Use of Bipolar Radiofrequency for the Treatment of Atrial Fibrillation During Cardiac Surgery

Leonardo Secchin Canale, Alexandre Siciliano Colafranceschi, Andrey José Monteiro, Marialda Coimbra, Clara Weksler, Ernesto Koehler, Bruno Miranda Marques, Marco Antonio Mattos, Fernando Eugênio dos Santos Cruz Filho, Roberto Luiz Menssing da Silva Sá

Instituto Nacional de Cardiologia, Rio de Janeiro, RJ - Brazil

Abstract

Background: Atrial fibrillation with tissue ablation device through bipolar radiofrequency in conjunction with cardiac surgery has proven to be an effective method to treat this arrhythmia.

Objective: Describe the initial experience of the *Instituto Nacional de Cardiologia* in the surgical treatment of atrial fibrillation using bipolar radiofrequency device in patients undergoing cardiac surgery, reporting the results of postoperative follow-up of one year.

Methods: Between January 2008 and March 2009, 47 consecutive patients (36 women), with mean age of 53.7 ± 10.6 years, with atrial fibrillation for a mean period of 34.6 months (3-192 months) underwent surgical ablation of this arrhythmia, through bipolar radiofrequency during the procedure which led to the indication of surgery. Eight of them showed intermittent atrial fibrillation and 39, continued. Eighty-one percent underwent valve surgery as the main procedure. This is a one-year postoperative retrospective, observational evaluation of clinical variables and 24-h Holter.

Results: Out of the 47 patients, 40 survived one year. Out of these, 33 underwent 24 h Holter, at an average interval of 401 days after the surgery. The following rhythm distribution was found: 24 (73%) sinus, five (15%) atrial fibrillation, three (9%) atrial flutter and one (3%) junctional rhythm. Two cerebrovascular accidents were observed, one of which was associated with supraventricular arrhythmia.

Conclusion: Surgical ablation of atrial fibrillation with bipolar radiofrequency device concomitant with cardiac surgery is an effective method for treating this arrhythmia. (Arq Bras Cardiol. 2011; [online].ahead print, PP.0-0)

Keywords: Atrial flutter; atrial fibrillation; ablation techniques; arrhythmias,cardiac; thoracic surgery.

Introduction

The tissue ablation by bipolar radiofrequency has been established as an effective methods for treatment of atrial fibrillation (AF) during cardiac surgery[1]. Although the Cox-Maze III surgerywith cutting and suturing technique delivers excellent short and long term results[2] both in reversion for sinus rhythm and in preventing thromboembolic events[3], its complexity and demand for a longer surgery discouraged many surgeons to use it routinely. In our environment, the feasibility and effectiveness of the Cox Maze III have been demonstrated by Kalil et al[4] and Canale et al[5]. Aiming to simplify the procedure, several alternative forms of energy for tissue ablation resulting in bidirectional electrical conduction block were studied to recreate the original lesions of the Cox-Maze III[1]. The bipolar radiofrequency device Atricure™ enables the creation of fast and safe tissue lesions covering the entire atrial wall thickness[6].

The purpose of this paper is to describe the initial experience of the Instituto Nacional de Cardiologia (INC) in treating atrial fibrillation during cardiac surgery with tissue ablation device by bipolar radiofrequency Atricure® and clinical evaluation and 24-hour ambulatory Holter one year postoperatively (PO).

Methods and patients

Between January 2008 and March 2009, 47 patients referred for cardiac surgery and atrial fibrillation associated underwent, with the main procedure, AF ablation with tissue ablation device by bipolar radiofrequency (RFB) Atricure™. This is one of the alternative energy options available in the Brazilian market.

RFB ablation uses alternating power current to heat the tissue, creating thermal lesion and resulting conduction block line[7]. The electrodes are located in the jaws of the instrument that consists in a a forceps, and each lesion should be made three times to ensure that the lesion is transmural[8]. The

Mailing address: Leonardo Secchin Canale •
R. Visconde de Pirajá, 302/601 - Ipanema - 22410-000 - Rio de Janeiro, RJ - Brazil
E-mail: leonardo.canale@gmail.com
Manuscript received September 28, 2010; revised manuscript received December 15, 2010; accepted December 21, 2010.

theoretical advantages over the unipolar RF include increased security on the dispersion of energy, creating continuous lesions and ability to assess whether the lesion has reached the entire thickness of the atrial wall through the feedback system of the forceps console[6,7].

It is a retrospective observational study with evaluation of patients, records and complementary tests, whose variables of interest investigated are in accordance with the guidelines on research of patients undergoing surgical treatment of atrial fibrillation[9]. The following variables were evaluated: age, type of AF, AF time reported prior to surgery, prior ablative procedures, presence of pacemaker (PM), cardiac diagnostic motivating indication for surgery, left atrial size, left ventricular ejection fraction, surgical procedure performed, set of lesions for AF treatment performed.

Patients were followed postoperatively with outpatient visits scheduled for one, three, 6 and 12 months after the operation. In these visits, patients were evaluated by an non-blind expert for the treatment of AF on the use of medications, cardiac rhythm, thromboembolic events, any percutaneous ablations performed postoperatively and reoperations. Three-channel Holter monitoring was requested from 04 months and was also assessed by a non-blind expert for the treatment of AF. The failure criterion used is of any therapeutic tachyarrhythmia with total length greater than 30 s in 24 h.

The study was evaluated and approved on February 02, 2010 by the Research Ethics Committee of the INC under number 0257.

Patients' characteristics

Out of the 47 patients, 36 were women (76%) and average age is 53.7 ± 10.6 years. The average reported AF time was 34.6 months (three to 192 months). The type of AF presented was: paroxysmal: 08; persistent: 05; and permanent: 34 (Figure 1). The left atrium had an average size of 54 ± 10.7 mm and left ventricular ejection fraction (LVEF) was: 58.6% ± 13.4%. Two patients had previous pacemaker, and none had been submitted to previous ablation of any arrhythmia. Three patients had a history of cerebrovascular accident. The event observed was related to AF in three patients. At surgery, one patient showed complete resolution of neurological sequelae and two remained with motor and speaking skills. See Table 1.

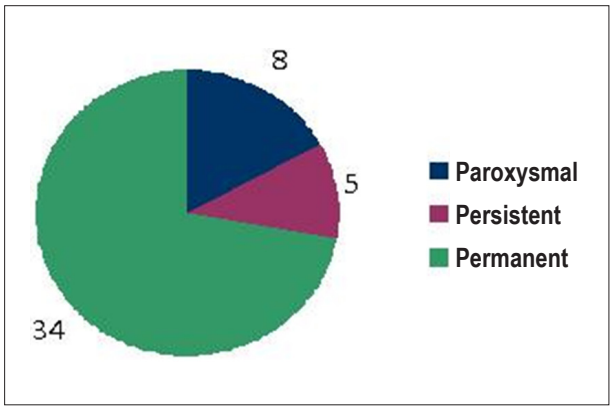

Figure 1 - Type of atrial fibrillation preoperatively.

Table 1 - Preoperative characteristics of patients

Variable	
Female sex - N (%)	36 (76%)
Age (years)	53.7 ± 10.6
Left atrial diameter (mm)	54 ± 10.7
Left ventricular ejection fraction (%)	58.6 ± 13.4
Previous pacemaker - N (%)	02 (4.30%)
Previous percutaneous ablation - N (%)	0 (0%)
Previous cerebrovascular accident - N (%)	03 (6.40%)
Average AF duration (months)	33.9 (3 to 192)

PM - pacemaker; CVA - cerebrovascular accident; AF - atrial fibrillation.

Most primary indications that have led these patients to surgical intervention were related to valve disease (81%). See Figure 2.

Description of lines of lesions for AF ablation

1) Isolation of pulmonary veins - Pulmonary vein isolation was performed by involving the right and left pulmonary veins in pairs epicardially (passing one of the electrodes of the ablation device beyond and the other below the pulmonary veins) during cardiac decompression with cardiopulmonary bypass, and therefore, with the patient heparinized, with the convexity of the device facing the left atrium in order to spare the pulmonary vein ostia. Before the main cardiac procedure, at least three periods of energy are applied until the buzzer of the occurrence of transmural lesion at the same point.

2) Left atrial connection lines - The connection lines between the pairs of the right and left pulmonary veins were made after opening the left atrium by placing one of the electrodes outside the LA posterior wall (epicardium) and another through inside (endocardium) such that the ablation lines, performed prior to the isolation of the pulmonary veins, were connected above and/or under. This procedure was performed during the primary cardiac procedure.

3) Connection line to the mitral annulus - The line connecting the mitral annulus was not performed with bipolar radiofrequency forceps due to anatomical impossibility. It was performed by employing the cutting and suturing technique, connecting the mitral valve annulus to the isolation line of the right inferior pulmonary vein.

4) Cavotricuspid line - The cavo-tricuspid line was made with the RFB forceps involving free wall of right atrium, after it was opened, in order to connect the atriotomy line to the tricuspid annulus posterior to the coronary sinus ostium venosum.

The choice of the number of lesions for the ablation as well as the handling of the left atrial appendage was at the discretion of each surgeon.

Statistical analysis

The comparison of continuous variables was performed with Student's t test and categorical variables were compared with Fisher's exact test. The results were

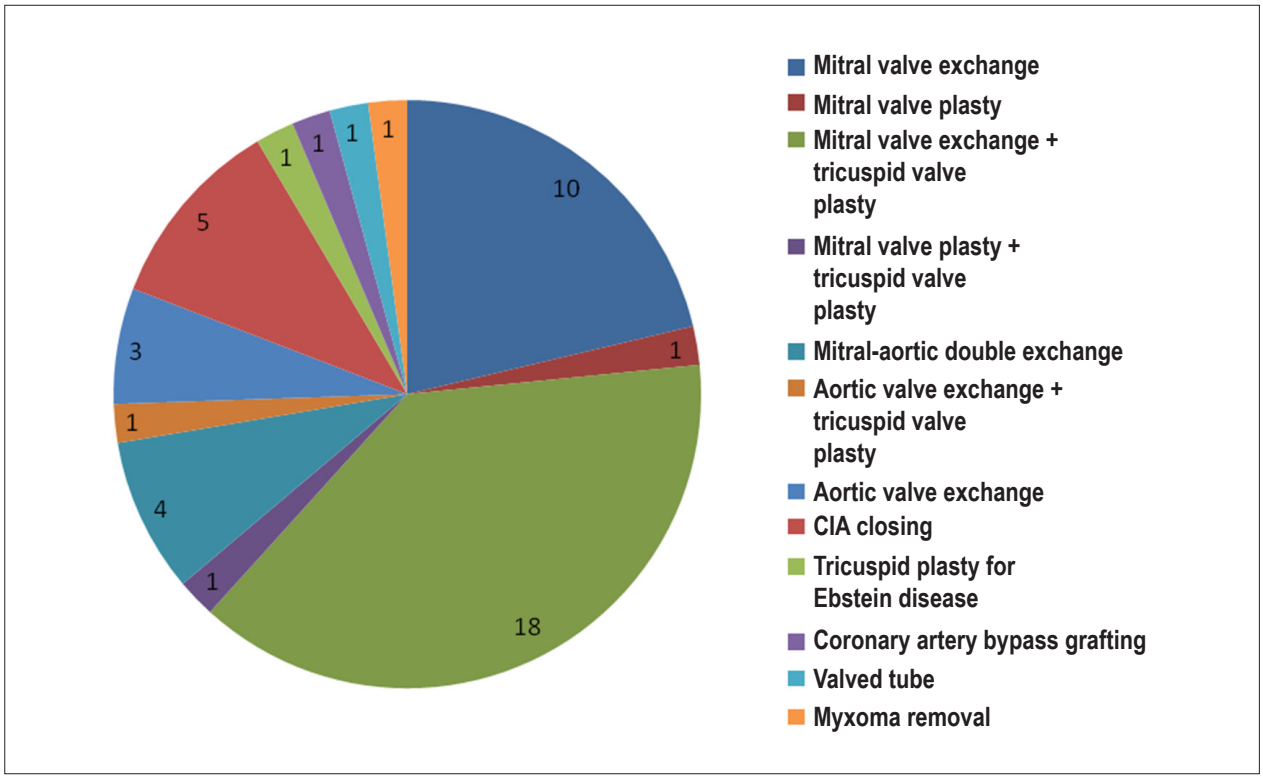

Figure 2 - Surgeries performed.

expressed as means with their standard deviation or, where appropriate, in percentage. We considered p values ≤ 0.05 statistically significant.

Results

There were 04 perioperative deaths and three during one-year follow-up. The causes of perioperative deaths were: two deaths from cardiogenic shock after atrioventricular disjunction, two deaths from septic shock. The two cases of atrioventricular disjunction were diagnosed in the operating room and in both, bovine pericardium was used for the suture of the junction, without success, though.

This surgical accident was not associated with surgical ablation since the lesion lines, in both cases, were performed away from the mitral annulus. The causes of late deaths were: one patient died at home (without a clear definition, PO: three months), a coumarin accident (PO: 04 months), one reoperation for mitral valve endocarditis (PO: 08 months). The coumarin accident was diagnosed in patients undergoing implantation of a mechanical valved tube and using anticoagulation with coumarin. The patient came to the hospital with an INR of 10, cardiogenic shock and images of bleeding around the aortic tube in chest computed tomography (CT). There was a history of chest trauma from falling to the ground a few days before. Despite an attempt to correct coagulopathy before emergency surgery with blood transfusion, the patient died of refractory cardiogenic shock.

Out of the 40 patients who survived the first year, 07 did not undergo 24-h Holter. The reason for that was: one moved to another state, one could not be contacted through telephone and 05 gave up performing the test. The 33 24 h Holter tests were performed averaging 401 ± 117 days post-surgery (ranging from 136 to 751 days).

Conventional ECGs of 07 patients who did not undergo 24-h Holter are available. The last ECG of each patient was performed in 278 days postoperatively in average. Six patients are in sinus rhythm and one patient with AF.

The characteristics of the 33 patients who underwent 24 h Holter do not differ significantly from the total group of 47 patients (p = NS). The mean age was 50.1 ± 9.4 years, mean SE was 52.6 ± 9.9 mm, EF, 56.6 ± 12.5% and the reported time of AF was 37.3 (three to 192 months). Twenty-four patients (73%) are in sinus rhythm, 5 patients in AF rhythm (15%), three in right atrial flutter rhythm (9%) and one patient in junctional rhythm (3%). See Table 2.

Considering the 40 patients surviving one year and all Holter and ECG tests together, 30 patients are in sinus rhythm

Table 2 - Results of mortality and heart rate after one year

Variable	Number (%)
Surgical mortality	4/47 (8,5%)
Mortality in one year	7/47 (15,0%)
Sinus rhythm	30/40 (75%)
AF/Flutter rhythm	9/40 (22,5%)
Junctional rhythm	1/40 (2,5%)

(75%), 06 patients in AF rhythm (15%), three patients in atrial flutter rhythm (7.5%), and one in junctional rhythm (2.5%) (Table 2).

Cardiac rhythm on the day of discharge was available only for 18 out of 43 patients who were discharged. Nine (50%) were in sinus rhythm and 09 with AF rhythm.

The set of ablation lines performed can be evaluated in Figure 3. The need to implant a permanent pacemaker postoperatively was zero.

Regarding the use of antiarrhythmic drugs, among 33 patients who underwent 24 h Holter, 05 were not using any drugs, 09 were using amiodarone, 09 were using only atenolol, 05 were using amiodarone and atenolol, and 05, no information (Figure 4). Regarding the use of anticoagulants and/or antiplatelet agent, 08 were not using any of these, 19 were taking warfarin, one was using ASA and for 04 there is no information (Figure 5). Out of the 24 patients in sinus rhythm by 24 h Holter monitoring, three (12.5%) were not using any anti-arrhythmic drug and 09 (37.5%) were not taking any anticoagulant drugs.

Two patients had neurological events in the postoperative period. One of them had complete resolution of neurological deficits after 7 days from the event and another remained with a slight left paresis, which did not compromise walking.

Percutaneous ablation of residual or recurrent arrhythmias was performed in only one patient for treatment of right atrial flutter.

Discussion

The development of the Cox-Maze III[10] surgery is a true example of a scientific method applied to experimental surgery in animals and, later, in humans, resulting in a highly effective option for treating atrial fibrillation. It is effective in maintaining sinus rhythm (90% after 10 years)[11-14], maintaining atrial contraction and preventing thromboembolism in the long term (annual incidence of events similar to patients who have never developed AF regardless of the level of anticoagulation used)[3,15]. On the other hand, the surgical procedure is complex, time-consuming, performed through cutting and suturing, it increases the risk of reoperation due to postoperative bleeding[10]. This is why few surgeons have developed a specific ability to perform it safely and effectively.

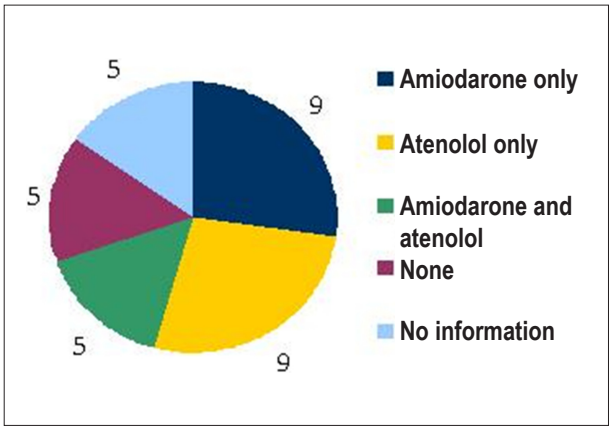

Figure 4 - Use of antiarrhythmics.

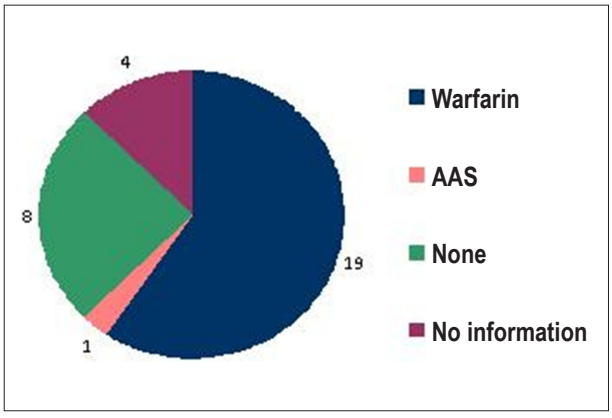

Figure 5 - Use of anticoagulants and antiplatelet agents. AAS - acetylsalicylic acid.

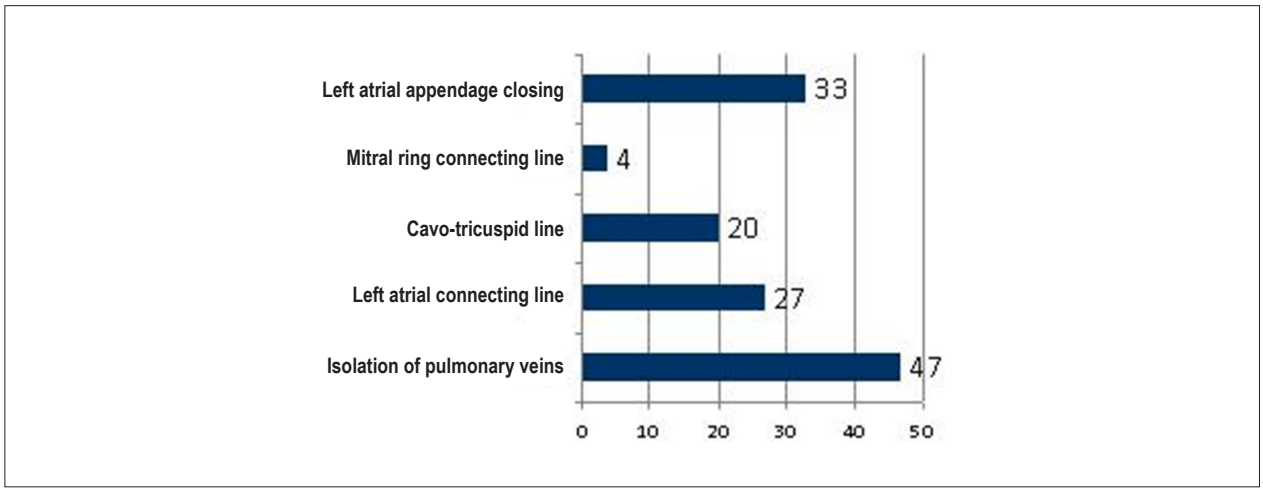

Figure 3 - Type of lesions performed done.

Based on that, with the development of technology, alternative forms of energy have emerged in order to simplify and shorten the time spent in the procedure, trying to keep the good success rates previously achieved. Moreover, the recent demonstration that, in most patients, the foci of atrial fibrillation come from pulmonary veins[16] and from the posterior wall of the left atrium[17,18] allowed the surgeon to reduce the number of ablation lines performed.

This paper presents the initial experience of the Instituto Nacional de Cardiologia in the surgical treatment of atrial fibrillation in cardiac surgery combined with the use of bipolar radiofrequency forceps performed by a mixed group of 10 surgeons, all of whom in phase of getting acquainted with the method and the technology.

Out of the 40 patients who survived the first year after the surgery, 24 h Holter monitoring was obtained from 33 patients (82.5%). Out of the 6 patients with paroxysmal AF, all of them underwent 24 h Holter and presented sinus rhythm.

Out of the 34 patients with continuous AF (persistent + permanent), we obtained 24 h Holter monitoring from 27 patients (79%). Ouf of these 27 patients, 18 (67%) were in sinus rhythm, one (4%) in junctional rhythm (which is not considered a treatment failure), 05 (19%) in AF and three (11%) in flutter. Therefore, 71% of the patients with persistent persistent/permanent AF are free of AF/flutter after the first year of the surgery, according to 24 h Holter.

The factors for persistence of AF after the ablation surgery are both related to the patient operated[19-22] and to the set of lesions performed[19]. Risk factors for treatment failure are: age, AF duration, type of AF and LA size. In our series, only the AF duration reported preoperatively proved to be a factor for treatment failure (Table 3).

We believe that the small number of patients in our experience explains the lack of correlation of the other classical factors. In patients with permanent AF, it has been reported[19] that the left atrial connecting lesions influence the long term outcome in the maintenance of sinus rhythm. The results of ablation with bipolar radiofrequency vary in literature as well as the research method of heart rate in each study. Gillinov et al[19], in reviewing 513 patients who underwent bipolar radiofrequency ablation and cryothermia through serial electrocardiograms, found a prevalence of sinus rhythm in 06 months of 87% and a total success in therapy in one year of 72%.

Table 3 - Analysis of risk factors for treatment failure

Variable	Sinus rhythm	AF/Flutter	p
AF duration (mean ± SD in months)	24 ± 30	105 ± 76	0.0011[1]
Age (mean ± SD in years)	50.6 ± 9.8	50.9 ± 9.9	0.95[1]
Left atrial size (mean ± SD in mm)	52 ± 10.7	55 ± 7.2	0.39[1]
Intermittent AF	100%	0%	0.29[2]
Continuous AF	70.3%	29.7%	0.29[2]

1 - Unpaired t test; 2 - Fisher's exact test. AF - atrial fibrillation; SD - standard deviation.

In this large series, 27% of patients had intermittent atrial fibrillation, 14% persistent and 56% permanent. The average duration of AF was 24 months and the average size of LA 51 ± 0.9 mm. The main indication for surgery was valve disease. Both the type of patient operated with the results of rhythm in one year are similar to our sample. In 2004, Gaynor et al[8] reported an initial experience with 40 patients whose AF was treated with bipolar RF forceps. Nineteen patients underwent isolated ablation of the arrhythmia and in 21, ablation was concomitant with another procedure which led to the surgery.

In this study, the average age was 62 years and median duration of AF of 3.8 years. Twenty-five patients (62%) had paroxysmal AF. The sinus rhythm index after 06 months was 91%. This group resembles our series, since half of the patients underwent isolated ablation of the arrhythmia and more than half had paroxysmal AF, admittedly a better prognosis than the continuous form.

More recently, Melby et al[20] reported results of 85% of sinus rhythm (via serial ECGs) after one year of follow-up in a series of 130 patients undergoing AF ablation in isolation (30 patients) or concomitant with the main surgery (100 patients). In 2008, Beukema et al[21] reported the follow-up of 285 older patients (mean age 68 years), with longer AF duration (60.9 months in average) and only with permanent AF. They have found 59% of patients with sinus rhythm on ECG in one year and 53.4% in 05 years.

Our results are consistent with the literature that reports success rates in one year ranging from 59% to 85%. In our country, this is the only series of patients undergoing intervention with the use of bipolar radiofrequency. Kalil et al[4] have published their experience with the classical Cox Maze III technique in our country. In a group of 61 patients, with mean age of 49 years, mostly undergoing valve surgery after an average of one year with conventional ECG follow-up in all survivors (51 patients) and 24 h Holter monitoring in 17 patients, sinus rhythm was found in 70.5%, atrial rhythm in 4%, atrial tachycardia in 2% and DDD pacemaker rhythm in 4% The need for permanent pacemaker was 11.4%. More recently, Canale et al[5] prospectively evaluated 07 patients who underwent conventional Cox-Maze, with a mean age of 61 years, 43% with permanent AF and valvular surgery indication in all of them. After 08 months of monitoring with serial ECGs and Holter monitoring in all of them, 100% were free of AF. One patient (14%) required a permanent pacemaker. Therefore, the results of this series are consistent with previous reports of Cox-Maze III in our field.

The surgical approach in our series, with respect to the sets of lesions performed, could be more complete. Figure 3 shows the lesions performed, in which the number of lesions in the posterior wall of LA (27 patients) is smaller than the number of patients with persistent/permanent AF (39 patients). We attribute this to the initial process of learning. Figure 3 also shows the number of closures of the left atrial appendage: there is a discrepancy between the observed (34 patients) and the ideal[23] (47 patients). In some surgeries, there was no need for opening the left atrium (coronary artery bypass grafting, implantation of a valved tube, Ebstein surgery etc.) and the surgeon chose not to add this procedure. The alternative for closing the left atrial appendage without opening the

left atrium was the approach with epicardial suturing of the appendage. However, this procedure, as shown by a recent study[24], has a disputable effectiveness, with high incidence of left atrial appendage remaining open and flowing.

Diagnoses of cerebrovascular accident (CVA) were delivered postoperatively in two patients. One of them had focal neurological signs on day 17 after surgery, back home. It is a 49-year old male patient with an EF of 30%, mitral and tricuspid regurgitation and continuous AF preoperatively. The patient underwent mechanical mitral valve replacement, tricuspid valve surgery, ablation of pulmonary veins and cavo-tricuspid line and closing of left atrial appendage. The discharge rhythm had been sinus rhythm, but the rhythm on the day of the event was AF. The patient had been taking Warfarin and amiodarone. There were no neurological sequelae and today the patient is in sinus rhythm on 24 h Holter monitoring. The second case was probably not associated with arrhythmia. The patient had a cardiorespiratory arrest (CRA) (duration 10 min) due to hypoxia in the first month after surgery in the ICU and diagnosis of cerebrovascular accident confirmed by CT scan showing scattered hypodense areas, consistent with cerebrovascular accident after cardiorespiratory arrest. Upon discharge, this patient had a mild left-side paresis, which did not interfere with walking. She was referred to physical therapy and motor rehabilitation.

The investigation of the benefits of ablative AF therapies in the prevention of systemic thromboembolism is difficult due to the low annual incidence of the event studied and the need for long-term monitoring. Although the studies by Cox et al[15] and Kalil et al[3] with the Maze III surgery showed an index of cerebrovascular accident in patients treated similar to the general population, regardless of whether or not using anticoagulants and antiarrhythmics, there are no similar investigations with ablations performed with alternative energy forms.

Only one of three patients with right atrial flutter detected by 24 h Holter postoperatively underwent percutaneous ablation (in month 9 postoperatively). The procedure was successful and the patient remained in sinus rhythm confirmed by serial ECGs. Out of these three patients, two received ablation of cavo-tricuspid line (including the patient who subsequently underwent percutaneous ablation of right atrial flutter). McCarthy et al[25], in applying electrophysiological study in patients with failure of ablative therapy (in a series where various forms of energy were used) showed that, when only the pulmonary veins were isolated, with or without left atrial connecting lines, 75% (6 out of 8) of the failures arise from foci in the right atrium. In the same study, 67% of patients undergoing percutaneous ablation of persistent/residual arrhythmia, after any ablative surgery, returned to sinus rhythm.

In our series, there was no need to implant a pacemaker in any patient. A review by Khargi al[1] points to the average incidence of a new PM implant in 5% when any alternative form of energy is used, without a significant difference between them. The main reason for pacemaker implantation is not the atrioventricular block, but the appearance of sinus node disease, previously existing, but hidden by the AF.

The treatment of atrial fibrillation concomitant with cardiac surgery using tissue ablation device with bipolar radiofrequency results in the absence of supraventricular arrhythmia in 76% of patients after one year.

References

1. Khargi K, Hutten BA, Lemke B, Deneke T. Surgical treatment of atrial fibrillation; a systematic review. Eur J Cardiothorac Surg. 2005;27(2):258-65.
2. Prasad SM, Maniar HS, Camillo CJ, Schuessler RB, Boineau JP, Sundt TM 3rd, et al. The Cox maze III procedure for atrial fibrillation: long-term efficacy in patients undergoing lone versus concomitant procedures. J Thorac Cardiovasc Surg. 2003;126(6):1822-8.
3. Kalil RA, Nesralla PLM, Lima GG, Leiria TL, Abrahão R, Moreno P, et al. Assessment of thromboembolism after the Cox-Maze procedure for chronic atrial fibrillation secondary to mitral valve lesion. Arq Bras Cardiol. 2002;78(4):378-81.
4. Kalil RA, Albrecht A, Lima GG, Vasconcellos D, Cunha B, Hatem D, et al. Results of the surgical treatment of chronic atrial fibrillation. Arq Bras Cardiol. 1999;73(2):139-48.
5. Canale LS, Monteiro AJO, Barbosa RM, Cortês DC, Fernandes MR, Colafranceschi AS, et al. Análise prospectiva do tratamento cirúrgico da fibrilação atrial em pacientes submetidos à cirurgia valvar. Rev SOCERJ. 2006;19(5):391-5.
6. Gillinov AM, McCarthy PM. Atricure bipolar radiofrequency clamp for intraoperative ablation of atrial fibrillation . Ann Thorac Surg. 2002;74(6):2165-8.
7. Gillinov AM. Bipolar radiofrequency ablation of atrial fibrilation. In: Sie HT, D'Ancona G, Bartolozzi F, Beukema W, Doty DB (eds). Manual of surgical treatment of atrial fibrillation. Massachusetts: Blackwell Futura; 2008. p. 155.
8. Gaynor SL, Diodata MD, Prasad SM, Ishii Y, Schuessler RB, Bailey MS, et al. A prospective, single-center clinical trial of a modified Cox maze procedure with bipolar radiofrequency ablation. J Thorac Cardiovasc Surg. 2004;128(4):535-42.
9. Shemin RJ, Cox JL, Gillinov AM, Blackstone EH, Bridges CR. Guidelines for reporting data and outcomes for the surgical treatment of atrial fibrillation. Workforce on Evidence-Based Surgery of the Society of Thoracic Surgeons. Ann Thorac Surg. 2007;83(3):1225-30.
10. Cox JL, Boineau JP, Schuessler RB, Jaquiss RD, Lappas DG. Modification of the Maze procedure for atrial flutter and atrial fibrillation. I: Rationale and surgical results. J Thorac Cardiovasc Surg. 1995;110(2):473-84.
11. McCarthy PM, Gillinov AM, Castle L, Chung M, Cosgrove D 3rd. The Cox-Maze procedure: the Cleveland Clinic experience. Semin Thorac Cardiovasc Surg. 2000;12(1):25-9.
12. Schaff HV, Dearani JA, Daly RC, Orszulak TA, Danielson GK. Cox-Maze procedure for atrial fibrillation: Mayo clinic experience. Semin Thorac Cardiovasc Surg. 2000;12(1):30-7.
13. Arcidi JM Jr, Doty DB, Millar RC. The Maze procedure: the LDS Hospital experience. Semin Thorac Cardiovasc Surg. 2000;12(1):38-43.
14. Kosakai Y. Treatment of atrial fibrillation using the maze procedure: the Japanese experience. Semin Thorac Cardiovasc Surg. 2000;12(1):44-52.
15. Cox JL, Schuessler RB, Lappas DG, Boineau JP. An 8 1/2-year clinical experience with surgery for atrial fibrillation. Ann Surg. 1996;224(3):267-73.

16. Haissaguere M, Jais P, Shah DC, Takahashi A, Hocini M, Quiniou G, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Eng J Med. 1998;339(10):659-66.

17. Harada A, Sasaki K, Fukushima T, Ikeshita M, Asano T, Yamauchi S, et al. Atrial activation during chronic atrial fibrillation in patients with isolated mitral valve disease. Ann Thorac Surg. 1996;61(1):104-12.

18. Sueda T, Nagata H, Orihashi K, Morita S, Okada K, Sueshiro M, et al. Efficacy of a simple left atrial procedure for chronic atrial fibrillation in mitral valve operations. Ann Thorac Surg. 1997;63(4):1070-5.

19. Gillinov AM, McCarthy PM, Blackstone EH, Rajeswaran J, Pettersson G, Sabik JF, et al. Surgical ablation of atrial fibrillation with bipolar radiofrequency as the primary modality. J Thorac Cardiovasc Surg. 2005;129(6):1322-9.

20. Melby SJ, Zierer A, Bailey MS, Cox JL, Lawton JS, Munfakh N, et al. A new era in the surgical treatment of atrial fibrillation: the impact of ablation technology and lesion set on procedural efficacy. Ann Surg. 2006;244(4):583-92.

21. Beukema WP, Sie HT, Misier ARR, Delnoy PP, Wellens HJJ, Elvan A. Predictive factors of sustained sinus rhythm and recurrent atrial fibrillation after a radiofrequency modified Maze procedure. Eur J Cardiothorac Surg. 2008;34(4):771-5.

22. Gaynor SL, Schuessler RB, Bailey MS, Ishii Y, Boineau JP, Gleva MJ, et al. Surgical treatment of atrial fibrillation: predictors of late recurrence. J Thorac Cardiovasc Surg. 2005;129(1):104-11.

23. Calkins H, Brugada J, Packer DL, Cappato R, Chen SA, Crijns HJG, et al. HRS/EHRA/ECAS Expert Consensus Statement on catheter and surgical ablation of atrial fibrillation: recommendations for personnel, policy, procedures and follow-up. A report of the Heart Rhythm Society (HRS) Task Force on catheter and surgical ablation of atrial fibrillation. Heart Rhythm. 2007;4(6):816-61.

24. Kanderian AS, Gillinov AM, Pettersson GB, Blackstone E, Klein AL. Success of surgical left atrial appendage closure: assessment by transesophageal echocardiography. J Am Coll Cardiol. 2008;52(11):924-9.

25. McCarthy PM, Kruse J, Shalli S, Ilkhanoff L, Goldberger JJ, Kadish AH, et al. Where does atrial fibrillation surgery fail? Implications for increasing effectiveness of ablation. J Thorac Cardiovasc Surg. 2010;139(4):860-7.