

Comparison of Radiofrequency Ablation and Cryoablation for the Recovery of Atrial Contractility and Survival

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Background: Limited comparative data are available on the efficacy of cryoablation versus radiofrequency ablation in patients with atrial fibrillation. This study aimed to compare radiofrequency ablation and cryoablation with regard to clinical outcomes and the restoration of sinus rhythm or atrial contractility. **Methods:** A total of 239 patients who underwent surgical ablation between August 2003 and December 2016 at our institution were included. The patients were divided into 2 groups according to the energy device that was used (group A: n=140, radiofrequency ablator; group B: n=99, cryoablator). Echocardiographic data, overall survival, and major cardiovascular and cerebrovascular event (MACCE)-free survival were compared between the 2 groups. **Results:** At 1 year of follow-up, the atrial contractility recovery rate was 32.2% (19 of 59) in group A and 48.8% (21 of 44) in group B. In addition, cryoablation was found to be a predictive factor for the recovery of atrial contractility (cryoablation vs. radiofrequency ablation: odds ratio, 2.540; 95% confidence interval, 1.063–6.071; p=0.036). The left ventricular ejection fraction was significantly higher in group B (53.1%±11.5% vs. 59.1%±6.3%, p=0.001). The median follow-up duration was 36 months. The 5-year overall survival rate was 80.1%±3.6% in group A and 92.1%±2.9% in group B (p=0.400). The 5-year MACCE-free survival rate was 70.3%±4.0% in group A and 70.9%±5.6% in group B (p=0.818). **Conclusion:** Cryoablation was associated with a higher atrial contractility restoration rate and better left ventricular function than radiofrequency ablation. However, no significant relationship was observed between the energy source and overall or MACCE-free survival.

Key words: 1. Cox-maze procedure
2. Atrial contraction
3. Radiofrequency
4. Ablation
5. Cryoablation

Introduction

Atrial fibrillation (AF) is the most common type of arrhythmia. It is associated with several long-term risks, including increased risks of stroke, heart fail-

ure, and all-cause mortality [1]. Performing a maze procedure for the treatment of AF concomitantly with other cardiac procedures can prolong the operation time, cardiopulmonary bypass (CPB) time, and cardiac arrest time. In addition, surgical ablation in-

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Table 1. Preoperative characteristics

Characteristic	Group A (n=140)	Group B (n=99)	p-value
Demographics			
Age (yr)	60.5±12.2	61.7±10.9	0.420
Male	67 (47.9)	42 (42.4)	0.406
Smoker			0.257
Never smoker	83 (59.3)	67 (67.7)	
Ex-smoker	33 (23.6)	22 (22.2)	
Current smoker	24 (17.1)	10 (10.1)	
Diabetes	26 (18.6)	11 (11.1)	0.116
Hypertension	46 (32.9)	43 (43.4)	0.096
Dyslipidemia	9 (6.4)	12 (12.1)	0.126
History of stroke	17 (12.1)	12 (12.1)	0.996
Chronic kidney disease	5 (3.6)	3 (3.0)	0.819
Acute renal failure	1 (0.7)	1 (1.0)	>0.999
Chronic obstructive pulmonary disease	13 (9.3)	9 (9.1)	0.959
Previous cardiac surgery	8 (5.7)	0	0.022
Infective endocarditis	4 (2.9)	3 (3.0)	0.999
Type of atrial fibrillation			0.999
Persistent	136 (97.1)	96 (97.0)	
Paroxysmal	4 (2.9)	3 (3.0)	
Preoperative echocardiography			
Left ventricle ejection fraction (%)	55.0±9.4	56.2±10.4	0.338
Left atrial dimension (mm)	55.8±10.0	55.4±9.8	0.775
Left ventricle end-diastolic dimension (mm)	54.6±10.8	52.47±9.7	0.119

Values are presented as mean±standard deviation for continuous variables and frequency (%) for categorical variables.

creases the risk of postoperative bleeding and the need for permanent pacemaker (PPM) insertion [2,3]. However, the substantial benefits from regaining sinus rhythm and atrial contractility warrant the potential risks [3]. Thus, performing surgical ablation concomitantly with other cardiac procedures is recommended in patients with AF [4]. Although the original 'cut-and-sew' Cox maze III procedure had higher efficacy, it was widely substituted with ablation using radiofrequency and cryothermal energy to overcome its technical complexity and to reduce the risk of postoperative bleeding [5-7]. However, few studies have compared the efficacy of radiofrequency ablation with that of cryoablation. The purpose of this study was to compare radiofrequency ablation and cryoablation with regard to clinical outcomes, including overall survival, major cardiovascular and cerebrovascular event (MACCE)-free survival, sinus rhythm restoration, atrial contractility, and overall cardiac function.

Methods

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital, which waived the need for informed consent (IRB approval no., B-1711-432-107).

1) Study population

A total of 239 consecutive patients who underwent surgical ablation at our institution with or without other cardiac procedures between August 2003 and December 2016 were included. Patients were divided into 2 groups according to the device utilized as an energy source for surgical ablation. Radiofrequency ablaters were either monopolar (Cardioblate; Medtronic Inc., Minneapolis, MN, USA) or bipolar (Cardioblate, Medtronic Inc.) and were used in 140 patients (group A), whereas cryoablaters ([Cardioblate, Medtronic Inc.] or [cryoICE; AtriCure Inc., Mason, OH, USA]) were used in 99 patients (group B). The preoperative characteristics of the patients are described in Table 1. A history of previous cardiac surgery was more

Table 2. Operative characteristics and maze lesion set

Characteristic	Group A (n=140)	Group B (n=99)	p-value
Urgency/emergency operation			0.037
Elective	131 (93.6)	99 (100.0)	
Urgency	8 (5.7)	0	
Emergency	1 (0.7)	0	
Concomitant procedure			
Valve	122 (87.1)	86 (86.9)	0.950
Coronary artery bypass graft surgery	17 (12.1)	2 (2.0)	0.004
Aorta	11 (8.0)	5 (5.1)	0.377
Other ^{a)}	13 (9.3)	9 (9.1)	0.959
Cardiopulmonary bypass time (min)	157.4±59.6	160.7±44.4	0.679
Aortic cross-clamping time (min)	120.6±48.9	129.4±143.6	0.551
Ablation lesion set			0.011
Bilateral	123 (87.9)	98 (99.0)	
Right-side	10 (7.1)	0	
Left-side	4 (2.9)	0	
Pulmonary vein isolation	3 (2.1)	1 (1.0)	

Values are presented as frequency (%) for categorical variables or mean±standard deviation for continuous variables.

^{a)}Repair of atrial septal defect, repair of ventricular septal defect, and tumor excision.

common in group A patients. Most of the patients had persistent AF, except for 7 (2.9%) who had paroxysmal AF.

2) Operative strategy and surgical ablation lesion set

The operative characteristics of the patients are described in Table 2. Replacement or repair of the valve was most frequently combined with surgical ablation. Concomitant coronary artery bypass grafting was more common in group A patients. Decisions on performing surgical ablation, the energy source, and the lesion set were made at the surgeon's discretion. Radiofrequency ablaters were available and used from the beginning of the study period, whereas cryoablaters were used starting in November 2009. The bilateral lesion sets did not change based on the choice of ablator. Radiofrequency ablation lesion sets were replaced by cryoablation lesion sets. The right atrial auricle was resected. A longitudinal line between the superior and inferior vena cava, a vertical line at the inferior vena cava, and an atrial septal line were cut and sewn. The lines of the tricuspid annulus, coronary sinus, pulmonary vein box, mitral annulus, left atrial auricle, and left atrial auricle to the mitral valve were ablated. When surgical ablation was conducted under CPB, the bypass and aortic cross-clamp time were recorded and compared be-

tween the patients in the 2 groups.

3) Clinical outcomes and echocardiography findings

Operative and anesthetic records of heart rhythm were reviewed at the end of each operation. The rhythm was assessed using a 12-lead electrocardiogram (ECG) or a 24-hour Holter monitor and compared between the groups at discharge and at a 1-year follow-up. Additionally, echocardiographic (echoCG) data were collected at discharge and at the 1-year follow-up. Measurements of the left ventricle ejection fraction (LVEF), left atrium anteroposterior dimension (LAD), and left ventricle end-diastolic dimension (LVEDD) were recorded. Atrial contractility was assessed by the presence of the A-wave (1: positive velocity from the left atrium to left ventricle was observed using Doppler echoCG after observing the p-wave on ECG or 2: atrial contraction was observed using tissue Doppler echoCG after observing the p-wave on ECG). Survival data were collected from outpatient clinical visits, telephone calls, or records of the Korean Ministry of the Interior and Safety. A MACCE was defined as the occurrence of any of the following: all-cause death, myocardial infarction, cardiac reoperation/reintervention, stroke, transient ischemia attack, or readmission for congestive heart failure.

Table 3. Sinus conversion and restoration of atrial contractility

Variable	Group A	Group B	p-value
Immediate postoperative rhythm			<0.001
Atrial fibrillation	30 (21.4)	8 (8.2)	
Sinus rhythm	100 (71.4)	66 (67.3)	
Sick sinus syndrome	10 (7.1)	24 (24.5)	
Rhythm at discharge			0.002
Atrial fibrillation	69 (49.3)	27 (27.6)	
Sinus rhythm	65 (46.4)	68 (69.4)	
Sick sinus syndrome	6 (4.3)	3 (3.1)	
Atrial contractility at discharge	14 (10.8)	20 (20.4)	0.043
Rhythm at 1 year			0.186
Atrial fibrillation	31 (30.7)	12 (19.7)	
Sinus rhythm	66 (65.3)	48 (78.7)	
Sick sinus syndrome	4 (4.0)	1 (1.6)	
Atrial contractility at 1 year	19 (32.2)	21 (48.8)	0.089
Left ventricle ejection fraction at 1 year (%)	53.1±11.5	59.1±6.3	0.001
Left atrial dimension at 1 year (mm)	48.3±8.5	52.0±17.7	0.164
Left ventricle end-diastolic dimension at 1 year (mm)	50.4±7.5	49±5.9	0.298
Permanent pacemaker insertion	8 (5.7)	2 (2.0)	0.202

Values are presented as frequency (%) for categorical variables or mean±standard deviation for continuous variables.

4) Statistical analysis

IBM SPSS Statistics ver. 22.0.0 (IBM Corp., Armonk, NY, USA) was used for statistical analyses. Continuous variables are presented as mean±standard deviation. The Student t-test was used to compare the results of continuous variables. The results for categorical variables are presented as frequency (%), and categorical variables were analyzed using the chi-square test or the Fisher exact test. Prognostic factors for atrial contractility were evaluated using multivariate logistic regression analysis. All p-values <0.05 were considered to indicate statistical significance. Survival data were depicted using a Kaplan-Meier curve and tested using the log-rank test.

Results

1) Sinus conversion and restoration of atrial contractility

Apart from 1 case of early death in group B, all patients had records of their immediate postoperative rhythm status and ECG before discharge. In the immediate postoperative period, the group A patients had a higher rate of AF, while the group B patients had a higher rate of abnormal sinus rhythm (Table 3). At discharge, the group A patients had a

higher rate of AF, whereas the group B patients had a higher rate of restoration of atrial contractility, which was less than half that of sinus conversion.

When rhythm and atrial contractility were compared at the 1-year follow-up using the available ECG and echoCG data, sinus rhythm and atrial contractility were more frequently found in the group B patients; however, no statistical significance was observed. In addition to atrial contractility, the LVEF was significantly higher in the group B patients, and was comparable with the preoperative data. The PPM insertion rate was higher in the group A patients. However, these differences were not statistically significant.

2) Predictive factors for restoration of atrial contractility

To assess the impact of the energy source used in the maze procedure on atrial contractility, logistic regression analysis was performed, with possible confounding factors including LAD, surgical ablation lesion set, and persistence of AF (Table 4). At discharge, it was found that the use of a cryoablator rather than a radiofrequency ablator contributed to the restoration of atrial contractility, which remained consistent at the 1-year follow-up (Table 5). Moreover,

Table 4. Predictive factor analysis for atrial contractility at discharge

Variable	Odds ratio (95% confidence interval)	p-value
Cryoablation (vs. radiofrequency)	2.603 (1.151-5.885)	0.022
Preoperative left atrial dimension	0.950 (0.910-0.991)	0.017
Bilateral ablation lesion set	0.550 (0.118-2.574)	0.448
Paroxysmal atrial fibrillation (vs. persistent)	0.544 (0.056-5.332)	0.602
Concomitant coronary artery bypass graft surgery	1.381 (0.306-6.236)	0.675

Multivariate logistic regression analysis.

Table 5. Predictive factor analysis for atrial contractility at 1-year follow-up

Variable	Odds ratio (95% confidence interval)	p-value
Cryoablation (vs. radiofrequency)	2.540 (1.063-6.071)	0.036
Preoperative left atrial dimension	0.964 (0.925-1.005)	0.084
Bilateral ablation lesion set	0.350 (0.041-2.986)	0.337
Paroxysmal atrial fibrillation (vs. persistent)	2.886 (0.226-36.796)	0.414
Concomitant coronary artery bypass graft	2.105 (0.127-34.834)	0.603

Multivariate logistic regression analysis.

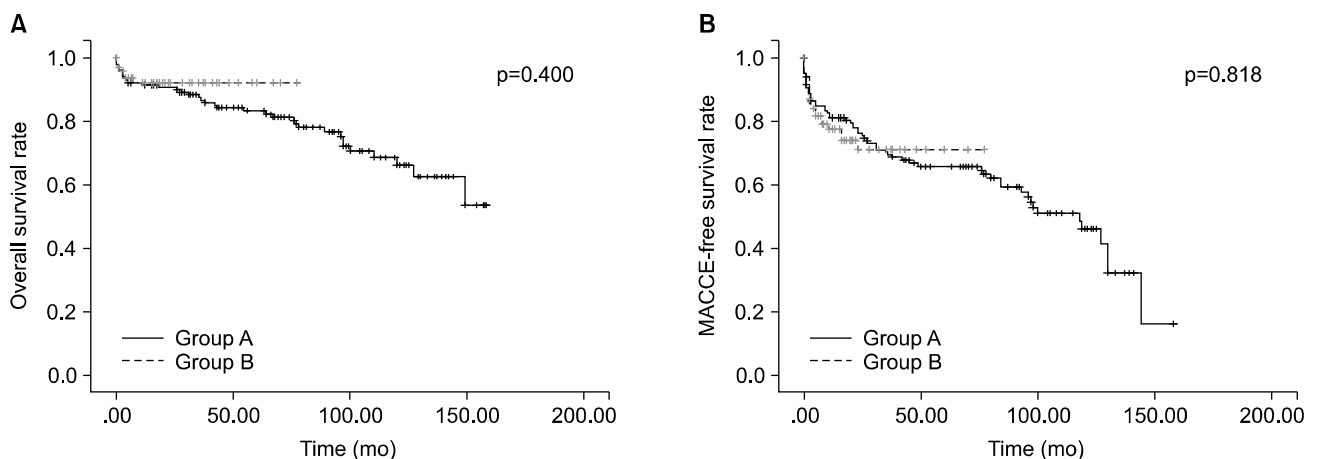


Fig. 1. Overall survival (A) and MACCE-free survival (B) of group A and group B. There was no significant difference in overall survival (p=0.400) or MACCE-free survival (p=0.818) between the 2 groups. MACCE, major cardiovascular and cerebrovascular event.

a smaller LAD was a predictive factor for restoration of atrial contractility at discharge (Table 4).

3) Survival analysis according to the energy source

There were 3 cases of early (30-day) mortality in both group A (3 of 140 [2.1%]) and group B (3 of 99 [3.0%]). At a median follow-up duration of 36 months (group A: 76.9 months; interquartile range [IQR], 33.2-111.5 months; group B: 18.6 months; IQR, 10.0-28.6 months), there were 44 overall mortalities. There was no significant difference in overall survival

between the 2 groups (Fig. 1A). The 1-year, 3-year, and 5-year overall survival rates were 91.4%±2.4%, 87.5%±2.8%, and 80.1%±3.6% in group A, respectively, and 95.9%±2.0%, 92.1%±2.9%, and 92.1%±2.9% in group B, respectively.

MACCE-free survival was not significantly different between the 2 groups (Fig. 1B). In group A, the 1-year, 3-year, and 5-year MACCE-free survival rates were 91.4%±2.4%, 80.2%±3.4%, and 70.3%±4.0%, respectively, while in group B, they were 92.8%±2.6%, 78.9%±4.3%, and 70.9%±5.6%, respectively.

Discussion

1) Sinus conversion

Both radiofrequency ablation and cryoablation are known to be safe and effective for restoring sinus rhythm in AF patients [5-12]. The sinus rhythm restoration rate has been reported to be between 61% and 85% [6-13], which is slightly lower than that reported for the standard 'cut-and-sew' Cox maze III procedure [5-12]. However, it has been argued that the restoration rate of the standard Cox-maze III has been overestimated, with the real restoration rate being approximately 80% [13].

Few studies have compared the results of the maze procedure according to the energy source used [8,9,12]. In the current study, the frequency of sinus rhythm was higher in the cryoablation group, whereas that of AF was higher in the radiofrequency ablation group at discharge. Similar to previous studies, the frequency of sinus rhythm at the 1-year follow-up increased in both groups [14]; however, this difference was not statistically significant.

2) Atrial contractility

The rate of restoration of atrial contractility, which has been reported to be 23%–76% [10,15,16], was found to be approximately 20% lower than that of sinus rhythm [9,14-16]. Theoretically, because of the atrial 'kick,' restoration of atrial contractility may be associated with increased ventricular preload, increased LVEF, reduced LAD, and reduced risk of stroke. However, its predictors have not yet been established [15,16]. In the current study, atrial contractility restoration rate at discharge was significantly higher in the cryoablation group than in the radiofrequency ablation group. And, the rate was associated with smaller preoperative LAD. In contrast, the only predictor of restoration of atrial contractility at the 1-year follow-up was cryoablation.

3) Clinical outcomes

There was no statistically significant difference in the overall survival and MACCE-free survival (including stroke) rates between the 2 groups. Owing to the restoration of atrial contractility, which was shown to be associated with the energy source used, the incidence of stroke or readmission for heart failure was expected to be lower in group B. However, be-

cause of the small number of patients and the short follow-up period, those clinical outcomes were not found to be significantly different between the 2 groups.

4) Echocardiographic

There were no significant differences in preoperative echoCG parameters between the 2 groups, while the group A patients showed higher LVEF, smaller LAD, and smaller LVEDD at the 1-year follow-up than the group B patients. The results of this study may be limited due to loss to follow-up and variations in the echoCG follow-up period. Accordingly, these outcomes should be interpreted with caution. However, these results imply that restoration of atrial contractility may be associated with good left heart function.

5) Permanent pacemaker insertion

According to the literature, the incidence of PPM insertion after the maze procedure is 7%–11% [2,5]. In this study, the incidence of PPM insertion was 5.7% in group A and 2.0% in group B; these rates are consistent with those reported in previous studies [2,5].

6) Limitation

This study was a retrospective single-center study. This center started performing surgical ablation in 2004. The energy sources and equipment used in surgical ablation have changed over time. Atrial contractility was only assessed by the presence of the A-wave in trans-mitral flow, rather than the A-wave in trans-tricuspid flow. In some studies, the clinical manifestations differed according to left and right atrial contractility [10,15,16]. In addition, although surgical ablation is known to affect the functional class of patients [3], our study did not include functional class assessments.

7) Conclusion

In the maze procedure, compared with radiofrequency ablation, cryoablation may be associated with improved atrial contractility recovery and left ventricular function, as observed on echoCG. However, no relationship between the energy source used in the maze procedure and overall or MACCE-free survival was observed.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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