Simple Surgical Isolation of Pulmonary Veins for Treating Secondary Atrial Fibrillation in Mitral Valve Disease

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Background. **hronic atrial fibrillation (AF) due to mitral valve disease has been successfully treated by surgery. We performed a study to evaluate the effectiveness of a surgical method of simple pulmonary vein isolation (PVI) without radiofrequency or cryoablation in the restoration of sinus rhythm in a group of patients.**

Methods. **Fifteen patients were operated on for mitral valve disease and chronic AF. The technique consists basically of a circumferential incision excluding the pulmonary vein ostia from the left atrium.**

Results. **Sinus rhythm was achieved in 92.3% of the patients at 6-month follow-up. Echocardiograms 2 months after surgery showed a mean decrease of 1.1 cm in left atrial size. Effective atrial ejection was reestablished in all patients in whom sinus rhythm was achieved (mean LA ejection fraction 41% ± 14%). Twenty-four hour Holter recordings did not show episodes of paroxysmal atrial fibrillation in any patients. Four patients had isolated episodes of ventricular ectopic beats. Stress electrocardiograms showed mean maximal ventricular response was 64% ± 11% and 73% ± 9% of predicted value at 2 and 6 months, respectively. All patients had improved NYHA functional class after surgery; 74% of patients were in NYHA functional class I at 6 months compared with 13.3% preoperatively.**

Conclusions. **Pulmonary vein isolation without the use of radiofrequency or cryoablation is effective in restoring sinus rhythm in patients with chronic AF secondary to mitral valve disease. Based on simple surgical incisions, this technique is more advantageous than others requiring additional instrumentation.**

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Chronic atrial fibrillatio (AF) is the most prevalent sustained arrhythmia affecting the general population and it is present in most patients in whom mitral valve surgery is required [1, 2]. Recently, AF has been successfully treated surgically by the maze procedure proposed by Cox and coworkers [3] even when primary or due to mitral valve disease [4–8]. The effectiveness of this surgical approach has led to its widespread use, as reflected by those reports. Our experience with the maze procedure without the use of cryoablation was recently published [9].

It has been demonstrated that trigger points located inside the pulmonary veins are responsible for the origin and maintenance of paroxysmal AF [10]. This has led to the development of several techniques for pulmonary vein isolation or ablation by many researchers to treat paroxysmal AF [11–13].

Variations of the maze procedure have been reported because the relative complexity of the surgical incisions has limited the popularity it might have had in clinical practice. In the presence of mitral valve disease, techniques for left atrial isolation [14] or exclusively pulmonary veins isolation with incisions and cryoablation [15] have proved effective to treat chronic AF. Many of these techniques use advanced instrumentation such as percutaneous or surgical radiofrequency ablation and surgical cryoablation. Several recent papers reported favorable results with alternative procedures [16, 17].

Based on the these considerations, we suggested that chronic AF secondary to mitral valve disease could be treated by simple surgical isolation of pulmonary veins without the use of any specialized instrumentation. Here we report our initial clinical experience.

Patients and Methods

Between July 1999 and February 2001, 15 consecutive patients with chronic AF underwent surgical repair or replacement of the mitral valve associated with simple pulmonary vein isolation (PVI) at the Instituto de Cardiologia do Rio Grande do Sul in Porto Alegre, Brazil. All patients fulfilled standard clinical and hemodynamic criteria for elective mitral valve surgery. The exclusion criteria for the AF procedure were age below 18 years, AF

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Table 1. Preoperative Patient Characteristics and Late Postoperative Rhythm

Patient Number	Sex	NYHA Class	AF Duration (Months)	Age	LA (cm)	EF (%)	Lesion	Late Postoperative Rhythm	Other Structural Lesion
1	F	III	24	60	6.8	72	MS	SIN	AS + AR
2	M	IV	84	36	5.8	47.2	MR	SIN	...
3	M	II	12	53	5.2	66.9	MR	SIN	TR
4	F	III	24	47	4.7	66	MS	SIN	...
5	F	III	24	64	4.5	78.2	MR	SIN	...
6	F	IV	8	43	5.5	69.5	MS	SIN	TR
7	F	III	132	61	5.6	81.2	MS	SIN	TR
8	M	I	15	64	6.4	72	MR	AF	ASD
9	F	III	22	57	4.5	47.9	MS+MR	SIN	...
10	F	II–III	18	56	4.9	50.8	MS	SIN[a]	...
11	F	I	336	70	6	62	MS	SIN	...
12	M	III	6	74	6	51	MS	SIN	...
13	M	IV	6	43	6	40	MR	SIN	...
14	F	IV	6	49	6.8	45.7	MS	SIN	...
15	F	IV	6	44	5.5	71.9	MS+MR	SIN[a]	AR + TR

Patients #1 through #8 1-year follow-up.

[a] = 2-month follow-up; others 6-months' follow-up.

F = female; M = male; MS = mitral stenosis; MR = mitral regurgitation; AS = aortic stenosis; AR = aortic regurgitation; TR = tricuspid regurgitation; ASD = atrial septal defect; LA = preoperative left atrial size; EF = left ventricular ejection fraction; SIN = sinus rhythm; AF = atrial fibrillation.

of less than 6 months' duration, ventricular ejection fraction lower than 20%, pregnancy, redo surgery, presence of pericardial adhesions, and nonagreement with protocol inclusion. The study was approved by the institution's ethics committee. All patients received an informed consent letter.

Preoperative Period

A clinical evaluation was performed before the operation in all cases to review the patients' clinical histories, duration of AF, previous laboratory investigations, echocardiograms, cardiac catheterization reports, and electrocardiograms. All patients underwent a baseline echocardiogram (M-mode and Doppler) before surgery to determine left atrial dimensions, presence of intracavitary thrombus, and severity of valvular disease. The same technician performed the echocardiographic studies.

Patients

Eight patients had mitral stenosis alone, 5 had mitral regurgitation, and 2 had mitral stenosis associated with mitral regurgitation; other valvular abnormalities are described in Table 1. Mean age was 54.73 ± 11 years, 66% of the patients were women. Ventricular ejection fraction was 61% ± 13%; left atrium diameter was 5.61 ± 0.7 cm. New York Heart Association (NYHA) functional class was IV in 33.3% of cases, III in 40%, and II and I in 13.3% each. Mean AF duration before surgery was 48.2 ± 86.86 months (range 6 months to 28 years).

Surgical Procedure

After anesthetic induction with thiopental, pancuronium bromide, and maintenance thereafter with an infusion of midazolam and fentanyl, occasionally supplemented by halothane, median sternotomy was performed and the pericardium opened longitudinally. Cardiopulmonary bypass was established by ascending aortic and bicaval metal-tipped right-angled cannulas. Previously, both venae cavae were dissected and mobilized as well as the roof of the left atrium in order to facilitate exploration of left atrial wall from inside and outside the heart. The aorta was clamped and St. Thomas crystalloid cardioplegic solution infused through the ascending aorta. Systemic temperature was cooled to 32°C. Immediately after aortic clamping a left atriotomy was performed parallel to the left interatrial groove, extending this incision widely around the four pulmonary veins. At this point the mitral valve was examined and treated appropriately to the lesion. After completion of mitral valve repair or replacement the circular incision was completed so that in the end all four pulmonary veins were separated from the heart. Then a perpendicular incision was made from the margin of that one to the mitral valve annulus, taking care not to injure the coronary sinus and left circumflex coronary artery. This perpendicular incision was performed from inside the left atrium just after repairing or replacing the mitral valve or even during repair or replacement. The atrial myocardium was dissected free of the fat pad, which included the coronary sinus and circumflex coronary artery, and then it was cut with scissors. The end of this cut as well as some remaining muscle fibers were electrocauterized. Then all the incisions were sutured with 3-0 monofilament polypropylene in a continuous single layer. The aortic clamp was opened. While the myocardium was reperfusing, a stump of left atrial appendage was resected externally and the base sutured with 3-0 polypropylene. Contrary to the maze procedure, no incision was placed between the left

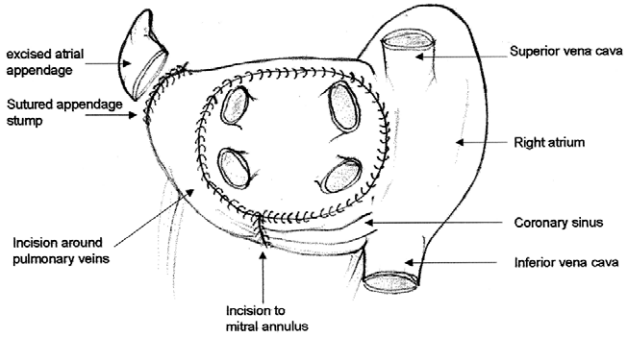

Fig 1. Three-dimensional posterior view of the heart after the procedure showing the suture line around the four pulmonary veins, exclusion of left atrial appendage, and perpendicular incision directed into the mitral annulus. (Reprinted from Kalil RAK, et al, Ann Thorac Surg; 2002;73:1022, with permission.)

atrial appendage suture line and the circular one around the pulmonary veins. No cryoablation or radiofrequency ablation other than electrocautery was used. No incisions were made in the right atrium or septum. The surgical procedure was performed by the same surgeon (also familiar with the maze III procedure) in all patients (Fig 1). Surgical data were registered in a form appropriate for future retrieval.

Postoperative Follow-up

Follow-up data were collected at a specific outpatient clinic and from referring physicians. Electrocardiograms, echocardiograms, 24-hour ECG readings (Holter), and exercise tolerance tests were obtained in the second and sixth month after the surgical procedure. Follow-up data until 6 months after the operation were available for all patients. The longest follow-up was 23 months.

Antiarrhythmic therapy was intensively instituted during the postoperative period. Bradycardia—fewer than 80 beats per minute—was treated by temporary atrial or atrioventricular pacing. Atrial tachyarrhythmias (fibrillation or flutter) were immediately treated by electrical cardioversion and sinus rhythm maintained by amiodarone administration for at least 30 days, when a withdrawal trial was performed.

Echocardiographic Examination

We used an echocardiographic system (Sonos 2500; Hewlett-Packard, Andover, MA) with the transducer operating at 2 to 2.5 MHz. The patients were examined in the left lateral decubitus position. The apical four-chamber view was chosen to estimate measures by the conventional acoustic quantitation (AQ) method of the left atrium.

Care was taken to obtain the maximal atrial dimensions and adequate margin detection. We adjusted the gain control to eliminate the cavity noise and to visualize the endocardium as clearly as possible. The echocardiographic images were considered acceptable for analysis when at least 75% of the endocardial border was clearly visualized. Then the AQ mode was activated in an area-length method to display the tissue-blood margins. A region of interest was manually drawn around the LA cavity and the endocardial border was automatically tracked. A real-time volume curve was displayed along with the electrocardiogram, and maximum volume at ventricular (systole) and minimum volume at ventricular (diastole) measurements were performed by the area-length formula built into the software and an atrial ejection fraction was estimated. The data were obtained by averaging seven consecutive cardiac cycles.

Exercise tolerance tests were performed using the modified Bruce protocol to evaluate maximal ventricular response related to a predicted value. Patients were recalled after 2 months and at 6 months for Holter recordings.

Statistical Analysis

All data obtained were stored in an EPI-INFO (version 6.06; World Health Organization, Geneva, Switzerland) database. The statistical software was SPSS (SPSS Inc, Chicago, IL). Continuous variables were expressed in mean ± one standard deviation and when necessary, categorized. Comparisons between preoperative and postoperative period data were made using the χ^2 test for categorical variables and Student-Fisher *t* test for continuous variables. In these comparisons the critical alpha value of 0.05 was considered statistically significant.

Results

There were no surgical deaths in this series. One patient had an episode of lower gastrointestinal bleeding that was controlled by endoscopy and alcoholization of the source of bleeding. During the postoperative period 1 patient needed permanent pacing for complete atrioventricular block. The pacemaker was a DDD programed in atrial trigger mode.

The mean aortic cross-clamping time was 70.7 ± 24.6 minutes and the mean extracorporeal perfusion time was 95.7 ± 36.1 minutes. For patients who underwent valve replacement, surgical time was increased on the average 24 minutes compared with valvuloplasty. Surgical data are summarized in Table 2.

Electrocardiographic analysis performed in the immediate postoperative period showed sinus rhythm in 73.3% (n = 11) of patients. In the nonsinus group (4 patients) 25% (n = 1) were in AF, 25% (n = 1) in atrial flutter, and 50% (n = 2) in junctional rhythm. At 6 months 92.3% of the patients were in sinus rhythm (Fig 2).

Antiarrhythmic therapy with amiodarone was used in

Table 2. Surgical Data From Patients Who Underwent Pulmonary Veins Isolation

Operative Data	n = 15
Mitral valve prosthesis	4
Mitral valvuloplasty	11
Associated aortic valvuloplasty	1
Associated aortic valve prosthesis	1
Tricuspid valvuloplasty	3
Associated atrial septal defect closure	1
Extracorporeal circulation time	95.7 ± 36.1 minutes
Aortic clamping time	70.7 ± 24.6 minutes

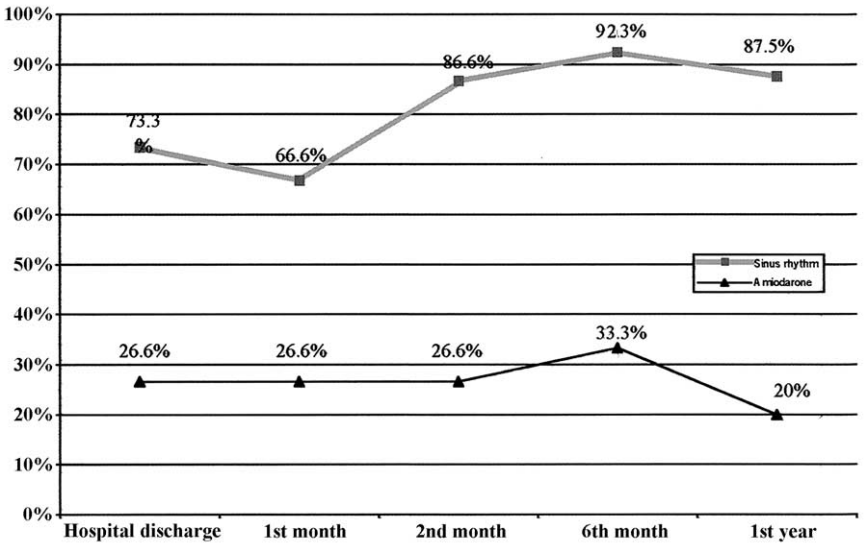

Fig 2. Follow-up of patients is shown according to the maintenance of sinus rhythm and use of amiodarone (at 6 months, n = 13; at 1 year, n = 8).

40% of patients (n = 6) between the second and sixth month. Four patients were submitted to electrical cardioversion after 4 weeks of anticoagulation (INR targeting 2 to 4); the mean energy delivered was 200 J. Electrical cardioversion was successful in 2 of those patients. At the end of 1 year of follow-up, 20% of the patients were on amiodarone therapy and 87.5% were in sinus rhythm.

Echocardiograms performed in the second month after surgery showed a mean decrease of 1.1 cm in the left atrial size ($p = 0.09$). Effective atrial ejection was reestablished in all patients in whom sinus rhythm was achieved with a mean LA ejection fraction of 41% ± 14%, using the AQ method by atrial volumes.

Twenty-four hour ECG recordings (Holter) did not show episodes of paroxysmal atrial fibrillation in any patients. Four patients had isolated episodes of ventricular ectopic beats and no other arrhythmias were documented in the recordings.

At standard stress electrocardiograms mean maximal ventricular response was 64% ± 11% and 73% ± 9% of the predicted value at 2 and 6 months, respectively. An improvement in NYHA functional class occurred in all patients after surgery. At 6 months 74% of patients were in NYHA functional class I compared with 13.3% in the preoperative period ($p = 0.0009$).

Comment

Since the development of the maze procedure by Cox and colleagues [8] several surgical centers started using this technique to manage patients with AF. The association of maze procedure and mitral valve repair has been effective for treatment of AF secondary to mitral valve disease [4–9]. The widespread use of this procedure, however, was limited by the complexity of incisions, which led researchers to the development of alternative surgical approaches to treat this arrhythmia [12–17].

In recent years the improved understanding of electrophysiologic mechanisms responsible for the initiation and perpetuation of AF led to a new hypothesis for the management of this arrhythmia. The discovery of trigger points for AF (mainly paroxysmal AF) located inside the pulmonary veins [10] has turned attention to this anatomic region inside the left atrium.

In our study, the use of a simple surgical technique, such as pulmonary veins isolation, arises as a new surgical choice for treatment of chronic AF. Ectopic trigger points inside the pulmonary veins are also responsible for the disease's pathogenesis. The results of this series compared with the previous series of the author [9] using the maze procedure show similar results in the maintenance of sinus rhythm. Permanent pacing was needed in one case in this series, as it occurred in some patients submitted to the maze procedure. Also atrial bradycardia was commonly seen in the early postoperative period. This might be explained by the lesion to the atrial or sinus node coronary artery when it rarely originates from the left coronary artery or for some other unexplained reason.

Chua and colleagues [18] studying the outcome of mitral valve repair alone in patients with preoperative atrial fibrillation reported 80% persistence of AF in those patients with preoperative AF and 0% in the subset of recent onset AF, thereby suggesting early surgery for better long-term atrial rhythm. Flugelman and associates [19] reported evidence that restoration and maintenance of the sinus rhythm after mitral valve operation for mitral stenosis was not achieved in patients with symptoms of more than 3 years' duration with a left atrial size of more than 52 mm and recommended avoidance of cardioversion postoperatively in those patients. In our series the left atrium size was larger and the mean duration of AF was longer than in those mentioned before.

In our experience [1] the patients who had spontaneous reversion to sinus rhythm were those whose left atrial dimension was smaller than 52 mm associated with mitral regurgitation.

In the pulmonary vein isolation series recovery of sinus rhythm, restoration of atrial function, and improvement of functional class were achieved in the majority of patients. Initial results with the PVI for patients suffering from chronic AF due to mitral valve disease seems to be

an effective form of treatment. A randomized trial controlled by simple valve repair is ongoing at our hospital to evaluate the effectiveness of this technique as compared with the maze procedure.

Recently Sueda and colleagues [20] reported one successful case in which a procedure very similar to ours was performed, differing in that the left atrial posterior wall in the direction of the mitral annulus was not incised nor was the left atrial appendage resected. We recognize that those are not essential for rhythm restoration, as the aim is to electrically isolate the pulmonary veins, but the former might be useful in preventing postoperative atrial flutter and the latter in preventing thromboembolism should the operation results not be successful. Thus our procedure might have an advantage over the previous Sueda technique by not requiring cryoablation and might otherwise be more effective against atrial tachyarrhythmias and thromboembolism by preventing atrial flutter and thrombus formation.

As can be seen in all the series mentioned previously in this article, restoration of sinus rhythm occurs uniformly when pulmonary veins are isolated from the rest of the heart. This is the common achievement of most techniques and might be the only really effective procedure to eliminate atrial fibrillation in most cases, leaving the others as adjunctive measures. Here we emphasize the theoretical importance of the perpendicular incision directed to the mitral annulus to prevent atrial flutter from macroreentrant circuits around the mitral annulus or the circumferential incision itself.

The simple surgical method that we propose, PVI, may be performed at any center as it does not require cryoablation or radiofrequency equipment, resources that are usually not available at most hospitals. Furthermore, it is very simple and easily performed. The only difficulty is incising posteriorly between the atrial appendage and left pulmonary veins. At this point a Semb clamp placed posteriorly by the first assistant can bring the atrial wall anteriorly, thus providing a better exposure of the area to be incised.

Preserving the atrial wall and the area of sinus node with fewer incisions might result in better atrial contraction and less arrhythmias, as we saw in this series. It must be kept in mind that atrial contraction not only depends on the atrial rhythm, however, but also on the atrial wall, which may be very thin and fibrosed in this kind of patient.

In conclusion, PVI for the surgical treatment of chronic atrial fibrillation in mitral valve disease is a simple and effective procedure that might be indicated for all patients undergoing cardiac surgery in whom sinus rhythm recovery is desirable. Because of its simplicity and avoidance of specialized instrumentation, it can be performed at any cardiac center.

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