of note, we were able to determine the probable influence of early sinus-rhythm conversion (at 3 months) on future favorable LVEF evolution, a result that almost certainly is associated with better quality of life. This matter needs further investigation.

Limitations and Conclusions. This trial has several limitations. First, it is a nonrandomized and retrospective study. Second, although close follow-up was maintained on most patients, none had continuous cardiac monitoring.

In conclusion, we can affirm that our last decade of experience with concomitant radiofrequency maze shows it to be safe and effective. Specifically, the achievement of its goals is favored by shorter preoperative atrial fibrillation duration, early sinus rhythm conversion, prompt treatment of every arrhythmia recurrence, and monopolar device use. The real significance of such findings (above all the last)—and the question of what cutoff in arrhythmia duration must be applied in selecting patients—are not fully elucidated. Nor do we know the best time for permanent pacemaker implantation in this peculiar subset of cardiac surgical patients. Yet our study highlights a significant advantage in LVEF gain among patients successfully treated by the maze procedure, thus clearly suggesting the beneficial effect of that procedure on heart performance.

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