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ORIGINAL PAPER

Safety and efficacy of cryoballoon ablation for the treatment of atrial fibrillation in elderly patients

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Abstract

Background Catheter ablation (CA) is an established therapy for treatment of atrial fibrillation (AF). However, data about AF ablation using the cryoballoon (CB) in the elderly population are sparse. The aim of this single center retrospective study is to evaluate the safety and efficacy of CB ablation in patients ≥ 75 years compared to patients < 75 years.

Methods and results Fifty-five consecutive patients aged ≥ 75 years (elderly group) were compared with 183 patients aged < 75 years (control group). All patients underwent pulmonary vein isolation (PVI) using the second-generation CB. The mean age in the elderly group was 78 ± 2.8 years and 60.8 ± 9.5 in the control group ($p < 0.001$). During 11.8 ± 5.4 months of follow-up, single procedure success rate for the elderly and the control group was 72.8 and 76%, respectively ($p = 0.37$). During redo ablation ($n = 40$), low-voltage areas in the LA were more frequently observed in elderly patients compared to the control group [1.0 (IQR 0–2.0) segments vs 2.0 (IQR 2.0–3.0) segments, respectively, $p = 0.03$]. The most common complication was transient phrenic nerve palsy, which only occurred in patients < 75 years (0 vs 7, $p = 0.33$). No severe complication such as procedure-related deaths, atrio-esophageal fistula, or cerebrovascular embolic events occurred.

Conclusions Our data strengthen the value of CB ablation for the treatment of AF as an effective and safe procedure in elderly patients, with similar success and complication rates when compared with a younger population.

Keywords Atrial fibrillation · Cryoballoon · Catheter ablation · Elderly

Introduction

Catheter ablation (CA) of symptomatic patients with atrial fibrillation (AF) by targeting the pulmonary veins (PV) is widely used as recommended by current guidelines [1–3]. Novel technologies such as cryoballoon (CB) technology have been developed aiming at facilitation of the ablation procedure and improved outcome [4]. In recent trials, this technology was non-inferior to the current gold standard of manual point by point ablation for AF with respect to success and complication rates [4, 5].

The necessity of treating elderly patients with AF is noticeably growing, as the prevalence of elderly population increases [6–8]. In recent years, CB-based PV isolation (PVI) is increasingly performed [5, 9]. Several non-randomized clinical studies have addressed the issue of CA in the elderly and have shown favorable rates of success [10, 11], but little is known about the results of CB-CA in the elderly population.

In this study, we therefore aimed to assess the safety and efficacy of AF ablation using the second-generation CB in patients ≥ 75 years compared to a control group of patients < 75 years and to analyze predictors of arrhythmia recurrence.

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Methods

Between July 2015 and March 2017, patients with symptomatic paroxysmal or persistent AF and indication for AF ablation according to current guidelines, who were scheduled for PVI using second-generation CB, were enrolled in this retrospective single center study. Patients with left atrial (LA) thrombus, uncontrolled thyroid dysfunction, contraindication to anticoagulation, pregnancy, previous AF ablation, severe valvular disease, and a LA size > 60 mm were excluded. Severity of symptoms was recorded according to European Heart Rhythm Association (EHRA) score. Informed consent was taken from each patient before the procedure. The study was in compliance with the principals outlined in the Declaration of Helsinki and approved by the local Ethics Committee (no. 17-298). Patients were divided into elderly group (equal or older than 75 years old) and controls (less than 75 years old).

Preprocedural management

Transesophageal echocardiography was performed in all patients prior to the procedure. Apart from echocardiography, no additional preprocedural imaging was performed. In patients on vitamin K antagonists, anticoagulation was continued throughout the procedure aiming at an INR of 2–3. In patients treated with novel oral anticoagulants (NOACs), the drug was discontinued ≥ 24 h prior to the procedure and and re-initiated 6 h post-ablation at half the regular dose, and at full dose the following day.

Procedural management

All procedures were performed with the use of analgosedation using midazolam, fentanyl, and propofol [12]. One 10-pole diagnostic catheter (Webster® CS Uni-Directional, Biosense Webster, Inc., CA, USA) was introduced via the right femoral vein and positioned within the coronary sinus. A single transseptal puncture was performed via the right femoral vein under fluoroscopic guidance, using a modified Brockenbrough technique and an 8.5 French transseptal sheath (SL1, St. Jude Medical, Inc., St. Paul, MN, USA or PREFACE Biosense Webster, Inc. Irvine, CA, USA). Heparin was administered after transseptal puncture to maintain an activated clotting time of ≥ 300 s. The transseptal sheath was then exchanged over a guidewire with a 12-French steerable sheath (Flexcath Advance, Medtronic, Inc. Minneapolis, MN, USA). To identify all PV ostia, selective PV angiography was performed. In all patients, an esophageal temperature probe (Sensitherm, St. Jude Medical, Inc. or CIRCA S-CATH™) was inserted and positioned according to the individual CB position to facilitate esophageal temperature monitoring during energy delivery. The second-generation 28 mm CB was advanced into the LA via the 12-French steerable sheath and a spiral mapping catheter (20 mm diameter; Achieve, Medtronic, Inc.) was advanced into the target PV to record electrical activity. The CB was inflated proximal to the PV ostium and gently pushed against the PV ostium to facilitate complete antral sealing. Contrast medium injected through the central lumen of the CB was used to verify complete occlusion of the PV ostium. Each freeze cycle duration lasted 180 s. If the time to PVI was longer than 60 s or no real-time PV isolation recording could be obtained, 240 s freeze cycle and one more 180 s bonus freeze cycle were applied. In patients demonstrating AF at the time of the procedure, electrical cardioversion was performed after the final freeze cycle and PVI was re-confirmed in sinus rhythm (SR). During energy delivery along the right PVs, continuous phrenic nerve pacing at maximum output and pulse width (12 mA, 2.9 ms) at a cycle length of 1000 ms was performed, using a diagnostic catheter positioned in the superior vena cava. Phrenic nerve capture was monitored by intermittent fluoroscopy and by tactile feedback of diaphragmatic contraction by the operator's hand positioned on the patient's abdomen. In addition, the continuous motor action potential (CMAP) was monitored. Refrigerant delivery was stopped immediately if weakening or loss of diaphragmatic movement, or the reduction of CMAP amplitude was noted. If phrenic nerve palsy (PNP) occurred, no additional freeze cycle was applied along the septal PVs. Cavotricuspid isthmus ablation (CTI), using an open irrigated radiofrequency catheter (Celsius ThermoCool or ThermoCool-SF, Biosense Webster Inc.), was solely performed in patients with documented or induced common type atrial flutter during the index procedure. PV abnormality was defined as left common ostium and/or a right middle PV.

Postprocedural management

Following ablation, all patients underwent transthoracic echocardiography to rule out a pericardial effusion. All patients were treated with proton-pump inhibitors twice daily after the procedure until discharge and once daily for 6 weeks thereafter. Anticoagulation was continued for at least 3 months and thereafter based on the individual CHA_2DS_2-VASC score. To prevent early recurrence, an antiarrhythmic drug (ADD) was administered throughout the 3 months blanking period (BP). Our institutional approach strongly recommends the administration of AAD and discontinuation after BP. Due to patient preference or referring physician preference AAD was continued. Follow-up was performed either by the outpatient clinic or the referring cardiologist at 3, 6, and 12 months after the index procedure, as well as in case of symptoms suggestive of

arrhythmia recurrence and included a ≥ 24 h Holter recording and interrogations of implanted devices, if present. Symptoms suggestive of recurrent atrial tachyarrhythmia (ATA) prompted additional outpatient clinic visits.

Repeat ablation was offered to patients with symptomatic ATA recurrence after the BP, or symptomatic drug-refractory recurrent ATA within the BP that could not be managed without intervention. Redo procedure was performed using 3D Navigation system (CARTO-3, Biosense Webster Inc,). PVs were assessed for reconnection and reisolation of the PVs was performed in case of recovered conduction. In case of AT, electro-anatomical mapping and entrainment mapping were performed to verify the mechanism and to guide the following radiofrequency ablation. Bipolar maps were created and low-voltage zone was defined as contiguous areas of bipolar voltage < 0.5 mV. The LA was divided into five segments (posterior wall, inferior LA, mitral isthmus, anterior wall, septum, omitting left atrial appendage).

The primary endpoint of this study was any episode of documented ATA recurrence lasting longer than 30 s after a 3 months BP or triggering a redo ablation within the blanking period.

Secondary endpoints were complications related to the procedure, such as pericardial tamponade, PNP, cerebrovascular events, and groin complications.

Statistical analysis

Continuous data are presented as mean ± standard deviation, skewed continuous parameters were expressed as median (interquartile range defined as Q1–Q3). Categorical data were summarized as frequencies and percentages and were compared using χ^2 test. Comparisons between baseline characteristics were performed by independent Student's *t*, Mann–Whitney rank sum, Fisher's exact, or χ^2 tests, where appropriate. To analyze the association between baseline and procedural parameters on AF recurrence, binary logistic regression analysis was used. Parameters that were found to be univariately associated with the outcome and those that show a slight association with the outcome with $p < 0.20$ were included in the multivariable analysis. Kaplan–Meier and Cox regression analyses were performed to describe ATA-free survival. Statistical analyses were performed using SPSS statistical software (version 22.0; SPSS Inc., Chicago, IL, USA). A two-tailed $p < 0.05$ was considered statistically significant.

Results

A total of 238 patients (55 patients in study group and 183 patients in control group) with paroxysmal (91/238; 38.2%) and persistent (147/238; 61.8%) AF [14 (5.9%) patients had concomitant documented typical atrial flutter] undergoing PVI using the second-generation 28 mm CB were included. Baseline characteristics of the study population are summarized in Table 1. The mean age in the elderly group was 78 ± 2.8 years and 60.8 ± 9.5 in the control group ($p < 0.001$). Patients in the elderly group had a higher CHA2DS2VASc score (4 vs 2, $p = 0.001$), a higher prevalence of previously known myocardial infarction (MI) (23.6 vs 6%, $p = 0.001$), and a higher rate of previous stroke/ transient ischemic attack (TIA) (23.6 vs 4.3%, $p = 0.001$). All targeted veins were isolated. Mean number of CB applications per PV and mean temperature per PV during the procedure as well as procedural characteristics are presented in Table 2. PV abnormality was observed in 9 patients (16.3%) in the elderly group and 34 (18.5%) patients in the control group ($p = 0.84$). Total procedural and fluoroscopy time in the elderly and control

Table 1 Baseline characteristics of study patients

	Control group	Elderly group	*p* value
Number of patients	183	55	
Age (years)	60.8 ± 9.5	78 ± 2.8	< 0.001
Male gender, *n*	120 (65.5%)	25 (45.4%)	0.01
Height (cm)	177.1 ± 10.4	171.9 ± 9.2	0.001
Weight (kg)	91.3 ± 20.1	79.6 ± 18.8	0.001
Hypertension, *n*	127 (69.3%)	47(85.4%)	0.02
Diabetes mellitus, *n*	16(8.7%)	11(20%)	0.36
Dyslipidemia, *n*	56 (30.6%)	34 (61.8%)	0.001
LA diameter (mm)	40.8 ± 6.6	40.8.6 ± 5.5	0.95
LVEF%	52.5 ± 8.0	51.6 ± 8.3	0.44
CHA2DS2VASc	2.0 ± 1.3	4.0 ± 1.3	0.001
EHRA score	2.5 ± 0.6	2.5 ± 0.7	0.55
HASBLED	1.2 ± 0.97	2.2 ± 0.89	0.001
Previous stroke/TIA, *n*	8 (4.3%)	13 (23.6%)	0.001
Previous MI, *n*	11(6%)	13 (23.6%)	0.001
Previous PCI, *n*	29 (15.8%)	23 (41.8%)	0.001
CABG operation, *n*	6 (3.2%)	3 (5.4%)	0.43
Cardiomyopathy, *n*	34 (18.5%)	13 (23.6%)	0.44
Non-ischeamic	25 (13.6%)	8 (14.5%)	0.82
Ischeamic	5 (2.7%)	5 (9%)	0.054
Hypertrophic	4 (2.1%)	0 (0%)	0.57
Implanted electrical device, *n*	14 (7.6%)	5 (9%)	0.67
Mean duration of AF (months)	21.9 ± 34.6	24.6 ± 34.1	0.60
Follow-up period (months)	11.7 ± 5.3	12.4 ± 5.9	0.36
Persistent AF, *n*	109 (59.5%)	38 (69%)	0.26
Documented atrial flutter, *n*	10 (5.4%)	4 (7.2%)	0.74

LA left atrium, *LVEF* left ventricular ejection fraction, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *CABG* coronary bypass grafting operation, *AF* atrial fibrillation, *EHRA* European heart rhythm association, *TIA* transient ischemic attack, *CTI* cavotricuspid isthmus, *LA* left atrium

Table 2 Procedural characteristics of study patients

	Control group	Elderly group	*p* value
Number of patients	183	55	
Additional CTI during the procedure, n	10 (5.4%)	4 (7.2%)	0.74
PV abnormality, n	34 (18.5%)	9 (16.3%)	0.84
LCPV	18 (9.8%)	8 (14.5%)	0.33
RMPV	18 (9.8%)	2 (3.6%)	0.17
Total procedure time (min)	97.6 ± 22.4	101.4 ± 32.5	0.54
Fluoroscopy time (min)	21.6 ± 34.6	24.6 ± 34.1	0.57
Freezes in LSPV (times)	1.4 ± 0.6	1.4 ± 0.6	0.96
Freezes in LIPV (times)	1.4 ± 0.5	1.4 ± 0.5	0.88
Freezes in RSPV (times)	1.2 ± 0.6	1.3 ± 0.6	0.24
Freezes in RIPV (times)	1.4 ± 0.6	1.5 ± 0.6	0.60
LSPV freeze duration (s)	279.9 ± 132.1	294.3 ± 130.1	0.47
LIPV freeze duration (s)	292.1 ± 127.1	271.5 ± 128.6	0.29
RSPV freeze duration (s)	237.4 ± 116.8	272.7 ± 158.7	0.13
RIPV freeze duration (s)	302.8 ± 149.5	303.2 ± 138.6	0.98
Minimum temperature in LSPV (°C)	48.2 ± 5.6	48.2 ± 5.7	0.95
Minimum temperature in LIPV(°C)	45.2 ± 6.1	45.2 ± 6.2	0.66
Minimum temperature in RSPV (°C)	49.3 ± 5.6	48.1 ± 6.4	0.17
Minimum temperature in RIPV (°C)	46.4 ± 6.2	45.5 ± 5.9	0.33
LSPV diameter (mm)	15.7 ± 3.8	16.8 ± 3.8	0.056
LIPV diameter (mm)	13.5 ± 2.8	14.0 ± 2.9	0.25
RSPV diameter (mm)	14.7 ± 3.3	15.2 ± 3.7	0.39
RIPV diameter (mm)	13.3 ± 3.0	12.8 ± 2.3	0.28
Real-time recordings in LSPV (*n*)	104 (56.8%)	24 (43.6%)	0.09
Real-time recordings in LIPV (*n*)	106 (57.9%)	29 (52.7%)	0.53
Real-time recordings in RSPV (*n*)	58 (31.6%)	24 (43.6%)	0.08
Real-time recordings in RIPV (*n*)	90 (49.1%)	30 (54.5%)	0.54
Balloon temperature < − 60 °C (*n*)	20 (10.9%)	4 (7.2%)	0.61
Initial sinus rhythm, *n*	91 (49.7%)	25 (45.4%)	0.64
Cardioversion during procedure, *n*	77 (42%)	27 (49%)	0.43
Recurrence in blanking period, *n*	26 (14.2%)	7 (12.7%)	0.48
Late recurrence, *n*	44 (24%)	15 (27.2%)	0.37

LIPV left inferior pulmonary vein, *LSPV* left superior pulmonary vein, *RIPV* right inferior pulmonary vein, *RMPV* right middle pulmonary vein, *RSPV* right superior pulmonary vein

groups were 101.4 ± 32.5 vs 97.6 ± 22.4 min ($p = 0.54$) and 21.6 ± 34.6 vs 24.6 ± 34.1 min ($p = 0.57$), respectively. Initial rhythm was SR in 25 (45.4%) patients in the elderly group and 91 (49.7%) in the control group ($p = 0.64$). During intrahospital stay, two of elderly patients and three of control patients had AF recurrence ($p = 0.26$).

Clinical follow-up

Overall, during 11.8 ± 5.4 months of follow-up, single procedure success rate was 72.8% in the elderly group (paroxysmal AF 64.7%; persistent AF 76.3%) and 76.0% in the control group (paroxysmal AF 87.8%; persistent AF 67.8%), ($p = 0.37$). Early recurrence of ATA within the first 3 months after index CB-CA occurred in 24% of patients in the study group and 27.2% in the control group ($p = 0.48$). In multivariable Cox regression analysis, presence of cardiomyopathy ($p = 0.008$), PV abnormality ($p = 0.001$), and arrhythmia recurrence during the BP ($p < 0.001$), but not advanced age, were found to be predictors of recurrence of ATA (Table 3). ADD was prescribed to all patients after index procedure. In 203/238 patients, AAD was discontinued after BP.

A total 40 of 92 (43.4%) patients (20% in the elderly group and 15.8% in the control group) underwent redo ablation for recurrent ATA. Six patients in elderly group and 19 in control group who were undergoing redo ablation were on AAD. The AAD was continued in these patients due to ATA recurrence. In 13 patients, the repeat procedure was performed during the BP due to the need for multiple and/or failure of electrical CV despite antiarrhythmic drug therapy.

Table 3 Cox regression analysis

	β	SE	Wald	df	Significance level	HR	CI 0.95	HR
Recurrence in blanking period	2.522	0.291	75.056	1	< 0.001	12.5	7.04	22.2
PV abnormality	0.898	0.282	10.166	1	0.001	2.45	1.41	4.27
Presence of Cardiomyopathy	0.769	0.289	7.078	1	0.008	2.15	1.22	3.80

Predictors of ATA recurrence after multivariate analysis

SE standard error, *df* degree freedom, *HR* hazard ratio, *PV* pulmonary vein

Pulmonary vein reconduction during redo ablation

Reconduction of at least one PV could be recorded in 24/40 (60.0%) patients as follows: in 4/11 (36.4%) elderly patients and 20/29 (69.0%) in the control group (Table 4). Reconnection of one PV was observed in 17/40 (42.5%) patients, of two PVs in 4/40 (10%) patients, and of all four PVs in 3/40 (7.5%) patients. The following PVs were reconnected: LSPV in 13/40 (32.5%), LIPV in 6/40 (15.0%), RSPV in 8/40 (20.0%), and RIPV in 10/40 (25.0%) patients.

Adverse events

Six groin complications occurred (four hematoma and two arterio-venous fistula) in two elderly and four in the control group. The groin complication prolonged hospital stay 2 days. Transient PNP occurred only in patients ≤ 75 (7 vs 0, $p = 0.33$). PNP had no effect on prolongation of hospital stay. All PNP cases resolved spontaneously during follow-up. In two cases pericardial tamponade occurred, that was managed by pericardial puncture (one in elderly, one in the control group). None of these patients required surgical treatment. Patients with pericardial tamponade discharged from hospital on the planned day. No severe complication such as procedure-related deaths, atrio-esophageal fistula, or cerebrovascular embolic events occurred.

Discussion

This retrospective analysis investigated the safety and efficacy of second-generation CB-CA in patients older than 75 years with paroxysmal and persistent AF and predictors of ATA recurrence. The current analysis demonstrates that CB-CA is a feasible and safe procedure in elderly patients with similar success and complication rates compared to a younger population. The presence of cardiomyopathy, PV abnormality, and ATA recurrence during the BP was found as predictors of recurrence of ATA.

AF is associated with an increased prevalence among the elderly population [11, 13, 14].

Most major PVI randomized control trials excluded elderly patients from their study cohorts [5, 15, 16]. One possible explanation is that PVI may have a lower success rate among these patients due to the aging effect on atrial remolding and fibrosis [17].

However, several non-randomized retrospective studies have investigated the effect of radiofrequency (RA) CA in elderly patients and have shown positive results [11, 18].

The long-term results of RF ablation in 93 patients older than 75 years were investigated by Metzner et al. [18]. After a mean follow-up of 37 ± 20 months, 35/93 (38%) patients were in stable SR (46% PAF, 31% persistent AF, and 10% long-standing persistent AF) following one procedure. In addition, they reported eight (5.8%) major complications (2 pericardial tamponade, 1 severe bleeding, and 2 heamothorax) and 26 minor (19%) complications.

In a recent study, Bulava et al. evaluated the safety and efficacy of RF-CA of AF in elderly patients [11]. Fifty patients aged ≥ 80 years were compared to 259 patients aged ≤ 50 years. The RF-CA complication rate did not differ between groups. Among patients with paroxysmal AF, 71.4% elderly vs 84.7% young patients were free of any arrhythmia. For non-paroxysmal AF, arrhythmia-free survival was significantly lower (58.6% elderly vs 81.2% younger patients, $p = 0.023$).

Currently, very little is known about the efficacy and safety of CB-CA in the elderly population. A recent small retrospective study assessed the efficacy of CA with the 2nd generation CB for symptomatic AF [paroxysmal ($n = 31$; 77.5%) or persistent ($n = 9$; 22.5%)] in 40 elderly patients over 75 years [19]. Freedom from arrhythmia recurrence was 86.4% at 12 months and 80.2% at 24 months. Also, one pericardial tamponade and three transient PNP were reported. However, this study included a small number of patients without control group.

More recently, Abugattas and colleagues evaluated the 1-year efficacy and safety of CB-CA in 53 patients older than 75 years compared with 106 younger patients [17]. There was no significant difference in success rate between older (10/53) and younger patients (16/106) (81.1 vs 84.9%, $p = 0.54$). The most common complication was transient PNP which occurred in eight patients in the younger group and three in the older group (7.5 vs 5.7%, respectively, $p = 0.66$). In our analysis, we showed approximately similar success rates within a larger cohort of patients including paroxysmal and persistent AF. Furthermore, the complication rates in our analysis were similar to previous publications

Table 4 Clinical and procedural parameters in patients, who underwent redo ablation, according to the mechanism of the recurrence

	Elderly group	Control group	*p* value
Number of patients	11/55 (20%)	29/183 (15.8%)	
Age (years)	76.9±1.9	59.2±9.5	0.001
Male gender, *n*	6 (54.5%)	18(62.1%)	0.66
BMI	26.2 (23.3–36.7)	26.5(24.4–28.6)	0.26
Persistent AF, *n*	7 (63.6%)	22 (75.9%)	0.43
CHA2DS2VASc	4.0 (3.0-4.25)	2.0 (1.0–3.0)	< 0.0001
HASBLED	2.0 (2.0–2.0)	1.0 (1.0–2.0)	0.017
EHRA score	3.0 (2.0–3.0)	2.5 (2.0–3.0)	0.45
Mean duration of AF (months)	20.0 (1.8–111.0)	12.0 (3.3–24.0)	0.59
Hypertension, *n*	11 (100%)	20 (69%)	0.043
Diabetes mellitus, *n*	2 (18.2%)	5 (17.2%)	1
Dyslipidemia, *n*	8 (72.7%)	6 (20.7%)	0.07
Previous MI, *n*	4 (36.4%)	1 (3.4%)	0.015
Previous PCI, *n*	6 (54.5%)	3 (10.3%)	0.007
CABG operation, *n*	1 (9.1%)	2 (6.9%)	1
Other heart operation, *n*	0(0%)	1 (3.4%)	1
Cardiomyopathy, *n*	3 (27.3%)	7 (24.1%)	1
Valvular heart disease, *n*	0(0%)	1(3.4%)	1
AT recurrence, *n*	7 (63.6%)	19 (65.5%)	1
LA diameter (mm)	44.1±6.1	41.1±6.4	0.17
LVEF (%)	50.0 (37.5–56.3)	53.0 (46.3–55.0)	0.72
Procedural parameters			
Total procedure time (min)	101.4 ± 32.5	97.6 ± 22.4	0.44
Fluoroscopy time (min)	21.9 (15.2–25.1)	23.1 (16.6–27.4)	0.92
Fluoro dose, cGy cm^2	35.3 (26.7–60.1)	87.9(32.7–123.0)	0.07
Initial sinus rhythm, *n*	6 (54.5%)	11 (37.9%)	0.34
Freezes in LSPV (times)	1.0 (1.0–2.0)	1.0 (1.0–2.0)	0.97
Freezes in LIPV (times)	1.0 (1.0–1.3)	1.0 (1.0–2.0)	0.83
Freezes in RSPV (times)	1.0 (1.0–1.3)	1.0 (1.0–2.0)	0.63
Freezes in RIPV (times)	1.0 (1.0–2.0)	1.0 (1.0–2.0)	0.83
LSPV freeze duration (s)	210 (170–480.0)	240 (180–405)	0.63
LIPV freeze duration (s)	180.0 (180.0–300.0)	240 (180–405)	0.17
RSPV freeze duration (s)	180.0 (169.8–345.0)	237.5 (180–240)	0.90
RIPV freeze duration (s)	240.0 (180.0–301.5)	240 (195–395)	0.95
Minimum temperature in LSPV (°C)	48.1 ± 5.7	47.0 ± 5.5	0.58
Minimum temperature in LIPV(°C)	44.8 ± 5.4	44.7 ± 5.0	0.94
Minimum temperature in RSPV (°C)	48.7 ± 7.0	50.2 ± 6.3	0.51
Minimum temperature in RIPV (°C)	47.4 ± 5.4	45.7 ± 5.9	0.42
Total number of applications, *n*	6 (5.0–6.0)	5 (4.0–6.5)	0.85
Total duration of application (s)	1062 (802.0–1200.0)	1060.0 (886.5–1371.0)	0.67
Balloon temperature < − 60 °C, *n*	0 (0%)	1 (3.4%)	1
Cardioversion during procedure, *n*	4 (36.4%)	15 (51.7%)	0.48
Additional CTI during the procedure, *n*	1 (9.1%)	2 (6.9%)	1
PV anatomy			
LSPV diameter (mm)	17.4 ± 3.4	16.8 ± 4.4	0.29
LIPV diameter (mm)	15.6 ± 3.1	13.7 ± 2.3	0.90
RSPV diameter (mm)	15.8 ± 3.8	14.5 ± 3.8	0.35
RIPV diameter (mm)	12.7 ± 2.2	14.0 ± 3.4	0.35
PV abnormality, n	4 (36.4%)	12 (41.4%)	0.99
LCPV, *n*	3 (27.3%)	6 (20.7%)	
RMPV, *n*	2 (18.2%)	6 (20.7%)	

Table 4 (continued)

	Elderly group	Control group	*p* value
Therapy in the follow-up			
Treatment with b-blocker, *n*	10 (90.9%)	18 (62.1%)	0.12
Flecainid, *n*	5 (45.5%)	13 (44.8%)	0.94
Sotalol, *n*	0 (0%)	2 (6.9%)	0.99
Amiodarone, *n*	1 (9.1%)	4 (13.8%)	0.65
PV reconnection after CB-CA			
Patients with PV reconnection	4 (36.4%)	20 (69%)	0.08
Number of PV reconnections, *n*	0 (0–1.0)	1 (0–1.0)	0.09
ATA recurrence after CB-CA			
Patients with AFL recurrence	2 (18.2%)	8 (27.6%)	0.69
Patients with left AT recurrence	5 (45.5%)	11 (37.9%)	0.66

AT atrial tachycardia, *AF* atrial fibrillation, *BMI* body mass index, *CABG* coronary bypass grafting operation, *CBA* second-generation cryoballoon ablation, *CMP* cardiomyopathy, *EHRA Score* European heart rhythm association score, *LA* left atrium, *LCPV* left common pulmonary vein, *LIPV* left inferior pulmonary vein, *LSPV* left superior pulmonary vein, *LVEF* left ventricular ejection fraction, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *RIPV* right inferior pulmonary vein, *RMPV* right middle pulmonary vein, *RSPV* right superior pulmonary vein

without significant differences between older (≥ 75 years) and younger patients [20].

Furthermore, our current analysis demonstrates that PV abnormality was found as one of the predictors of recurrence of ATA. Heeger et al. reported high acute success rates and procedural safety for the treatment of left common pulmonary veins (LCPV) [21]. Freedom from ATA recurrence was similar between patients with and without LCPV. On the contrary, Shigeta et al. found that the presence of LCPV was associated with poor clinical outcome of AF ablation in patients undergoing second-generation CB-CA [22]. There are several explanations for the higher recurrence rate in patients with anatomical variants of the PVs. The anatomical variant may pose technical challenges during the procedures, thus potentially compromising effective lesion formation. However, the authors believe that the most likely mechanism of the higher recurrence rate is the more distal PV isolation in common PV ostia which results in a smaller substrate modification of the LA and PV antrum [21, 22].

The results of our analysis as well as of the above mentioned studies suggest that CB-CA might be helpful in treating elderly patients presenting with symptomatic AF and should be considered with the same level of recommendation as younger patients. Moreover, age as a sole factor should not be an excluding criteria for CB-CA. Consequently, old patients with good functional status should be carefully evaluated and considered to receive CB-CA with a favorable success rate and similar complication rate in comparison to younger patients.

However, there are limitations of this study that need to be acknowledged. The major limitation of this study is the selection bias due to its retrospective nature. In the elderly group, frail patients were less likely to be ablated. Therefore, this might be a selection of particularly healthy elderly patients. This analysis is retrospective in nature without preprocedural cardiac imaging. Moreover, our follow-up did not include routine continuous monitoring with implanted devices or 7-day-Holter recording and therefore our success rate may be overestimated. Nevertheless, follow-up included 24 h Holter monitoring, and/or device interrogations (if present), at 3, 6, and 12 months. Finally, no systematical esophagoscopy was performed in this study. Consequently, no data about the incidence of esophageal injury are available.

Conclusions

Our data strengthen the value of CB-CA for the treatment of AF as an effective and safe procedure in elderly patients, with similar success and complications rates compared to a younger population.

Compliance with ethical standards

Conflict of interest K. Yalin received research and educational grant from Turkish Society of Cardiology. E. Lyan received travel grants and Speaker's Bureau Honoraria from BiosenseWebster, Medtronic, Boston Scientific. R. Tilz received travel grants from St. Jude Medical, Topera, BiosenseWebster, Daiichi Sankyo, Sentrheart and Speaker's Bureau Honoraria from BiosenseWebster, Biotronik, Pfizer, Topera, Bristol-Myers Squibb; Bayer, Sanofi Aventis. Christian Heeger received travel grants and research grants by Medtronic, Claret Medical and SentreHeart. All other authors have no disclosures.

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