Efficacy of Cut-and-Sew Surgical Ablation for Atrial Fibrillation in Patients With Giant Left Atria Undergoing Mitral Valve Surgery: A Propensity-Matched Analysis

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Surgical management for patients with long-standing persistent (LSP) AF and giant left atria (GLA) associated with mitral valve diseases remains a challenge. We aimed to assess the efficacy of the cut-and-sew maze procedure (CSM) in this subgroup of patients, in terms of maintenance of sinus rhythm (SR), atrial function, and to identify the operative risks of this procedure. A total of 229 patients with LSP-AF underwent CSM at our institution from December 2013 to October 2017. Patients were divided into 2 groups based on LA diameter: NGLA group (<65 mm, $n = 171$), GLA group (≥65 mm, $n = 58$). Patients with GLA were propensity score matched to patients without GLA resulting in 45 pairs of patients. Early death occurred in 1 (2.2%) in GLA group and no deaths in NGLA group ($P = 0.315$). Early complications did not differ significantly between the 2 groups. The GLA group showed similar rates of SR on and off antiarrhythmic drugs compared with NGLA group at 2 years (86.36% vs 93.9%, $P = 0.338$; 81.82% vs 90.91%, $P = 0.322$). At 2 years, LA contraction was comparable between patients with and without GLA (81.81% vs 90.9%, $P = 0.322$). Right atrial contraction recovery rate was 96% in NGLA group, and 86.36% in GLA group ($P = 0.138$). Concomitant CSM is effective and feasible for restoration of SR and atrial contraction, for patients with LSP-AF and GLA associated with mitral valve diseases with acceptable operative risks.

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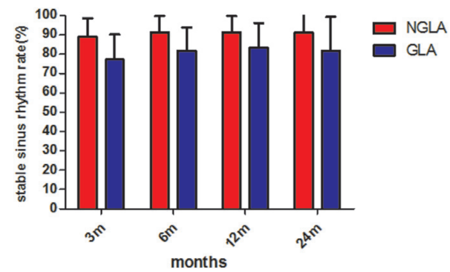
Keywords: Surgical ablation, Giant left atrium



Maze III may be an option for patients with giant left atria.

Central Message

Maze III plus tricuspid isthmus cryoablation is effective for atrial fibrillation in patients with giant left atria associated with mitral valve diseases with acceptable operative risks.

Perspective Statement

Surgical management for patients with long-standing persistent atrial fibrillation and giant left atria associated with mitral valve diseases remains a challenge. We aimed to assess the efficacy of the cut-and-sew maze procedure in this subgroup of patients, in terms of maintenance of sinus rhythm, atrial function, and to identify the operative risks of this procedure.

Abbreviations: AF, atrial fibrillation; CSM, cut-and-sew maze procedure; GLA, giant left atrium; LA, left atrium; LSP, long-standing persistent; LVEF, left ventricular ejection fraction; NGLA, nongiant left atrium; NYHA, New York Heart Association; SR, sinus rhythm

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INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia.[1] AF may result in a decreased cardiac output by loss of atrial contraction, an increased risk of systemic embolism and mortality.[2] An estimated 5% of patients undergoing cardiac surgery have AF, making it an important clinical problem.[3] In 1987, the cut-and-sew maze procedure (CSM) was introduced by Dr James Cox as a surgical treatment for patients with AF.[4,5] It has been well established that increasing left atrium (LA) size was a significant risk factor of treatment failure of AF after a maze procedure.[6,7] LA size itself may also influence the chance of recovery and maintenance sinus rhythm (SR).[8,9] Kamata et al first demonstrated that giant left atrium

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(GLA, LA diameter >65 mm) was the predictor of AF recurrence in the late postoperative period of maze III procedure.[10] Yet, Lee et al recently reported that patients with a giant LA undergoing MV surgery may benefit from an addition of maze procedure.[11] To date, surgical treatment of long-standing persistent (LSP) AF in patients with GLA remains controversial, and the risk-benefit profile of CSM in this patient population is still questionable.[8,9,12]

Most surgeons are reluctant to perform CSM due to its technical complexity and assumed high risks of this procedure. A prospective study has demonstrated that CSM can decrease the risk of stroke or death and achieve a high SR rate at 1 year without increasing the operative risks regardless of LA size.[13] We suppose that, by utilizing CSM for this subgroup of patients who were considered unlikely to benefit from CSM procedure may have as successful outcomes with acceptable operative risks. Therefore, the purpose of this study was to access the efficacy and operative risks of CSM in this subgroup of patients.

MATERIALS AND METHODS

Data were collected retrospectively from patients undergoing CSM for LSP-AF concomitantly with mitral operations, including combined tricuspid valve repair, aortic valve replacement, or coronary artery bypass grafting. Patients with infective, ischemic mitral regurgitation or patients with paroxysmal and persistent AF were excluded. A total of 229 patients underwent mitral operations plus CSM at our institution by 1 surgeon between December 2013 and October 2017. LSP-AF was defined as AF duration lasting >1 year.[14] Patients were divided into 2 groups: NGLA group (LA diameter <65 mm, $n = 171$; 115 women and 56 men; age range 34−75 years), GLA group (LA diameter ≥65 mm, $n = 58$; 36 women, 22 men; age range 30−74 years; Table 1). The study was approved by the institutional ethics review board at Shenyang Northern Hospital. The diagnosis of AF is based on the patient's clinical history and physical examination and is confirmed by 24-hour Holter monitor by electrophysiological doctors. GLA was determined as an anterior-posterior diameter of LA measured on M-mode tracing taken from a parasternal long-axis view greater than or equal to 65 mm.

Operative Approach

The details of the CSM were based primarily on the description by Wang.[13] In brief, the biatrial lesion sets were performed by the cut-and-sew procedure, with 5 additional cryolesions. One cryolesion is at the 1.5-cm junction of the LA appendage and the pulmonary vein encircling incisions, the other 3 are 1 at the mitral isthmus, 2 at the level of the tricuspid annulus. We also added 1 cryolesion at the tricuspid valve isthmus. Double full-layer inverting mattress running sutures with 4-0 or 5-0 polypropylene were used for all left-side incisions to

Table 1. Preoperative Patient Characteristics

	Unmatched Sample			Matched Sample		
	NGLA ($n = 171$)	GLA ($n = 58$)	Standardized Difference	NGLA ($n = 45$)	GLA ($n = 45$)	Standardized Difference
Age	57.87 ± 7.24	54.97 ± 7.79	0.386	54.58 ± 7.07	54.82 ± 8.39	0.031
Weight (kg)	62.62 ± 10.82	65.78 ± 12.37	0.259	65.47 ± 8.86	66.58 ± 14.3	0.093
Height (cm)	163.56 ± 7.3	165.66 ± 8.6	0.262	165.73 ± 7.5	166.24 ± 9.1	0.061
BSA (m^2)	1.76 ± 0.16	1.81 ± 0.21	0.275	1.81 ± 0.14	1.83 ± 0.22	0.091
Female (%)	115 (67.3)	36 (62.1)	0.109	28 (62.2)	28 (62.2)	0.000
Cause						
Rheumatic (%)	128 (74.9)	43 (74.1)	0.018	31 (68.9)	30 (66.7)	0.047
Degenerative (%)	43 (25.1)	15 (25.9)	0.018	14 (31.1)	15 (33.3)	0.047
Mitral lesion set						
MS (%)	0 (0)	0 (0)	–	0 (0)	0	–
MR (%)	43 (25.1)	15 (25.9)	0.018	14 (31.1)	15 (33.3)	0.047
MS + MR (%)	128 (74.9)	43 (74.1)	0.018	31 (68.9)	30 (66.7)	0.047
Combined lesion						
Aortic lesion (%)	48 (28.1)	15 (25.9)	0.050	2 (4.4)	2 (4.4)	0.000
TR (%)	67 (39.2)	27 (46.6)	0.150	17 (37.8)	21 (46.7)	0.265
Coronary artery disease (%)	14 (8.2)	4 (6.9)	0.049	5 (11.1)	3 (6.7)	0.155
History of						
stroke (%)	18 (10.5)	5 (8.6)	0.065	1 (2.2)	3 (6.7)	0.220
LA thrombosis (%)	26 (14.7)	6 (10.3)	0.147	2 (4.4)	5 (11.1)	0.253
Hypertension (%)	32 (18.7)	6 (10.3)	0.240	5 (11.1)	6 (13.3)	0.067
Diabetes (%)	4 (2.3)	4 (6.9)	0.221	2 (4.4)	4 (8.9)	0.181
NYHA > II (%)	171 (100)	58 (100)	0.000	45 (100)	45 (100)	0.000
LVEF	0.56 ± 0.04	0.55 ± 0.03	0.238	0.56 ± 0.04	0.55 ± 0.04	0.156

GLA, giant left atrium; LA, left atrium; LVEF, left ventricular ejection; MR, mitral regurgitation; MS, mitral stenosis; NGLA, nongiant left atrium; NYHA, New York Heart Association; TR, tricuspid regurgitation.

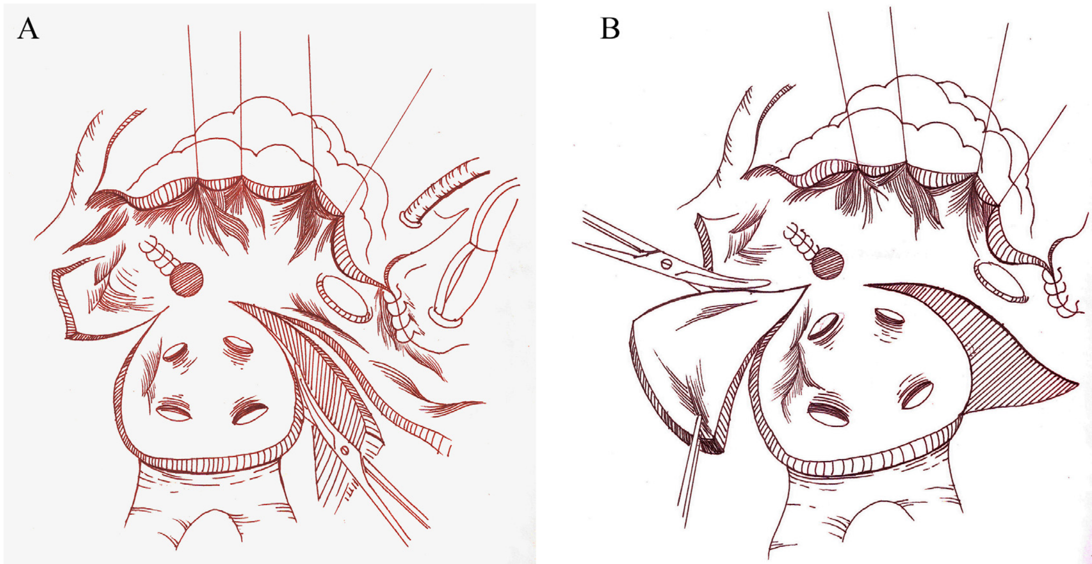


Figure 1. (A) Left atrial (LA) reduction plasty was used if LA diameter >75 mm. A strip of the roof of left atrial posterior wall is removed during the creation of the pulmonary vein encircling incisions closely follows the mitral annulus. (B) The other method of left atrial reduction is achieved by partial excision of the roof the atrium.

prevent the bleeding risk of LA posterior walls. Atrial reduction plasty/resection was not used routinely unless LA diameter >75 mm. A strip of the roof of LA and/or LA posterior wall tissue was resected during the creation of the pulmonary vein encircling incisions[9] (Fig. 1).

Postoperative Protocols

For the patients who received mechanical prosthesis, warfarin was continued, while those patients who received a bioprosthetic implant, if stable SR was achieved, warfarin was administered for 3 months. However, if AF or atrial flutter persisted, warfarin was continued beyond this time point. The target range for prothrombin time/International Normalized Ratio (INR) was 2.0−2.5. Amiodarone was used during hospitalization and was continued for 3 months.

Follow-Up

Twenty-hour Holter monitoring was checked before discharge and at 1, 3, 6, and 12 months after operation, and then annually at our outpatient clinic. All ultrasound examinations were performed by the same echocardiographic doctors with a Philips ultrasound system (Philips iE33 ultrasound machine; Philips Healthcare, Andover, Mass). Transmitral and transtricuspid A waves and the magnitude of peak A waves velocity were measured in the apical 4-chamber view by pulsed Doppler echocardiography. A wave peak velocity ≥10 cm/s indicated effective atrial contraction. Recurrence was defined as the occurrence of AF, atrial flutter, or atrial tachycardia lasting longer than 30 seconds after a period of at least 3-month follow-up.[15]

Statistical Analysis

Categorical variables, presented as percentages, were compared using the chi-square tests or Fisher's exact test. Continuous variables were presented as mean ± standard deviation. Student's test was used to analyze the normally distributed variables, while Mann-Whitney U test for non-normally distributed data. Echocardiography measures between-group differences from baseline to 2 years after surgery were evaluated by repeated-measures analysis of variance.

Propensity score (PS) matching was conducted between the 2 groups to simulate randomization in this observational study. PS was estimated by logistic model and matched between the 2 groups within a caliper of 0.1 PS standard deviations. The covariates were based on 16 clinical variables, including gender, age, height, body weight, body surface area, etiology of mitral disease, mitral lesion set, combined with aortic lesion, tricuspid regurgitation, or coronary artery disease, the history of hypertension, diabetes, and stroke, New York Heart Association (NYHA) classification >II, left atrial thrombosis, and left ventricular ejection fraction (LVEF). All data were analyzed in SPSS version 24.0 software (SPSS, Inc., Chicago, IL). P values were 2-sided, and $P < 0.05$ was considered statically significant.

RESULTS

Baseline Characteristics

After PS matching, the sample remains were 90 patients (45 pairs). Unmatched data and matched data were listed in Table 1. There were no significant differences in preoperative variables between the 2 matched groups.

Early Outcomes

The distribution of concomitant procedures and operative outcomes remained comparable between the 2 groups. No patients died in the NGLA group, and 1 patient (2.2%) died in the GLA group ($P = 0.315$). The patient died of multiple organ failure due to left ventricular rupture 4 days after operation. No differences were found in the postoperative outcomes with regard to reoperation for bleeding, the length of stay in ICU or postoperative hospital, the rates of stroke, application of electrical cardioversion, renal failure, pneumonia, etc (Table 2).

Follow-Up Outcomes

Eighty-nine early survivors (100%) were all followed up. No patients were lost and there were no deaths and strokes occurred during the follow-up. In the NGLA group, the return to SR were documented at 95.55% (43/45) at 3, 6, and 12 months, and at 93.9% (31/33) at 2 years, with 88.89% (40/45), 91.11% (41/45), 91.11% (41/45), and 90.91% (30/33) off antiarrhythmic drugs (AADs) at 3, 6, 12, and 24 months, respectively. The GLA group showed return to SR at 88.64% (39/44) at 3, 6 months, and 86.11% (31/36) at 1 year, and 86.36% (19/22) at 2 years, respectively. Meanwhile, free from AADs were 77.27% (34/44), 81.81% (36/44), 83.33% (30/36), and 81.82% (18/22), at 3, 6, 12, and 24 months, respectively. The GLA group was similar to the NGLA group in SR restoration rate at 1 year ($\chi^2 = 2.26$, $P = 0.133$) or 2 years ($\chi^2 = 0.917$, $P = 0.338$) and off AADs (1 year: $\chi^2 = 1.118$, $P = 0.29$; 2 years: $\chi^2 = 0.982$, $P = 0.322$). Rates of SR on and off AADs at 1 year in patients with LA diameter ≥75 mm were 60% (3/5), in LA diameter ≥80 mm were 33.3% (1/3) at 6 months. Transmitral and transtricuspid A waves were not significantly different at any time point between the 2 groups ($P > 0.05$; Fig. 2). The comparisons of transmitral and transtricuspid A waves are shown in Table 3. Only 20% (1/5) appeared A waves in patients with LA diameter more than 75 mm. Both groups showed significant reductions in LA diameter and improvement in LVEF compared with preoperative findings ($P < 0.001$). Patients without GLA had significantly smaller LA diameter and left ventricular end-diastolic dimension than those with GLA($P < 0.001$ and $P = 0.017$, respectively), but there were no significant differences in left ventricular end-systolic dimension and LVEF ($P = 0.119$ and $P = 0.055$, respectively; Table 4). At the last follow-up, all patients were all in cardiac function NYHA grade I or I∼II.

Discussion

To the best of our knowledge, this is the first study to evaluate the efficacy of cut-and-sew maze for restoring sinus rhythm and effective atrial contraction for patients with LSP-AF and giant LA associated with mitral valve disease. The present study reveals 2 major findings. First, concomitant CSM resulted in a comparable SR rate and recovery of atrial contraction to patients without GLA. Second, CSM did not increase the operative risk in this patient population during mitral valve operations. In our patient population, nearly 86% of patients with GLA were in SR at 1 year postoperatively, as well as a relatively high rate of return

Table 2. Perioperative Results

	NGLA ($n = 45$)	GLA ($n = 45$)	*P* Value
MV repair (%)	12 (26.7)	8 (17.8)	0.310
MV replacement (%)	33 (73.3)	37 (82.2)	0.310
Concomitant surgery			
Tricuspid annuloplasty (%)	17 (37.8)	21 (46.7)	0.393
CABG (%)	5 (11.1)	3 (6.7)	0.459
LA thrombectomy (%)	2 (4.4)	5 (11.1)	0.238
AVR (%)	2 (4.4)	2 (4.4)	1.000
ACC time (min)	90.42 ± 20.91	94.00 ± 16.86	0.374
CPB time (min)	176.38 ± 24.49	175.76 ± 31.36	0.917
ICU stay time (h), median(range)	24 (22−56)	25 (18−144)	0.247
Postoperative hospital stay (d), median (range)	14 (12−20)	15 (6−25)	0.632
Intraoperative bleeding (mL)	408.00 ± 95.67	410.00 ± 105.85	0.925
Temporary pacemaker use (%)	23 (51.1)	24 (53.3)	0.833
Complications	11 (24.4)	19 (42.2)	0.074
Reoperation for bleeding (%)	0 (0)	1 (2.2)	0.315
Low-cardiac-output syndrome (%)	1 (2.2)	2 (4.4)	0.557
Heart failure (%)	0 (0)	1 (2.2)	0.315
II atrioventricular block (%)	1 (2.2)	2 (4.4)	0.557
Complete atrioventricular block (%)	0	0	
Pneumonia (%)	1 (2.2)	2 (4.4)	0.557
New-onset stroke (%)	0	0	
Atrial arrhythmias (%)	3 (6.7)	4 (8.9)	0.694
Ventricular arrhythmias (%)	2 (4.4)	3 (6.7)	0.645
Mortality (30-d) (%)	0 (0)	1 (2.2)	0.315
Electrical cardioversion (%)	3 (6.7)	3 (6.7)	1.000

ACC, aortic cross-clamping; CABG, coronary artery bypass graft; CPB, cardiopulmonary bypass; GLA, giant left atrium; ICU, intensive care unit; LA, left atrium; MV, mitral valve; NGLA, nongiant left atrium.

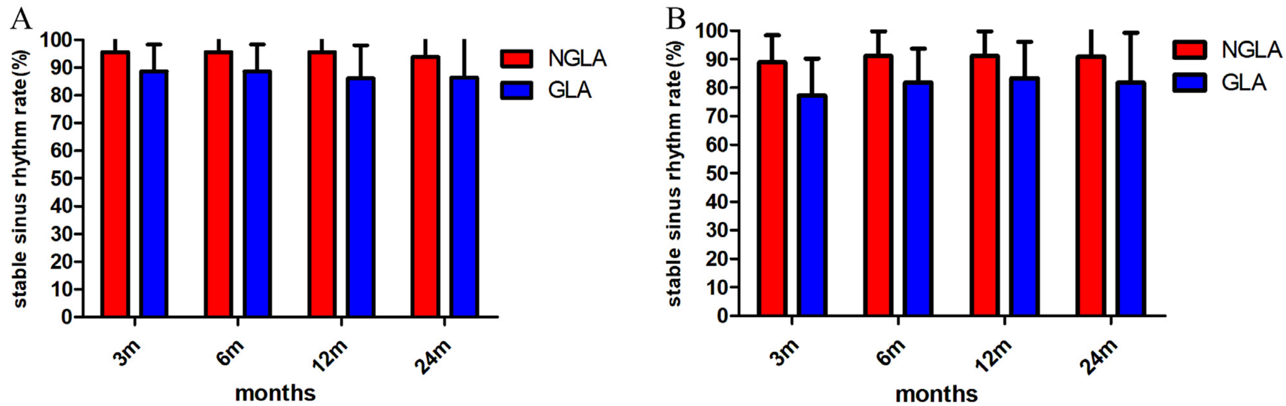


Figure 2. (A) Comparison of stable sinus rhythm rate between nongiant left atria (NGLA, LA diameter <65 mm) group and giant left atria (GLA, LA diameter ≥65 mm) group. All of them underwent CSM plus tricuspid isthmus cryoablation, and atrial reduction resection was used if LA diameter >75 mm. The GLA group showed similar sinus rhythm rate at each time interval during the follow-up in 2 years. Maze III may be an option for patients with giant left atria. (B) Comparison of stable sinus rhythm rate off antiarrhythmic drugs (AADs) between nongiant left atria (NGLA, LA diameter <65 mm) group and giant left atria (GLA, LA diameter ≥65 mm) group. All of them underwent CSM plus tricuspid isthmus cryoablation, and atrial reduction resection was used if LA diameter >75 mm. The GLA group was similar to the NGLA group in SR restoration rate off AADs at each time interval during the follow-up in 2 years. Maze III may be an option for patients with giant left atria.

to SR without AADs (83%). By 2 years postoperatively, the rates of sinus conversion with and without AADs were similar (86.36% and 81.82%, respectively). This study also reveals that patients with an extremely large LA (LA diameter >75 mm) obtained an acceptable SR restoration rate (60%) whether on or off AADs. We believe such excellent results are due to consistent trasmurality of the lesions performed by means of cut-and-saw technique.[16] Although CSM has been a gold standard for treatment of AF combined with mitral valve diseases, this procedure has been regarded as time consuming, prone to bleeding, and technique-demanding. Surgical ablation with devices has been increasingly performed worldwide. Because, by using alternate energy sources, instead of the cut-and-suture technique, it simplifies the ablation procedure consistently, making it much quicker. However, SR conversion rate with device ablation differ greatly among different doctors, particularly as a challenge in patients with giant LA.[17,18] So CSM may be better alternative for this subgroup of patients.

When performing maze procedures for patients with GLA, some surgeons would perform LA volume reduction routinely. In our experience, there is no need to perform LA volume reduction when LA diameter was less than 75 mm. When we made extensive suturing of the LA wall, we used double full-layer inverting mattress running suture, thus LA volume was reduced simultaneously. Postoperative echocardiography confirmed that LA diameters were significantly reduced especially for those patients who have converted to SR and restored atrial contraction. However, the risk benefit profile of the maze procedure for patients with LA greater than 80 mm is still unclear. Kosakai et al showed that when the LA dimension was over 87 mm, the success rate was 0%.[19] In this study, among patients with LA size greater than 80 mm (4 patients) who underwent resection of the posterior wall of LA, 3 survived and 1 (33.3%) returned to SR at a mean 14 months' follow-up.

It is important that restoring SR should be accompanied with the restoration of atrial contractions. Unfortunately, restoring SR does not guarantee restoring of atrial contraction, which may result from scars and electrical isolation areas created during the procedure.[20] Buber et al reported that absence of LA contraction, despite SR restoration, was associated with a significant increase in the risk of thromboembolic stroke after maze procedure, which was related to the loss of atrial contractile function.[21] In the present study, effective atrial contraction was seen in most patients with GLA (65−75 mm) at 1 year postoperatively. This functional recovery may have important implications on long-term survival, heart function, and clinical decision-making of long-term anticoagulation therapy.[22] However, fewer patients with LA diameter greater than 75 mm could resume effective left atrial contraction, despite 60% of patients returned to SR. This study also demonstrates that right atrial contraction maintained in most patients with GLA.

There has been a concern that the addition of the CSM may increase clamp time, further aggravate cardiac function and increase early mortality and postoperative complications. In addition, some surgeons worry about bleeding with CSM in a thin and fragile LA wall, which is the typical feature of a GLA. We routinely used double full-layer inverting mattress running sutures with 5-0 polypropylene for all left-side suture line in the thin and fragile wall of LA, which was proven to be an effective technique in preventing bleeding. We did not encounter any uncontrolled bleeding after suturing the thin atrial wall in all 229 patients.

Table 3. The Transmitral and Transtricuspid A Wave

	NGLA						GLA					
Variable	Preoperation	1 m	3 m	6 m	12 m	24 m	Preoperation	1 m	3 m	6 m	12 m	24 m
Transmitral A wave (%)	–	53.33 (24/45)	84.44 (38/45)	82.2 (37/45)	82.2 (37/45)	90.9 (30/33)	–	47.72 (21/44)	86.36 (38/44)	86.36 (38/44)	80.56 (29/36)	81.81 (18/22)
Transtricuspid A wave (%)	–	62.22 (28/45)	88.88 (40/45)	86.66 (39/45)	86.66 (39/45)	96 (32/33)	–	65.91 (29/44)	86.36 (38/44)	86.36 (38/44)	86.11 (31/36)	86.36 (19/22)

GLA, giant left atrium; NGLA, nongiant left atrium.
A wave peak velocity ≥10 cm/s indicated effective atrial contraction.

Table 4. Comparison of Echo Measurements Between the 2 Groups

	NGLA						GLA					
Variable	Preoperation	1 m	3 m	6 m	12 m	24 m	Preoperation	1 m	3 m	6 m	12 m	24 m
LAD (mm)	48.24 ± 5.45	40.64 ± 4.53	41.18 ± 6.09	42.24 ± 5.44	41.82 ± 5.19	40.52 ± 4.40	67.41 ± 4.37	50.77 ± 6.79	50.86 ± 5.80	51.73 ± 6.06	49.59 ± 5.67	48.27 ± 6.59
LVEDD (mm)	49.06 ± 7.18	44.85 ± 5.16	44.88 ± 5.27	44.79 ± 4.48	43.55 ± 5.41	43.39 ± 4.79	53.23 ± 9.48	48.41 ± 5.35	47.32 ± 4.89	47.59 ± 4.11	47.09 ± 4.55	45.95 ± 4.02
LVESD (mm)	35.55 ± 4.87	32.82 ± 3.96	32.85 ± 4.60	32.15 ± 4.15	30.91 ± 4.69	28.58 ± 5.37	38.45 ± 7.02	34.68 ± 4.34	33.41 ± 3.11	33.5 ± 3.23	32.14 ± 3.36	30.27 ± 3.29
LVEF	0.57 ± 0.04	0.60 ± 0.04	0.59 ± 0.06	0.58 ± 0.05	0.58 ± 0.04	0.61 ± 0.06	0.55 ± 0.04	0.56 ± 0.04	0.57 ± 0.04	0.58 ± 0.02	0.58 ± 0.03	0.60 ± 0.03

GLA, giant left atrium; LAD, left atrial dimension; LVEDD, left ventricular diastolic dimension; LVEF, left ventricular ejection fraction; LVESD, left ventricular systolic dimension; NGLA, nongiant left atrium.

LIMITATIONS

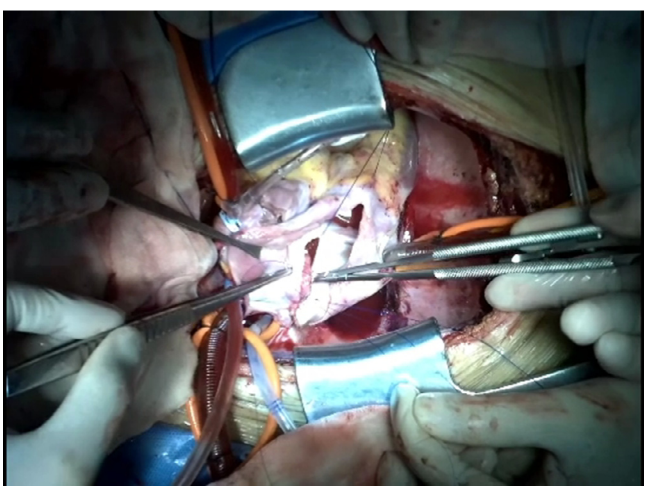
First of all, it is a retrospective study at a single center, although we used propensity score analysis in an effort to simulate randomization. Another limitation is that our patient population consisted of a relatively small number and the follow-up time does not exceed 2 years. Thus, further evaluation with a prospective large sample cohort with long-term follow-up should be necessary. Furthermore, only CSM was performed in the 2 groups; therefore, it does not provide any guidance as to whether radiofrequency ablation or cryoablation are equivalent in this subgroup of patients. Finally, the efficacy of CSM for patients with a LA diameter greater than 75 mm remains unclear due to the small sample size; therefore, further studies on this cohort are needed.

CONCLUSIONS

In conclusion, cut-and-sew maze is effective and feasible for restoration and maintenance of sinus rhythm and atrial contraction for patients with GLA and LSP-AF associated with mitral valve diseases.

SUPPLEMENTARY MATERIAL

The following is the supplementary data to this article:



Video 1. Surgical procedure.

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