ORIGINAL ARTICLE

Effect of cryoballoon ablation parameters on recurrence in patients with paroxysmal atrial fibrillation

Paroksismal atriyal fibrilasyonlu hastalarda kriyobalon ablasyon parametrelerinin nüks üzerine etkisi

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ABSTRACT

Objective: The aim of this research was to investigate the relationship between atrial fibrillation (AF) recurrence and second generation cryoballoon ablation (CBA) procedural parameters in patients with non-valvular paroxysmal AF (PAF).

Methods: A total of 131 patients with a PAF diagnosis who underwent second-generation CBA (59 male; mean age: 55.2±10.6 years) were enrolled. Recurrence was defined as the detection of AF on a 12-lead electrocardiography (ECG) recording, or an attack lasting at least 30 seconds observed on Holter ECG records. CBA procedural data and echocardiographic findings were recorded and compared.

Results: After 1 year of follow-up, AF recurrence was detected in 27 patients. Patients with recurrence were older and had higher rates of hypertension and diabetes (p<0.05 for both). Left atrial diameter, left atrial volume (LaV), left atrial volume index, and the averaged warming angle (calculated by combining lowest temperature point and balloon temperature at 20°C point) were significantly higher in the recurrence group. Balloon warming time was significantly longer in the non-recurrence group (p<0.001). In binary logistic regression analysis, the averaged warming angle (odds ratio [OR]: 1.559, 95% confidence interval [CI]: 1.342–1.811; p<0.001) and LaV (OR: 1.063, 95% CI: 1.028–1.100; p<0.001) were found to be independent parameters for predicting recurrence. The cutoff value of the warming angle obtained with ROC curve analysis was 50° for the prediction of recurrence (sensitivity: 94.3%, specificity: 88.5%, area under the curve: 0.909; p<0.001). The cutoff value of LaV obtained by ROC curve analysis was 53.5 for prediction of recurrence (sensitivity: 77.8%, specificity: 74.5%; p<0.001).

Conclusion: Measurement of balloon warming angle during CBA and increased LaV may predict the AF recurrence.

ÖZET

Amaç: Bu çalışmada, valvüler olmayan paroksismal atriyal fibrilasyonu (PAF) olan hastalarda AF nüksü ile ikinci jenerasyon kriyobalon ablasyon (KBA) prosedürü parametreleri arasındaki ilişkiyi araştırmayı planladık.

Yöntemler: İkinci jenerasyon KBA (59 erkek; ort. yaş 55.2±10.6 yıl) yapılan PAF tanısı alan 131 hasta dahil edildi. Nüks, 12 derivasyonlu elektrokardiyografide (EKG) AF görülmesiyle ya da ritim Holter kayıtlarında en az 30 saniye süren AF ataklarının saptanması olarak tanımlandı. Bazı KBA prosedür verileri ve ekokardiyografik bulgular kaydedildi ve karşılaştırıldı.

Bulgular: Bir yıl sonra izlemde 27 hastada AF nüks tespit edildi. Nüksü olan hastalar daha yaşlıydı ve daha yüksek hipertansiyon ve diyabet oranları vardı (hepsi için, p<0.05). Sol atriyum çapı (SaD), sol atriyum volümü (SaV), sol atriyum volümü indeksi (SaVI) ve ortalama ısınma açısı (en düşük sıcaklık noktasını ve balon sıcaklığını 20°C noktasının birleştirilmesi ile elde edilen) nüks grubunda anlamlı olarak artmıştı. Nüks olmayan grupta balon ısınma süresi önemli ölçüde uzamıştı (p<0.001). İkili lojistik regresyon analizinde, ortalama ısınma açısı (OO=1.559, %95 GA: 1.342–1.811, p<0.001) ve sol atriyum volümü (SaV, OO: 1.063, %95 GA: 1.028–1.100, p<0.001) nüks tahmini için bağımsız parametreler bulundu. ROC eğrisi analizi ile elde edilen ısınma açısının kestirim değeri, nüks tahmini için 50° idi (duyarlılık: %94.3, özgüllük: %88.5, EAA: 0.909, p<0.001). ROC eğrisi analizi ile elde edilen SaV'nin kesme değeri, nüks tahmini için 53.5 idi (duyarlılık: %77.8, özgüllük: %74.5, p <0.001).

Sonuç: Kriyobalon ablasyon sırasında balon ısınma açısının ölçülmesi ve artan SaV, AF nüksetmesini öngörebilir.

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Atrial fibrillation (AF) is a significant form of cardiac arrhythmia with a prevalence that increases with age.[1] Cryoballoon (CB) ablation (CBA) and radiofrequency ablation are recommended as class 1 treatment for drug-resistant paroxysmal AF (PAF) according to the European Society of Cardiology guideline.[2] CBA has a high acute success rate in patients with PAF and persistent AF.[3] The success rate after a single ablation procedure has been reported to range between 80% and 84% in patients with PAF.[4–6]

Complete pulmonary vein (PV) isolation (PVI) has been shown to be the most important predictor of acute success after CBA. However, it is not possible to perform complete PVI in every case.[7] A closed PV ostium is the optimal outcome of PVI. The lowest tissue temperature, the lowest balloon temperature, and the balloon warming time are also factors in PVI.[8,9] Although all the procedural parameters are accepted as factor in the success of PVI, there is no clear information as to the parameters most associated with recurrent AF.

The association between clinical AF recurrence and CBA temperature parameters has not yet been fully researched and reported in the literature. The aim of this study was to investigate the relationship between AF recurrence and the procedural parameters of second- generation CBA in non-valvular PAF patients.

METHODS

Study protocol and study population

A total of 131 patients with a diagnosis of PAF who underwent second-generation CBA for AF were included in the study. The study group comprised (59 (45%) men and 72 (55%) women with a mean age of 55.2±10.6 years. The patients were divided into 2 groups: (I) AF Recurrence (n=27) and (II) AF Nonrecurrence (n=104). AF was diagnosed with a 12-lead electrocardiography (ECG) recording at admission. Patients with spontaneous conversion to sinus rhythm and medical or electrical cardioversion within 7 days were considered to have PAF. Patients with acute or end-stage liver or renal disease, severe chronic obstructive pulmonary disease, acute coronary syndrome, malignancy, active infection within the last 2 weeks, severe aortic or mitral valve disease, left atrium (LA) diameter (LaD) >55 mm, and left ventricular (LV) systolic dysfunction (LV ejection fraction [LVEF] <45%) were excluded from the study. Following a complete physical examination and a detailed evaluation of medical history for each patient, baseline characteristics, including age, gender, hypertension (HT), diabetes mellitus (DM), hyperlipidemia, current smoking status, family history of cardiac disease, and medication use, were recorded. ECG, telecardiography, complete blood count, fasting blood glucose, uric acid, N-terminal pro b-type natriuretic peptide, serum electrolytes, serum lipids, prothrombin time, and renal and liver function tests were performed for each patient. The patients were classified according to the modified European Heart Rhythm Association score for AF-related symptoms. The CHA_2DS_2-VASc (Congestive heart failure, Hypertension, Age, Diabetes, Stroke - Vascular disease, Age, Sex) and HAS-BLED (Hypertension, Abnormal renal/liver function, Stroke, Bleeding history or predisposition, Labile international normalized ratio, Elderly, Drugs/alcohol) scores for stroke and bleeding risk were also calculated. The study protocol was approved by the local institutional ethics committee and written, informed consent was obtained from each participant.

Pre-procedural evaluation

All of the patients were evaluated using standard transthoracic echocardiography (TTE) to rule out structural abnormalities. Ejection fraction (EF), LaD, LA volume (LaV), and LA volume index (LaVI) were recorded using TTE. A transesophageal echocardio-

Abbreviations:

AF	*Atrial fibrillation*
CAD	*Coronary artery disease*
CB	*Cryoballoon*
CBA	*Cryoballoon ablation*
CHA_2DS_2-VASc	*Congestive heart failure, Hypertension, Age, Diabetes, Stroke - Vascular disease, Age, Sex*
CI	*Confidence interval*
DM	*Diabetes mellitus*
ECG	*Electrocardiography*
EF	*Ejection fraction*
HAS-BLED	*Hypertension, Abnormal renal/liver function, Stroke, Bleeding history or predisposition, Labile international normalized ratio, Elderly, Drugs/alcohol*
HT	*Hypertension*
LA	*Left atrium*
LaD	*Left atrial diameter*
LaV	*Left atrial volume*
LaVI	*Left atrial volume index*
LV	*Left ventricle*
OR	*Odds ratio*
PAF	*Paroxysmal AF*
PV	*Pulmonary vein*
PVI	*Pulmonary vein isolation*
PVr	*Pulmonary vein reconnection*
ROC	*Receiver operating characteristic*
TTE	*Transthoracic echocardiography*

gram was performed to exclude LA thrombus and to determine the diameter of the pulmonary veins. The use of oral anticoagulants was terminated before the procedure, and the pre-procedural interval was bridged with enoxaparin. Antiarrhythmic drugs were discontinued 5 half-lives prior to the procedure.

Cryoablation procedure

All of the cryoablation procedures were performed in a single clinic with second-generation CBA under sedation with midazolam. The CBA was performed using a technique previously described.[10,11] Invasive arterial blood pressure, oxygen saturation, and ECG were continuously monitored throughout the entire procedure. Femoral venous access was achieved via the right and left femoral veins using the Seldinger technique. A 6-F steerable decapolar catheter (Dynamic Deca; Bard Electrophysiology, Lowell, MA, USA) was placed into the coronary sinus. Transseptal access was achieved with a transseptal needle using a modified Brockenbrough technique (BRK-1; St. Jude Medical, St. Paul, MN, USA). An 8-F guiding transseptal sheath (Biosense Webster, Irvine, CA, USA) was placed into the LA. Bolus doses of heparin were used in order to ensure an activated clotting time between 300 and 350 seconds. Subsequently, the sheath was exchanged for a 12-F steerable transseptal sheath (FlexCath; Medtronic CryoCath, Quebec, Canada). PV recordings were performed with an Achieve recording catheter (Medtronic, Dublin, Ireland). A total of PVI procedures were performed in each patient using a single, large (28 mm) cryoablation balloon (Arctic Front; Medtronic CryoCath, Quebec, Canada). Occlusion was assessed with a 50% diluted contrast injection. All of the PVs and their variations were viewed and recorded via injection of a contrast agent into the vein lumen. Two freeze cycles of 240 seconds or a single freeze cycle of 300 seconds were applied per PV. At the end of the procedure, PV conduction was reevaluated using the Achieve recording catheter. Successful PVI was defined as the elimination (or dissociation) of all of the PV potentials recorded on the Achieve recording catheter. Direct palpation of the right hemidiaphragmatic excursion was performed during phrenic nerve stimulation.

Cryoballoon ablation parameters

During the ablation procedure, a total of 10 consecutive variables were recorded for each PV (i.e., left upper PV, left inferior PV, right upper PV, and right inferior PV). These variables were (I) basal body temperature, (II) temperature at the 90th second, (III) time from the beginning of the freezing process until reaching -40°C (time to -40 °C), (IV) lowest temperature (minimum temperature), (V) time to minimum temperature, (VI) time from the lowest temperature until reaching 20°C (balloon warming time), (VII) number of freeze cycles, (VIII) freeze time, (IX) the angle obtained by combining the initial point to the first -40°C (freezing angle), and (X) the angle obtained by combining the lowest temperature point and the balloon temperature at the 20°C point (warming angle; Fig. 1). Mean values of all of these parameters were determined for each PV.

Post-ablation evaluation and the definition of atrial fibrillation recurrence

Oral anticoagulation therapy was initiated 6 hours after conclusion of the procedure and was continued for at least 3 months. This oral anticoagulation requirement was evaluated 3 months after the procedure, based on the CHA_2DS_2 score. Antiarrhythmic drug treatment (propafenone 150 mg 2x1 or amiodarone 200 mg 2x1) was also maintained for 3 months in all cases. Patients with a history of coronary artery disease (CAD) were prescribed amiodarone or thyrotoxicosis, and those with no history of CAD were prescribed propafenone. Regular follow-up visits were

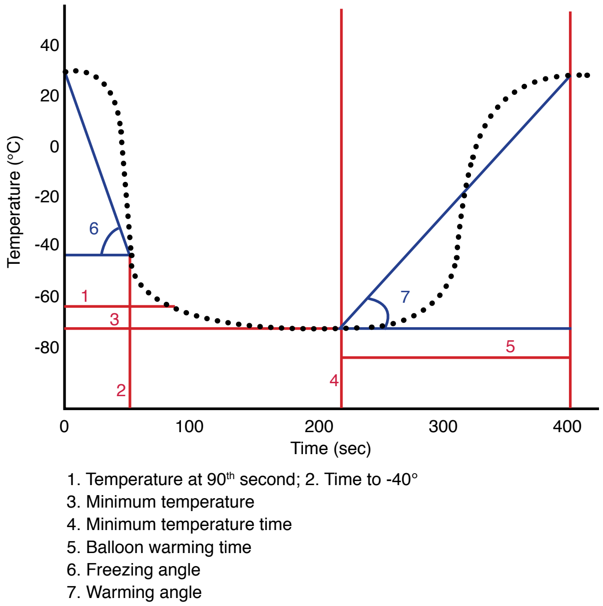

Figure 1. Cyoballoon ablation parameters.

performed every 3 months for each patient, including a clinical examination and evaluation of medical history, 12-lead ECG, and 48-hour Holter ECG monitoring. AF recurrence was defined as the detection of AF on 12-lead ECG or an attack lasting for at least 30 seconds recorded on the Holter ECG device.

Statistical analysis

The study data were analyzed using IBM SPSS for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA) The variables were divided into categorical and continuous variables. In comparisons of categorical variables, if the expected frequency was less than 5 in at least 1 of the cells, Fisher's exact test was used, and Pearson's chi-square test was used when the expected frequency was between 5 and 25. Continuous variables were expressed as mean±SD. The Kolmogorov-Smirnov test was used to determine the normal distribution of continuous variables. Those with normal distribution were compared using an independent samples t-test, and the variables that were not normally distributed were compared using the Mann-Whitney U test. Binary logistic regression analysis was performed for the variables with a p value of <0.05. Independent predictors were determined for AF recurrence. The statistical results were expressed using the p value and the odds ratio (OR) at a confidence interval (CI) of 95%. Receiver operating characteristic (ROC) analysis was used to determine the cutoff value for the predictors of AF recurrence. A p value of <0.05 was considered significant.

RESULTS

The 27 patients classified in the AF Recurrence group had a mean follow-up period of 12.1±1.4 months and the 104 patients in AF Non-recurrence group were followed up for a mean period of 11.9±1.1 months. Based on the baseline characteristics of both groups, it was revealed that the patients in the recurrence group were older (p=0.002) and had higher prevalence of HT (p<0.001) and DM (p=0.01) compared with those in the non-recurrence group, although the other baseline characteristics and medications were similar in the 2 groups (Table 1). The LaD, LaV, and LaVI values were significantly higher in the AF Recurrence group compared with the AF Non-recurrence group (p<0.001 for each), whereas all the other

Table 1. Baseline characteristics and medications of patients with and without AF recurrence

	Patients with AF recurrence (n=27)			Patients without AF recurrence (n=104)			*p*
	n	%	Mean±SD	n	%	Mean±SD	
Age (years)			59.8±7.12			54.1±10.04	0.002
Gender (male) (%)	10	37.0		49	47.1		0.348
Diabetes mellitus	7	25.9		7	6.7		0.009
Hypertension	21	77.8		38	36.5		<0.001
Smoking	7	25.9		46	44.2		0.084
Coronary artery disease	3	11.1		7	6.7		0.429
Body mass index (kg/m²)			29.2±5.03			28.3±4.71	0.367
Systolic blood pressure (mm Hg)			126.3±16.24			120.4±16.82	0.104
Diastolic blood pressure (mm Hg)			80.4±10.61			76.2±10.91	0.083
Pulse (beats/minute)			81.3±11.12			78.1±12.44	0.211
ACE or ARB	9	33.3		31	29.8		0.723
Beta blocker	27	100		99	95.2		0.245
Amiodarone	6	22.2		10	9.6		0.098
Propafenone	3	11.1		7	6.7		0.429

Continuous variables are expressed as mean±SD and were compared with an independent samples t-test. Categorical variables are expressed as absolute and percentage (in parentheses) and compared with the Pearson chi-square or Fisher's exact test. AF: Atrial fibrillation; ACE: Angiotensin converting enzyme; ARB: Angiotensin receptor blockers; SD: Standard deviation.

Table 2. Echocardiographic findings of patients with and without AF recurrence

	Patients with AF recurrence (n=27)	Patients without AF recurrence (n=104)	*p*
	Mean±SD	Mean±SD	
Ejection fraction (%)	65.3±3.41	62.6±9.92	0.180
Left atrial diameter (mm)	38.9±3.92	35.9±3.94	<0.001
Left atrial volume	59.3±11.74	48.1±12.83	<0.001
Left atrial volume index	32.4±6.13	26.2±6.94	<0.001
Left superior pulmonary vein diameter	17.4±2.14	17.3±2.11	0.828
Left inferior pulmonary vein diameter	17.6±2.11	17.3±2.13	0.568
Right superior pulmonary vein diameter	18.7±2.74	18.7±2.62	0.988
Right inferior pulmonary vein diameter	20.3±0.71	20.2±0.74	0.805

Continuous variables are expressed as mean±SD and were compared with an independent samples t-test. AF: Atrial fibrillation; SD: Standard deviation.

echocardiographic parameters were similar (Table 2). All of the CB temperature parameters and anatomical variations were evaluated separately for each PV and then the average value of all of the parameters was calculated. The balloon warming time in all of the PVs was significantly lower and the warming angle in all of the PVs was significantly higher in the AF Recurrence group compared to the AF Non-recurrence group (p<0.05 for both). The time needed for the right inferior PV was significantly greater in the AF Non-recurrence group (p=0.004), whereas the other CBA parameters were similar in the 2 groups (Table 3 and 4). In the binary logistic regression analysis, an average warming angle (OR: 1.559, 95% CI: 1.342–1.811; p<0.001) and average LaV (OR: 1.063, 95% CI: 1.028–1.100; p<0.001) were found to be independent parameters for predicting AF recurrence. The cutoff value for the warming angle obtained in the ROC analysis for the prediction of AF recurrence was 50° (sensitivity: 94.3%, specificity: 88.5%, positive predictive value: 91.5%, negative predictive value: 89.2%) and the area under the curve (AUC) was 0.909 (95% CI: 0.824–0.993; p<0.001) (Fig. 2). The cutoff value for LaV derived in the ROC analysis for the prediction of AF recurrence was 53.5 (sensitivity: 77.8%, specificity: 74.5%) and the AUC was 0.765 (95% CI: 0.664–0.867; p<0.001), (Fig. 3).

DISCUSSION

The present study revealed that the balloon warming angle during CBA was closely associated with AF recurrence. When 50° was used as the cutoff value, AF recurrence was determined with 94.3% sensitivity and 88.5% specificity and LaV was found to be an independent predictor for AF recurrence.

Previous studies of AF recurrence have indicated that the most common finding in patients with recurrence is PV reconnection (PVr).[12–14] In AF ablation procedures performed with first- generation CB devices, PV occlusion has been shown to be the most critical parameter for the determination of PVI. Additionally, the CB warm-up period, the cooling rate, and the lowest balloon temperature have also been shown to be associated with PVr.[8,9] In addition, it has been shown that faster balloon warming results in a shorter balloon-tissue contact period. Therefore, it has been suggested that a balloon that warms more slowly may cause greater tissue damage, since it allows more time for the formation of intracellular ice crystals.[15]

The geometric data detected during the CBA is, in fact, a reflection of balloon warming time as a procedural angle: The shorter the warming time of the balloon, the higher the warming angle value. Although balloon warming time was significant in univariate analysis, it did not appear as significant in multivariate analysis. The lowest heat and a longer balloon warming time can be used as an indicator for an active CBA. Ghosh et al.[8] investigated the effect of procedural parameters on PVr and reported that the balloon warming time, wider PV diameter, and poorer occlusion were associated with PVr. Among these, the balloon warming time showed the strongest relationship to PVr. In the same study, the relationship between PVr and the time between 0°C and -30°C (called

Table 3. **Cryoballoon temperature parameters for each pulmonary vein of patients with and without AF recurrence**

	Patients with AF recurrence (n=27)	Patients without AF recurrence (n=104)	*p*
Body temperature (°C)	36.5±0.81	36.7±0.64	0.093
Left superior pulmonary vein			
Temperature at 90th second (°)	-40.1±3.83	-40.8±3.74	0.426
Time to -40°(s)	102.0±30.41	93.1±39.12	0.032
Minimum temperature (°)	-46.9±4.51	-47.2±4.14	0.805
Minimum temperature time (s)	230.3±49.84	219.6±41.53	0.254
Balloon warming time (s)	33.4±5.52	45.7±14.53	<0.001
Freezing angle (degrees)	69.9±6.52	72.9±4.71	0.055
Warming angle (degrees)	46.0±3.81	35.2±5.01	<0.001
Number of freeze cycles (n)	1.5±0.53	1.6±0.51	0.851
Freeze time (s), IQR	598 (235)	580 (270)	0.255
Pulmoner vein isolation time (s)	60.4±12.81	64.6±11.14	0.243
Left inferior pulmonary vein			
Temperature at 90th second (°)	-36.9±22.73	-39.7±9.31	0.543
Time to -40°(s)	92.4±33.64	92.8±48.04	0.941
Minimum temperature (°)	-48.4±6.61	-47.4±4.24	0.51
Minimum temperature time (s)	262.5±28.22	257.1±31.13	0.410
Balloon warming time (s)	35.0±9.94	46.4±12.31	<0.001
Freezing angle (degrees)	83.9±2.44	84.3±2.4	0.350
Warming angle (degrees)	48.5±4.91	34.4±3.74	<0.001
Number of freeze cycles (n)	1.4±0.53	1.3±0.42	0.639
Freeze time (s), IQR	363.5 (254.6)	373.4 (232.8)	0.689
Pulmoner vein isolation time (s)	58.7±9.41	65.5±12.73	0.054
Right superior pulmonary vein			
Temperature at 90th second (°)	-40.2±10.93	-39.6±12.31	0.241
Time to -40°(s)	90.9±37.92	87.8±35.92	0.698
Minimum temperature (°)	-51.2±5.71	-50.6±4.21	0.596
Minimum temperature time (s)	249.6±25.72	236.8±45.8	0.062
Balloon warming time (s)	44.9±19.92	52.3±12.91	0.008
Freezing angle (degrees)	84.5±1.52	84.0±3.12	0.185
Warming angle (degrees)	45.4±3.71	35.7±3.72	<0.001
Number of freeze cycles (n)	1.4±0.52	1.4±0.43	0.896
Freeze time (s), IQR	389.4 (254.5)	461.1 (216.9)	0.431
Pulmoner vein isolation time (s)	61.7±7.52	61.6±12.9	0.987
Right inferiorr pulmonary vein			
Temperature at 90th second (°)	-37.8±8.83	-41.1±13.81	0.051
Time to -40° (s)	80.5±14.61	72.9±26.62	0.074
Minimum temperature (°)	-51.0±4.92	-51.2±4.42	0.856
Minimum temperature time (s)	224.0±15.72	228.4±46.91	0.439
Balloon warming time (s)	37.5±16.11	50.6±12.43	<0.001
Freezing angle (degrees)	84.2±1.92	84.2±1.81	0.916
Warming angle (degrees)	44.1±7.83	35.7±5.32	<0.001
Number of freeze cycles (n)	1.1±0.33	1.2±0.43	0.113
Freeze time (s), IQR	381.8 (369.1)	366.6 (243.4)	0.132
Pulmoner vein isolation time (s)	69.2±12.31	58.1±9.24	0.004

Normally distributed variables are expressed as mean±SD and were compared with an independent samples t-test. Non-normally distributed variables are expressed as median and IQR and were compared with the Mann-Whitney U test. AF: Atrial fibrillation.

Table 4. Average cryoballoon procedural parameters and anatomical variations of patients with and without AF recurrence

	Patients with AF recurrence (n=27)			Patients without AF recurrence (n=104)			*p*
	n	%	Mean±SD	n	%	Mean±SD	
Temperature at 90th second (°)			-38.1±6.9			-40.5±5.5	0.071
Time to -40°(s)			88.2±17.1			85.3±21.7	0.567
Minimum temperature (°)			-49.3±4.4			-49.1±2.5	0.855
Minimum temperature time (s)			242.9±9.3			235.2±31.7	0.051
Balloon warming time (s)			38.5±10.9			49.1±9.1	<0.001
Freezing angle (degrees)			84.4±1.1			84.3±1.4	0.723
Warming angle (degrees)			46.0±3.9			35.3±2.8	<0.001
Number of freeze (n)			1.4±0.2			1.4±0.3	0.650
Pulmonary vein isolation time (sec)			63.7±4.3			63.1±4.6	0.710
Total time (left+right) duration (sec)			1731±549			1885±318	0.175
Common left pulmonary vein	3	11.1		5	4.8		0.361
Common right pulmonary vein	2	7.4		2	1.9		0.188
Middle right pulmonary vein	2	87.49		3	2.9		0.274

AF: Atrial fibrillation.

“freezing time”) was also evaluated, but no significant relationship was found.

In our study, the balloon warming time was found to be significant in the univariate analysis but was not independently associated with AF recurrence in the multivariate analysis. Therefore, we think that the warming angle could be more sensitive than the balloon warming time for the prediction of AF recurrence. Fürnkranz et al.[9] used second- and third-generation CBs, and obtained higher PVI rates with

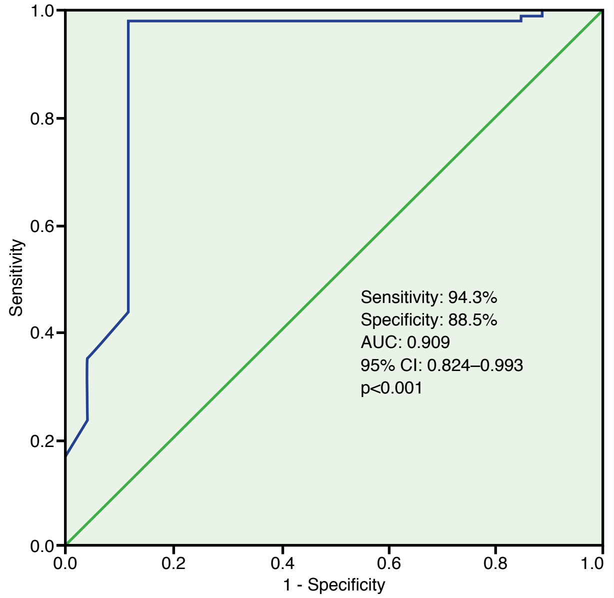

Figure 2. Receiver operating characteristic curve analysis to predict the value of the warming angle in atrial fibrillation recurrence.

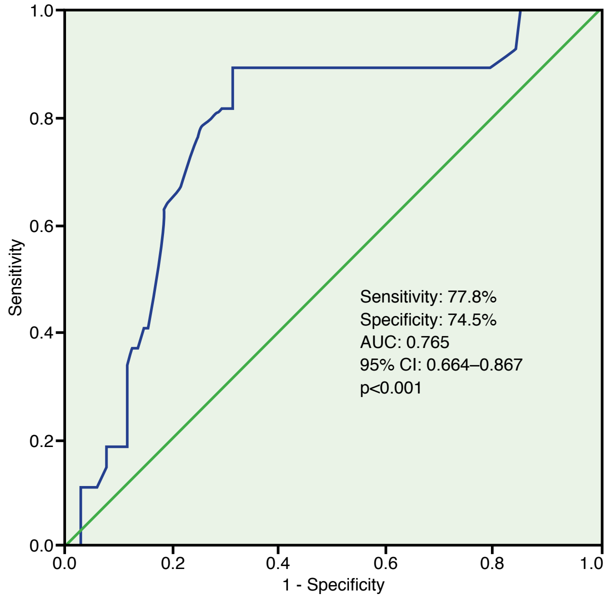

Figure 3. Receiver operating characteristic curve analysis to predict the value of left atrial volume in atrial fibrillation recurrence.

third-generation CBs due to the shorter tip design. The acute purpose of CBA is to achieve complete PVI. However, in the long term, the purpose of CBA is to prevent PVr and hence, AF recurrence. In our study, we investigated the utility of the thermodynamic parameters obtained using second-generation CBA for the prediction of long-term AF recurrence and we found that the balloon warming angle was associated with AF recurrence. Aryana et al.[16] investigated the procedural and biophysical determinants of effective PVI during CBA and reported that the time and the number of procedural processes were not determinative in the achievement of PVI. Moreover, the authors also noted that the primary factor was the time to reach 0°C. The incidence of PVr was significantly lower in cases in which PVI was achieved within 10 to 60 seconds. Early PVI and early attainment of 0°C were found to be correlated with PV occlusion. A previous study evaluating the physiology of PV during CBA reported that the likelihood of success was remarkably higher with a PVI cutoff time of 83 seconds.[17] Theoretically, rapid freezing and PVI achievement are important determinants of the efficiency of CBA. In routine practice, the balloon cooling time, the minimum temperature achieved at 30 seconds and 90 seconds, the minimum temperature and time plane and their relationship with the cooling, and the PVI occurrence time and temperature are used to determine the acute success rate of AF ablation. In our study, the examination of PVs indicated that only the PVI value of the right lower PV was significantly longer in the AF Recurrence group when compared with the AF Non-recurrence group, and no significant difference was found with regard to other veins and other mean values. However, this finding is inconsistent with the findings presented by similar studies in that it suggests that the PVI time is not associated with AF recurrence. In our study, PVI was performed with a duration ranging from 55 to 70 seconds in all of the patients. If our study population had been larger and there was a greater difference in the PVI achievement time, longer PVI duration could have been seen in the AF recurrence group.

The primary limitation of our study is that it had a retrospective design. Second, PVr was not evaluated in our study, although it has been evaluated in similar studies. In addition, transesophageal echocardiography was performed only to assess the thrombus in the heart chambers in our routine clinical practice, although pulmonary venous anatomy has been assessed with tomography or transesophageal echocardiography in other studies. Finally, only second- generation balloons were used in the present study.

Conclusion

The results indicated that a higher balloon warming angle during CBA led to a higher likelihood of recurrence. In patients with a greater balloon warming angle, performing an additional freezing procedure by establishing good contact with the PVduring the same procedure may be necessary. Recurrence can be predicted by observing the balloon warming angle during the procedure, and medical treatment can be regulated accordingly or closely followed. The balloon warming angle may be a practical means to predict AF recurrence. However, further comprehensive studies are needed to substantiate our findings.

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