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Outcomes of Surgical Atrial Fibrillation Ablation: The Port Access Approach vs. Median Sternotomy

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Background: The aim of this study is to evaluate the clinical and rhythm outcomes of atrial fibrillation (AF) ablation through a port access approach compared with sternotomy in patients with AF associated with mitral valve diseases. ***Materials and Methods:*** From February 2006 through December 2009, 135 patients underwent biatrial AF ablation with a mitral operation via either a port-access approach (n=78, minimally invasive cardiac surgery [MICS] group) or a conventional sternotomy (n=57, sternotomy group). To adjust for the differences in the two groups' baseline characteristics, a propensity score analysis was performed. ***Results:*** After adjustment, there were no significant differences in the two groups' baseline profiles. The cardiopulmonary bypass time was significantly longer (p=0.045) in the MICS group (176.0±49.5 minutes) than the sternotomy group (150.0±51.9 minutes). There were no significant differences (p=0.31) in the two groups' rate of reoperation for bleeding (MICS=6 vs. sternotomy=2, p=0.47) or the requirement for permanent pacing (MICS=1 vs. sternotomy=3). The major event-free survival rates at two years were 87.4±8.1% in the MICS group and 89.6±5.8% in the sternotomy group (p=0.92). Freedom from late AF at 2 years was 86.8±6.2% in the MICS group and 85.0±6.9% in the sternotomy group (p=0.86). ***Conclusion:*** Both the port-access approach and sternotomy showed tolerable clinical outcomes following biatrial AF ablation with mitral valve surgery.

Key words: 1. Arrhythmia surgery
2. Minimally invasive surgery
3. Mitral valve
4. Atrial fibrillation

INTRODUCTION

The Cox maze procedure is the most effective procedure for eliminating atrial fibrillation (AF) and restoring a normal sinus rhythm, and it has evolved from a cut-and-saw technique to ablation using alternative energy sources such as cryothermia and radiofrequency [1-3]. As the operative techniques continue to advance, a minimally invasive approach for surgical AF ablation has also been developed [4]. The wound from minimally invasive cardiac surgery (MICS) is cosmetically superior, and earlier recovery is expected compared to a sternotomy approach. However, there are concerns about a minimally invasive approach to AF ablation surgery in that the rhythm outcomes may be poorer than the sternotomy approach because the completeness of the transmural lesions may be disturbed by limited incisions. In patients with AF

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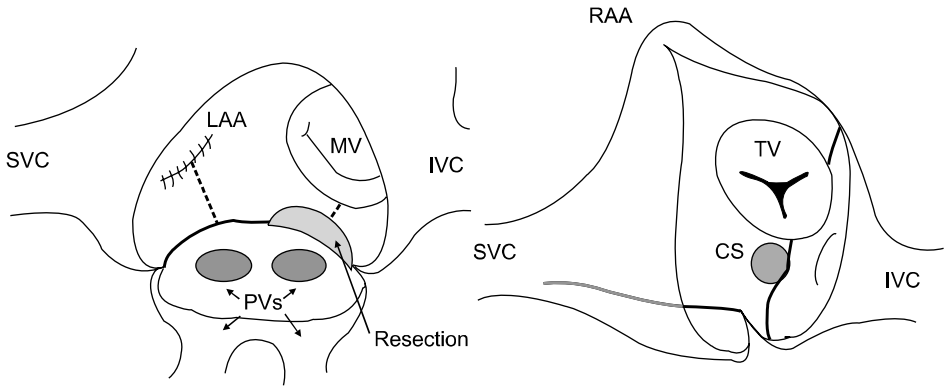

Fig. 1. The lines of the maze operation are shown. The left side includes a box lesion for the pulmonary vein isolation, a line toward the left atrial appendage, and a line toward the mitral annulus. The right side ablation was performed with the method in which the cavo-tricuspid isthmus was isolated using ablation lines. Another ablation line was made toward the superior vena cava. SVC=superior vena cava; LAA=left atrial auricle; MV=mitral valve; PV=pulmonary vein; IVC=inferior vena cava; RAA=right atrial auricle; TV=tricuspid valve; CS=coronary sinus.

associated with mitral valve (MV) disease, the port-access approach can establish a complete endocardial lesion set under cardiopulmonary bypass (CPB) support, which easily enables the combination of the maze procedure with MV surgery.

The aim of this study is to evaluate the clinical and rhythm outcomes of the AF ablation procedure thorough a port access mini-thoracotomy approach compared with conventional sternotomy in patients with AF associated with MV diseases.

MATERIALS AND METHODS

1) Patients

Between February 2006 and December 2009, a total of 199 patients underwent MV surgery with biatrial AF ablation in our institution. Excluding 64 patients who underwent aortic valve replacement or coronary artery bypass grafting surgery resulted in a final total of 135 subject patients. Among them, 78 underwent surgery through the port-access approach (the MICS group) by an automated endoscope system using an optimal positioning Aesop 3000 system (Computer Motion Inc., Santa Barbara, CA, USA), whereas 57 patients underwent a median sternotomy (the sternotomy group). The operative technique was chosen according to the surgeon's preference.

2) Surgical techniques

In the sternotomy group, conventional aortic and bicaval cannulation was used, and in the MICS group, the right femoral artery, right femoral vein, and right internal jugular vein cannulation procedure was used. About a 4 to 6 cm main mini-thoracotomy incision with an intercostal muscle division was made over the 4th intercostal space and another three small port incisions were made for the insertion of a Chitwood clamp, a thoracoscopy, and a vent sucker.

The AF ablation was performed using a flexible cryoablation system (SurgiFrost; Medtronic, Minneapolis, MN, USA). The right side ablation included cavo-tricuspid isthmus isolation and a line toward the superior vena cava. The left side ablation included a box lesion for isolation of the pulmonary veins, a line toward the left atrial appendage, and a line toward the mitral annulus, extending posteriorly (Fig. 1). The cryoablation was conducted at -120^{o}C for 1 or 2 minutes.

3) Postoperative management and follow-up

During the hospitalization, standard 12-channel surface electrocardiography (ECG) was checked daily. Patients with postoperative AF, atrial flutter, or atrial tachycardia were treated with amiodarone [5]. The patients with remaining AF were treated with amiodarone. The amiodarone therapy was

Table 1. Baseline characteristics of patients

Variables	MICS	Sternotomy	p-value
No. of patients	78	57	
Age (yr)	53.7±12.2	60.7±10.6	0.001*
Male gender	29 (37.2)	25 (43.8)	0.43
Diabetes mellitus	10 (12.8)	4 (5.1)	0.39
Hypertension	14 (17.9)	9 (11.5)	0.82
History of thromboembolic events	5 (6.4)	10 (17.5)	0.048*
CVA or TIA	4	10	
Other sites	1	0	
Prior cardiac surgery	3 (3.8)	3 (5.3)	0.70
AF profiles			
AF duration (yr)	5.0±6.7	9.3±8.5	0.001*
Fine (<1 mm) AF wave	17 (21.8)	29 (50.9)	<0.001*
AF type, n (%)			0.17
Paroxysmal	5 (6.4)	2 (3.5)	
Persistent (≤1 yr)	20 (25.6)	8 (14.0)	
Longstanding (>1 yr) persistent	53 (67.9)	47 (82.5)	
Mitral diagnosis			0.059
Rheumatic	54 (69.2)	28 (49.1)	
Degenerative	22 (28.2)	26 (45.6)	
Others	2 (2.5)	3 (5.3)	
Presence of left atrial thrombus	7 (9.0)	9 (15.8)	0.28
Echocardiographic data			0.81
Mitral regurgitation grade 0	12 (15.4)	7 (12.3)	
1	9 (11.5)	7 (12.3)	
2	10 (12.8)	9 (15.8)	
3	9 (11.5)	10 (17.5)	
4	38 (48.7)	24 (42.1)	
Mitral valve area (cm^2)	2.5±1.4	2.7±1.4	0.32
Tricuspid regurgitation grade 0	4 (5.1)	5 (8.8)	0.17
1	8 (10.2)	11 (19.3)	
2	17 (21.8)	15 (26.3)	
3	29 (37.2)	11 (19.3)	
4	20 (25.6)	15 (26.3)	
Left ventricular ejection fraction	55.8±8.1	57.2±6.6	0.26
Left atrial dimension (mm)	58.1±9.2	61.8±11.7	0.040*
Trans-tricuspid peak pressure gradient (mmHg)	37.2±12.0	39.1±16.7	0.43
Mitral valve operation			0.75
Repair	35 (44.9)	24 (42.1)	
Replacement	43 (55.1)	33 (57.9)	
Concomitant cardiac surgery			
Tricuspid valve repair	59 (75.6)	42 (73.7)	0.80
Atrial or ventricular septal defect closure	4 (5.1)	1 (1.8)	0.40

Values are presented as mean±standard deviation or number (%).
MICS=minimally invasive cardiac surgery; CVA=cerebral vascular accident; TIA=transient ischemic accident; AF=atrial fibrillation.
*$p<0.05$.

initiated with 900 to 1,200 mg intravenous loading for 24 hours followed by 600 to 900 mg per day for 1 to 2 weeks as a maintenance therapy. The patients with rapid ventricular rhythm despite the amiodarone medication were treated with a beta-blocker, calcium-channel blocker, or digitalis. In the valve repair or bioprosthetic valve insertion patients, warfarin

Table 2. Summary of early postoperative complications

Complications	MICS	Sternotomy	p-value
No. of patients with early complications	11 (14.1)	8 (14.0)	>0.99
Reexploration for bleeding	6 (7.7)	2 (3.5)	0.47
LV rupture	2 (2.6)	0	0.51
LCOS	1 (1.3)	1 (1.8)	>0.99
CVA	0	1 (1.8)	0.42
Acute renal failure	2 (2.6)	0	0.51
SSS or complete AVB	1 (1.3)	3 (5.3)	0.31
Pericardial effusion	2 (2.6)	3 (5.3)	0.65
Wound revision	1 (1.3)	0	>0.99
Early death	1 (1.3)	0	>0.99

Values are presented as number (%). $p < 0.05$.
MICS=minimally invasive cardiac surgery; LV=left ventricle; LCOS=low cardiac output syndrome; CVA=cerebral vascular accident; SSS=sick sinus syndrome; AVB=atrioventricular block.

was administered for three to six months with a target international normalized ratio (INR) of 1.5 to 2.5. The target INR was 2.5 to 3.5 for patients with a mechanical valve implant.

Early AF events were defined as AF events during the initial 3 months postoperatively. Late AF events were defined as the episodes of AF, atrial tachycardia, or atrial flutter after the initial 3 month period. The primary endpoint was the time to the first AF event.

4) Statistical analysis

Data were processed with SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA). The continuous variables are presented as mean±standard deviation or median and range and were compared using the Student's unpaired t-test or the Mann-Whitney U-test. The categorical variables were compared using the chi-square test or Fisher's exact test. Kaplan-Meier curves were generated to delineate freedom from AF or freedom from major adverse events. For comparisons of the incidence of time-related events between the two groups, a log-rank test was performed. To reduce the effect of a treatment selection bias and potential confounding, we performed an adjustment for the differences in the baseline characteristics by use of propensity score analysis [6]. The propensity scores were estimated without regard to outcome variables, with multiple logistic regression analysis. The prespecified covariates listed in Table 1 were included for the calculation of the propensity scores. The discrimination and calibration abilities of the propensity score model were assessed by means of C statistics and the Hosmer-Lemeshow test. The model had a C statistic of 0.842 and a Hosmer-Lemeshow goodness-of-fit p-value of 0.55, indicating the model was well calibrated with strong discrimination. There was limited overlap in the propensity scores between the two groups; therefore, the propensity score was used as a covariate in statistical models.

RESULTS

1) Baseline profiles

The baseline characteristics of the patients are shown in Table 1. The patients in the MICS group were younger than the patients in the sternotomy group. The AF duration was longer and the fine AF wave had more frequency in the sternotomy group. The left atrial (LA) size was significantly larger in the sternotomy group. All these findings were suggestive of a higher risk of postoperative AF recurrence in the sternotomy group than the MICS group [7].

2) Operative results

The CPB time and aortic cross clamping (ACC) time were approximately 20 to 30 minutes longer in the MICS group (CPB time: 176.0±49.5 minutes vs. 150.0±51.9 minutes, p=0.045; ACC time: 115.0±28.5 minutes vs. 98.3±33.9 minutes, p=0.037). The early postoperative complications are shown in Table 2. A total of 4 patients were required to have

Table 3. Freedom from AF (off AAD)

	3 mo		6 mo		12 mo		24 mo	
	MICS	STERN	MICS	STERN	MICS	STERN	MICS	STERN
Freedom from AF (off AAD)	66/71	43/52	62/67	42/50	59/63	39/46	43/47	19/20
p-value	0.091		0.23		0.20		>0.99	
Adjusted p-value	0.55		0.80		0.85		0.36	

AF=atrial fibrillation; AAD=anti-arrhythmic drugs; MICS=minimally invasive cardiac surgery; STERN=sternotomy.

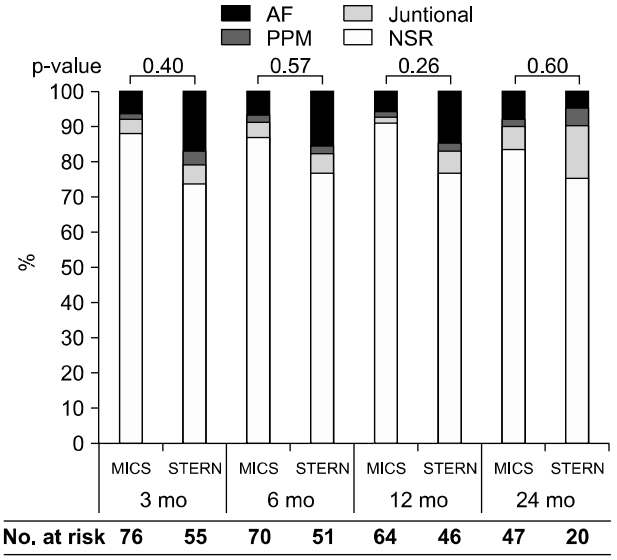

Fig. 2. The cardiac rhythm outcomes at 3-, 6-, 12- and 24-months after the operation. There were no significant differences in the rate of the normal sinus rhythm (NSR) or atrial fibrillation (AF) between the two groups at each point. MICS=minimally invasive cardiac surgery; STERN=sternotomy; PPM=permanent pacemaker rhythm; Junctional=junctional rhythm.

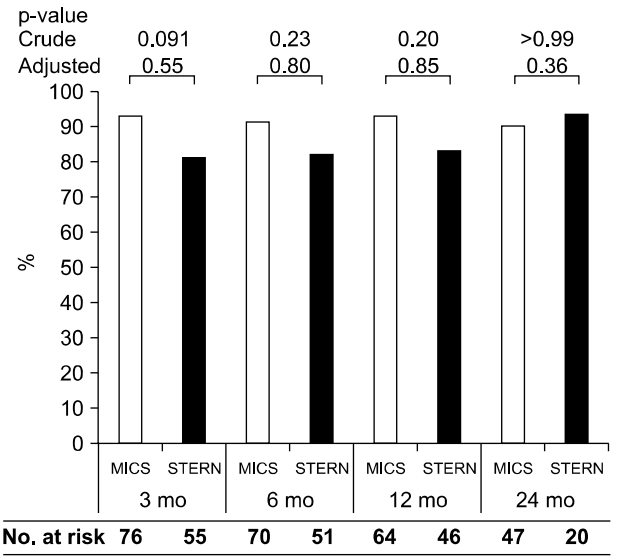

Fig. 3. The freedom from atrial fibrillation/atrial flutter/atrial tachyarrhythmia without anti-arrhythmic medications at each postoperative period in the minimally invasive cardiac surgery (MICS) group and the sternotomy group. There were no significant differences between the two groups in the crude and adjusted analyses until two years after surgery. STERN=sternotomy.

a permanent pacemaker implanted due to sick sinus syndrome or a complete atrioventricular block. There was only one early mortality in the MICS group (n=1, 1.3%); the cause of death was rupture of the left ventricle following a tissue valve replacement for rheumatic mitral stenosis. There were no significant differences between the two groups in the rate of reoperation for bleeding (6 vs. 2, p=0.47), requirement for permanent pacing (1 vs. 3, p=0.31), stroke (0 vs. 1, p=0.42), or wound problems (1 vs. 0, p=0.49).

3) Rhythm outcomes

A rhythm follow-up more than three months after surgery was possible in 131 patients (96.3%) with a median follow-up period of 18.3 months (range, 0.1 to 44.7 months), during which a total of 758 ECGs (5.7/patient) and 120 Holter monitoring data (0.9/patient) were acquired for analyses. Early AF events occurred in 17 patients (5 [6.5%] in the MICS group and 9 [16.3%] in the sternotomy group, p=0.40). In addition, 31 patients experienced late AF events during the follow-up period (13 [18.5%] in the MICS group and 18 [31.3%] in the sternotomy group, p=0.64). The rhythm outcomes at 3-, 6-, 12-, and 24-month points in time after operation are summarized in Table 3 and are illustrated in Fig. 2. There were no significant differences in the rate of the normal sinus rhythm or AF between the two groups over

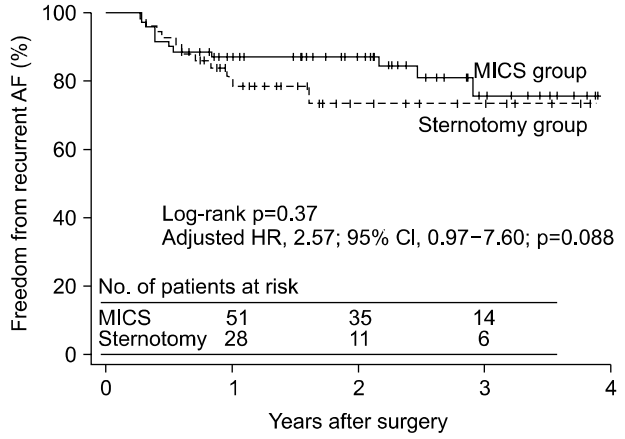

Fig. 4. The freedom from recurrent atrial fibrillation/atrial flutter/atrial tachyarrhythmia without anti-arrhythmic medications, and the Kaplan-Meier curve after adjustment. The two groups show similar rates of freedom from atrial fibrillation (AF) in the simple comparison and adjusted analysis. MICS=minimally invasive cardiac surgery; HR=hazard ratio; CI=confidence interval.

the course of the 2 years postsurgery. The two groups also had no significant differences in the freedom from AF without anti-arrhythmic agents on crude and adjusted analyses for two years after surgery (Fig. 3). When the freedom from recurrent AF was estimated with the Kaplan-Meier method, the two groups showed similar rates of freedom from AF in the simple comparison (Log-Rank p=0.37) and in an adjusted analysis (adjusted hazard ratio, 2.57; 95% confidence interval, 0.98－7.60; p=0.088) (Fig. 4).

4) Late clinical outcomes

A clinical follow-up was completed in 129 patients (95.6%) with a median follow-up period of 27.1 months (range, 0.1 to 58.1 months). The major complications are shown in Table 4. There were 9 late deaths (4 [5.1%] in the MICS group and 5 [8.8%] in the sternotomy group). In the MICS group, there were unknown causes for the following conditions: death in 1 patient, aortic pseudoaneurysm rupture in 1 patient, metabolic encephalopathy in 1 patient, and sepsis in 1 patient. In the sternotomy group, there were unknown causes for the following conditions: death in 3 patients, sequelae after stroke in 1 patient, and intracranial hemorrhage in 1 patient. Hemorrhagic events occurred in 7 patients (2 [2.6%] in the MICS group and 5 [8.8%] in the sternotomy group). There was only one reoperation in the sternotomy group due to an infective endocarditis at 30 months after a mechanical valve replacement. There were no significant differences in the rate of death and major complications in the propensity score adjusted comparison between the two groups (Table 5).

Table 4. Major complications

	MICS group	Sternotomy group
Late death	4 (5.1)	5 (8.8)
Stroke	0	1 (1.8)
Reoperation	0	1 (1.8)
Anticoagulation-related hemorrhages	2 (2.6)	5 (8.8)
Prosthetic mitral valve thrombosis	0	1 (1.8)
Congestive heart failure	0	1 (1.8)

Values are presented as number (%).
MICS=minimally invasive cardiac surgery.

Table 5. Hazard ratios for the clinical outcomes of the MICS group compared with the sternotomy group

Outcomes	HR	95% CI	p-value
Death			
Crude	0.65	0.19－2.26	0.50
Propensity score adjusted	0.39	0.09－1.76	0.39
Major complications			
Crude	0.18	0.04－0.89	0.035*
Propensity score adjusted	0.25	0.04－1.76	0.17
Death＋major complications			
Crude	0.50	0.18－1.35	0.50
Propensity score adjusted	0.39	0.11－1.37	0.14
Late AF episodes off AAD			
Crude	0.68	0.30－1.56	0.37
Propensity score adjusted	2.57	0.87－7.60	0.088

MICS=minimally invasive cardiac surgery; HR=hazard ratio; CI=confidence interval; AF=atrial fibrillation; AAD=anti-arrhythmic drugs.
*$p < 0.05$.

DISCUSSION

In this study, the clinical and rhythm outcomes of the MICS and sternotomy groups were comparable. Port-access mitral valve operations have been reported to provide accept-

able results, showing excellent cosmetic outcomes, shorter hospitalization, and reduced surgical trauma. The benefits of this approach may be maximized in patients with poor pulmonary function because it is reported to better preserve pulmonary function compared to conventional sternotomy [8,9].

In a study involving patients who underwent video-assisted pulmonary vein isolation using a bipolar radiofrequency ablation system, 72.5% of the patients were found to have recovered normal sinus rhythm postoperatively [10]. However, in the cited study, only 40% of the patients with long-standing AF had a normal sinus rhythm at discharge. This limited success rate may be attributable to the incomplete lesion sets and questionable transmurality of the ablation lesions [11].

Recent studies suggest that adding a maze operation to MV surgery does not increase operative mortality and morbidity [12,13]. Moreover, this procedure is reported to result in better rhythm outcomes and consequently reduce thromboembolic events in the long-term follow-up [14,15].

In our study, the AF recurrence rate of patients who underwent the port-access mini-thoracotomy approach was not higher than those in the sternotomy groups. These results may be attributable to the completeness of lesion sets (biatrial full maze) and transmurality of the lesions comparable to a standard sternotomy under the endocardial approach and full CPB support [15,16]. Although there were no significant differences in the patient profiles of two groups except age and AF duration, these two variables affected the surgical outcomes. AF tends to recur in patients who have factors such as an LA size larger than 60 mm, patients older than 60 years, and fine AF [7].

A limitation of this study is that it is a retrospective work with a non-randomized design. The relatively small number of patients in this study is another limitation, but data from a larger population of patients with a longer follow-up duration might resolve this limitation.

CONCLUSION

In conclusion, the port-access AF ablation is an effective and safe approach compared with the sternotomy approach in patients undergoing biatrial AF ablation combined with MV surgery. Therefore, the port-access approach may offer an additional surgical option for patients, with the benefit of having superior cosmetic results or less surgical trauma for the treatment of AF associated MV disease.

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