Atrial Contraction Recovery after Left MAZE III Surgery

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SUMMARY

Introduction
Left MAZE III surgery has proven a high level of effectiveness in restoring the sinus rhythm. However, the effectiveness in restoring the atrial systole in individuals with structural heart disease and the prevalence of rheumatic disease are still uncertain areas.

Objective
To assess the effectiveness of the MAZE surgery in restoring the atrial systole in patients with structural heart disease.

Material and Methods
We conducted a prospective and consecutive study in 27 patients with persistent or chronic atrial fibrillation with indication of cardiovascular surgery, who underwent MAZE technique for treating the arrhythmia.
The presence of atrial systole was assessed by lateral mitral annular tissue Doppler imaging.

Results
In a population characterized by rheumatic heart disease predominance (41%) and long arrhythmia evolution (61 months on average), 87% individuals had sinus rhythm and 80% had mechanical activity at the end of the follow-up. A history of rheumatic heart disease, an arrhythmia lasting more than 5.5 years, the fact of being female, and mitral valve replacement were statistically significant variables, considering the absence of atrial systole. Factors like age, left ventricle ejection fraction, and left atrial size were not significant.

Conclusion
In this population, the absence of correlation between the sinus rhythm and the atrial systole is significant. Tissue Doppler imaging is a useful method to identify those patients with no atrial contraction. The clinical impact of this finding is related to the decision on continuing the anticoagulant therapy.

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Key words > Atrial Fibrillation - Thoracic Surgery - Doppler Echocardiography - Atrial Appendage

Abbreviations >

STK	Stroke	**LVSD**	Left ventricular systolic diameter
RA	Right atrium	**AF**	Atrial fibrillation
LA	Left atrium	**EF**	Ejection fraction
CPB	Cardiopulmonary bypass	**NIR**	International normalized ratio
CABGS	Coronary artery bypass graft surgery	**MVR**	Mitral valve replacement
LVDD	Left ventricular diastolic diameter		

BACKGROUND

Atrial fibrillation (AF) is a frequent arrhythmia that affects 1% of the population and 6% of 65-year-old adults or older. (1)

This condition has a strong impact on health care system due to its complications, frequent rehospitalizations and the necessity to use multiple treatment regimens.

Stroke is the major complication of atrial fibrillation, with an annual prevalence of 5% to 12% according to the individual risk. (2) Approximately 30% of strokes that occur in people older than 60 years are due to cardioembolism. (3)

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Although anticoagulant therapy significantly reduces the risk of stroke, its annual incidence is 2% to 3% (4, 5) and the annual risk of bleeding complications is 0.5% to 2.8%. (6)

In our country, this arrhythmia is associated with structural heart disease and is a highly prevalent risk factor for stroke. However, the use of anticoagulant therapy is not generalized. (7)

Failure of treatments produces repeated hospitalizations due to decompensated heart failure.

Pharmacological and electrical therapeutic strategies are generally inadequate to achieve rhythm control are not free from multiple adverse events. (8)

Atrial fibrillation is present in several clinical scenarios, such as hypertensive heart disease, pulmonary diseases, metabolic and endocrine disorders, and particularly in rheumatic valve disease: almost 60% of patients undergoing valve replacement have atrial fibrillation (9, 10)

Therapeutic procedures that correct atrial fibrillation are available for this population undergoing surgery.

Cox-Maze surgery, developed in the eighties, demonstrated a rate of long-term success of 80% to 97%. (11, 12) Despite its effectiveness in curing atrial fibrillation, the procedure is so complex that its adoptability is minimal. (13)

The technique was subsequently modified resulting in less complex operations with lower cardiopulmonary bypass time that were used more frequently by different surgical teams.

The classical atrial incision was replaced by the use of radiofrequency, cryothermia with helium or argon, or laser energy sources for creating rapid and effective lines of conduction block in the reentrant pathways that generate and perpetuate the arrhythmia. (14)

Restoration of sinus rhythm is not always followed by the return of left atrial mechanical function, a condition that is essential to reduce the factors related to thrombosis. (15)

The decision to maintain anticoagulant therapy during long-term follow-up after surgery relies on the assessment of the mechanical function of the left atrium.

The current scenario includes the use Maze III surgery procedure and the absence of knowledge of the capability of the new techniques to restore atrial contraction. The goal of the present study was to analyze the time to recover atrial electrical and mechanical activity, and its relationship and variables associated to success in sinus rhythm restoration in a population of consecutive patients with persistent atrial fibrillation undergoing heart surgery.

MATERIAL AND METHODS

Between September 2005 and March 2007, we performed a prospective cohort study of 27 consecutive patients with atrial fibrillation undergoing heart surgery in combination with a modified left atrial Maze III procedure.

We included patients with AF lasting one year under rate control strategy, according to the definitions of the current guidelines. (16)

The presence of the arrhythmia was documented through electrocardiograms, 24-hour Holter monitoring and clinical records.

Patients gave their consent to undergo this therapeutic strategy and to participate in long-term follow- up of this pilot study.

Surgical technique

After median sternotomy, the patient was placed on cardiopulmonary bypass (CPB) using bicaval cannulation.

The heart was arrested using blood cardioplegia. A left atriotomy was performed through the interatrial septum and the left atrial appendage was excised. Then we continued with the schematic diagram of atrial lesions: encircling isolation of the pulmonary veins, connecting lesion from left atrial appendage to the left pulmonary veins. A linear lesion was performed connecting the pulmonary veins and the atriotomy, and from the latter to the mitral annulus at the level of the P2 and P3 scallops according to coronary artery anatomy (Figure 1). In the right atrium a lesion was performed in the cavotricuspid isthmus.

The atrial lesions were carried out with a bipolar, saline-irrigated radiofrequency ablation device (Medtronic Cardioblate BP Surgical Ablation System®). The surgical hand piece incorporates 2 electrodes on separate arms of a hemostat instrument able to deliver bipolar radiofrequency energy and features saline irrigation to allow better power delivery to the tissue from the generator. The device continuously monitors tissue impedance, current, voltage delivered, and the duration of ablation in real time.

By continually calculating the change in impedance, the tissue is ablated until there is a plateau in the impedance that is considered as the point of transmurality. At that moment, the objective feedback of transmurality is provided by an audible signal.

The technique for left atrial volume reduction was included in only one case in a patient with a giant left atrium of 60 cm^2 area.

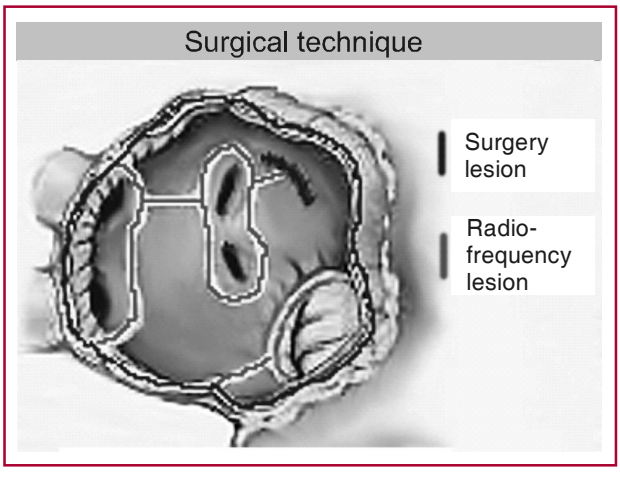

Fig. 1. Diagram of radiofrequency lesions. See explanation in the text.

Follow-up

Postoperative continuous electrocardiographic monitoring was performed in the coronary care unit and daily electrocardiograms were taken during hospitalization.

Patients follow-up at 1, 3, 6 and 12 months after surgery included 24-hour Holter monitoring and color-Doppler echocardiography.

Preoperative and postoperative echocardiographic measurements were compared, and included: diastolic left ventricular (DDLV) diameter, systolic left ventricular diameter (SLVD), ejection fraction (EF), anteroposterior, transverse and longitudinal diameter of the left atrium (LA), and areas of the LA and right atrium (RA). Transvalvular mitral flow was registered.

From the apical 4-chamber view, a tissue Doppler imaging sample volume was placed at the lateral portion of the mitral annulus to record late diastolic velocity (Aa wave, atrial systole). The spectral Doppler signal parameters were adjusted to obtain velocity scale limits between 15 and 20 cm/s by use of the lowest filter settings and the optimal gain to eliminate the spectral signal produced by blood flow. The results were expressed in cm/sec.

Atrial pacing at a rate of 90-100 beats per minute was combined with intravenous infusion of amiodarone, 300 mg/day, at the operation room and during the first 48 hours following surgery. Thereafter, patients received 400 mg of oral amiodarone during 4 months in absence of contraindications.

Anticoagulation therapy was started with acenocumarol and anticoagulant dosage was adjusted to achieve an INR between 2.3 and 2.6.

Statistical Analysis

Data were prospectively obtained and were analyzed using the chi square test or Fisher test. Receiver operating characteristic (ROC) curves were used to define the cutoff point in continuous variables. The Kaplan-Meier curve was obtained using SPSS-13.0 statistical analysis software.

RESULTS

The principal characteristics of the study population are described in Table 1. Mean age was 64.7 (35-78) years and 60% were women.

Surgery was indicated due to rheumatic mitral stenosis in 10 patients (37%), aortic stenosis in 5 (18.5%), mitral regurgitation in 6 (22%), and coronary artery disease in 1 patient (4%).

The following procedures were performed: mitral valve replacement (MVR) 44%, aortic valve replacement (AVR) 33%; combined aortic and mitral valve replacement 7%, mitral valve repair 4%, coronary artery bypass graft surgery (CABGS) 4%, combined mitral valve repair with CABGS 4% and combined AVR with CABGS in 4%. Fifteen percent of these interventions were reoperations. Mechanical heart valve prostheses were used in 40.7% of cases (11 patients).

Valvular hart disease was due to rheumatic heart disease defined by personal history and echocardiography in 11 cases (41%), myxomatous mitral valve in 6 (22%), degenerative aortic valve stenosis in 5 (18.5%), annuloaortic ectasia in 4 (15%) and bicuspid aortic valve in 1 (4%).

Tabla 1. Características basales de la población

N	27
Male gender	40.7%
Mean age	64.7 years (35-78)
AF duration	61 months (12-180)
AF duration 5 years	48%
HT	81%
Diabetes	30%
Smoking habits	11%
Dyslipemia	51%
Mitral stenosis	37%
Mitral regurgitation	22%
Aortic regurgitation	18.5%
Aortic stenosis	18.5%
Combined surgery	4%
Coronary revascularization	4%
Heart reoperation	15%
Left atrial area (cm^2)	34
Ejection fraction	49.5%
LVDD (mm)	50.6
Cardiopulmonary bypass time (min)	131 (70-215)
Ablation time (min)	14 (12-17)

The mean time of duration of AF was 61 months (± 12-180) in 48% of patients had had the arrhythmia for 5 years; left atrial area was 34 cm^2 (± 21-60) and left ventricular ejection fraction was 49.5% (± 26-71) before surgery.

Mean cardiopulmonary bypass time was 131 minutes (± 70-215) and the mean time taken to perform ablation of atrial tissue was 14 minutes (± 12-17).

All patients were admitted to the coronary care unit immediately after surgery with an epicardial pacemaker implanted, and stayed in the unit for an average of 4 days (± 2-16).

There was no need to implant a permanent pacemaker during immediate postoperative or during long-term follow-up. Fifteen percent of patients underwent elective electrical cardioversion during follow-up due to recurrent AF within the first 2 weeks after surgery. No episodes of recurrent AF occurred after that period of time. All patients received amiodarone until 4 months after the procedure; there was no need to discontinue the drug due to adverse events and treatment continued if necessary.

Mean follow-up was 9 months (6-16) and survival was 85.2%.

By th end of follow-up 87% of patients (20/23) were on sinus rhythm and 80% of these patients presented mechanical activity (16/20).

Sinus rhythm recovery was 61% (14/23) during the first month and increased to 81% and 83% at 3 and 6 months, respectively. However, recovery of sinus rhythm was not immediately effective as left atrial mechanical activity was detected in only 39% of patients during the first month and 61%at 3 and 6 months following surgery (Figure 2).

There were no significant differences in age (61 versus 64.7 years), left atrial area (34 versus 37 cm^2) and ejection fraction (54% versus 49.5%) in patients in sinus rhythm and mechanical activity compared to subjects in sinus rhythm and absence of mechanical activity.

All men (8/8) and only 66% of women (8/12) in sinus rhythm had effective atrial systole ($p < 0.029$).

The presence of atrial mechanical activity during sinus rhythm was detected in 42% (3/7) of patients with rheumatic valvular heart disease and in 85% (11/13) of non-rheumatic patients ($p < 0.02$).

In 44% (4/9) of patients undergoing mitral valve replacement sinus rhythm was not associated with recovery of mechanical activity, while all patients (11/11) undergoing other surgical procedures recovered atrial contraction ($p < 0.014$).

All patients with AF lasting less than 5.5 years recovered atrial mechanical activity (13/13), while only 42% (3/7) with AF duration > 5.5 years normalized atrial activity during sinus rhythm ($p< 0.001$) (Figure 3).

ROC curve analysis showed that the cutoff point of 0.97 (0,91-1,03) had a specificity of 93% and a sensitivity of 85% to predict absence of recovery of left atrial mechanical activity after surgery when AF duration was > 5.5 years (Figure 4).

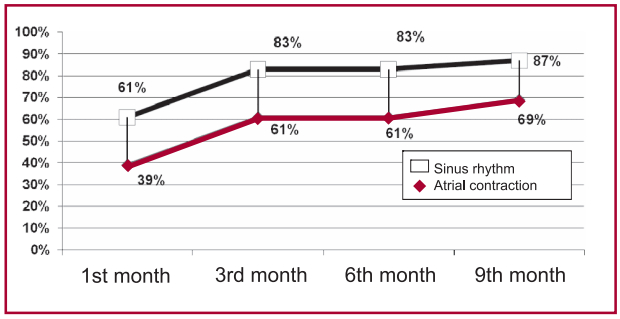

Fig. 2. Sinus rhythm and atrial contraction evolment during follow-up.

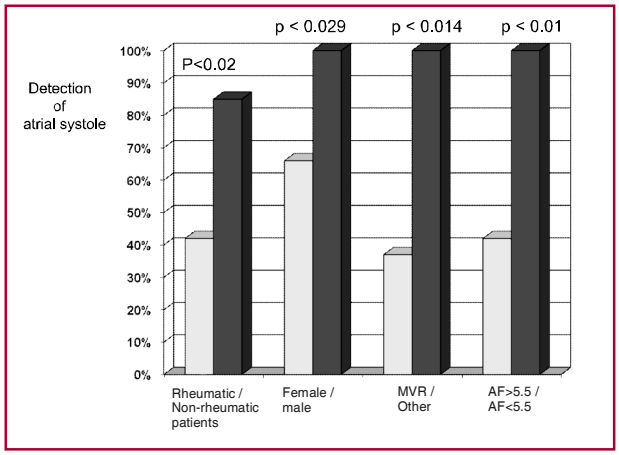

Fig. 3. Variable related to the presence of left atrial contraction.

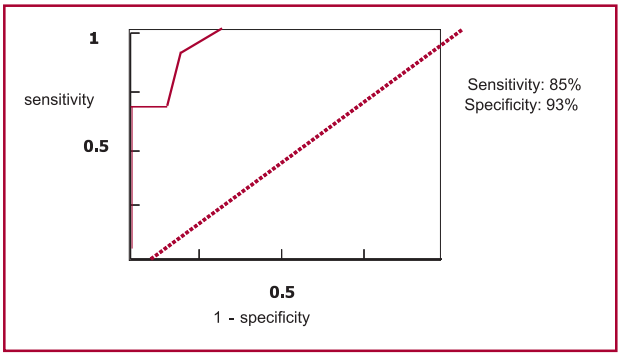

Fig. 4. ROC curve: AF > 5.5 years. Area under the curve: 0.97 (0.91-1.03).

DISCUSSION

Atrial fibrillation represents a clinical condition with high prevalence and the main therapeutic goal is to prevent cardioembolism.

Rhythm control strategy has tried to reduce the risk of stroke with the possibility of avoiding anticoagulant therapy at the long-term. In addition, other benefits include low risk of developing tachycardia induced cardiomyopathy and better exercise capacity related to atrioventricular synchrony. (17) Yet, the ability to maintain sinus rhythm is often poor with antiarrhythmic drugs, which may also have serious adverse events; in addition, AF recurrences are frequent. (18)

The presence of spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins (19) allowed the development of invasive therapeutic techniques which are still limited to selected cases.

MAZE surgery, developed more than 20 years ago, was the first nonpharmacological strategy for management of AF. The procedure, proposed by James Cox in the eighties, has been widely accepted due to its high effectiveness and to the fact that modifications of the original procedure have simplified the method. (20)

International guidelines recommend its use in patients with AF undergoing cardiovascular surgery. (16-21)

Restoration of sinus rhythm is about 90%; however, it not always associated with re-establishment of atrial mechanical function. This may be due to the numerous incisions performed in both atria that modify their architecture.

Impairment in atria contraction is a frequent finding in the original studies; however, its incidence is less than 10% in the last years as a result of modifications in the original technique. (22)

Our findings are similar to those reported by the international literature: recovery to sinus rhythm was high (87%), but restoration of the mechanical activity was low. Forty percent of our patients had not recovered the atrial systole one month following surgery, and 6 months later 30% remained in the same conditions. Other studies that also included patients with structural heart disease have reported recovery to sinus rhythm in 81% to 95% of patients after 5 years of follow-up; however, these studies do not mention the status of atrial mechanical function. (23, 24)

Probably, this difference may be related to the type of population undergoing surgery.

The initial studies included patients with low incidence of structural heart disease, similar proportion of cases of persistent AF and paroxysmal AF, and in most cases patients underwent only MAZE procedure. The characteristics of these populations might justify the excellent outcomes in the long-term and the absence of ischemic neurological events during follow-up, regardless of the efficiency of the atrial systole. (25)

The population intervened in our study was unselected and is more representative of developing countries, with predominance of rheumatic heart disease. (40%)

This condition produces a significant impairment in the structure of atrial tissue leading to remodeling that compromises atrial contraction. (26, 27)

These patients had little recovery of atrial mechanical function; only 40% presented atrial contraction in contrast with non-rheumatic patients in whom atrial systole was present in 85% of subjects.

The duration of AF at the moment of surgery is another particular feature of this population: in 50% of patients the arrhythmia lasted more than 5 years. Atrial fibrillation duration is inversely related to sinus rhythm restoration; however, there are few data regarding the recovery of atrial contraction. (28)

We have found that this is a detrimental factor. The duration greater than 5 years is highly specific and sensitive to predict failure in the recovery of atrial mechanical activity.

Left atrial area, ejection fraction and age are predictors of restoration of electrical activity, yet little is known about their role in mechanical recovery. (6, 29, 30) In our study, we did not find any relationship between these variables and the absence or the presence of mechanical activity.

The choice of the method for assessing atrial mechanical activity is an inconvenience. Transesophageal echocardiography was used in the early stages of the MAZE procedure to measure the velocities in the left atrial appendage; however this method is no longer used due to the resection of this structure with the new technique.

Pulsed Doppler echocardiography imaging detects the A wave of transvalvular mitral flow. Multislice computed tomography is not only expensive but requires the implementation of a complex model to measure atrial volumes by dividing the atrium in multiple segments. (31)

We have chosen tissue Doppler imaging at the level of the mitral annulus as a diagnostic tool as it is a safe and easily reproducible method, with high sensitivity and specificity, available and with low cost.

The findings of our pilot experience show a significant absence of correlation between sinus rhythm and atrial systole that may have clinical implications in decision-making regarding the continuation of anticoagulation during follow-up of patients with no mechanical heart valve prostheses. (32, 33)

We are not in a position to state the real clinical impact of our findings, as this study was not focused on the analysis of events during follow-up.

CONCLUSIONS

We believe that in patients undergoing MAZE surgery it is necessary to confirm the atrial mechanical activity using a diagnostic method to define the necessity to continue the anticoagulant therapy and thus reduce the incidence of late cardioembolic events.

RESUMEN

Recuperación de la contracción auricular luego de la cirugía de MAZE III izquierdo

Introducción

La cirugía de MAZE III izquierdo demostró una efectividad elevada en la restauración a ritmo sinusal. Sin embargo, la efectividad en la restauración de la sístole auricular en poblaciones con cardiopatía estructural y el predominio de enfermedad reumática resultan áreas de incertidumbre.

Objetivo

Evaluar la efectividad de la cirugía de MAZE en la restauración de la sístole auricular en pacientes con cardiopatía estructural.

Material y métodos

Estudio prospectivo, consecutivo de 27 pacientes portadores de fibrilación auricular crónica persistente con indicación

de cirugía cardiovascular y en los que se realizó la técnica de MAZE como tratamiento de la arritmia. La presencia de sístole auricular se evaluó mediante Doppler tisular del anillo mitral lateral.

Resultados

En una población caracterizada por predominancia de cardiopatía reumática (41%) y tiempo prolongado de evolución de la arritmia (61 meses promedio), al final del seguimiento el 87% se encontraba en ritmo sinusal en el 80% de los casos con actividad mecánica. El antecedente de cardiopatía reumática, una duración de la arritmia mayor de 5,5 años, el sexo femenino y el reemplazo de válvula mitral fueron variables estadísticamente significativas en cuanto a la ausencia de sístole auricular. No tuvieron significación la edad, la fracción de eyección del ventrículo izquierdo y el tamaño de la aurícula izquierda.

Conclusiones

En esta población es significativa la falta de correspondencia entre ritmo sinusal y sístole auricular. El Doppler tisular es un método útil para identificar a aquellos pacientes sin contracción auricular. El impacto clínico de este hallazgo está vinculado con la decisión en la continuidad del tratamiento anticoagulante.

Palabras clave > Fibrilación auricular - Cirugía torácica - Ecocardiografía Doppler - Apéndice auricular

BIBLIOGRAPHY

1. Go AS, Hillek EM, Phillips KA, Chang Y, Henault LE, Selby JV, et al. Prevalence of diagnosed atrial fibrillation in adults: national implications for rhythm management and stroke prevention: The anticoagulation and risk factors in atrial fibrillation (ATRIA) study. JAMA 2001;285:2370-5.

2. Wolf PA, Mitchell JB, Backer CS, Kannel WB, D'Agostino RB. Impact of atrial fibrillation on mortality, stroke, and medical costs. Arch Intern Med 1998;158:229-34.

3. Petersen P. Thromboembolic complications in atrial fibrillation. Stroke 1990;21:4-13.

4. Petersen P, Boysen G, Godtfredsen J, Andersen E, Andersen B. Placebo-controlled randomized trial of warfarin and aspirin for prevention of thromboembolic complications in chronic atrial fibrillation: The Copenhagen AFASAK study. Lancet 1989;1:175-8.

5. Conolly S, Laupacic A, Gent M. Canadian atrial fibrillation anticoagulation (CAFA) study. J Am Coll Cardiol 1991;18:349-55.

6. Fihn SD. Aiming for safe anticoagulation. N Engl J Med 1995; 333:54-5.

7. Labadet C, Liniado G, Ferreirós ER, Molina Viamonte V, Di Toro D, Cragnolino R y col. Resultados del Primer Estudio Nacional, Multicéntrico y Prospectivo de Fibrilación Auricular Crónica en la República Argentina. Rev Argent Cardiol 2001;69: 49-67.

8. Wise DG, Waldo AL, DiMarco JP, Domanski MJ, Rosenberg Y, Schron EB, et al. Atrial fibrillation Follow up Investigation of Rhythm Management (AFFIRM) Investigators. A comparison of rate control and rhythm control in patients with atrial fibrillation. N Engl J Med 2002;347:1825-33.

9. Allesie MA, Boyden PA, Camm AJ, Kleber AG, Lab MJ, Legato MJ, et al. Pathophysiology and prevention of atrial fibrillation. Circulation 2001;103:769-77.

10. Feinberg WM, Blackshear JL, Laupacis A, Kronmal R, Hart RG. Prevalence, age distribution and gender of patients with atrial fibrillation: analysis and implications. Arch Intern Med 1995;155:469-73.

11. Cox JL, Ad N, Palazzo T, Fitzpatrick S, Suyderhoud JP, De Groot KW, et al. Current status of the Maze procedure for the treatment of atrial fibrillation. Semin Thorac Cardiovasc Surg 2000;12:15-9.

12. Schaff HV, Dearani JA, Daly RC, Orszulak TA, Danielson DK. Cox-Maze procedure for atrial fibrillation: Mayo clinic experience. Semin Thorac Cardiovasc Surg 2000;12:30-7.

13. Cox JL. Atrial Fibrillation II: rationale for surgical treatment. J Cardiothorac Surg 2003;126:1693-700.

14. Haissaguerre M, Shah DC, Jais P, et al. Electrophysiological breakthroughs from the left atrium to pulmonary veins. Circulation 2000;102:2463-5.

15. Thomas L, Boyd A, Thomas SP, et al. Atrial structural remodeling and restoration of atrial contraction after linear ablation for atrial fibrillation. Eur Heart J 2003;24:1942-51.

16. Fuster V, Ryden LE, Cannom DS, Crijin HJ, Curtis AB, Zamorano JL, et al. ACC/AHA/ESC 2006 guidelines for the management of patients with atrial fibrillation: a report of American College Cardiology/ American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Revise the 2001 Guidelines for the Management of Patients With Atrial Fibrillation). Circulation 2006;114:e257-e354.

17. Dorian P, Werner J, Newman D, Paquette M, Wood K, Akhtar M, et al. The impairment of health related quality of life in patients with intermittent atrial fibrillation: implications for the assessment of investigational therapy. J Am Coll Cardiol 2000;36:1303-9.

18. The AFFIRM investigators. A comparison of rate control and rhythm control in patients with atrial fibrillation. N Engl J Med 2002;347:1825-33.

19. Haissaguerre M, Jais P, Shah D, Takahashi A, Hocini M, Clementy J, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med 1998;339:659-66.

20. Sie HT, Beukema WP, Missier ARR, et al. Radiofrequency modified MAZE in patients with atrial fibrillation undergoing concomitant cardiac surgery. J Thorac Cardiovasc Surg 2001;122:249-56.

21. Cox JL. The central controversy surrounding the interventional-surgical treatment of atrial fibrillation. J Thorac Cardiovasc Surg 2005;129:1-4.

22. Cox JL, Scheussler RB, Lappas DG, Boineau JP, An 8,5 year clinical experience with surgery for atrial fibrillation. Ann Surg 1996; 224:267-75.

23. Bando K, Kobayashi J, Kosakai Y, Hirata M, Sasako Y, Hitamura S, et al. Impact of Cox-maze procedure on outcomes in patients with atrial fibrillation and mitral valve disease. J Thorac Cardiovasc Surg 2002;124:575-83.

24. Prasad M, Maniar H, Camillo C, Boineau P, Sundt T, Damiano R. The Cox - maze III procedure for atrial fibrillation: long term efficacy in patients undergoing lone versus concomitant procedures. J Thorac Cardiovasc Surg 2003;126:1822-7.

25. Cox JL, Niv A, Palazzo T. Impact of the Maze procedure on the stroke rate in patients with atrial fibrillation. J Thorac Cardiovasc Surg 1999;118:833-40.

26. Sanfilippo AJ, Abascal VM, Sheehan M. Atrial enlargement as a consequence of atrial fibrillation: A prospective echocardiografic study. Circulation 1990;82:792-7.

27. Wijffels MC, Kirchhof CJ, Dorland R, et al. Atrial fibrillation begets atrial fibrillation. A study in awake chronically instrumented goats. Circulation 1995;92:1954-68.

28. Gillinov M, Sirak J, Blackstone E, McCarthy P, Rajeswaran J, Natale A, et al. The Cox Maze procedure in mitral valve disease: Predictors of recurrent atrial fibrillation. J Thorac Cardiovasc Surg 2005;130:1653-60.

29. Gaynor SL, Schuessler RB, Bailey SM, Ishii Y, Boineau JP, Gleva

MJ, et al. Surgical treatment of atrial fibrillation: predictors of late recurrence. J Thorac Cardiovasc Surg 2005;129:104-11.
30. Kosakai Y. Treatment of atrial fibrillation using the Maze procedure: The Japanese experience. Semin Thorac Cardiovasc Surg 2000;12:44-52.
31. Yamanaka K, Fujita M, Doi, K, Tsuneyoshi H, Yamazato A, Komeda M, et al. Multislice Computed Tomography Accurately Quantifies Left Atrial Size and Function Alter the MAZE Procedure. Circulation 2006;114(Suppl I):I-5-I-9.
32. Jordan RA, Schiefly CH, Edwards JE. Mural thrombosis and arterial embolism in mitral stenosis. Circulation 1951;3:363.
33. Stoddard MF, Dawkins PR, Prince CR, Longaker RA. Transesophageal echocardiography guidance of cardioversion in patients with atrial fibrillation. Am Heart J 1995;129:1204.

Competing interests

None declared.