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Left atrial wall tension directly affects the restoration of sinus rhythm after Maze procedure☆

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Abstract

Objective: The surgical treatment of permanent atrial fibrillation (AF) continues to be a clinical challenge. Increased left atrial (LA) wall tension affected by LA wall thickness and volume has been associated with poor restoration of sinus rhythm after the Maze procedure. This study was designed to investigate the impact of conversion rates to sinus rhythm using LA wall tension reduction techniques in conjunction with aggressive postoperative pharmacological therapy in comparison to a modified Maze procedure alone. **Methods:** From 1999 to 2008, 322 patients with permanent AF and biatrial enlargement, who required mitral valve ± tricuspid valve surgery were exactly randomized into two groups: The study group used biatrial reduction with reef-imbricate suture technique concomitant with the Maze procedure and aggressive postoperative pharmacological therapy; the control group was treated with the Maze procedure alone. LA dimension was measured by transesophageal echocardiogram (TEE) or transthoracic echocardiography (TTE); LA wall thickness was measured by TEE and manually during surgery. Pulmonary artery (PA) pressures were measured by PA catheter or TTE, BNP test and clinical follow-up at discharge, 3 months, 6 months and 1 year. There were 187 woman (58%) and 135 men (42%). Their mean age was 45 ± 9.5 years. **Results:** Overall restoration of sinus rhythm was significantly improved in the group with aggressive reduction of LA wall tension during 1-year clinical follow-up (89.3% vs 67.2%, $p < 0.001$). Calculated LA wall tension was significantly reduced at discharge in the study group versus control group (4.012 ± 1.650 dyn cm^{-1} vs $20\,384 \pm 3313$ dyn cm^{-1} ($p < 0.001$)) and at 1-year follow-up (1059 ± 1161 dyn cm^{-1} vs $17\,139 \pm 3170$ dyn cm^{-1} ($p < 0.001$)), respectively. Significant differences in changes in LA dimension were detected at discharge and 1-year follow-up in the study group versus control group (43 ± 7 vs 61 ± 11, $p < 0.001$). LA wall (3.9 ± 1.3 vs 2.3 ± 0.9) thickness also significantly differed at the 1-year follow-up. **Conclusion:** An aggressive approach to reduce LA wall tension significantly improves restoration of sinus rhythm after the Maze procedure. LA wall tension directly affects sinus conversion. Further studies using pharmacologic intervention to reduce LA wall tension for maintenance of sinus rhythm need to be evaluated.

Keywords: Atrial fibrillation; Maze procedure; Atrial reduction; Atrial wall tension

1. Introduction

The surgical treatment of permanent atrial fibrillation (AF) in patients with concomitant mitral valve (MV) disease continues to be a clinical challenge particularly with significant left atrium (LA) enlargement. MV repair or replacement alone often does not result in restoration of sinus rhythm. Moreover, AF surgically treated with the Maze procedure may reoccur weeks or months afterward. Increased left atrial wall tension affected by left atrial wall thickness and volume has been associated with poor restoration of sinus rhythm after the Maze procedure.

The traditional cut-and-sew Cox-Maze III operation serves as the benchmark in AF surgical treatment, providing 90–97% freedom from AF [1]. However, concerns about procedural complexity have limited the acceptance of this surgical technique [2]. Recent modifications, including the use of ablative therapies and different approaches to atrial reduction, have increased the application of the Maze procedure with concomitant MV surgery. However, the rates of conversion to normal sinus rhythm following these surgical approaches are suboptimal [3], particularly in patients with long-standing AF and a giant left atrium (GLA) [4].

In general, it is easy to convert AF to sinus rhythm, but very difficult to maintain it. The long-term recurrence rates of AF as high as 59% are observed [5]. It is found that left atrial

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wall tension directly affects restoration of sinus rhythm and is proportionate to left atrial volume multiplied by the left atrial radius and divided by the left atrial wall thickness (law of Laplace).

Recently, many have argued whether the Maze procedure should be performed on all patients with GLA [6]. Marui and Nishina have reported LA reduction with continuous horizontal mattress sutures along with pulmonary vein isolation to reduce left wall tension during MV surgery, and have proved its safety and efficacy [7]. There are several other reports regarding the efficacy of the Maze procedure with cut-and-sew left atrial reduction during concomitant mitral surgery. However, to date, no reports have focused on reducing left atrial wall tension using biatrial reduction with reef-imbricate suture technique in conjunction with aggressive postoperative pharmacological therapy and its advantage in increasing conversion rates to sinus rhythm compared with a modified full Maze procedure.

In this study, we describe an aggressive approach to decrease left atrial wall tension by reducing LA volume, shortening LA radius, and increasing LA wall thickness. We propose that significant reduction of LA wall tension has successful outcomes by restoring a regular rhythm and thereby reducing long-term morbidity.

2. Patients and methods

2.1. Patient group

Between January 1999 and December 2008, 322 consecutive patients with permanent AF and biatrial enlargement, who required MV $\pm$ tricuspid valve surgery, were exactly randomized into two groups: The study group used biatrial reduction with reef-imbricate suture technique concomitant with the Maze procedure and aggressive postoperative pharmacological therapy; the control group was treated with the Maze procedure alone. All patients had the primary diagnosis of rheumatic heart disease. The patients were operated upon in four geographic locations including three hospitals in China and one hospital in the United States. Enlarged LA (ELA) in this report was defined as a left atrial diameter $\geq$ 55 mm on m-mode echocardiogram and GLA as a left atrial diameter $\geq$ 75 mm (Fig. 1). Permanent AF was defined as AF that was present continuously $\geq$1—2 months and was resistant to electrical or pharmacologic cardioversions.

The study comprised of 135 men (42%) and 187 women (58%) with mean age of 45 $\pm$ 9.5 years (range 34—61 years). Mean duration of AF in the series was 48.4 $\pm$ 21.4 months (range 13 $\pm$ 40 months). The preoperative mean atrial size was 64 $\pm$ 12 mm in the study group and 56 $\pm$ 17 mm in control group. All patients underwent a modified full Cox-Maze III procedure using supplemental radio frequency (RF) ablation and bilateral atrial appendage resection. The following methods of assessment were used: left atrial dimension measured by transesophageal echocardiogram (TEE) or transthoracic echocardiography (TTE); and left atrial wall thickness measured by TEE and manually during surgery. Pulmonary artery (PA) pressures measured by PA catheter or TTE, blood BNP test and LA wall tension were calculated by Law of Laplace $\sigma = (Pr)/h$ (P, atrial pressure; r, atrial radius; and h, atrial wall thickness). Severity of tricuspid regurgitation was classified as 0 (none), 1 (trivial), 2 (mild), 3 (moderate), 3.5 (moderate—severe), and 4 (severe) by two-dimensional and Doppler echocardiographic evaluation before surgery and at postoperative follow-up at discharge, 6 months and 1 year (Table 1).

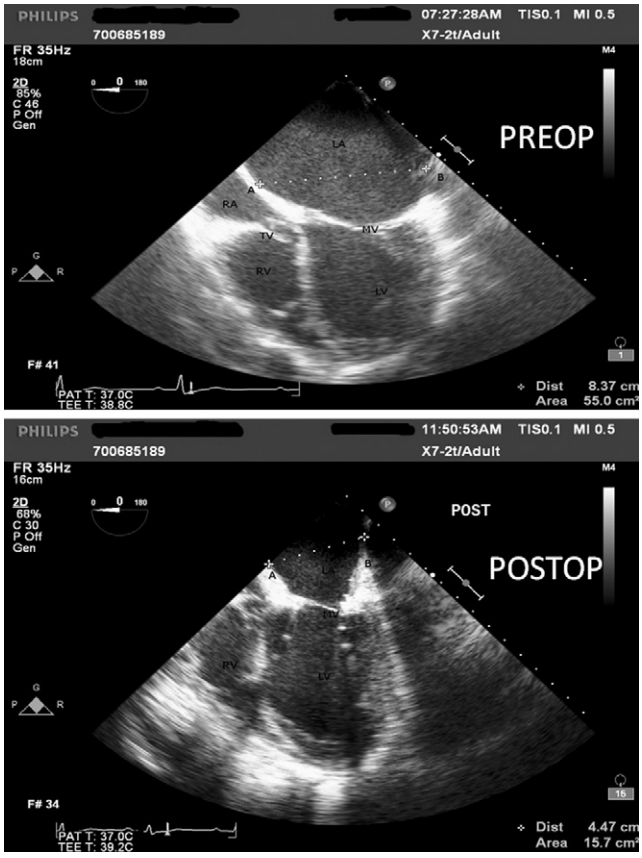

Fig. 1. Representative preoperative and postoperative echocardiography findings. The diameter of giant left atrium was 83.7 mm preoperatively and it was considerably reduced to 44.7 mm by using the reef-imbricate suture technique. LA: left atrium; LV: left ventricle; AB: left atrium diameter; and MV: mitral valve.

2.2. Operative procedure

A TEE or TTE echocardiogram was performed on all patients. Operations were performed via a median sternot-

Table 1. Patient demographics.

Characteristic	Study	Control	Total value
Patient (N)	161	161	322
M/F	71/90	64/97	—
Age	38 $\pm$ 10.4	42 $\pm$ 7.3	—
NYHA class	2.1 $\pm$ 0.7	2.3 $\pm$ 0.9	—
Hx of stroke n%	6 (3%)	4 (2%)	—
Atrial appendage clot	49	42	91
Mitral stenosis and insufficiency	141	139	280
Mitral insufficiency	11	14	25
Aortic stenosis and insufficiency	97	81	178
Tricuspid insufficiency	135	134	269
Ejection fraction	48 $\pm$ 8	46 $\pm$ 11	—
Duration of AF (month)	45 $\pm$ 87	47 $\pm$ 67	—
Left atrial diameter (mm)	64 $\pm$ 12	56 $\pm$ 17	—

omy and standard cardiopulmonary bypass with bicaval cannulation and mild hypothermia (32 °C). A combined antegrade and retrograde blood cardioplegic technique was used to induce cardiac arrest and deliver myocardial protection. A left atriotomy incision was made through the Waterson's grove and the LA appendage thrombus was first evacuated, if present. The left pulmonary veins were carefully dissected and isolated using the blunt technique. The bipolar RF Atricure clamp (Atricure, Inc., Cincinnati, OH, USA) was then placed on the left pulmonary vein with which the rim of the atrial tissue surrounding the pulmonary veins was ablated. The left atrial appendage was amputated and bipolar RF ablation was performed between the LA appendage and the left superior pulmonary vein by placing one jaw on the endocardium and one jaw on the epicardium. Then the dome of the LA was ablated with the RF clamp through the amputated left atrial appendage and transverse sinus. The LA appendage was then oversewn. The standard left atriotomy was then extended into the dome of the LA and inferiorly around the orifice of the right inferior pulmonary vein. The bipolar RF Atricure clamp was placed on the rim of the right pulmonary vein for ablation. A connecting ablation lesion was performed from the inferior aspect of the LA into the left inferior pulmonary vein. In the GLA, a second connecting ablation was placed from the mid-inferior wall of the LA into the left superior pulmonary vein. Finally, a bipolar RF ablation line was performed by placing one jaw of the clamp from the inferior end of incision down to the mitral annulus at a point on theP3 area and another jaw at a point marked as the left isthmus ablation in between the circumflex artery and right coronary sinus. In the study group, the LA was plicated mainly between the left and right pulmonary vein down to the inferior end of left atrial incision on the half-moon shape (Fig. 2). The reef-imbricated suture

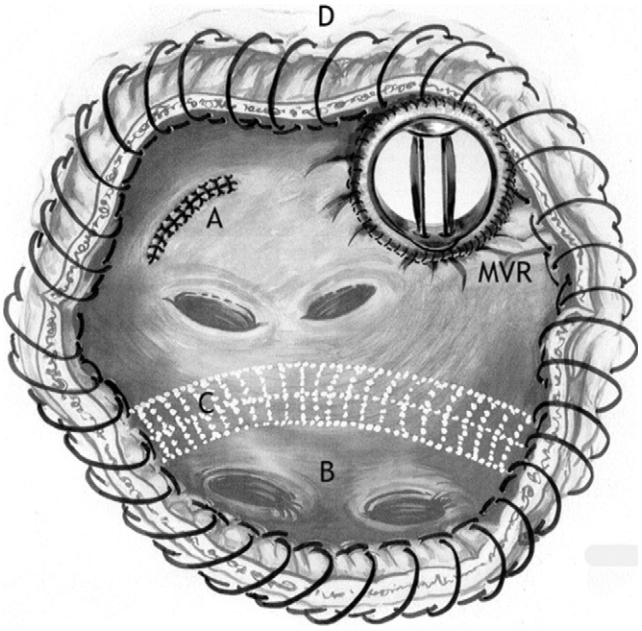

Fig. 2. Left atrial reduction plasty with reef-imbricate technique adjuncted to Maze procedure. A. Amputated left atrial appendage. B. Right pulmonary veins. C. Half-moon shape reef imbricated around 2 cm with a continuous running suture line. D. Aggressive closure suture line of the redundant LA free wall.

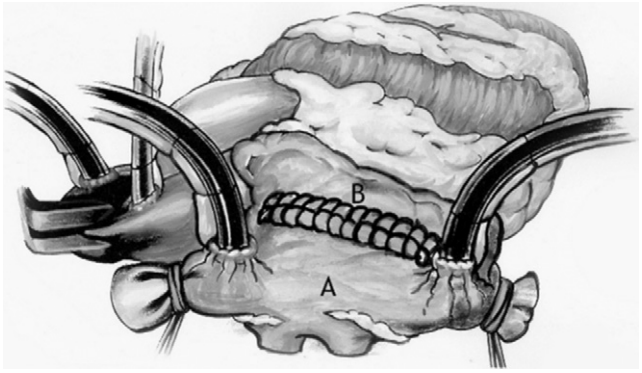

Fig. 3. A. Right atrium and B. right atrial reduction plasty with aggressive reef-imbricated closure suture line. AF: atrial fibrillation; ELA: enlarged left atrium; MVR: mitral valve replacement; LA: left atrium; MV: mitral valve; PFOC: patent foramen ovale closure; RA: right atrium; LAD: left atrial diameter; LATE: left atrial thrombus evacuation; GLA: giant left atrium; RF: radio frequency; and TV: tricuspid valve.

was placed at least 2 cm away from the mitral annulus and the circumflex artery to maintain LA function. The posterior wall of the redundant LA was reef-imbricated around 2 cm with a continuous running suture to exclude toward the outside of the LA cavity. After aggressive closure of the redundant free wall of the LA, the right atrial appendage was excised and an incision was carried from the right atrial stump parallel to right atrioventricular groove extending toward the inferior vena cava. Standard RF ablation lesions were then placed to isolate the tricuspid annulus and continue across the atrial septum. The redundant right atrial wall and incision were reef-imbricated closure with 4/0 running prolene sutures (Fig. 3). Additional procedures performed in this study include MV replacement, MV repair, tricuspid valve repair, aortic valve replacement and patent foramen ovale closure (Table 2).

2.3. Postoperative care and patient follow-up

After the operation, all patients were monitored continuously for arrhythmias. All patients in the study group received an intra-operative intravenous loading dose of amiodarone (150 mg) followed by a 12-h postoperative infusion, aggressive postoperative diuresis and intravenous administration of Nesiritide. Upon endotracheal tube removal, oral amiodarone of 400 mg twice daily and Viagra 50 mg daily was administered as tolerated and continued

Table 2. Distribution of operative procedures.

Procedure	*N* (%)
MV repair only	23 (7.1)
MVR only	19 (5.9)
MVR + TV repair	269 (83)
MVR + AVR + TV repair	178 (55.2)
MVR + TV repair + LATE	91 (28)
MVR + CABG	16 (4.9)
MVR + TV repair + PFOC	19 (5.9)

MV: mitral valve; MVR: mitral valve replacement; AVR: aortic valve replacement; LATE: left atrial thrombus evacuation; PFOC: patent foramen ovale closure; TV: tricuspid valve; and CABG: coronary artery bypass graft.

until hospital discharge. Electrical cardioversion was performed prior to hospital discharge in any patient not in normal sinus rhythm. Oral amiodarone, 200 mg twice daily and Viagra 25 mg daily were continued for 3–6 months after hospital discharge. If a patient was not able to tolerate amiodarone postoperatively, then sotalol was used for the same duration.

Anticoagulation therapy was determined by the valve surgery performed and the postoperative diameter of LA. If a mechanical prosthesis was implanted, warfarin therapy was initiated on the third postoperative day and continued permanently. For patients with a postoperative LA diameter >7 cm, anticoagulation with Coumadin was used for the first 3 postoperative months.

Follow-up was done through a combination of outpatient clinic visits and phone interviews with local doctors. Postoperative follow-ups were scheduled at 3, 6, and 12 months and then annually thereafter. At all visits, a history, physical examination and electrocardiogram were obtained, and all patients underwent TTE twice to confirm atrial contraction at 6 and 12 months. In patients with symptoms such as palpitations and other evidence of atrial arrhythmias, a 48-h Holter monitor recording was obtained.

2.4. Data analysis

All values are expressed as the mean ± standard deviation. Statistical analysis comparing the data between two groups was performed with the Fisher's exact test for categorical variables. Continuous variables were compared using a two-sample *t*-test and the Wilcoxon rank-sum test where appropriate. Data collected were analyzed using the number cruncher statistical systems software (NCSS, Kaysville, UT, USA). A significant difference between measurements was defined as $p \leq 0.001$.

3. Results

All 322 patients underwent MV replacements with mechanical prostheses or MV repairs and concomitant modified Cox-Maze III RF ablations. In the study group, 166 patients underwent an aggressive reduction of the left atrial wall tension with concomitant left atrial reduction plasty with reef-imbricate suture technique with adjunctive aggressive postoperative pharmacological therapy including diuresis and intravenous administration of Natrecor and oral Viagra. In the control group, 166 patients underwent modified full Maze III RF ablations. Other concomitant procedures included mechanical aortic valve replacement in 178 (55%) patients, tricuspid valve repair with a ring or band in 269 (83%) patients, left atrial thrombus evacuation in 91 (28%) patients, and coronary artery bypass grafting in 16 (4.9%) patients. The distribution of operative procedures is summarized in Table 2.

Mortality was defined as death occurring within 90 days following initial surgery or during the same admission. Mortality in the control group was four and three in the study group. Three patients died of congestive heart failure and four patients died due to severe pneumonia and respiratory failure. Hospital morbidity included re-operation for bleeding in 18 (5%) patients and the requirement for permanent pacemaker insertion in eight (3%) patients.

Overall restoration of sinus rhythm was significantly improved in the study group with aggressive reduction of left atrial wall tension during 1-year clinical follow-up (89.3% vs 67.2%, $p < 0.001$). Calculated LA wall tension was significantly reduced at discharge in the study group versus the control group (4012 ± 1650 dyn cm^{-1} vs $20\,384 \pm 3313$ dyn cm^{-1} ($p < 0.001$)) and at 1-year follow-up (1059 ± 1161 dyn cm^{-1} vs $17\,139 \pm 3170$ dyn cm^{-1} ($p < 0.001$)), respectively. Significant differences in changes in left atrial dimension were detected at discharge and 1-year follow-up in the study group versus control group (43 ± 7 vs 61 ± 11, $p < 0.001$). Left atrial wall thickness (3.9 ± 1.3 vs 2.3 ± 0.9) also significantly differed at the first year follow-up, but not at discharge ($p < 0.005$). Blood BNP values were significantly different through the first year ($p < 0.001$) favoring the study group. PA pressures were significantly lower (26 ± 12 vs 30 ± 14, $p < 0.01$) at 6 months and 1 year follow-up in the study group.

Long-term follow-up was completed in 96% of patients with a mean follow-up time of 19 ± 16 months (range 1–58 months). On follow-up, 144 of the 166 patients (86%) in the study group and 116 of 166 patients (69%) in the control group were in sinus rhythm. Patients in the study group maintained a higher sinus rhythm recovery rate than those in the control group at the 12-month follow-up ($p < 0.001$). Of 322 study patients, 67 (20%) underwent electrical cardioversions, all of which occurred within the first 3 months. Ten (3%) patients required permanent pacemaker implantation for completed A-V block.

TTE examinations were performed perioperatively and postoperatively at 12 months' follow-up. Among the patients in the study group, the LA diameter at discharge was significantly smaller than the preoperative LA diameter (51 ± 11 vs 64 ± 12, $p < 0.001$). Among the control group, the left atrial diameter at discharge was only slightly reduced in comparison with the preoperative diameter (49 ± 8 vs 56 ± 17). However, the LA diameter at 12 months was not significantly changed in comparison with the LA diameter at discharge in both groups.

4. Discussion

Dilatation and structural changes in the LA secondary to persistent LA pressure or volume overload in MV disease may be associated with poor restoration of sinus rhythm after the Maze procedure. Although the electrophysiological effects of chronic volume and pressure overloads are incompletely understood, mechanoelectrical feedback may play an important role in the maintenance of Sinus rhythm [8]. Histological and electrophysiological changes in the atrial myocardium such as fibrosis, necrosis, inhomogeneous depolarization potentials, refractory periods, and unidirectional conduction block may all produce reentrant circuits leading to the eventual recurrence of AF in these patients after the Maze procedure.

GLA, which is invariably associated with AF, is a frequent occurrence in MV disease, especially in rheumatics. Its presence is usually indicative of long-standing MV disease

with secondary changes in the atrial myocardium, such as wall thinning, which may lead to poor contractility and high LA wall tension after the Maze procedure. Because an atrial-stretch mechanism is considered a primary cause of AF in MV disease, the elimination of pressure/volume overloads and reducing wall tension on the LA is mandatory to prevent further atrial myocardial damage. Atrial dilatation from increased atrial pressure has been shown to greatly increase vulnerability to AF [9]. Therefore, effective elimination of LA pressure or volume overloads and aggressive left atrial size reduction may be key factors for maintenance of sinus rhythm after the Maze procedure.

This report demonstrates that reduction of left atrial wall tension using biatrial reduction with reef-imbricate suture technique in conjunction with aggressive postoperative diuresis and intravenous administration of Natrecor and oral Viagra can have a successful outcome. In this study, we found that 89.3% of patients in the study group regained sinus rhythm after surgical treatment, and 86% of patients in this group also remained in sinus rhythm at 1 year's follow-up. Comparatively, only 67.2% of patients in the control group regained sinus rhythm, and only 57% of these patients remained in sinus rhythm after 1-year follow-up.

It is generally agreed that patients with enlarged LA require some supplementary procedure as an adjunct to Maze at the time of MV surgery for effective treatment of AF. The greater the LA diameter, the lower is the sinus conversion rate [10]. AF is rare when LA diameters are less than 40 mm [11]. Cox et al. [12] suggested that LA size (diameter $>$ 60 mm) was an important factor in the development, persistence, and recurrence of AF. Kawaguchi et al. [13] stratified patients with AF as being 'Maze-amenable' or 'Maze-refractory' based on their LA size. Yuda et al. [14] reported that the Maze procedure was able to achieve a sinus rhythm restoration in 50% of chronic AF patients with GLA. Scherer et al. [15] reported a sinus conversion rate of 66% with sole atrial reduction in patients having valvular disease and AF. It is our contention that surgery should address not only the matter of correcting the AF but also reduction of the enlarged LA to decrease wall tension. Furthermore, LA size reduction may have a positive effect in restoring atrial contractile function. Wang et al. [16] suggested that reduction of atrial size by the Maze procedure may reduce atrial wall stress and facilitate atrial contraction. Therefore, we adopted a policy of aggressively reducing LA size to include not only those patients meeting the criteria of a GLA but also those patients in whom the antero-posterior diameter as measured on the parasternal long axis view and or the left atrial posterobasal segment appeared greater than normal or where the LA wall simply appeared dilated and thin, less then 4 mm during surgery.

Although a Maze procedure can be easily executed in GLA patients, macro reentrance can form between lesions and AF often persists if the lesions are too far away from one another. Early perioperative conversion to sinus rhythm is most optimal, but the maintenance of sinus rhythm continues to be a clinical challenge. Increasing atrial size ultimately increases the wall stress and tension of the chamber, which generates primary stimulus and permanent chaotic wavelets leading to persistent and chronic AF. Therefore, we believe that surgical reduction in atrial size and postoperative pharmacologic management of LA volume overload play a significant role in the restoration of normal geometric size and wall stress for those large atria.

In this report, we evaluated the impact of using the reef-imbricated suture technique on the sinus rhythm recovery as well as the long-term maintenance of sinus rhythm. The cut-and-sew surgical technique for atrial reduction in the treatment of AF is considered by many surgeons to be difficult, time-consuming, technically demanding, and causing an increase in postoperative bleeding particularly in patients with giant atria (LA diameter $>$ 80 mm). Bando [17] and Romano [18] reported that LA reduction via traditional cut-and-sew technique to remove excess atrial wall tissue was 92% effective in sinus rhythm recovery with up to 1-year freedom from AF. This traditional procedure, however, can extend operative cardiac ischemic time, thereby affecting left ventricular function and potentially increasing postoperative bleeding. Marui et al. [7] reported LA plication by means of continuous horizontal mattress sutures instead of additional cut-and-sew procedures drastically reducing the cross-clamp time and risk of bleeding.

Our findings suggest four significant points. First, LA reduction procedures using only continuous horizontal mattress suture plications are not sufficient in reducing the LA and may only reduce LA diameter by one-third. Our reef-imbricated suture technique first pulled up the LA excess wall tissue, and then rolled it over with a continuous running suture. It was very effective in reducing LA diameter and, more importantly, the oversewn ridge seemed to serve as an artificial barrier disrupting LA wall chaotic wavelets and macro-reentry circuit. In addition, it significantly improved LA hemostasis and reduced the opportunity for subsequent LA thrombus formation due to a much smaller atrium chamber and smooth endocardial surface. We have found this technique to be technically simple and quick to accomplish and, most importantly, effective in relieving AF without adding any complications.

Second, a full-modified Maze procedure alone without atrial reduction is not a complete therapy for this subset of patients. Left atrial geometry with rheumatic MV disease presents unique characteristics that stretch the LA wall or excess atrial wall tissue usually located between the left and right pulmonary veins, left atrial posterior wall, and left atrial free wall. The thickness of the LA wall usually is very thin, approximately 2–4 mm. The reef-imbricated suture line on the half-moon shape distal to the posterior mitral annulus was found to be effective in eliminating redundant LA wall tissue and preventing injury to the circumflex coronary artery. It also preserved the LA as a functional anatomic unit to restore atrial contraction and improve functional capacity.

Third, rheumatic MV disease not only contributes to GLA and AF but also to tricuspid valvular regurgitation, pulmonary hypertension, and giant right atria in advanced stages. We found a high prevalence of significant late postoperative tricuspid regurgitation with De Vega annuloplasty in patients with AF treatment failure and those with late AF recurrence. The correction of tricuspid regurgitation with annuloplasty ring, right atrial reduction plasty using the reef-imbricated technique, and a right-sided Maze procedure could be important in long-term outcomes. Furthermore, it is thought

to eliminate the risk of atrial flutter, which may originate at the right atrial isthmus.

Lastly, we found that enlarged atria are best correlated with increased wall tension because of intermittent chronic elevation of ventricular filling pressures. Enlarged atria reflect the remodeling process, and represent a quantifiable surrogate of the arrhythmogenic substrate. The LA volume, as a marker of chronically increased filling pressures, is strongly related to the recurrence of AF after the Maze procedure. Therefore, pharmacologic intervention to reduce preload and afterload is essential to maintain sinus rhythm after Maze procedure.

5. Conclusion

An aggressive approach to reduce left atrial wall tension significantly improves restoration of sinus rhythm after the Maze procedure. Biatrial reduction plasty with the reef-imbricate technique in combination with an RF full Maze procedure is an effective modality for treating permanent AF in patients with giant atrium undergoing concomitant mitral surgery. In addition, it is important to realize that left atrial wall tension directly affects conversion and maintenance of sinus rhythm. Further studies using pharmacologic intervention to reduce LA wall tension for the maintenance of sinus rhythm need to be evaluated.

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Appendix A. Conference discussion

Dr K. Khargi (*The Hague, Netherlands*): Indeed an interesting topic. Last year at the EACTS meeting in Vienna, the authors presented their reef-imbricate technique in an observational study. This study included 102 patients with a modified RF procedure. They solely performed this reef-imbricate atrial plasty. But in this study, they have included 322 patients and they did a reef plus a Viagra medication to these patients.

My question is: Are the patients from the previous study also included in this study? And if that is the case, then they had a different type of therapy.

My second comment is that the authors challenged the conventional wisdom that atrial fibrillation is related to a critical atrial mass of tissue. The implication of your study is very interesting, because you presume that the atrial wall tension is the common denominator, where either plication or a resection could be effective. However, the data of your study are incomplete and they cannot substantiate the conclusions. The relationship between the surgical intervention, the atrial tension reduction, as well as the postoperative outcome, is extremely difficult to evaluate from the data you provided in your manuscript.

The measured parameters of the left atrial, the atrial wall thickness, the pulmonary artery and the wedge pressure used to calculate the atrial wall tension are invariably missing at 6 months, 1 year and 19 months postoperatively. For instance, you're describing the atrial wall tension at 6 months and at 12 months, but the other parameters are missing.

In addition to that, you are describing data in your manuscript which are sometimes conflicting. For example, in the tables you're saying the left atrium is 84 mm, while in the discussion it is 64 mm.

And lastly, in the table, for instance, where you give the preoperative demography of the patients, the statistical analysis is missing.

So my second question is: Why do the authors think that a reduction of the atrial wall tension is more important than a reduction of the critical mass?

And finally, the postoperative follow-up as done by the authors is a combination of outpatient clinic visits and phone interviews. The authors only did a Holter 24-hour registration in symptomatic patients. So they presumed that asymptomatic patients don't have atrial fibrillation. I believe that it's mandatory to have 24-Holter ECG systematically in each and every patient to assess the stability of sinus rhythm and an echocardiogram to assess atrial contraction.

So my final question is: Could the author comment why their postoperative sinus rhythm data are still valid?

Dr Wang: Regarding your first question, last year we presented 161 patients having isolated aggressive reduction with the reef-imbricate technique which was not randomized. However, we randomized from 1999 to 2008. It's actually the same group, we just picked 161 out of the group of patients with an isolated reef-imbricate procedure. It's the same group, not a new group. Number one question.

Number two, it's the same, left atrial wall tension is directly related to your critical mass reduction. I think that is basically the two issues. Atrial fibrillation is a multifactorial issue. You cannot separate critical mass from atrial wall tension. So you have to do a critical mass reduction in addition to a pharmacological reduction. Number two.

Number three, regarding follow-up of the patients. During the first couple of years we did not use the Holter to follow up the patients, we just used a telephone interview. But for the last 8 years, we routinely followed up patients with maze procedure using a Holter monitor in addition to performing an echocardiogram twice yearly to confirm left atrial contractility.