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Original Article / Özgün Makale

Long-term results of monopolar versus bipolar radiofrequency ablation procedure for atrial fibrillation

Atriyal fibrilasyon için monopolara kıyasla bipolar radyofrekans ablasyon işleminin uzun dönem sonuçları

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ABSTRACT

Background: In this study, we aimed to evaluate the long-term outcomes of monopolar or bipolar radiofrequency ablation concomitant to mitral valve surgery in patients with atrial fibrillation.

Methods: We retrospectively evaluated a total of 167 patients (67 males, 100 females; mean age 56.8±6.9 years; range, 48 to 65 years) with atrial fibrillation who underwent monopolar or bipolar radiofrequency ablation concomitant to mitral valve surgery between September 2001 and January 2015. The patients were divided into two groups according to the procedure applied as those undergoing monopolar ablation (group 1, n=68) and those undergoing bipolar ablation (group 2, n=99). All patients were followed by electrocardiogram and 24-h Holter monitoring. Echocardiography was performed before discharge, at three and 12 months postoperatively, and annually thereafter. Left atrial volume index, left atrial diameter, and left ventricular ejection fraction were recorded.

Results: There was no significant correlation between the procedure applied and hypertension, hyperlipidemia, diabetes mellitus, chronic obstructive pulmonary disease, history of the cerebrovascular events (p>0.05). The mean preoperative left atrial diameter decreased from 5.3±0.5 cm to 4.9±0.5 cm postoperatively in all patients (p=0.0001). The mean preoperative left atrial volume index decreased from 53.8±0.4 mL/m^2 to 43.7±6.2 mL/m^2 in the postoperative period (p=0.0001). During follow-up, 61.8% (n=42) of the patients in group 1 and 62.6% (n=62) of the patients in group 2 remained in sinus rhythm. One patient (1.5%) in group 1 and two patients (2.0%) in group 2 developed early postoperative cerebrovascular accident.

Conclusion: Monopolar and bipolar ablation methods are safe and effective methods to ensure long-term sinus rhythm. Both procedures do not increase the morbidity risk with very low thromboembolic complication rates.

Keywords: Radiofrequency ablation; atrial fibrillation; monopolar ablation; bipolar ablation.

ÖZ

Amaç: Bu çalışmada, atriyal fibrilasyonlu hastalarda mitral kapak cerrahisine ek olarak monopolar veya bipolar radyofrekans ablasyon tedavisinin uzun dönem sonuçları değerlendirildi.

Çalışma planı: Eylül 2001-Ocak 2015 tarihleri arasında mitral kapak cerrahisine ek olarak monopolar veya bipolar radyofrekans ablasyon yapılan toplam 167 atriyal fibrilasyonlu hasta (67 erkek, 100 kadın; ort. yaş 56.8±6.9 yıl; dağılım, 48-65 yıl) retrospektif olarak değerlendirildi. Hastalar uygulanan işleme göre monopolar ablasyon yapılanlar (grup 1, n=68) ve bipolar ablasyon yapılanlar (grup 2, n=99) olmak üzere iki gruba ayrıldı. Tüm hastaların takibi elektrokardiyografi ve 24 saatlik Holter monitörizasyonu ile yapıldı. Ekokardiyografi taburculuktan önce ve ameliyat sonrası üç ve 12. ayda ve sonrasında yıllık olarak çekildi. Sol atriyal hacim indeksi, sol atriyal çap ve sol ventrikül ejeksiyon fraksiyonu kaydedildi.

Bulgular: Yapılan işlem ve hipertansiyon, hiperlipidemi, diabetes mellitus, kronik obstrüktif akciğer hastalığı ve serebrovasküler olay öyküsü arasında anlamlı bir ilişki bulunamadı (p>0.05). Tüm hastalarda ameliyat öncesi ortalama sol atriyal çap 5.3±0.5 cm'den ameliyat sonrası 4.9±0.5 cm'ye düştü (p=0.0001). Ameliyat öncesi sol atriyal hacim indeksi 53.8±0.4 mL/m^2'den ameliyat sonrası dönemde 43.7±6.2 mL/m^2'ye geriledi (p=0.0001). Takip döneminde grup 1'deki hastaların %61.8'i (n=42) ve grup 2'deki hastaların %62.6'i (n=62) sinüs ritmindeydi. Grup 1'de bir hastada (%1.5) ve grup 2'de iki hastada (%2.0) ameliyat sonrası erken serebrovasküler olay gelişti.

Sonuç: Uzun dönem sinüs ritminin sağlanmasında monopolar ve bipolar ablasyon yöntemleri güvenli ve etkilidir. Her iki işlem de çok düşük tromboembolik komplikasyon oranları ile morbidite riskini artırmaz.

Anahtar sözcükler: Radyofrekans ablasyon; atriyal fibrilasyon; monopolar ablasyon; bipolar ablasyon.

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Atrial fibrillation (AF) is associated with significant morbidity resulting from loss of synchronous atrioventricular contraction and the need for anticoagulation. Despite anticoagulation, AF has been implicated in up to 15% of all thromboembolic strokes.[1] The Cox-Maze procedure was first developed in 1987 in an effort to surgically treat AF.[2-4] After several modifications, the Cox-Maze III (CMIII) procedure became the gold standard for surgical treatment of AF during the 1990s. In our clinic, we routinely apply two different types of radiofrequency (RF) ablation including monopolar and bipolar RF ablations.

In the present study, we aimed to evaluate the long-term outcomes of monopolar or bipolar RF ablation concomitant to mitral valve surgery in patients with AF.

PATIENTS AND METHODS

In this retrospective, single-center study, a total of 1,220 mitral valve repair operations which were conducted between September 2001 and January 2015 were screened. We evaluated a total of 167 patients (67 males, 100 females; mean age 56.8±6.9 years; range, 48 to 65 years) with AF who underwent monopolar or bipolar RF ablation concomitant to mitral valve surgery. The patients were divided into two groups according to the procedure applied as those undergoing monopolar ablation (group 1, n=68) and those undergoing bipolar ablation (group 2, n=99). *Exclusion criteria were as follows:* a left atrial (LA) diameter of >5.8 cm, low cardiac output (ejection fraction <30%), calcified LA wall, age over 75 years, having redo or concomitant aortic valve and coronary artery bypass grafting. A written informed consent was obtained from each patient. The study protocol was approved by institutional Ethics Committee (2016-44140529/2016-53). The study was conducted in accordance with the principles of the Declaration of Helsinki.

All patients were followed by electrocardiography (ECG) and 24-h Holter monitoring before discharge and at one, three, six, and 12 months postoperatively and annually thereafter. Echocardiography was also performed before discharge and at three and 12 months and annually after surgery. The left atrial volume index (LAVI), LA diameter, and left ventricular ejection fraction (LVEF) were also recorded. All operations were performed by a single cardiovascular surgery team. Type of AF was determined according to the Heart Rhythm Society guidelines.

Monopolar RF ablation system

The Medtronic Cardioblade™ (Cardioblade, Medtronic Inc., MN, USA) ablation system was used for monopolar RF ablation. Operations were performed through median sternotomy under cardiopulmonary bypass (CPB). Systemic mild hypothermia was also applied and the patients were cooled to 32°C after the beginning of bypass. Myocardial protection was achieved by delivering intermittent antegrade blood cardioplegia. Radiofrequency lesions were created in an endocardial manner and the ablation lines are described in Figure 1. During the procedure, the pen is slowly oscillated over the tissue. The power generator can produce a power output ranging from 20 to 30 Watts/5 mL irrigation/min. The heart was arrested and the left atriotomy was performed, and a semicircular ablation line in the endocardium was performed to isolate the right pulmonary veins. Two lines around the left pulmonary veins were made. Both encircling lesions were connected with an ablation line in the posterior wall of the LA. A connecting line from the atriotomy to the mitral valve annulus was performed.

Bipolar RF ablation system

The Medtronic Cardioblate™ (Cardioblate, Medtronic Inc., MN, USA) bipolar ablation system, which consists of a power generator and an ablation clamp, was used for bipolar RF ablation. Irrigation was applied between the clamp and the tissue surface to cool the tissue and maintain the tissue temperature between 45 and 55°C. The bipolar device was clamped around the atrial cuff containing the right pulmonary veins.

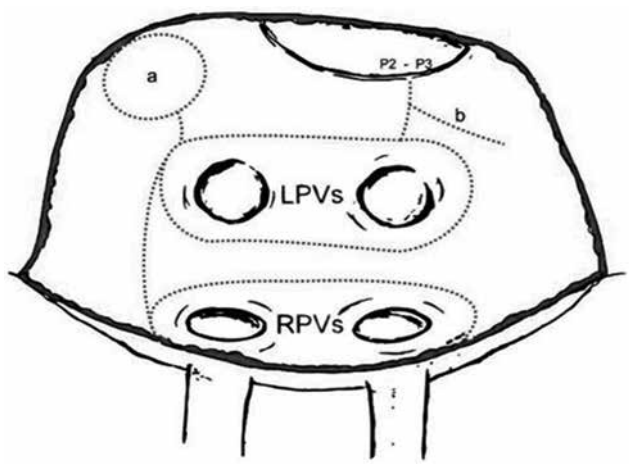

Figure 1. Ablation lesion sets performed at left atrial endocardium.

LPVs: Left pulmonary veins; RPVs: Right pulmonary veins; a line: Left atrial appendage; b line: Coronary sinus.

During CPB before cross-clamping, the right pulmonary veins were encircled and ablated and the heart was, then, lifted and the left pulmonary veins were ablated. Both pulmonary vein ablations were repeated twice to avoid gaps. The LA was opened on cardioplegic arrest and an additional ablation line connecting both pulmonary isolation lines was performed. Another lesion was created from the left atriotomy lesion toward to P2-P3 leaflet of mitral valve by bipolar clamp (Figure 1). In all patients, we plicated the LA appendage.

Postoperative medical treatment

Intravenous amiodarone administration was initiated before the end of CPB at a dose of 300 mg and continued for 24 h at a dose of 500 to 900 mg/24 h depending on the frequency. On the second postoperative day, amiodarone 200 mg and metoprolol 50 mg per oral were prescribed until the third month postoperatively. In case of bradycardia or atrioventricular block, amiodarone was avoided. Warfarin was started on the postoperative first day and was discontinued after three months, when sinus rhythm was documented. In case of recurrent AF, we continued lifelong warfarin. Cardioversion was utilized in cases of early AF after surgery. Atrial and ventricular temporary epicardial wires were applied to all patients.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD) or number and frequency. The Wilcoxon Z signed-rank test was used for the intra-group comparisons, while the Mann-Whitney U test was used to analyze significant differences between the groups. The Kaplan-Meier curves were used to estimate survival. A p value of <0.05 was considered statistically significant.

RESULTS

Of the patients, there were 45 females and 23 males in group 1 with a mean age of 55.6±7.4 years and 55 females and 44 males in group 2 with a mean age of 58.0±6.4 years, indicating no significant difference between the groups. Demographic and clinical characteristic of patients are shown in Table 1. In addition, there was no significant correlation between the type of procedure applied and hypertension, hyperlipidemia, diabetes mellitus, chronic obstructive pulmonary disease, history of the cerebrovascular events ($p>0.05$). Comorbidities of patients are shown in Table 2. No complication including esophageal or bronchial tree injuries related to the ablation procedure occurred in any patients.

The mean duration of the CPB was 142.8 min in group 1 and 132.0 min in group 2 ($p=0.0001$). Persistent AF was observed in 60 patients (88.1%) in group 1 and 85 patients (85.8%) in group 2. Longstanding AF was detected in eight patients (11.9%) in group 1 and 14 patients (14.2%)

Table 1. Demographic and clinical characteristics of patient groups

Groups	Group 1	Group 2	
	Mean±SD	Mean±SD	p
Age (year)	55.6±7.4	58.0±6.4	0.049
Body mass index (kg/m^2)	28.0±3.0	28.0±3.1	0.861
Ejection fraction (%)	53.5±6.3	54.0±6.1	0.828
Preoperative LA diameter (cm)	5.3±0.4	5.3±0.5	0.718
Postoperative LA diameter (cm)	4.8±0.5	4.9±0.6	0.372
Preoperative LAVI (mL/m^2)	53.5±4.2	54.0±4.5	0.409
Postoperative LAVI (mL/m^2)	43.6±6.5	43.8±6.0	0.943
CPB time (min)	142.8±8.7	132.0±11.8	0.0001
Cross-clamp time (min)	92.6±10.9	90.6±9.2	0.447
Duration for ventilation (h)	6.1±1.2	5.7±1.2	0.118
Duration for ICU stay (day)	1.3±0.5	1.4±0.6	0.161
Duration for hospital stay (day)	6.9±0.7	6.9±0.7	0.923
Follow-up (year)	11.4±2.3	11.2±2.6	0.269

SD: Standard deviation; LA: Left atrium; LAVI: Left atrial volume index; CPB: Cardiopulmonary bypass; ICU: Intensive care unit.

Table 2. Comorbidities of patients

	Group 1		Group 2		
	n	%	n	%	*p*
Hypertension	22	32.4	36	36.4	0.357
Hyperlipidemia	7	10.3	18	18.2	0.117
Diabetes mellitus	13	19.1	18	18.2	0.517
Chronic obstructive pulmonary disease	8	11.8	12	12.1	0.573
Cerebrovascular event	3	4.4	9	9.1	0.201
Atrial fibrillation in hospital	11	16.2	14	14.1	0.440
Postoperative cerebrovascular event	1	1.5	2	2.0	0.638
Postoperative pulmonary embolism	1	1.5	2	2.0	0.638
Sinus rhythm during long-term follow-up	42	61.8	62	62.6	0.458
Cerebrovascular accident during follow-up	7	10.3	7	7.1	0.321
Mortality	13	19.1	23	23.2	0.331

Table 3. Left atrial diameter and left atrial volume index measurements in overall patients

	Preoperative	Postoperative			
Measurements	Mean±SD	Mean±SD	n	z	*p*
Left atrium diameter (cm)	5.3±0.5	4.9±0.5	167	-7.991	0.0001
Left atrial volume index (mL/m^2)	53.8±4.4	43.7±6.2	167	-10.847	0.0001

SD: Standard deviation.

in group 2. Early AF occurred during hospital stay before discharge; four (5.8%) in group 1 and seven (6.9%) in group 2. No significant relationship was found between the time of AF and surgery (p=0.440). At one-year follow-up, two patients in group 1 and three patients in group 2 had still AF; therefore, we considered failure of procedure in these patients. One patient (1.5%) in group 1 and two patients (2.0%) in group 2 developed early postoperative cerebrovascular accident. Early postoperative pulmonary embolism was diagnosed in one patient (1.5%) in group 1 and two patients (2.0%) in group 2 (p=0.638).

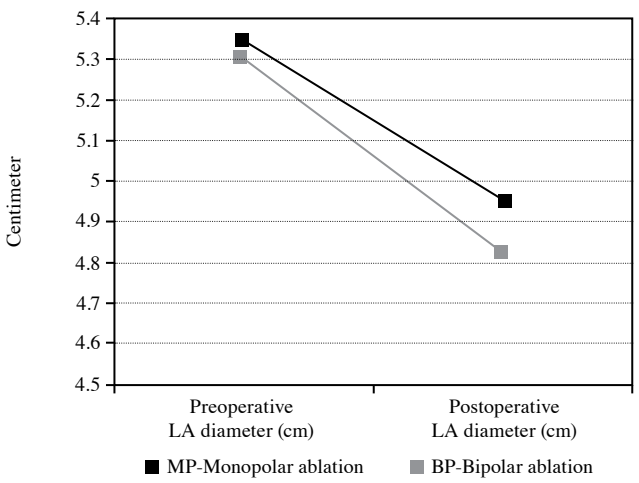

Figure 2. Changes in pre- and postoperative left atrial diameter.
LA: Left atrium.

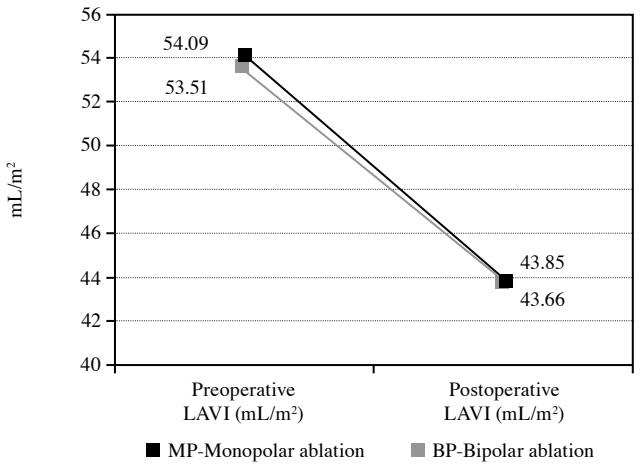

Figure 3. Changes in pre- and postoperative left atrial volume index.
LAVI: Left atrial volume index.

Table 4. Left atrial diameter and left atrial volume index measurements in Group 1

	Preoperative	Postoperative			
Measurements	Mean±SD	Mean±SD	n	z	*p*
Left atrium diameter (cm)	5.3±0.4	4.8±0.5	68	-5.254	0.0001
Left atrial volume index (mL/m^2)	53.5±4.2	43.6±6.5	68	-6.872	0.0001

SD: Standard deviation.

Table 5. Left atrial diameter and left atrial volume index measurements in Group 2

	Preoperative	Postoperative			
Measurements	Mean±SD	Mean±SD	n	z	*p*
Left atrium diameter (cm)	5.3±0.5	4.9±0.6	99	-6.025	0.0001
Left atrial volume index (mL/m^2)	54.0±4.5	43.8±6.0	99	-8.403	0.0001

SD: Standard deviation.

In all groups, the mean preoperative LA diameter decreased from 5.3±0.5 cm to 4.9±0.5 cm in the postoperative period, indicating a statistically significant difference (p=0.0001). In addition, the mean LAVI, which was 53.8±0.4 mL/m^2 in the preoperative period, decreased to 43.7±6.2 mL/m^2 in the postoperative period in all patients (n=167), indicating a statistically significant difference (Table 3, p=0.0001).

In group 1, the mean preoperative LA diameter decreased from 5.3±0.4 cm to 4.8±0.5 cm in the postoperative period, indicating a statistically significant difference (Figure 2, p=0.0001). In addition, the mean preoperative LAVI was 53.5±4.2 mL/m^2 and the mean postoperative LAVI was 43.6±6.5 mL/m^2, indicating a statistically significant difference (Figure 3, Table 4, p=0.0001).

In group 2, the mean preoperative LA diameter (5.3±0.5 cm) showed a decrease and became 4.9±0.6 cm in the postoperative period with a statistically significant difference (p=0.0001). Similarly, in group 2, the mean preoperative LAVI was 54.0±4.5 mL/m^2 and the mean postoperative LAVI was 43.8±6.0 mL/m^2, indicating a statistically significant difference (Table 5, p=0.0001).

During the long-term follow-up, two patients from each group required permanent pacemaker implantation due to atrioventricular block. Also, in the long-term follow-up, seven patients in both groups had a transient ischemic attack without any neurological sequelae.

No significant correlation was found between the mortality and procedure type during long-term follow-up (Figure 4). Late mortality was observed in 13 patients (19.1%) (n=7 cardiac, n=1 unspecified, and n=5 non-cardiac) in group 1 and 23 patients (23.2%) (n=13 cardiac, n=3, and n=7 non-cardiac) in group 2 (p=0.331). We found no statistically significant relationship between sinus rhythm and the operation type during long-term follow-up. In group 1, 61.8% patients (n=42) remained in sinus rhythm after a mean follow-up of 11.4±2.3 years, while 62.6% patients

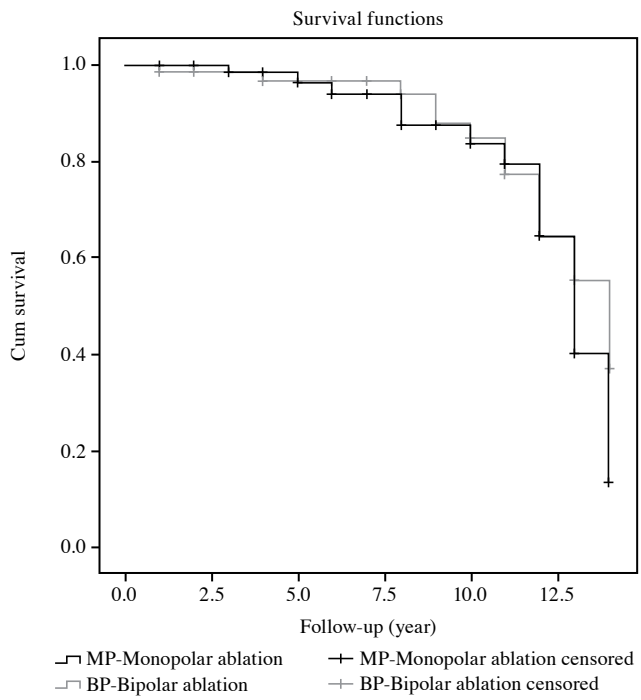

Figure 4. Survival analysis.

(n=62) maintained sinus rhythm after a mean follow-up of 11.2±2.6 years in group 2. Furthermore, there was no statistically significant difference in the survival rates between the groups (p>0.05).

DISCUSSION

The main goal of surgical treatment of AF is to block macro re-entry and focal triggering through transmural lesions and, thus, to ensure that the sinus impulse reaches the atrioventricular node and delivers the atrial contraction function. Nevertheless, the success rate of ablation methods other than the Maze method varies between 76% and 92%.[4] By understanding of pathogenesis of AF and development of new ablation technologies, a great interest in surgically curing AF has occurred. Until now, many sources of energy have been proposed and used in different ways. However, RF is the most frequently used technique.[5]

Grigioni et al.[6] reported that the risk for AF development was about 15 to 21% over five years, if conservative treatment was used to manage patients with functional mitral valve disease and was 42 to 54% of the patients developed AF at 10 years. Moreover, AF was associated with a high risk for cardiac death or heart failure with the risk of AF increasing with age and LA size.

It is obvious that, by restoring the sinus rhythm, both the risk of thromboembolism and the need for oral anticoagulation may be reduced.[7] Furthermore, sudden cardiac death or heart failure may be prevented. In addition, AF has been shown to be an independent significant predictor for long-term mortality.[8]

Approximately 40 to 50% of patients undergoing mitral valve surgery have a remarkable history of AF.[9] These patients usually remain in AF with low rates of conversion to sinus rhythm following a successful mitral valve surgery, if a surgical ablation procedure is not performed.[10] The potential benefits as well as the safety and efficacy of a surgical ablation procedure for AF during mitral valve operations are well-documented in the literature.[11]

Our results are comparable to several other reports published. Bogachev-Prokophiev et al.[12] included 47 patients who underwent bipolar left-sided ablation procedure with either mitral valve repair or replacement (n=47) and monitored the patients by a subcutaneous continuous monitoring system. At 12 months, the authors found that 65.2% of the patients (n=30) had no AF and 6.5% of the patients (n=3) experienced atrial flutter. The effect of preoperative AF in patients undergoing mitral valve surgery was also studied by Ngaage et al.[13] who reported that preoperative AF was associated with increased morbidity and decreased survival, if left uncorrected.

The goal of bipolar ablation is the isolation of triggering focus of AF episodes from the conduction system. Success rates for restoring sinus rhythm of AF patients with the bipolar RF ablation procedure ranged from 54 to 90%.[14] In this study, the mean follow-up duration of group 1 was 11.4±2.3 years and the rate of sinus rhythm was 61.8%. In addition, the mean follow-up duration of group 2 was 11.2±2.6 years with a rate of 62.6% sinus rhythm. Achieving a transmural and continuous lesion is critical for the procedural success. The main drawback with the monopolar system is the uncertainty in achieving a transmural lesion. Therefore, one can expect superior outcomes with the bipolar system theoretically, although this was not the case in our study.

In their study, La Meir et al.[15] showed that only patients who underwent the bilateral approach showed a significant improvement in the LA function and a significant reduction in the LA dimensions and LAVI. In our study, in both groups, the mean preoperative LA diameter decreased from 5.3±0.5 cm to 4.9±0.5 cm in the postoperative period. Also, the mean LAVI, which was 53.8±0.4 mL/m^2 in the preoperative period, decreased to 43.7±6.2 mL/m^2 in the postoperative period.

The main cause of early AF recurrence may be a transient stimulatory effect of inflammatory factor after the damage of histopathological tissue caused by ablation, electrical conduction between the LA and pulmonary veins reconnection, and transient imbalance of the autonomic nervous system.[16] Based on our experience, 16.2% patients (n=11) in group 1 and 14.1% patients (n=14) in group 2 had AF during the early postoperative period. We believe that patients experiencing no early AF recurrence are more likely to be away from late AF recurrence. Similarly, early AF recurrence has been demonstrated to be an independent risk factor for late AF recurrence.[17]

The need for early postoperative pacemaker after surgical procedures has been reported as ranging from 6 to 23%,[18] depending on the lesion pattern chosen or energy source applied. It has been suggested that the patients whose preoperative LA diameter is large and who are in sinus rhythm are more likely to need a permanent pacemaker. In our study, we performed pacemaker implantation in two patients in either

group, although there was no statistically significant difference between the groups.

In another study, Scherer et al.[19] concluded that LA size reduction after RF ablation contributed to a higher restoration of sinus rhythm (70%) throughout a three-year follow-up period. In our study, the LA size reduction from 69±19 mm to 51±8 mm caused a decrease in late thromboembolic complications. In addition, we plicated the LA appendage in all patients to prevent possible thromboembolic events.

Nonetheless, there are some limitations to this study. First, this study has a retrospective design and a further prospective study is still ongoing. Second, the sample size is relatively small. Finally, creating additional lesions to bond the isolation circles over the ablation lines would further increase the success rate of the technique in patients undergoing bipolar RF ablation.

In conclusion, both monopolar and bipolar radiofrequency ablation methods do not cause any additional complication in either short-term or long-term follow-up and are safe and effective methods to ensure long-term sinus rhythm. Both procedures are also associated with low morbidity risk and thromboembolic complication rates.

Declaration of conflicting interests

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