Port-access versus sternotomy for treatment of long-standing persistent rheumatic atrial fibrillation combined with mitral valve surgery

Huy Q. Dang [1,], Tung V. Pham[2], Hong H. Nguyen[2], Hoa T. Tran[2], Ngoc M. Nguyen[3], Nga Q.Vu[2]*

ABSTRACT

Objectives: To compare the efficiency of atrial fibrillation (AF) ablation combined with mitral valve (MV) surgery through port-access with through traditional approach.

Methods: From July 2019 to October 2021, 81 patients with long-standing persistent rheumatic AF underwent biatrial ablation using monopolar radiofrequency devices combined with MV surgery. Patients were divided into two groups: sternotomy group (n=44) and totally endoscopic surgery (TES) group (n=37). Left atrial reduction was performed in all patients. The postoperative and follow-up results were analyzed and compared between the two groups. The mean follow-up times of the sternotomy and the TES groups were 22.2 ± 6.1 months and 20.3 ± 7.7 months, respectively.

Results: The perioperative characteristics did not differ between the two groups except that the aortic cross-clamp time and the cardiopulmonary bypass time of the TES group were longer than that of the sternotomy group. One patient in the TES group underwent reoperation. During the follow-up period, one death due to an unknown cause, one stroke for each group, and two patients with prosthetic dysfunction. The rates of atrial rhythm categories at the time of post-operation, discharge, 3-month, 6-month, and 1-year follow-up did not differ between the two groups. At 1-year follow-up, the rates of freedom from AF of the sternotomy group and the TES group were 90.9% and 91.9%, respectively; meanwhile, the rates of sinus rhythm were 86.4% and 86.5%, respectively.[1]

***Conclusions*:** AF ablation combined with mitral valve surgery can be performed through port-access as safely and effectively as through the traditional approach.

Keywords: Long-standing persistent AF, rheumatic mitral disease, biatrial ablation, left atrial reduction, port access.

[1] *Division of Minimally Invasive Cardiac Surgery, Cardiovascular Center, Hanoi Heart Hospital, Hanoi, Vietnam*

[2] *Department of cardiology, Hanoi Heart Hospital, Hanoi, Vietnam*

[3] *Department of vascular surgery, Cardiovascular Center, Hanoi Heart Hospital, Hanoi, Vietnam*

* *Corresponding author: Huy Q. Dang, Ph.D., MD.*

Tel: +84 - 982024618; E-mail: dangquanghuy@timhanoi.vn

Received date: 11/05/2023 Accepted date: 28/06/2023

1. INTRODUCTION

Atrial fibrillation (AF) is a common complication of mitral valve (MV) disease, primarily due to the rheumatic mechanism. The outcome of AF ablation depends on many factors. Among them, long-standing persistent AF, rheumatic mechanism, and dilated left atrium (LA) are the main causes leading to the failure of surgery ablation [1]. Conversely, LA reduction is approved to increase the rates of freedom from AF and restore sinus rhythm (SR) [2, 3]. Biatrial ablation has been shown to have a significantly higher success rate than pulmonary vein isolation or LA ablation [4-6]. Due to its low-cost value, the monopolar RF device was commonly used, but its effectiveness depended on surgeons' experience and was lower than the bipolar and cryoablation devices [7, 8].

Port access, also called totally endoscopic surgery (TES) without using a rib retractor, could improve the quality of life for patients compared to thoracotomy or sternotomy [9, 10]. However, there were few reports on the application of TES for AF ablation concomitant with MV surgery. A clinical question is raised whether the effectiveness of AF ablation combined with MV surgery through port-access is worse than the traditional approach. We designed this comparative study to answer the above question.

2. MATERIAL AND METHODS

2.1. Study design

The criteria for patient selection included: (1) rheumatic MV disease, which required surgery; (2) AF lasting at least 12 months. Exclusion criteria included: (1) former MV surgery; (2) giant LA (anteroposterior diameter of LA on transthoracic echocardiography was more than 70 mm); (3) age over 70 years; (4) rheumatic tricuspid valve disease and (5) aortic valve disease which required surgery.

From July 2019 to October 2022, 114 consecutive patients with rheumatic MV disease and long-standing persistent AF required surgical intervention. Among these, 61 patients were not eligible, and two lost contact. Finally, 81 subjects with written consent were enrolled in a prospective, non-randomized study. The ethics committee of the hospital approved the study. Patients were divided into two groups: (1) TES group; surgeries were performed through port and trocars, and (2) sternotomy group. Before surgery, all the patients and their families were informed about the operation's advantages, disadvantages, and possible complications. All the patients agreed to participate in the study and allowed the use of information, images, and videos during surgery for scientific purposes.

2.2. Endpoints

Primary endpoints related to one-year outcomes included cardiac death, stroke, recurrent atrial arrhythmias (AF, atrial flutter, atrial tachycardia), and SR rate. Cardiac death was defined as deaths caused by cardiovascular or unknown causes. Stroke was described as postoperative strokes not related to the operation. Any documented episode of atrial arrhythmias lasting more than 30 seconds (by ECG or Holter) was considered a recurrent arrhythmic event.

Secondary endpoints included reoperation, endoscopic failure, prosthetic dysfunction, permanent pacemaker (PPM) implantation, and conversion rate. Endoscopic failure was described as having to enlarge the incision or convert to sternotomy. It was designated as reoperation if the patients in the TES group had to be reoperated through sternotomy due to (bleeding or left ventricle rupture…). Prosthetic dysfunction was described as a prosthetic valve failure requiring fibrinolytic therapy or reoperation. Conversion rate was defined as the ratio of patients who underwent conversion during the entire follow-up period to the total number of patients.

Table 1. Preoperative patient characteristics

	Sternotomy group n = 44	**TES group** n = 37	**p**
Age, years	54.7 ± 8.0	53.2 ± 9.1	0.429
Female, n (%)	37 (84.1)	26 (70.3)	0.136
BSA, m^2	1.496 ± 0.134	1.541 ± 0.133	0.141
NYHA functional class > II, n (%)	2 (4.5)	3 (8.1)	0.656
History of stroke, n (%)	5 (11.4)	1 (2.7)	0.212
History of balloon mitral valvotomy, n (%)	5 (11.4)	10 (27.0)	0.071
Tricuspid valve regurgitation ≥ II, n (%)	32 (72.7)	25 (67.6)	0.612
Mitral valve disease			
Stenosis, n (%)	19 (43.2)	18 (48.6)	0.218
Regurgitation, n (%)	8 (18.2)	2 (5.4)	
Stenosis + regurgitation, n (%)	17 (38.6)	17 (45.9)	
Left atrial anteroposterior diameter, mm	52.9 ± 6.4	54.8 ± 7.4	0.231
Left atrial volume index (LAVI), ml/m^2	105.0 ± 38.4	103.5 ± 30.9	0.846
Left atrial appendage thrombosis, n (%)	10 (22.7)	6 (16.2)	0.463
LV end-diastolic diameter (mm)	47.1 ± 7.4	46.8 ± 3.6	0.772
LV ejection fraction (EF), %	57.2 ± 10.2	57.5 ± 7.9	0.875
Right ventricular end-diastolic diameter, mm	21.7 ± 5.0	22.0 ± 4.0	0.791
Systolic pulmonary artery pressure, mmHg	44.0 ± 12.3	43.8 ± 11.4	0.921
Preoperative antiarrhythmic medication			
β-blocker, n (%)	19 (43.2)	14 (37.8)	0.360
Digoxin, n (%)	8 (18.2)	8 (21.6)	
β-blocker + Digoxin, n (%)	3 (6.8)	0 (0)	
***BSA**: body surface area, **LV**: left ventricle, **NYHA**: New York Heart Association*			

2.3. Surgical procedures

All operations were performed by a single surgeon with an identical surgical protocol (except the approaches).

a. Totally endoscopic surgery

General anesthesia was achieved with a single-lumen trachea tube. Peripheral cannulation was established with a Dacron graft (Uni-Graft® K DV, B-Braun, Tuttlingen, Germany) anastomosed to the right common femoral artery, SVC, and IVC cannulas through the right internal jugular and right femoral veins.

Port and trocars on the right chest included: (1) a 3-4 cm main working port at the 5th intercostal space (ICS) on the anterior axillary line, exposure achieved by the smallest size wound protector (SurgiSleeve™ Wound Protector Extra Small Incision Size 2 - 4 cm, Covidien, Mansfield, MA, USA), without the use of a rib retractor; (2) a 5.5 mm trocar port (Thoracoport™ 5.5 mm, Covidien, Mansfield, MA, USA) at the 4th ICS on the midaxillary line for left-hand instrument and Chitwood clamp; (3) another 5.5 mm trocar at the 5th ICS on the midaxillary line for endoscopic camera and CO2 insufflation; and (4) a 5 mm trocar at the 6th ICS on the midaxillary line for LA suction tube (Fig. 1). Right after port/trocars installation, the pleural and pericardial spaces were filled with CO_2 at the rate of 2 l/min. After the aortic occlusion with a Chitwood clamp through the chest wall, Custodiol™ solution (Franz Kohler Chemie GMBH, Alsbach-Hähnlein, Germany) was perfused through an aortic root needle and was aspirated nearly entirely at the coronary sinus.

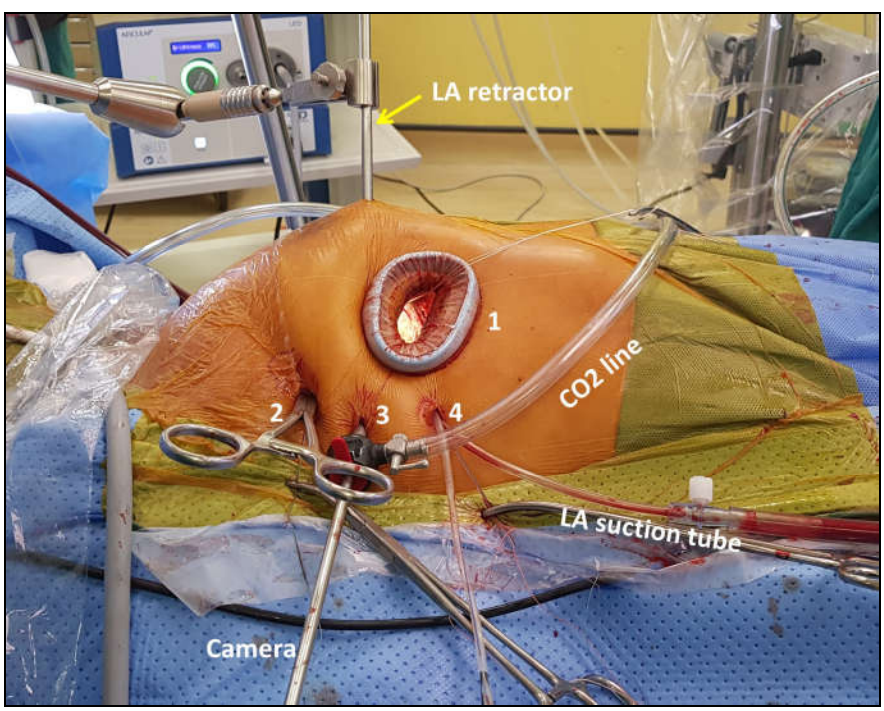

Figure 1: *Port and trocars installation.* ***LA****: left atrium;****(1)****:3-4cm main working port;* ***(2)****: clamp Chitwood;* ***(3)****: trocar for camera and* CO_2 *line;* ***(4):*** *trocar for left atrium suction tube*

b. Left atrial reduction

LA reduction was performed in all patients, with a suture line starting from the posterolateral wall of LA, passing the area between MV and left pulmonary veins, LA appendage, and reaching the anterolateral wall of LA. The LA appendage stayed inside the LA reduction suture line.

c. Biatrial ablation

For ablation, radiofrequency (RF) energy was used with a conventional monopolar device (Cardioblate® Surgical Ablation Pen, Medtronics Inc, MN, USA) for the sternotomy approach and a longer device (Cardioblate® XL Surgical Ablation Pen, Medtronics Inc, MN, USA) for port-access.

Left-sided ablation lesions including isolation of left (1) and right (2) pulmonary veins; (3) LA roof linear block; (4) LA posterior wall linear block; (5) LA appendage isolation; (6) mitral isthmus block. All the ablation lesions were endocardial (Fig. 2A). The ablation line (4) and part of the ablation lines (1), (2), and (6) were also epicardial ablations.

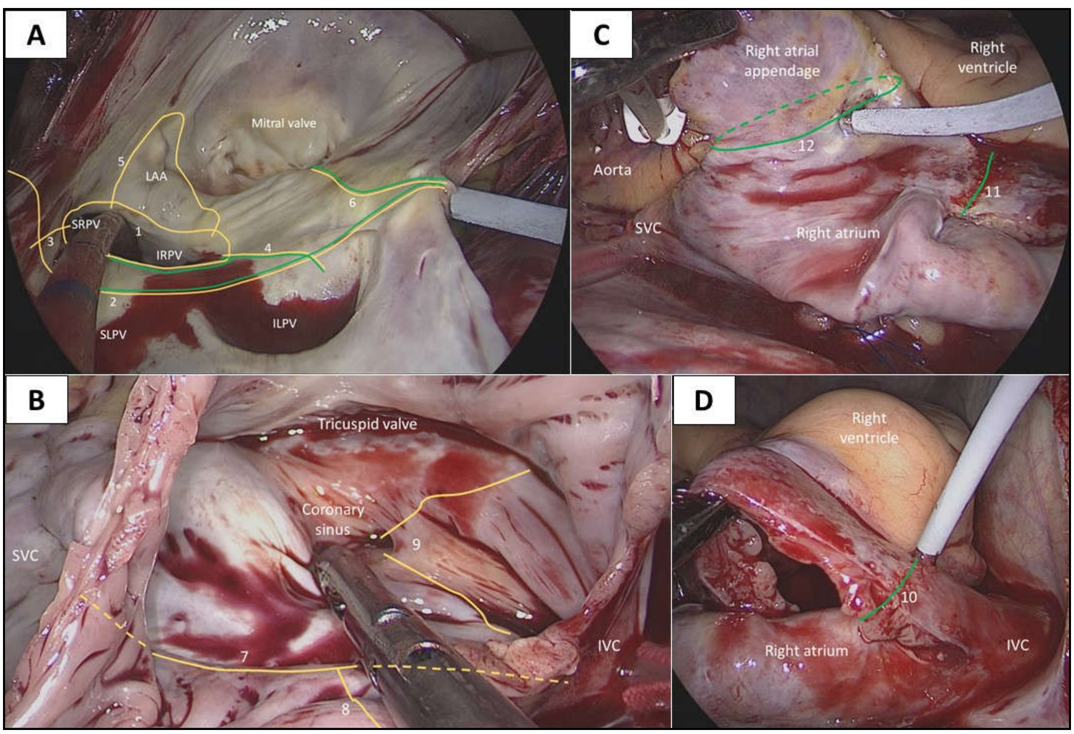

Figure 2: *Biatrial ablation set.* ***A.*** *Left-sided ablation lesions including isolation of left (1) and right (2) pulmonary veins; (3) LA roof linear block; (4) LA posterior wall linear block; (5) LA appendage isolation; (6) mitral isthmus block.* ***B, C,*** *and* ***D.*** *Right-sided ablation lesions including (7) SVC to IVC line; (8) connecting right atrium (RA) incision to the line (7), this ablation could be ignored if line (7) connected with RA incision; (9) cavotricuspid isthmus lesion; (10) and (11): lines connecting RA incision to the tricuspid annulus at 3 and 11 clock directions; (12) RA appendage isolation.* ***Yellow line****: endocardial ablation,* ***green line****: epicardial ablation.* ***LAA****: left atrial appendage;* ***ILPV****: inferior left pulmonary vein;* ***IRPV****: inferior right pulmonary vein;* ***IVC****: inferior vena cava;* ***SLPV****: superior left pulmonary vein;* ***SRPV****: superior right pulmonary vein;* ***SVC****: superior vena cava*

Right-sided ablation lesions including (7) SVC to IVC line; (8) connecting right atrium (RA) incision to the line (7), this ablation could be ignored if line (7) connected with RA incision; (9) cavotricuspid isthmus lesion; (10) and (11): lines connecting RA incision to the tricuspid annulus at 3 and 11 clock directions; (12) RA appendage isolation. The ablation lines (7), (8), and (9) were endocardial. The rest were epicardial (Fig. 2B, C, and D).

2.4. Perioperative care

All patients routinely received echocardiography, standard ECG, and 24h Holter ECG pre-operatively. Postoperative patients were monitored with 12-channel ECG and 24-hour Holter ECG. Arrhythmia recurrence was treated with intravenous amiodarone with a dose of 150 mg for 30 minutes, then 0.5mcg/kg/min for 24 hours. Later, oral amiodarone 200 mg per day was used. Oral amiodarone therapy was indicated for patients with SR and normal atrioventricular conduction. This therapy was not meant for patients with junctional rhythm or SR with atrioventricular block.

Electrical cardioversion could be done immediately after one or some failed drug conversion or at the next visit with a controlled ventricular rate. PPMs were indicated for patients presenting sinus node failure for third-degree atrioventricular block.

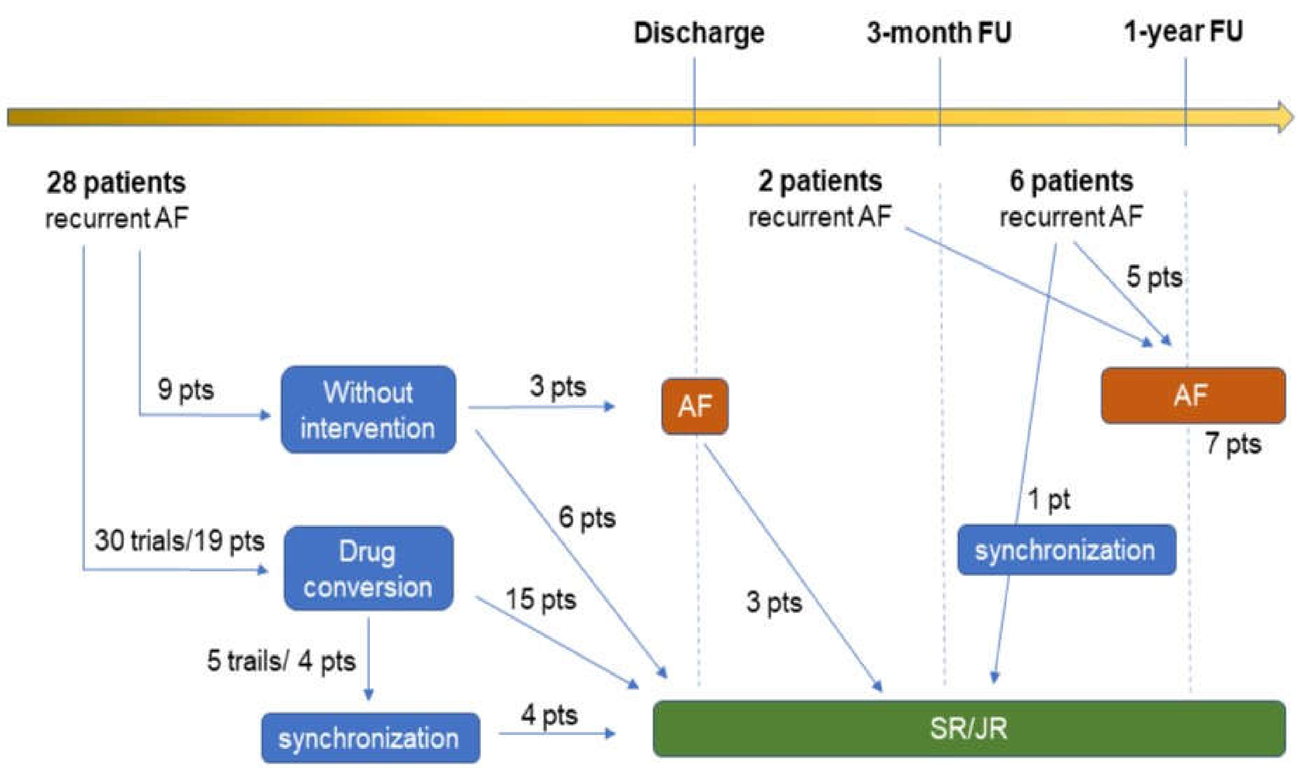

Figure 3: *Conversion process.* ***AF****: atrial fibrillation;* ***FU****: follow-up;* ***JR****: junctional rhythm;* ***Pt****: patient;* ***SR****: sinus rhythm*

2.5. Follow-up

All patients were followed up in the outpatient clinic every month. Standard ECG, 24-hour Holter ECG, and echocardiography were obtained every six months.

During the follow-up period, the anticoagulation dose was adjusted. Oral amiodarone therapy mentioned above was maintained until six months follow-up. It would be altered or ceased if complications (bradycardia, hypothyroidism, coagulation disorders) occurred. In case of arrhythmia recurrence, we tried pharmacologic conversion or electrical cardioversion. If the above attempts failed, drugs to control ventricular rate were used.

2.6. Data analysis

R statistical software version 4.2.1 and SPSS software version 22.0 (SPSS Inc., Chicago, IL, USA) were used for statistical analysis. Continuous variables were expressed as $\bar{X} \pm$ SD and categorical variables as percentages. Comparisons between groups were performed using the T-test for continuous variables and the Chi-square test or Fisher's exact test for categorical variables. The outcomes were compared using survival analysis (Kaplan-Meier and Cox analysis). The results were statistically significant with a p-value ≤ 0.05.

3. RESULTS

3.1. Baseline characteristics

There were no significant differences between the two groups in (1) anthropometric characteristics (age, sex, body surface area), (2) history of balloon mitral valvotomy and stroke, (3) valvular diseases (MV stenosis ± regurgitation, degree of tricuspid regurgitation grade II or higher, LA appendage thrombosis, LA size), (4) disease severity (NYHA, left ventricle end-diastolic diameter, left ventricle ejection fraction, right ventricle end-diastolic diameter, and systolic pulmonary arterial pressure), and (5) preoperative antiarrhythmic medication. The details of the baseline characteristics are presented in Table 1.

Table 2. Perioperative and postoperative parameters

	Sternotomy group n = 44	**TES group** n = 37	**p**
MV surgery			
MV replacement, n (%)	42 (95.5)	37 (100)	0.498
MV repair, n (%)	2 (4.5)	0	
TV surgery, n (%)			
TV ring annuloplasty, n (%)	27 (61.4)	16 (43.2)	0.197
TV posterior leaflet annuloplasty, n (%)	11 (25.0)	16 (43.2)	
Ablation time, minutes	19.3 ± 2.1	19.6 ± 2.9	0.655
ACC time, minutes	86.9 ± 11.8	122.5 ± 18.5	< 0.001
CPB time, minutes	119.6 ± 19.7	205.2 ± 26.1	< 0.001
Ventilation time, days	1.39 ± 0.75	1.51 ± 1.07	0.534
ICU stay time, days	3.0 ± 1.2	3.6 ± 1.5	0.057
Postop hospital stay time, days	12.1 ± 4.3	16.1 ± 7.6	0.004
LA reduction in diameter, mm	11.4 ± 7.7	12.5 ± 7.4	0.500
LA reduction in volume, ml/m^2	48.6 ± 33.5	49.8 ± 22.4	0.853

***ACC**: aortic cross-clamp, **CPB**: cardiopulmonary bypass, **LA**: left atrium, **MV**: mitral valve, **ICU**: intensive care unit, **TV**: tricuspid valve*

3.2. Surgical data

There was no significant difference in the MV and tricuspid valve techniques between the two groups. Except for two patients in the sternotomy group, all the remaining patients in both groups received MV replacement. The first patient with MV repair had commissurotomy and annuloplasty, while the other had posterior leaflet extension and annuloplasty. Both had mild mitral regurgitation at the last follow-up. The ablation time and the effect of LA reduction were similar between the two groups. The aortic cross-clamp (ACC) time and cardiopulmonary bypass (CPB) time in the TES group were significantly longer than the sternotomy group, with $p < 0.001$. The endoscopic approach prolonged ACC time by 35.6 minutes and CPB time by 84.3 minutes compared to the sternotomy approach. However, the recovery times (ventilation time, intensive care unit stay time) did not differ between the two groups. The postoperative hospital stay time of the TES group was longer than that of the sternotomy group.

Table 3: Complications

	Sternotomy group n = 44	**TES group** n = 37
Perioperative complications		
Thirty-day mortality, n (%)	0	0
Low cardiac output, n (%)	0	0
Pericardial effusion tamponade, n (%)	0	0
Embolism, n (%)	0	0
Reoperation, n (%)	0	1 (2.0)
Complications during follow-up		
Cardiac death, n (%)	1 (2.3)	0
Stroke, n (%)	1 (2.3)	1 (2.7)
Intracranial hemorrhage, n (%)	1 (2.3)	0
Prosthetic dysfunction		
Fibrinolytic therapy, n (%)	1 (2.3)	0
Re-operation, n (%)	1 (2.3)	0

3.3. In-hospital outcome

One patient in the TES group underwent reoperation after MV replacement because of a left ventricular rupture at the ICU. This patient was discharged after 44 days without neurological complications, and the SR was maintained at 26 months follow-up. No thirty-day mortality and failure of port-access were noted.

3.4. Complications during follow-up

The mean follow-up times of the sternotomy and the TES groups were 22.2 ± 6.1 months and 20.3 ± 7.7 months, respectively. Each group recorded one case of stroke. Prosthetic dysfunction was recorded in two patients in the sternotomy group, in which one patient was successfully treated with fibrinolytic therapy while the other patient underwent valve replacement. One patient died of an unknown cause 16 months after surgery. The details are presented in Table 3.

3.5. AF ablation outcomes

There were no significant differences in the two groups' early and late recurrence rates (Table 4). Most of them were early recurrent before discharge, with rates of 31.8% and 37.8% in the sternotomy and TES groups, respectively. The rate of drug conversion and the number of attempts did not differ between the two groups. The details of the conversion process are illustrated in Fig 3.

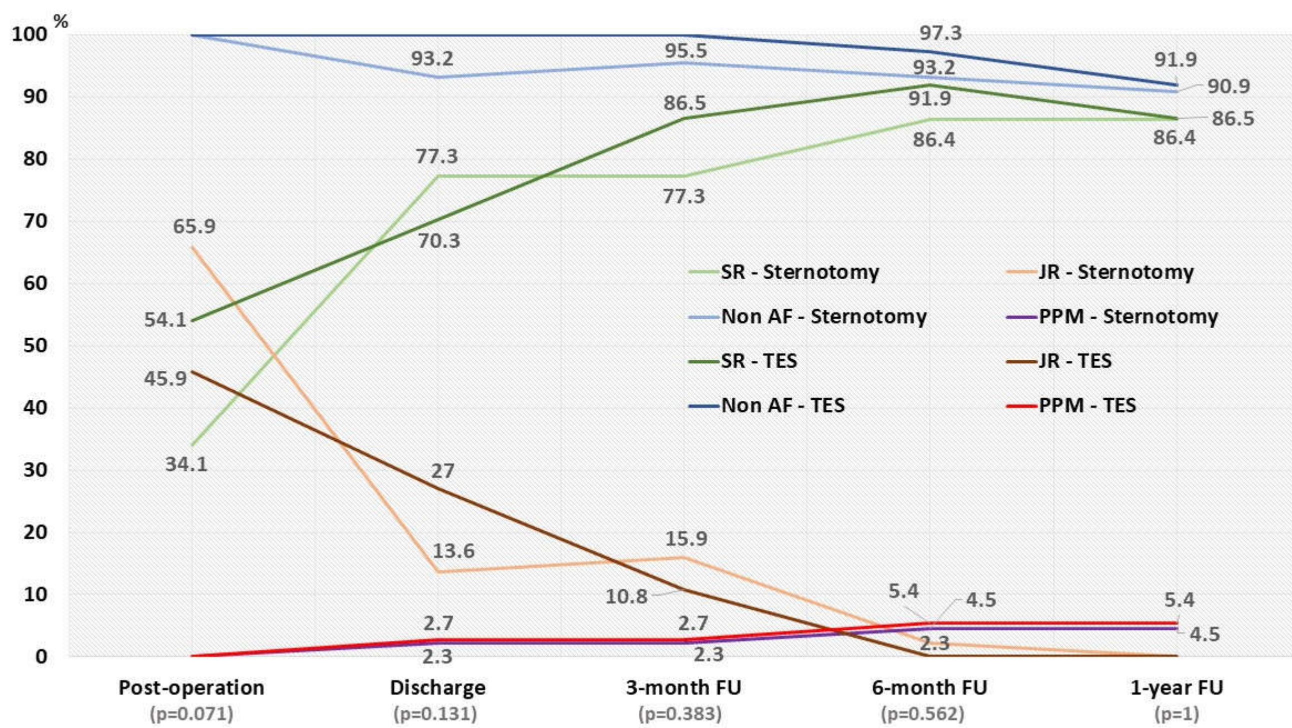

Figure 4: *Heart rhythm modification during first-year follow-up.* ***AF****: atrial fibrillation;* ***FU****: follow-up;* ***JR****: junctional rhythm;* ***PPM****: permanent pacemaker;* ***SR****: sinus rhythm;* ***TES****: totally endoscopic surgery*

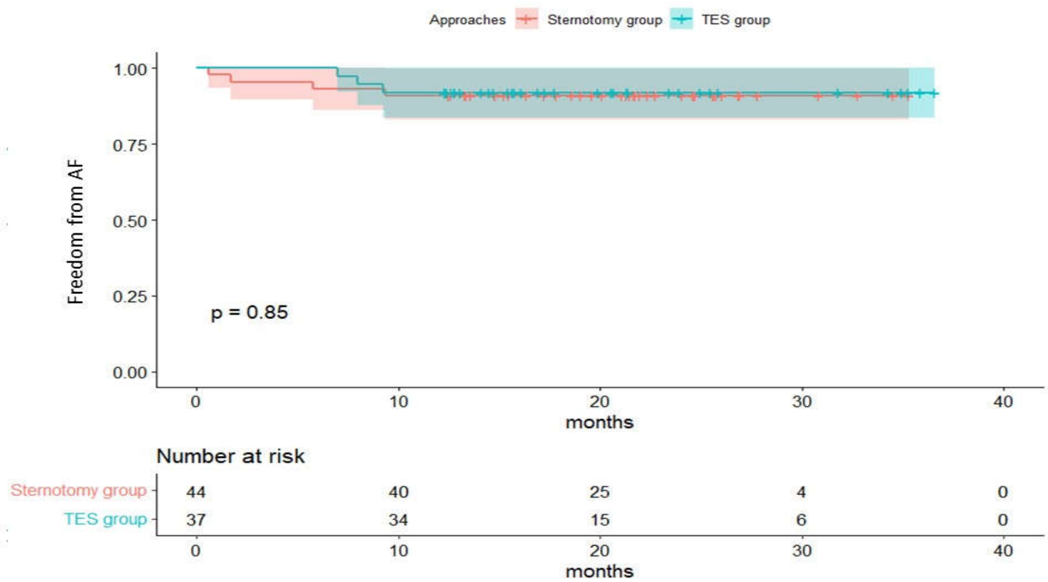

Figure 5: *Kaplan-Meier curves of freedom from atrial fibrillation*

There was no difference in heart rhythm modification at time points during the first-year follow-up, with the rates of AF free and SR at 1-year follow-up were 90.9% and 86.4% in the sternotomy group, 91.9% and 86.5% in the TES group (Table 4, Fig 4 and 5).

Table 4: Outcomes of atrial fibrillation ablation

	Sternotomy group n = 44	**TES group** n = 37	**p**
Follow-up time, months	22.2 ± 6.1	20.3 ± 7.7	0.205
AF recurrence			
Early recurrence, n (%)	15 (34.1)	14 (37.8)	0.726
During hospitalization, n (%)	14 (31.8)	14 (37.8)	
From discharge to 3-month follow-up, n (%)	2 (4.6) *	0	
Late recurrence, n (%)	2 (4.5)	4 (10.8)	0.404
Drug conversion, n (%)	8 (18.2)	12 (32.4)	0.138
One attempt, n (%)	5 (62.5)	5 (41.7)	
Two attempts, n (%)	3 (37.5)	5 (41.7)	0.563
Three attempts, n (%)	0	2 (16.7)	
Atrial rhythm at 1-year follow-up			
Sinus rhythm, n (%)	38 (86.4)	32 (86.5)	
A.F., n (%)	4 (9.1)	3 (8.1)	1
PPM, n (%)	2 (4.5)	2 (5.4)	

AF*: atrial fibrillation*

**: 1 patient had AF recurrence and underwent cardioversion successfully before discharge. Then, he had AF recurrence again before 3-month follow-up.*

4. DISCUSSION

AF ablation is a common indication associated with MV surgery. The effectiveness of AF ablation depends on many factors. The rheumatic mechanism, long-standing persistent AF, and dilated LA are considered the most critical risk factors for AF ablation [1]. In addition, the source of energy and the device (monopolar or bipolar) also significantly affect the success rate of surgery. Although cryoablation demonstrated high therapeutic efficiency, the requirement for a rare gas supply system and the high cost may prevent it from being widely applied [11, 12]. RF is the most common energy source used, and the bipolar device is demonstrated to be more reliable in creating transmural lesions than the monopolar device [8]. In this study, we selected patients with adverse factors, including rheumatic mechanism, long-standing persistent AF, and dilated LA Monopolar RF device was used in this study because cryoablation was not available in our country.

Some approaches for AF ablation combined with MV surgery include partial sternotomy, mini-thoracotomy, and port-access with or without robotic assistance. Mini-thoracotomy with rib retractor and direct vision is most used because of convenient manipulation and proximity to the traditional approach [11, 13-15]. In addition, robotic-assisted endoscopic surgery has been widely applied with good results, but the high treatment cost has made it unsuitable for developing countries [16-18]. There are only some reports on using port-access without robotic assistance for concomitant AF ablation in patients undergoing MV surgery due to its complete endoscopic manipulation and prolonged surgical times [19-21]. A clinical question is raised whether the surgical efficiency through this approach is worse than the traditional approach. The surgical efficiency includes: (1) techniques are not restricted by access, (2) perioperative outcomes and survival, and (3) AF ablation outcomes.

In TES, surgeons tend to minimize techniques due to the difficulties of manipulation and the pressure of prolonged surgical times [19, 21]. In our study, we recorded the similarity in techniques applied between the two groups, including MV replacement/ repair, techniques for tricuspid valve repair, LA reduction with the same method, and biatrial ablation with the same scheme in all patients (Table 2).

The perioperative outcomes were similar between the two groups, including ablation time, ventilation time, ICU stay time, and probability of major complications. In the TES group, no case required incision enlargement or conversion to sternotomy, while Akpinar et al. had to enlarge the incision in 2 patients [19]. No major complication was noted, except in one case in the TES group that needed reoperation because of left ventricular rupture. Lawrance et al. reported that the reoperation rate for bleeding was 2% in the mini-thoracotomy group [22]. Furthermore, other studies noted various complications, including mortality, myocardial infarction, low cardiac output, stroke, cardiac tamponade, and excessive bleeding [19-21]. In our study, the ACC and CPB time of the TES group was significantly more prolonged than that of the sternotomy group, 35.6 minutes and 85.6 minutes, with $p< 0.001$, respectively. The postoperative hospital stay time of the TES group was longer than that of the sternotomy group because one patient in the TES group underwent reoperation, and some patients experienced cardioversion (single drug or combined with electric cardioversion) more times than in the sternotomy group before discharge. However, this difference was not significant (Table 4).

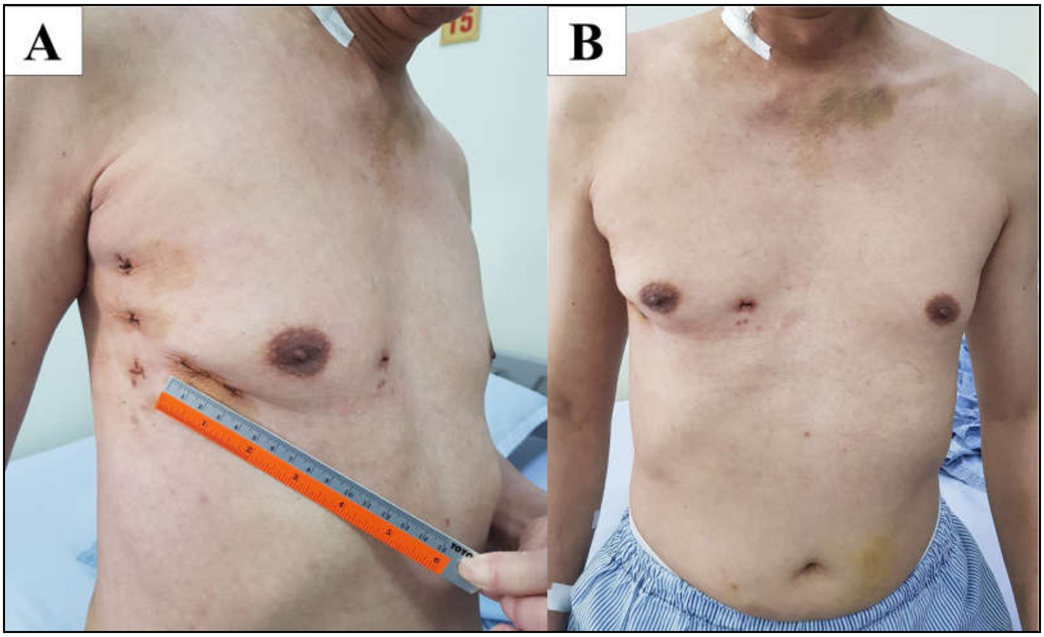

Figure 6: *Scars at discharge*

We based on the heart rhythm modification of patients during the first-year follow-up to compare the efficiency of AF ablation between the two groups. We noted that the rates of atrial rhythm categories at the time of post-operation, discharge, 3-month, 6-month, and 1-year follow-up did not differ between the two groups (Fig 4). At 1-year follow-up, the rates of freedom from AF of the sternotomy group and the TES group were 90.9% and 91.9%, respectively; meanwhile, the rates of SR of these two groups were 86.4% and 86.5%, respectively. Our results were like that in the study of Akpinar et al. using monopolar RF device through port-access [19], similar to the results in the study of Chavez et al. using bipolar RF device on rheumatic patients [23], and also the results in the research of Niv et al. using cryoablation combined with RF bipolar device [24]. We attribute the high rate of 1-year success to three factors, including: (1) systematic and effective LA reduction, (2) systematic biatrial ablation, and (3) in case of AF recurrence, cardioversion was performed as many times as possible until success before discharge and during the follow-up period.

LA size assessed by anteroposterior diameter and volume plays a vital role in surgical ablation. Besides preoperative LA anteroposterior diameter, Kasemsarn et al. showed that the postoperative LA anteroposterior diameter > 50 mm is a risk factor for ablation failure with HR = 4.26, p< 0.001 [3]. LA reduction had a proven role in improving LA function [25], increasing the success rate of SR cardioversion [26], and reducing the risk of recurrent AF [3]. Unlike sternotomy, LA reduction techniques are more challenging and take more time than through port-access. Besides our study, only Aydin et al. routinely practiced this technique in the robotic-assisted endoscopic method [27]. We noted no difference between the two groups in the efficiency of LA reduction in anteroposterior diameter and LA volume index (Table 2). Most of the patients in our study had LA anteroposterior diameters less than 50 mm, which may be the critical factor in maintaining SR and successful cardioversion.

Biatrial ablation has been shown to have a significantly higher success rate than pulmonary vein isolation or LA ablation [4-6]. Monopolar RF devices must be applied point-by-point, prolonging ablation time [23]. For AF ablation through port-access, authors performed left-sided ablation in all patients [20, 27], or in most cases [19] to save the ACC time. Despite the longer operation times, the rates of freedom from AF and SR at 1-year follow-up in our TES group (biatrial ablation) were 91.9% and 86.5%, respectively, which were higher than that in the study using pulmonary vein isolation of Jeanmart et al. (71.7% and 69.7%, respectively) [20]. Otherwise, biatrial ablation has been shown to increase the incidence of PPM [5, 6] or make no difference in comparison with LA ablation [28]. In our study, the PPM rates during the follow-up period were 4.5% in the sternotomy group and 5.4% in the TES group. These results were acceptable compared to the rate of 6.9% to 11% in some previous reports [24, 29].

Although blank period, the atrial rhythm category at discharge plays an essential role in the 1-year success rate and should be controlled. According to the 2017 expert consensus statement, the early recurrence rate is as high as 50%, and only 50% of these patients will be freedom from AF during long-term follow-up [1]. Niv et al. showed that early atrial rhythm control after surgical ablation reduced the early recurrence rate from 52% to 19% [30]. In addition to the tissue inflammatory response [1], preoperative LA volume > 24 cm^2 and especially rheumatic mechanism were pointed out by Rostagno et al. as risk factors for early recurrence before discharge with OR of 1.07 and 4.52, respectively [31]. There is a trial designed to investigate the efficiency of perioperative intravenous amiodarone on cardioversion of AF early after ablation [32]. We recorded that the rates of recurrent atrial arrhythmias before discharge were 31.8% in the sternotomy group and 37.8% in the TES group. This rate was 53% and 29.9%, according to Niv et al. and Zhu et al., respectively [24, 33]. We performed cardioversion for most patients with AF recurrence during hospitalization so that the rate of AF at discharge is as low as possible. The high rate of successful cardioversion in this period was also noted in the study of Niv et al. [24].

Study limitations:

The study needs to be expanded to increase the number of patients and achieve long-term follow-up to record more late recurrent events and analyze risk factors for the failure of AF ablation.

5. CONCLUSION

With our experience, AF ablation using a monopolar RF device combined with mitral valve surgery can be performed through port-access as safely and effectively as through the traditional approach.

REFERENCES

1. Calkins, H., G. Hindricks, R. Cappato, Y.H. Kim, E.B. Saad, L. Aguinaga, T. Yamane, 2017 HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. Europace, 2018. 20(1): p. e1-e160.

2. Yalcinkaya, A., A.I. Diken, E. Aksoy, G. Lafci, O.F. Cicek, E. Kadirogullari, K. Cagli, Effect of Left Atrial Reduction on Restoration and Maintenance of Sinus Rhythm in Patients Undergoing Mitral Valve Replacement: A Pilot Study. Thorac Cardiovasc Surg, 2016. 64(5): p. 441-6.

3. Kasemsarn, C., P. Lerdsomboon, V. Sungkahaphong, and T. Chotivatanapong, Left atrial reduction in modified maze procedure with concomitant mitral surgery. Asian Cardiovasc Thorac Ann, 2014. 22(4): p. 421-9.

4. Blackstone, E.H., H.L. Chang, J. Rajeswaran, M.K. Parides, H. Ishwaran, L. Li, . . . A.M. Gillinov, Biatrial maze procedure versus pulmonary vein isolation for atrial fibrillation during mitral valve surgery: New analytical approaches and end points. J Thorac Cardiovasc Surg, 2019. 157(1): p. 234-243 e9.

5. Phan, K., A. Xie, Y.C. Tsai, N. Kumar, M. La Meir, and TD. Yan, Biatrial ablation vs. left atrial concomitant surgical ablation for treatment of atrial fibrillation: a meta-analysis. Europace, 2015. 17(1): p. 38-47.

6. Zheng, S., H. Zhang, Y. Li, J. Han, Y. Jia, and X. Meng, Comparison of Left Atrial and Biatrial Maze Procedure in the Treatment of Atrial Fibrillation: A Meta-Analysis of Clinical Studies. Thorac Cardiovasc Surg, 2016. 64(8): p. 661-671.

7. Comas, G.M., Y. Imren, and M.R. Williams, An overview of energy sources in clinical use for the ablation of atrial fibrillation. Semin Thorac Cardiovasc Surg, 2007. 19(1): p. 16-24.

8. Bugge, E., I.A. Nicholson, and S.P. Thomas, Comparison of bipolar and unipolar radiofrequency ablation in an in vivo experimental model. Eur J Cardiothorac Surg, 2005. 28(1): p. 76-80; discussion 80-2.

9. Ma, ZS, Q.Y. Yin, M.F. Dong, Z.Y. Feng, and L.X. Wang, Quality of life in patients undergoing totally thoracoscopic closure for atrial septal defect. Ann Thorac Surg, 2011. 92(6): p. 2230-4.

10. Cherup, L.L., RD Siewers, and J.W. Futrell, Breast and pectoral muscle maldevelopment after anterolateral and posterolateral thoracotomies in children. Ann Thorac Surg, 1986. 41(5): p. 492-7.

11. Li, X., L. Liu, L. Song, C. Luo, B. Yang, and Y. Liu, [Application of cryoablation in minimally invasive mitral valve surgery]. Zhong Nan Da Xue Xue Bao Yi Xue Ban, 2016. 41(3): p. 295-9.

12. Blomström-Lundqvist, C., B. Johansson, E. Berglin, L. Nilsson, S.M. Jensen, S. Thelin, . . . P. Blomström, A randomized double-blind study of epicardial left atrial cryoablation for permanent atrial fibrillation in patients undergoing mitral valve surgery: the SWEDish Multicentre Atrial Fibrillation study (SWEDMAF). Eur Heart J, 2007. 28(23): p. 2902-8.

13. Jiang, Z., M. Tang, N. Ma, H. Liu, F. Ding, C. Bao, and J. Mei, Right minithoracotomy versus conventional median sternotomy for patients undergoing mitral valve surgery and Cox-maze IV ablation with entirely bipolar radiofrequency clamp. Heart Vessels, 2018. 33(8): p. 901-907.

14. Massimiano, P.S., B. Yanagawa, L. Henry, SD. Holmes, G. Pritchard, and N. Ad, Minimally invasive fibrillating heart surgery: a safe and effective approach for mitral valve and surgical ablation for atrial fibrillation. Ann Thorac Surg, 2013. 96(2): p. 520-7.

15. Mei, J., N. Ma, Z. Jiang, D. Zhao, C. Bao, and F. Ding, Concomitant Maze IV Ablation Procedure Performed Entirely by Bipolar Clamp Through Right Lateral Minithoracotomy. Ann Thorac Surg, 2016. 102(5): p. e473-e475.

16. Ju, M.H., J.H. Huh, C.H. Lee, H.J. Kim, H.G. Je, J.B. Kim, . . . J.W. Lee, Robotic-

Assisted Surgical Ablation of Atrial Fibrillation Combined With Mitral Valve Surgery. Ann Thorac Surg, 2019. 107(3): p. 762-768.

17. Roberts, H.G., L.M. Wei, A. Dhamija, C.C. Cook, and V. Badhwar, Robotic assisted cryothermic biatrial Cox-Maze. J Cardiovasc Electrophysiol, 2021. 32(10): p. 2879-2883.

18. Almousa, A., J.H. Mehaffey, L.M. Wei, A. Simsa, J.W.A. Hayanga, C. Cook, . . . V. Badhwar, Robotic-assisted cryothermic Cox maze for persistent atrial fibrillation: Longitudinal follow-up. J Thorac Cardiovasc Surg, 2022.

19. Akpinar, B., M. Guden, E. Sagbas, I. Sanisoglu, U. Ozbek, B. Caynak, and O. Bayindir, Combined radiofrequency modified maze and mitral valve procedure through a port access approach: early and mid-term results. Eur J Cardiothorac Surg, 2003. 24(2): p. 223-30.

20. Jeanmart, H., F. Casselman, R. Beelen, F. Wellens, I. Bakir, F. Van Praet, . . . H. Vanermen, Modified maze during endoscopic mitral valve surgery: the OLV Clinic experience. Ann Thorac Surg, 2006. 82(5): p. 1765-9.

21. Güden, M., B. Akpinar, E. Sagbas, I. Sanisoglu, M.U. Ergenoglu, and U. Ozbek, A radiofrequency modified maze and valve procedure through a port-access approach. Heart Surg Forum, 2003. 6(5): p. 292-6.

22. Lawrance, C.P., M.C. Henn, J.R. Miller, L.A. Sinn, R.B. Schuessler, H.S. Maniar, and R.J. Damiano, Jr., A minimally invasive Cox maze IV procedure is as effective as sternotomy while decreasing major morbidity and hospital stay. J Thorac Cardiovasc Surg, 2014. 148(3): p. 955-61; discussion 962-2.

23. Chavez, E.K., A.S. Colafranceschi, A.J.O. Monteiro, L.S. Canale, E.T. Mesquita, C. Weksler, . . . A. Oliveira, Surgical Treatment of Atrial Fibrillation in Patients with Rheumatic Valve Disease. Braz J Cardiovasc Surg, 2017. 32(3): p. 202-209.

24. Ad, N., S. Barnett, E.A. Lefrak, A. Korach, A. Pollak, D. Gilon, and A. Elami, Impact of follow-up on the success rate of the cryosurgical maze procedure in patients with rheumatic heart disease and enlarged atria. J Thorac Cardiovasc Surg, 2006. 131(5): p. 1073-9.

25. Marui, A., Y. Saji, T. Nishina, E. Tadamura, S. Kanao, T. Shimamoto, . . . M. Komeda, Impact of left atrial volume reduction concomitant with atrial fibrillation surgery on left atrial geometry and mechanical function. J Thorac Cardiovasc Surg, 2008. 135(6): p. 1297-305.

26. Marui, A., T. Nishina, K. Tambara, Y. Saji, T. Shimamoto, M. Nishioka, . . . M. Komeda, A novel atrial volume reduction technique to enhance the Cox maze procedure: initial results. J Thorac Cardiovasc Surg, 2006. 132(5): p. 1047-53.

27. Aydin, U., O. Sen, E. Kadirogullari, Z. Kahraman, and B. Onan, Robotic Mitral Valve Surgery Combined with Left Atrial Reduction and Ablation Procedures. Braz J Cardiovasc Surg, 2019. 34(3): p. 285-289.

28. Kim, J.B., JH Bang, S.H. Jung, S.J. Choo, C.H. Chung, and J.W. Lee, Left atrial ablation versus biatrial ablation in the surgical treatment of atrial fibrillation. Ann Thorac Surg, 2011. 92(4): p. 1397-404; discussion 1404-5.

29. Pecha, S., T. Schäfer, Y. Yildirim, T. Ahmadzade, S. Willems, H. Reichenspurner, and F.M. Wagner, Predictors for permanent pacemaker implantation after concomitant surgical ablation for atrial fibrillation. J Thorac Cardiovasc Surg, 2014. 147(3): p. 984-8.

30. Ad, N., SD. Holmes, D.J. Shuman, G. Pritchard, and C.E. Miller, Amiodarone after surgical ablation for atrial fibrillation: Is it really necessary? A prospective randomized controlled trial. J Thorac Cardiovasc Surg, 2016. 151(3): p. 798-803.

31. Rostagno, C., S. Gelsomino, I. Capecchi, A. Rossi, G.F. Montesi, and P.L. Stefàno, Factors related to sinus rhythm at discharge after radiofrequency ablation of permanent atrial fibrillation in patients undergoing mitral valve surgery. Heart Vessels, 2016. 31(4): p. 593-8.

32. Zhang, Z., X. Zhou, C. Gong, Y. Chen, and Y. Fang, Effect of perioperative intravenous amiodarone on cardioversion of atrial fibrillation early after video-assisted thoracoscopic surgical ablation: Study protocol for a double-blind randomized controlled trial. Contemp Clin Trials Commun, 2022. 30: p. 101010.

33. Zhu, X., Q. Li, Y. Li, and Z. Wu, Analysis of Bipolar Radiofrequency Ablation in Treatment of Atrial Fibrillation Associated with Rheumatic Heart Disease. PLoS One, 2016. 11(3): p. e0151248.