Impact of left atrial volume reduction concomitant with atrial fibrillation surgery on left atrial geometry and mechanical function

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Objective: Left atrial geometry and mechanical functions exert a profound effect on left ventricular filling and overall cardiovascular performance. We sought to investigate the perioperative factors that influence left atrial geometry and mechanical functions after the Maze procedure in patients with refractory atrial fibrillation and left atrial enlargement.

Methods: Seventy-four patients with atrial fibrillation and left atrial enlargement (diameter ≥ 60 mm) underwent the Maze procedure in association with mitral valve surgery. The maximum left atrial volume and left atrial mechanical functions (booster pump, reservoir, and conduit function [%]) were calculated from the left atrial volume-cardiac cycle curves obtained by magnetic resonance imaging. A stepwise multiple regression analysis was performed to determine the independent variables that influenced the postoperative left atrial geometry and function.

Results: The multivariate analysis showed that left atrial reduction surgery concomitant with the Maze procedure and the postoperative maintenance of sinus rhythm were predominant independent variables for postoperative left atrial geometry and mechanical functions. Among the 58 patients who recovered sinus rhythm, the postoperative left atrial geometry and function were compared between patients with (VR group) and without (control group) left atrial volume reduction. At a mean follow-up period of 13.8 months, sinus rhythm recovery rate was better (85% vs 68%, $P < .05$) in the VR group and maximum left atrial volume was less (116 ± 25 mL vs 287 ± 73 mL, $P < .001$) than in the control group. The maximum left atrial volume reduced with time only in the VR group (reverse remodeling). Postoperative booster pump and reservoir function in the VR group were better than in the control group (25% ± 6% vs 11% ± 4% and 34% ± 7% vs 16% ± 4%, respectively, $P < .001$), whereas the conduit function in the VR group was lower than in the control group, indicating that the improvement of the booster pump and reservoir function compensated for the conduit function to left ventricular filling.

Conclusion: Left atrial reduction concomitant with the Maze procedure helped restore both contraction (booster pump) and compliance (reservoir) of the left atrium and facilitated left atrial reverse remolding. Left atrial volume reduction and postoperative maintenance of sinus rhythm may be desirable in patients with refractory AF and left atrial enlargement.

ACD

Left atrial (LA) enlargement has been reported to be a predictor for recurrent atrial fibrillation (AF) after the Maze procedure.[1-3] We and others have reported that LA volume reduction surgery concomitant with the Maze procedure facilitated sinus rhythm recovery even in patients with refractory AF and LA enlargement.[4-7] However, little is known about the recovery of LA geometry and mechanical function after these procedures.

The left atrium serves 3 major roles—booster pump, reservoir, and conduit—that exert a profound effect on left ventricular (LV) filling and overall cardiovascular

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Abbreviations and Acronyms
AF = atrial fibrillation
BPF = booster pump function
CF = conduit function
LA = left atrial
LV = left ventricular
MRI = magnetic resonance imaging
RF = reservoir function

performance.[8,9] We evaluated the LA booster pump function (BPF) early after LA reduction surgery concomitant with the Maze procedure using magnetic resonance imaging (MRI).[10] We did not evaluate the reservoir and conduit function (CF). Several factors, such as mitral valve pathology (regurgitation or stenosis) and operations (repair or replacement), also influence postoperative LA geometry and mechanical function.

We sought to determine the independent variables that influence postoperative LA geometry and global mechanical function after mitral valve surgery in patients with refractory AF and LA enlargement. We investigated the influences of these factors on the restoration of LA geometry and mechanical functions.

Patients and Methods

Study Population

Between 2000 and 2006, 127 patients with chronic (permanent or persistent) AF underwent the Maze procedures associated with mitral valve surgery at Kyoto University. Among them, 83 patients had preoperative LA enlargement (LA dimension ≥ 60 mm). LA diameter was measured by means of M-mode transthoracic echocardiography. Of the 83 patients, 7 with contraindications for MRI (eg, pre- or postoperative implantation of permanent pacemaker, implantable cardioverter defibrillator, or intracranial surgical clip) were excluded. Two urgent operations were also excluded because of a lack of preoperative MRI scans. Consequently, 74 patients were retrospectively analyzed (Table 1).

Surgical Procedure

In June of 2002, we began performing LA volume reduction surgery in association with the Maze procedure in patients with LA enlargement. Before June of 2002, 28 patients underwent the Maze procedure alone. After June of 2002, 46 patients underwent the Maze procedure concomitant with the LA reduction surgery that we developed.[4] The Maze procedures were primarily based on the modified Cox-Maze III with cryoablation[11] or the LA Maze procedure.[12] The LA lesion set was similar in both procedures. The LA volume reduction technique without cut and sew was performed as previously described[4] (Figure 1). Briefly, via a standard right-sided left atriotomy, continuous horizontal-mattress suture was placed on the LA wall along the pulmonary vein isolation line. The suture was tightened so that the redundant left atrium was plicated. Confinement cryoablation was applied to the suture line so that the plicated left atrium was both anatomically and electrically isolated. Other cryoablation was applied as previously reported.[4,11,12] We used the cryoablation only for the ablation device. Mitral valve repair or prosthetic valve replacement was performed immediately before or after the VR technique. The same surgeon (M.K.) performed the operations in all patients in a homogenous fashion during the entire study period.

TABLE 1. Preoperative data

Demographics	
Patients, n	74
Male sex, n (%)	32 (43%)
Age (y)	62 ± 14
NYHA class	2.7 ± 1.0
Duration of AF (y)	10 ± 6
Type of AF	
Permanent, n (%)	56 (76%)
Persistent, n (%)	18 (24%)
Mitral valve cause	
Regurgitation, n (%)	47 (64%)
Stenosis, n (%)	27 (36%)
Preoperative MRI data	
Maximum LA volume (mL)	361 ± 74
Booster pump function (%)	N/A
Reservoir function (%)	13 ± 5
Conduit function (%)	62 ± 9
LVEF (%)	48 ± 15
LVEDV (mL)	131 ± 34

NYHA, New York Heart Association; *AF,* atrial fibrillation; *LA,* left atrium; *LVEF,* left ventricular ejection fraction; *LVEDV,* left ventricular end-diastolic dimension; *MRI,* magnetic resonance imaging; *N/A,* not applicable.

Magnetic Resonance Imaging and Image Interpretation

MRI was performed with a 1.5-T whole-body imager (Symphony; Siemens, Erlangen, Germany) with multiple surface coils connected to phased-array receivers. Breath-hold cine MRI was performed with the segmented steady-state free precession sequence.[13] MRI scans were analyzed by an observer without any clinical information but with the aid of commercially available software (Argus, Siemens).[14]

Left atrial parameters. Axial slices over the entire LA cavity were used for the subsequent quantitative assessment. The left atrium was encompassed by 8-mm slices with 2-mm interslice gaps. Each slice was obtained for 10 heart beats with an electrocardiographically prospectively gated fast low-angle shot cinematographic pulse sequence, with echocardiography sharing to improve the temporal resolution.[15] The LA area (centimeters squared) of each slice was calculated from manually drawn endocardial boundaries of the LA cavity using ExaVision software (Ziosoft, Inc, Tokyo, Japan). LA volume was achieved using the slice summation method, which is based on the summation of the volume of each slice taking the slice thickness and interslice distance into account.[16-18] LA volume-time curves were depicted by plotting each instantaneous LA volume against the time after the R-wave of electrocardiogram (Figure 2).[16-19]

The reservoir volume was calculated as the difference between volume B (maximum LA volume) and volume C (LA volume at the end of rapid emptying).[16] The booster pump volume was calculated as the difference between volume D (LA volume before contraction) and volume A (minimum LA volume). The conduit