Radiofrequency modified maze in patients with atrial fibrillation undergoing concomitant cardiac surgery

Hauw T. Sie, MD^a
Willem P. Beukema, MD^a
Anand R. Ramdat Misier, MD^a
Arif Elvan, MD^a
Jacob J. Ennema, MD^a
Max M. P. Haalebos, MD^a
Hein J. J. Wellens, MD^b

See related article on page 212.

From the Departments of Cardiothoracic Surgery and Cardiology and Cardio-anesthesiology, Isala Klinieken, Hospital De Weezenlanden, Zwolle,^a and the Academic Hospital Maastricht, Maastricht,^b The Netherlands.

Received for publication June 6, 2000; revisions requested Sept 29, 2000; revisions received Dec 4, 2000; accepted for publication Jan 22, 2001.

Address for reprints: Hauw T. Sie, MD, Department of Cardiothoracic Surgery, Isala Klinieken, Hospital De Weezenlanden, Groot Wezenland 20, 8011 JW Zwolle, The Netherlands (E-mail: hauwsie@worldonline.nl).

J Thorac Cardiovasc Surg 2001;122:249-56
Copyright © 2001 by The American Association for Thoracic Surgery
0022-5223/2001 \$35.00 + 0 12/1/114633
doi:10.1067/mtc.2001.114633

Objective: In the majority of patients with chronic atrial fibrillation the arrhythmia will persist after correction of the underlying structural abnormality. The maze procedure is an effective surgical method to eliminate atrial fibrillation and to restore atrial contractility.

Methods: In this study we used radiofrequency energy to create lines of conduction block in both atria during cardiac surgery as a modification of the maze III procedure. One hundred twenty-two patients with atrial fibrillation for at least 1 year and structural heart disease underwent open heart operation and a radiofrequency modified maze procedure.

Results: In 108 (89%) of 122 patients mitral valve surgery was performed, and in this group 86 patients (80%) underwent 121 concomitant procedures. Fourteen patients (11%) underwent cardiac surgery not involving the mitral valve. The additional crossclamp time required for the left atrial part of the radiofrequency modified maze procedure was 14 ± 3 minutes. The in-hospital mortality rate was 4.1%. The overall 39-month survival was 90%, and freedom of atrial flutter or atrial fibrillation was $78.5\% \pm 5.1\%$. Eighty-nine survivors with sinus, atrial rhythm, or atrioventricular sequential pacemaker had Doppler echocardiography, and right atrial transport function was documented in 83% and left atrial transport function in 77% of patients.

Conclusion: We concluded that the radiofrequency modified maze procedure as an adjunctive procedure is safe, time-sparing, and effective in eliminating atrial fibrillation and restoring atrial transport function.

Atrial fibrillation (AF) is a common arrhythmia, present in 0.4% of the general population and in greater than 1% of the population older than 60 years of age.^{1,2} About 40% to 60% of patients undergoing mitral valve (MV) operations have AF at the time of the operation.³⁻⁵ Although cardiac contractile function usually improves after MV surgery, in many patients long-standing AF will persist after valve surgery.⁶ Pharmacological and electrical cardioversion in this

Figure 1. RF-modified maze: schematic view of the dorsal aspect of the heart. (A) Lines of electrical activation; (B) zigzag lines depicting the incisions in the atria; (C) dotted lines depicting the endocardial ablation lines. IVC, Inferior vena cava; LAA, left atrial appendage; LPV, left pulmonary veins; RAA, right atrial appendage; RPV, right pulmonary veins; SVC, superior vena cava.

Figure 2. Lateral aspect of the right atrium. (A) Lateral incision in the right atrial wall; (B) anterior incision in the right atrial wall; (C) left atrial incision in the interatrial groove. The intercaval endocardial ablation lines are depicted as dotted lines a and b. IVC, Inferior vena cava; RAA, right atrial appendage; RPV, right pulmonary veins; SVC, superior vena cava.

setting is often ineffective, and attempts to establish sinus rhythm by serial cardioversions are disappointing; therefore, this arrhythmia is usually considered to be permanent.

During the past decades several surgical methods have been designed to treat AF. The most effective one seems to be the maze procedure developed by Cox and associates.^{7,8} The maze procedure restores sinus rhythm and atrioventricular (AV) synchrony with demonstrable atrial transport function. In patients undergoing complex cardiac procedures, surgeons are reluctant to expose their patients to the risks of the maze procedure.

Radiofrequency (RF) catheter ablation has become an important mode of treatment in patients with supraventricular and ventricular tachycardias.⁹⁻¹¹ In patients with atrial flutter (AFL) or atrial re-entrant tachycardias, RF energy is used to create continuous linear lesions in the atrium, interrupting a critical part of the re-entrant circuit.¹² Recent results of application of RF catheter ablation to mimic the surgical maze procedure in a canine model of AF were encouraging.¹³ The purpose of the present study was to determine whether intraoperative RF ablation was feasible and could restore sinus rhythm and atrial contractility in patients with chronic AF undergoing cardiac surgery.

Methods

Patient Characteristics

All patients included in this study had an indication for cardiac surgery irrespective of AF. Inclusion criterion for AF surgery was atrial fibrillation lasting for more than 1 year. The decision to perform cardiac surgery was made by the patient's cardiologist and

cardiothoracic surgeon. Conventional clinical and hemodynamic criteria were applied to assess the indication for surgery. Before the surgical intervention, clinical characteristics of each patient including New York Heart Association (NYHA) classification and medication were assessed by one investigator. Rhythm characteristics (presence and duration of AF) were assessed by using the patient's history and previous electrocardiograms. Echocardiographic data were obtained within 3 months before cardiac surgery. Patients who needed urgent cardiac surgery were excluded from this study. From November 1995 through July 1999, 122 consecutive patients (48 men, 74 women) with a mean age of 69 ± 10 years (range, 33 to 83 years) with chronic AF underwent an RF modified maze procedure in combination with surgery for structural heart disease. One hundred five (86%) patients were in NYHA class III-IV preoperatively (Table 1). Hemodynamically significant MV disease was present in 110 (90%) patients, aortic valve disease in 32 (26%) patients, and 60 (49%) patients had significant tricuspid valve incompetence secondary to MV disease. Coronary artery disease was present in 41 (34%) patients. Six patients had an atrial septal defect, 4 associated with MV disease, 1 as an isolated lesion, and 1 in combination with coronary artery disease. Eight patients (6%) had previously undergone cardiac surgery (MV surgery in 7 patients and aortic valve replacement in 1 patient). Duration of AF ranged from 1 to 49 years (mean, 5.6 ± 6.7 years). The mean left atrial dimension was 50 ± 9 mm (range, 31 to 80 mm) as measured on an M-mode tracing taken from a 2-dimensional parasternal long-axis view (Sonos 5500; Hewlett-Packard, Palo Alto, Calif). This study was approved by the board of directors of the hospital.

Preoperative Management

In the 122 patients enrolled in the study, ventricular rate control medication, that is, calcium blockers and/or digoxin, was allowed to continue until the day before surgery. Oral anticoagulant therapy (warfarin sodium) for the prevention of thromboembolism sec-

Figure 3. View inside the right atrium. The right atrium is exposed by stay sutures. The ablation lines are presented as dotted lines (c, d, and e). CS, Coronary sinus; FO, foramen ovale; IVC, inferior vena cava; RAA, right atrial appendage; SVC, superior vena cava; TV, tricuspid valve.

ondary to chronic AF was discontinued 2 days before surgery. β -Adrenergic blockers were continued.

Postoperative Management and Follow-up

Early postoperative care, including anticoagulant management, was similar as for routine cardiac surgery. Cardiac rhythm was continuously monitored after surgery until stable rhythm returned. Temporary epicardial wires attached to the right ventricle as well as to the right atrium were used to pace the patient, to monitor the rhythm, or to overdrive the atrium. Postoperative atrial arrhythmias were treated with sotalol 80 to 120 mg or amiodarone 200 mg and combined with direct-current cardioversion if necessary. All patients were operated in one institution and by the same surgeon (H.T.S.). After discharge, patients were seen in the outpatient clinic within 4 weeks, at 3 months and at 6 months after operation, or earlier when necessary. Antiarrhythmic drugs were tapered gradually after cardiac rhythm was considered stable. The presence of atrial contraction as documented by transthoracic and transesophageal Doppler echocardiography was performed at 3 and 6 months after surgery and related to the presence of electrical activity in the surface electrocardiogram. After 6 months and up to 3 years, patient status was determined by screening records of outpatient visits and correspondence with referring physicians.

RF Ablation

RF energy was used to create long continuous endocardial lesions under direct vision with a hand-held cooled tip probe. The RF energy was administered by using a continuous sinusoidal unmodulated waveform of 500 kHz (HAT 200S; Sulzer-Osypka GmbH, Grenzach-Wyhlen, Germany) and delivered in a unipolar mode between the 4-mm tip electrode of a specially designed probe and a 10 × 16 cm external backplate electrode that was underneath the back of the patient. The ablation probe had a thermistor embedded centrally in the distal part of the tip electrode for continuous monitoring of

Figure 4. View inside the left atrium. The left atrium is exposed by stay sutures. The ablation lines are depicted as dotted lines (f, g, h, j, and k). LAA, Left atrial appendage; LPV, left pulmonary veins; RPV, right pulmonary veins.

catheter tip temperature. The ablation procedure was done in a bloodless operating field, and temperature-guided energy applications were performed with a preselected catheter tip temperature of 60°C. The tip was irrigated with saline solution at a flow rate of 4 mL/min.

Surgical Procedure

The heart was exposed through a median sternotomy and suspended in a pericardial cradle. Cardiopulmonary bypass was instituted by using standard aortic and bicaval cannulation and moderate hypothermia (28°C). All atrial incisions currently used in the Cox maze procedure were replaced in our RF modification by endocardial linear ablation lines as illustrated in Figures 1 through 4 except for the incisions to enter the left and right atrial cavity. According to the original maze III both appendages were excised as well. There was no need for additional cryosurgical applications.

Concomitant procedures (eg, aortic valve replacement and coronary bypass grafting) were performed immediately after aortic crossclamping and before completing the left-sided maze and the MV procedure.

Right-sided maze procedure. After both caval cannulas were snared, the right atrium was opened through a posterior longitudinal incision starting caudally of the superior caval cannulation site at the dorsolateral aspect of the right atrium (Figures 1 and 2). This incision was extended along the border of the interatrial septum, slightly curved and finally ending at the AV groove opposite the inferior caval cannulation site (Figure 2, A).

The right atrial appendage was excised, and an anterior incision (Figure 2, B) of approximately 4 cm was made from the middle of the anterolateral aspect of the base of the amputated auricle toward the inferior caval vein orifice. RF energy was then used to extend the electrical block caused by the first surgical incision (Figure 2, A) cranially as far as possible toward the superior caval cannulation site (Figure 2, dotted line a) and caudally toward the inferior caval cannulation site (Figure 2, dotted line b). Additional RF abla-

Figure 5. Actuarial survival for the entire study group of 122 patients. Figure depicts number of patients at risk.

Figure 6. Freedom from permanent AF or atrial flutter (AFI) using the Kaplan-Meier actuarial curve in 107 patients. Figure depicts number of patients at risk in each 9-month interval.

tion lines (Figure 3) were drawn from the medial aspect of the base of the excised right atrial appendage into the annulus of the tricuspid valve (Figure 3, *dotted line c*) and from the caudal end of the first surgical incision at the AV groove (Figure 2, *A*) to the posterior part of the annulus of the tricuspid valve (Figure 3, *dotted line d*). This part of the maze procedure was performed on the beating heart without a crossclamp.

The septal part of the procedure was performed in a later stage of the operation, just before closing the left atrium to prevent tearing of the septum.

Left-sided maze procedure. The aorta was crossclamped, and the heart was arrested with cold cardioplegic solution. Access to the inside of the left atrium was gained via a standard atriotomy in the interatrial groove, as for an MV procedure (Figure 2, *C*). After excision of the left atrial appendage and resuturing of the amputation site, the left-sided maze was performed by linear ablation lines as illustrated in Figure 4. In addition to the incision in the interatrial groove (Figure 2, *C*), isolation of the right pulmonary veins was completed by a unilateral ablation line

(Figure 4, *dotted line g*). The left pulmonary veins were encircled (Figure 4, *dotted line f*), and a connecting line (Figure 4, *dotted line h*) was drawn between both islands of pulmonary veins. Ablation lines were also performed from the ablation line isolating the left pulmonary vein to the base of the left atrial appendage amputation site (Figure 4, *dotted line k*) and to the posterior MV annulus (Figure 4, *dotted line j*). Subsequently the MV procedure was carried out. The maze procedure was then completed with an ablation line drawn on the right-sided aspect of the interatrial septum starting from the middle of the posterior longitudinal right atriotomy (Figure 2, *A*) across the interatrial septum up to the caudal aspect of the os of the coronary sinus extended to the inferior vena cava cannulation site (Figure 3, *dotted line e*).

After rewarming the left atrium was closed and the cross-clamp released. The heart was then deaired extensively before defibrillation and to closing of the right atrium. Occasionally atrial pacing or AV pacing was needed to wean the patient from bypass.

TABLE 1. Clinical characteristics of study patients

	N (%)
Patient No.	122 (100)
Female	74 (61)
Age (y)	69 ± 10
Rhythm characteristics	
Persistent AF before surgery	122 (100)
Duration of persistent AF (y)	5.6 ± 6.7
Functional class	
NYHA II	17 (14)
NYHA III	103 (84)
NYHA IV	2 (2.0)
Echocardiographic data (mm)	
Parasternal long axis	50 ± 9
Left ventricular end-diastolic dimension	54 ± 8

Statistical Analysis

Unless stated otherwise, mean values and standard deviations are reported. For the comparison between subgroups, a Student *t* test was used for normally distributed variables and a Wilcoxon-Mann-Whitney test for non-normally distributed variables. In case of categorical variables, a χ^2 test with continuity correction or a Fisher exact test was used when appropriate. Analysis of variance was applied to compare effects over time and effects per time point (3 and 24 months after surgery). Bonferroni correction was performed to correct for multiple comparisons. The arrhythmia-free survival curves were constructed by using the Kaplan-Meier method; differences between the curves were investigated with a log-rank test.

Results

Operative Findings and Immediate Postoperative Follow-up

The study population consisted of 122 patients with chronic AF who underwent an RF modified maze with 252 concomitant cardiac procedures. One hundred eight (89%) patients had MV surgery, of whom 48 (39%) had MV repair and 60 (49%) patients had MV replacement. In this group associated procedures included aortic valve replacement (*n* = 26), coronary artery bypass grafting (*n* = 33), tricuspid valve repair (*n* = 54), closure of atrial septal defect or patent foramen ovale (*n* = 3), correction of cor triatriatum (*n* = 1), clearing of carotid artery obstruction (*n* = 1), left ventricle reconstruction (*n* = 1), ascending aorta replacement (*n* = 1), and aortic root replacement (*n* = 1). Fourteen patients (11%) underwent 23 cardiac surgical procedures not involving the MV (Table 2). The mean aortic crossclamp time and cardiopulmonary bypass times were 119 ± 46 minutes and 227 ± 65 minutes, respectively. The additional ischemic time needed to perform the left-sided maze procedure was 14 ± 3 minutes. There were 5 (4.1%) in-hospital deaths. One 68-year-old female patient died intraoperatively as a result of rupture of the mitral annulus, and a 64-year-old female patient died

TABLE 2. Concomitant cardiac procedures with and without involving MV surgery in study patients

	N (%)
Concomitant procedures in 108 patients with MV surgery	
MV repair	48 (39)
MV replacement	60 (49)
+ AVR	26
+ CABG	33
+ TVP	54
+ Closure ASD	3
+ Correction of cor triatriatum	1
+ Carotid artery desobstruction	1
+ Left ventricle reconstruction	1
+ Ascending aorta replacement	1
+ Aortic root replacement	1
Concomitant procedures in 14 patients without MV surgery	
AVR	2
AVR + TVP	4
CABG + TVP	6
AVR + CABG	4
Closure ASD	1
Closure ASD + CABG	4
TVP	1
CABG	1

AVR, Aortic valve replacement; ASD, atrial septal defect; CABG, coronary artery bypass grafting; TVP, tricuspid valve repair.

TABLE 3. In-hospital morbidity

	N (%)
Rethoracotomy	11 (9)
Intra-aortic balloon pump	7 (5.7)
Recurrent AF/AFL	4 (3.3)
Dual-chamber pacemaker	4 (3.3)
Right ventricular perforation	2 (1.6)
Sternal wound infection	1 (0.8)
Endocarditis	1 (0.8)
Stroke	1 (0.8)

of coma vigil due to a late tamponade after a redo MV replacement. Two female patients aged 73 years and 74 years, respectively, who were preoperatively in NYHA class IV, died of low cardiac output syndrome after combined MV surgery and coronary artery bypass grafting, and a 72-year-old woman died of multiple organ failure after a redo double valve replacement. The nonfatal in-hospital complications are summarized in Table 3.

Survival and Events

All surviving patients were monitored for at least 3 months up to 3 years after surgery. The overall 3-year survival was 90% ± 3.1% as shown in Figure 5. There were 10 late deaths (8.3%) including 5 cardiac, 1 nonspecified, and 4 non-cardiac-related deaths.

Figure 7. Bar graph showing the cardiac rhythm at the latest follow-up. **SR**, Sinus rhythm; **DDDR**, dual chamber rate responsive pacemaker; **AR**, atrial rhythm; **VVIR**, ventricular based rate responsive pacemaker; **AF**, atrial fibrillation; **AFL**, atrial flutter.

Cardiac Rhythm

Because early recurrences of AF may be caused by mechanisms other than chronic AF, we chose to analyze the incidence of AF after the first 3 postoperative months. As seen in Figure 6, freedom from AF was $98\% \pm 1.5\%$ at 1 year, $86\% \pm 3.7\%$ at 2 years, and $78\% \pm 5.1\%$ at 3 years after surgery. Among 107 survivors, 77 patients (72%) were in sinus rhythm, 6 patients (5.6%) had an atrial rhythm, and 18 patients (16.8%) had persistent AF or AFL 39 months after surgery. In addition, 6 patients (5.6%) were having an AV sequential pacemaker; 2 were implanted before surgery in combination with His bundle ablation and 1 of these patients (0.9%) received a pacemaker because of symptomatic sinus node dysfunction. Four patients (3.7%) underwent His bundle ablation and received a ventricular rate responsive pacemaker because of symptomatic AFL (Figure 7). In 4 patients with postoperative AFL electroanatomic mapping was performed (Carto system; Biosense Ltd, Tirat Carmel, Israel), which revealed a discontinuity in the tricuspid annulus–inferior vena cava isthmus lesion close to the tricuspid valve annulus. All patients were successfully treated by RF ablation.

Atrial Transport

The average preoperative left atrial size in patients who remained in sinus rhythm and in those with postoperative AF or AFL was 48 ± 7.6 mm and 53 ± 8.9 mm, respectively ($P < .01$).

Among 107 survivors, 89 patients (83%) with sinus rhythm, atrial rhythm, or AV sequential pacemaker had a Doppler echocardiographic examination; an A wave was

detected in 69 patients (77%) for transmitral flow and in 74 patients (83%) for transtricuspid flow.

Discussion

The negative sequelae of AF are widely known, particularly in combination with MV disease.¹⁴ The majority of patients undergoing MV surgery have been reported to be in AF preoperatively, and 80% of these patients will remain in AF after surgical correction of the underlying cardiac disease.³⁻⁵ Therefore, a specific surgical intervention is needed to eliminate AF. Only in patients with intermittent AF or AF of duration less than 1 year, MV surgery alone is sufficient to restore sinus rhythm in the majority of patients.^{3,15} In this study we have only included patients with a history of at least 1 year of AF in whom it is unlikely that sinus rhythm will be regained after valve surgery.

Excellent results have been described for the surgical treatment of chronic AF associated with organic heart disease at the expense, however, of considerable prolongation of time required for cardiac arrest and cardiopulmonary bypass.^{4,16} In an attempt to reduce procedure time and to simplify the surgical procedure, modifications of the original maze procedure⁸ have been developed, including the use of cryoablation and changes in atriotomies¹⁷ and application of RF energy alone¹⁸ or with cryoablation.¹⁹ Treatment of AF by application of contiguous RF-induced lesions in the atria are based on the concept of preventing functional re-entrant circuits^{18,20} or to eliminate anatomically determined circuits.²¹

Patwardhan and colleagues²⁰ use a bipolar forceps to create RF lesions, whereas in this study RF energy is delivered

in unipolar mode between a probe and a cutaneous dispersive pad. Furthermore, we apply a saline-cooled ablation technique, allowing creation of deeper lesions without the need for cryoablation. All the lesions are made endocardially and replace most of the surgical incisions. The reason we chose the surgical maze III⁸ as the basis for our RF modified maze is because at the start of this study the Cox maze was the only proven therapy to cure AF and the unilateral maze modifications were inadequately evaluated.²² The elective cardiac arrest time required to complete the maze procedure in the present investigation was 10 to 15 minutes in contrast to at least 30 minutes for the Cox maze III^{5,20} or the modification of Cox's maze III by Kosakai and colleagues¹⁷ or the combination of RF energy and cryoablation to complete the left-sided maze.¹⁹

Although the complexity of the combined approach carries potential risks, this is not supported by our data. In a recent editorial Grover and Edwards²³ are reporting similar mortality rates between the Society of Thoracic Surgeons and the New York State Database, ranging from 5.9% for isolated MV replacement to 13.3% for combined MV replacement and coronary artery bypass grafting. Despite the complexity of the surgical procedures performed in this group of patients, the in-hospital mortality rate was comparable to previous reports on patients who underwent mainly isolated MV surgery with or without AF surgery.^{3,24,25}

The aim of AF surgery is restoration of sinus rhythm and re-establishment of atrial mechanical function. In our patient group, atrial rhythm and atrial contractility were documented in 77% of patients, which is comparable with the results of the surgical maze III procedure in patients with long-standing AF and structural heart disease.^{5,17,24,26} Melo and associates²⁷ performed intraoperative endocardial bilateral isolation of the pulmonary veins in patients with chronic AF and MV disease. An atrial rhythm and contractility was restored in only 50% of the patients. The concept of AF being triggered by foci in the pulmonary veins in patients with chronic AF is questionable. From experimental and clinical studies it was demonstrated that AF or AFL can occur in the absence of any electrical input from the pulmonary veins.²²

The importance of interrupting conduction along the coronary sinus to avoid development of post-maze AFL has been recognized.²⁸ The incidence of postoperative AFL in our study was 14% at 39-month follow-up. We performed electroanatomic mapping (CARTO system) in 4 patients with post-maze AFL. In all patients we found a discontinuity in the tricuspid annulus-inferior vena cava isthmus lesion close to the tricuspid valve annulus. All patients were successfully treated with RF catheter ablation.

The incidence of sinus node dysfunction after surgery (0.1%) requiring pacemaker implantation in this patient group was lower than in previous reports on patients who underwent the Cox maze III with structural heart dis-

ease^{20,24,29} and comparable with the modification of the maze atriotomies by Kosakai and colleagues³⁰ aimed to preserve a better arterial blood supply to the sinus node.

In conclusion, the use of RF energy intraoperatively is safe and effective and simplifies the maze procedure in patients undergoing cardiac surgery. In the majority of patients sinus rhythm is restored and atrial transport re-established.

Study Limitations

Local electrogram amplitude reduction and temperature monitoring have been used to prove transmural and contiguity of RF lesions.³¹ In this study RF lesions are created under direct vision. Because local atrial electrograms are not recorded as a routine during operation, it is not certain whether the ablation lines represent complete conduction block. However, ablation of AF does not per se require contiguous and transmural lesions.³¹ In the operating room measurements of endocardial signals to verify effective lesion formation is time-consuming and limited to the right atrial RF maze. Finally, the left-sided RF maze is preferably performed with moderate hypothermia, which will influence electrical activity of the atria and after cardioplegic arrest of the heart electrical activity will cease.

References

- Ostrander LD, Brandt RL, Kjelsberg MO, Epstein FH. Electrocardiographic findings among the adult population of a total natural community, Tecumseh, Michigan. *Circulation*. 1965;31:888-98.
- Rose G, Baxter PJ, Reid DD, McCartney P. Prevalence and prognosis of electrocardiographic findings in middle-age men. *Br Heart J*. 1978;40:636-43.
- Chua LY, Schaff HV, Orszulak TA, Morris JJ. Outcome of mitral valve repair in patients with preoperative atrial fibrillation. *J Thorac Cardiovasc Surg*. 1994;107:408-1.
- Kawaguchi AT, Kosakai Y, Sasako Y, Eishi K, Nakano K, Kawashima Y. Risks and benefits of combined maze procedure for atrial fibrillation associated with organic heart disease. *J Am Coll Cardiol*. 1996;28:985-90.
- Handa N, Schaff HV, Morris JJ, Anderson BJ, Kopecky SL, Enriquez-Sarano M. Outcome of valve repair and the Cox maze procedure for mitral regurgitation and associated atrial fibrillation. *J Thorac Cardiovasc Surg*. 1999;118:626-35.
- Brodel GK, Cosgrove D, Schiavone W, Underwood DA, Loop FD. Cardiac rhythm and conduction disturbances in patients undergoing mitral valve surgery. *Cleve Clin J Med*. 1991;58:397-9.
- Cox JL, Schuessler RB, D'Agostino HJ Jr, Stone CM, Chang BC, Caine ME, et al. The surgical treatment of atrial fibrillation. (III) Development of a definitive surgical procedure. *J Thorac Cardiovasc Surg*. 1991;101:569-83.
- Cox JL, Jaquiss RDB, Schuessler RB, Boineau JP. Modification of the maze procedure for atrial flutter and atrial fibrillation. II. Surgical technique of the maze III procedure. *J Thorac Cardiovasc Surg*. 1995;110:485-95.
- Jackman WM, Wang X, Friday KJ, Roman CA, Moulton KP, Beckman KP, et al. Catheter ablation of accessory atrioventricular pathways (Wolff-Parkinson-White syndrome) by radiofrequency current. *N Engl J Med*. 1991;324:1605-11.

10. Jazayeri MR, Hempe SL, Sra JS, Dhala AA, Blanck Z, Deshpande SS, et al. Selective transcatheter ablation of the fast and slow pathways using radiofrequency energy in patients with atrioventricular nodal reentrant tachycardia. *Circulation*. 1992;85:1318-28.
11. Wen M-S, Yeh S-J, Wang C-C, Lin F-C, Chen I-W, Wu D. Radiofrequency ablation therapy in idiopathic left ventricular tachycardia with no obvious structural heart disease. *Circulation*. 1994;89:1690-6.
12. Cauchemez B, Haissaguerre M, Fischer B, Thomas O, Clementy J, Coumel P. Electrophysiological effects of catheter ablation of inferior vena-tricuspid annulus isthmus in common atrial flutter. *Circulation*. 1996;93:284-94.
13. Elvan A, Pride HP, Eble JN, Zipes DP. Radiofrequency catheter ablation of the atria reduces inducibility and duration of atrial fibrillation in dogs. *Circulation*. 1995;91:2235-44.
14. Kannel WB, Abbott RD, Savage DD, McNamara PM. Epidemiologic features of chronic atrial fibrillation: the Framingham study. *N Engl J Med*. 1982;306:1018-22.
15. Obaida JF, El Farra M, Bastien OH, Lièvre M, Martelloni Y, Chassignolle JF. Outcome of atrial fibrillation after mitral valve repair. *J Thorac Cardiovasc Surg*. 1997;114:179-85.
16. Hioki M, Ikeshita M, Iedokoro Y, Nitta T, Harada A, Asano T, et al. Successful combined operation for mitral stenosis and atrial fibrillation. *Ann Thorac Surg*. 1993;55:776-8.
17. Kosakai Y, Kawaguchi AT, Isobe F, Sasako Y, Nakano K, Eishi K, et al. Cox maze procedure for chronic atrial fibrillation associated with mitral valve disease. *J Thorac Cardiovasc Surg*. 1994;108:1049-55.
18. Wellens HJ, Sie HT, Smeets JL, Ramdat Misier AR, Beukema WP, Doevendans PA. Surgical treatment of atrial fibrillation. *J Cardiovasc Electrophysiol*. 1998;9:S1514.
19. Chen M-C, Guo GB-F, Chang J-P, Yeh K-H, Fu M. Radiofrequency and cryoablation of atrial fibrillation in patients undergoing valvular operations. *Ann Thorac Surg*. 1998;65:1666-72.
20. Patwardhan AM, Dave HH, Tamhane AA, Pandit SP, Dalvi BV, Kaul A, et al. Intraoperative radiofrequency microbipolar coagulation to replace incisions of maze III procedure for correcting atrial fibrillation in patients with rheumatic valvular disease. *Eur J Cardiothorac Surg*. 1997;12:627-33.
21. Hindriks G, Mohr FW, Autschbach R, Kottkamp H. Antiarrhythmic surgery for treatment of atrial fibrillation: new concepts. *Thorac Cardiovasc Surg*. 1999;47(suppl):365-9.
22. Cox JL, Ad N. New surgical and catheter-based modifications of the maze procedure. *Semin Thorac Cardiovasc Surg*. 2000;12:68-73.
23. Grover FL, Edwards FH. Similarity between the STS and New York State databases for valvular disease. *Ann Thorac Surg*. 2000;70:1143-6.
24. Izumoto H, Kawazoe K, Kitahara H, Kamata J. Operative results after Cox/maze procedure combined with mitral valve operation. *Ann Thorac Surg*. 1998;66:800-4.
25. Yau MT, Farag-EL-Ghoneimi YA, Armstrong S, Ivanov J, David TE. Mitral valve repair and replacement for rheumatic disease. *J Thorac Cardiovasc Surg*. 2000;119:53-61.
26. Kamata J, Kawazoe K, Izumoto H, Kitahara H, Shiina Y, Sato Y, et al. Predictors of sinus rhythm restoration after Cox maze procedure concomitant with other cardiac operations. *Ann Thorac Surg*. 1997;64:394-8.
27. Melo JQ, Neves J, Adragão P, Ferreira MM, Pinto MM, Rebocho MJ, et al. Surgery for atrial fibrillation using radiofrequency catheter ablation: assessment of results at one year. *Eur J Cardiothorac Surg*. 1999;15:851-5.
28. Cox JL, Ad N. The importance of cryoablation of the coronary sinus during the maze procedure. *Semin Thorac Cardiovasc Surg*. 2000;12:20-4.
29. Kim K-B, Cho KR, Sohn D-W, Ahn H, Rho JR. The Cox-maze procedure for atrial fibrillation associated with rheumatic mitral valve disease. *Ann Thorac Surg*. 1999;68:799-804.
30. Kosakai Y, Kawaguchi AT, Isobe F, Sasako Y, Nakano K, Eishi K, et al. Modified maze procedure for patients with atrial fibrillation undergoing simultaneous open heart surgery. *Circulation*. 1995;92(Suppl):359-64.
31. Avitall B, Gupta G, Bharati S. Are transmural contiguous lesions essential? Post atrial fibrillation ablation: lesion morphology vs outcome [abstract]. *J Am Coll Cardiol*. 1998;31:367A.

Online—www.aats.org

Now you can get **The Journal of Thoracic and Cardiovascular Surgery** online. The Journal online brings you faster delivery time, easy searching of current and back issues, links to PubMed, AATS, WTSA, and other important sites, and more. Visit the Journal online today.

Receive tables of contents by e-mail

To receive the tables of contents by e-mail, sign up through our Web site at <http://www.mosby.com/jtcvs>
 Choose **E-mail Notification**
 Simply type your e-mail address in the box and click the **Subscribe** button.
 Alternatively, you may send an e-mail message to majordomo@mosby.com.
 Leave the subject line blank and type the following as the body of your message:
 subscribe jtcvs_toc
 You will receive an e-mail to confirm that you have been added to the mailing list.
 Note that TOC e-mails will be sent out when a new issue is posted to the Web site.