Acute efficacy, safety, and long-term clinical outcomes using the second-generation cryoballoon for pulmonary vein isolation in patients with a left common pulmonary vein: A multicenter study

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BACKGROUND Second-generation cryoballoon (CB2)-based pulmonary vein isolation (PVI) has demonstrated encouraging clinical results in the treatment of paroxysmal (PAF) and persistent atrial fibrillation (PersAF). However, the CB2 features a maximal diameter of 28 mm, and its adaptability to anatomic variations of the pulmonary veins (PVs) might be challenging.

OBJECTIVE The purpose of this study was to assess the acute efficacy, safety, and long-term clinical results of CB2-based PVI in patients with a left common pulmonary vein (LCPV).

METHODS Six hundred seventy consecutive patients underwent CB2-based PVI in 3 electrophysiology centers. In 74 patients (11%), an LCPV was identified (LCPV group). The data were compared to those from matched patients (n = 74) with normal pulmonary veins and comparable baseline characteristics (control group). An antral occlusion of the complete LCPV ostium was feasible in 50% of patients in the LCPV group. If an antral occlusion could not be obtained, a sequential isolation of the first superior and inferior branches was applied.

RESULTS All 74 LCPVs were successfully isolated. A total of 64% patients (LCPV group) and 66% patients (control group) remained in sinus rhythm after mean follow-up of 1.9 ± 0.9 years (P = .820). In 18 of 26 patients (69%) with atrial tachyarrhythmia recurrence, a repeat procedure using radiofrequency energy was performed, and a total of 56% LCPVs were found to be persistently isolated (control group: 61% of left-sided PVs, P = .801).

CONCLUSION Patients with an LCPV undergoing CB2-based PVI demonstrate a high acute success rate. Comparable results with regard to clinical success and durability of PVI were shown when comparing patients of the LCPV group and the control group.

KEYWORDS Atrial fibrillation; Pulmonary vein isolation; Cryoballoon; Long-term follow-up; Left common pulmonary vein

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paroxysmal atrial fibrillation (PAF) and persistent atrial fibrillation (PersAF). The randomized FIRE AND ICE trial proved noninferiority of CB2- to radiofrequency (RF)-based PVI with regard to efficacy and safety for treatment of patients with PAF. Furthermore, statistically significant differences in favor of the CB2 in terms of repeat ablations, all-cause rehospitalization, and cardiovascular rehospitalization were assessed. However, the CB2 is available in only 2 different balloon sizes (23 and 28 mm). Therefore, its adaptability to anatomic variations of pulmonary vein (PV) anatomy is limited. In RF procedures, some anatomic variants, such as left common pulmonary vein (LCPV) or right common PV, were reported to be associated with procedural challenges, thus resulting in compromised lesion formation and lesion quality as well as impaired clinical outcomes.

The incidence of LCPV in patients scheduled for PVI varies but has been reported at 13%–29%. Data on the impact of LCPV on acute efficacy, safety, and long-term clinical outcomes in CB2-based PVI are not available yet.

Methods

Patient characteristics and study design
All patients referred to 3 experienced electrophysiology centers in Germany (Asklepios Klinik St. Georg, Hamburg; Asklepios Klinik Harburg, Hamburg; Charité Universitätsmedizin Berlin, Campus Benjamin Franklin, Berlin) were analyzed retrospectively. Patients with drug-refractory PAF or PersAF scheduled for CB2-based PVI and LCPV based on periprocedural selective PV angiography were included (Figure 1). LCPV was defined as the presence of bifurcated PVs entering the left atrial (LA) contour together and a distance between the virtual border of the LA and the bifurcation of both PVs ≤5 mm. Exclusion criteria were prior LA ablation, LA diameter >60 mm, severe valvular heart disease, long-standing PersAF, or contraindications to postinterventional oral anticoagulation. Transeosophageal echocardiography was performed before ablation to assess the LA diameter and to rule out intracardiac thrombi. No additional preprocedural imaging was performed. Follow-up and procedural data of patients who underwent CB2-based PVI with a LCPV (LCPV group) were compared to matched patients with normal PV anatomy (control group).

All patients provided written informed consent, and all patient information was anonymized. The study was approved by the local ethic’s board and was performed in accordance with the ethical standards given in the 1964 Declaration of Helsinki and its later amendments.

Intraprocedural management
Principles of CB2-based PVI have been described previously. In brief, all procedures were performed with...
patients under deep sedation using midazolam, fentanyl, and propofol. Single transseptal puncture was performed using a modified Brockenbrough technique and an 8.5Fr transseptal sheath (SL1, St. Jude Medical, St. Paul, MN). The transseptal sheath was exchanged over a wire for a 12Fr steerable transseptal sheath (Flexcath Advance, Medtronic). After transseptal puncture, heparin bolus were administered targeting an activated clotting time >300 seconds. Selective PV angiographies were performed to identify the individual PV ostia. A temperature probe (Sensitherm, St. Jude Medical; or Circa S-Cath, Circa Scientific, Englewood, CO, USA) was placed within the esophagus to monitor esophageal temperatures during freeze cycles. The intraluminal esophageal temperature cutoff was set at 15°C.19

During CB2 applications along the septal PVs, continuous pacing of the phrenic nerve (PN) was performed via a diagnostic catheter positioned within the superior vena cava (7Fr, Webster, Biosense Webster, Diamond Bar, CA).18 Pacing was set at maximum output and pulse width, and a cycle length of 1000 ms. Monitoring of PN was based on tactile feedback of diaphragmatic contraction and on assessment of the right diaphragmatic compound motor action potential.20,21 Energy delivery was interrupted immediately if weakening or loss of diaphragmatic contraction was noted or a decrease of the compound motor action potential amplitude ≥30% was observed. In case of persistent PN palsy (PNP), no further cryoenergy was delivered along the septal PVs.

**PVI using the second-generation CB**

The CB2 was advanced into the LA over a spiral mapping catheter (Achieve, Medtronic). Only the 28-mm CB2 in combination with the 20-mm Achieve was used in this population. The CB2 was inflated proximal to the PV ostium, followed by gentle push aiming for complete sealing at the antral aspect of the PV. Complete PV occlusion was verified by contrast medium injection through the central lumen of the CB2. Total PV occlusion was considered if no backflow of contrast to the LA was documented. For LCPVs the following ablation strategies were applied: If an antral occlusion of the LCPV, determined by contrast injection and fluoroscopy, was achieved, the freeze cycle was initiated (standard ablation approach [group I]; Figure 2). If an antral LCPV occlusion could not be obtained despite multiple attempts, we adapted a sequential ablation approach (group II; Figure 3). At first the first superior branch of the LCPV was targeted, followed by ablation of the first inferior branch, thus accepting rather distal ablation without treatment of the antral aspect of the LCPV. To verify complete occlusion of the targeted LCPV branch, contrast medium was injected as described earlier.

Different ablation protocols were applied. The first 29 consecutive patients were treated with a “bonus freeze” protocol (freeze-cycle duration of 240 seconds followed by 1 additional bonus freeze cycle of 240-second duration after PVI).1 Another 26 consecutive patients were treated with a “no bonus freeze” protocol (freeze cycle duration of 240 seconds without an additional bonus freeze cycle following PVI).18 The last 19 consecutive patients were treated based on a “time-to-effect” guided ablation protocol (after real-time PVI another 120 seconds was applied without an additional freeze cycle).22 In the control group, the following protocols were used: “bonus freeze” in 23, “no bonus freeze in 24, and time to effect in 27. Procedural endpoint was defined as persistent PVI verified by spiral mapping catheter recordings 30 minutes after the last energy application.

**Postprocedural care**

After PVI, all patients underwent transthoracic echocardiography to rule out pericardial effusion. All patients were treated with proton pump inhibitors twice daily for 6 weeks. Low-molecular-weight heparin was administered to patients receiving vitamin K antagonists and with an international normalized ratio (INR) <2.0 until a therapeutic INR of 2–3 was achieved. Novel oral anticoagulants were reinitiated 6 hours postablation at half dose, followed by standard dose the next day. Anticoagulation was continued for at least 3 months and thereafter based on the individual CHA2DS2-VASc score. Previously ineffective antiarrhythmic drugs were continued for 3 months.

![Figure 2](image)  
Figure 2  Cryoballoon-based pulmonary vein in a patient with left common pulmonary vein (LCPV). Standard ablation approach. A: Angiography of LA and LCPV in left anterior oblique (LAO) 40°. B: Application of contrast medium through the CB2 into the LCPV. C: Schematic image of panel B. Note complete occlusion of the LCPV ostium. CB = cryoballoon; CS = coronary sinus catheter; LA = left atrium; TP = temperature probe; TSS = transseptal sheath.
Repeat procedures

Repeat procedures in patients admitted because of recurrence of atrial fibrillation (AF) or atrial tachycardia (AT) were performed as previously described.23 The presence or absence of electrical reconduction of the PVs was assessed using selective PV angiographies and a spiral mapping catheter. An electroanatomic LA map (Carto, Biosense Webster) was generated, and the PV ostia were tagged. Identified reconduction gaps were closed by RF applications using a 3.5-mm irrigated-tip catheter (Navi-Star, Thermo-Cool, Biosense Webster). Procedural endpoint was complete PVI. In patients with persistent isolation of all PVs and who were admitted in sinus rhythm, fractionated ostial potentials along previously performed ablation lines were identified and ablated and/or linear lesion sets were applied if substrate was demonstrated.23 In patients with previously performed sequential ablation approach and evidence of ostial potentials along the LCPVs despite persistent isolation at a more distal level, an antral circumferential ablation around the LCPV was performed. In patients admitted in AF/AT and with persistent isolation of all PVs, ostial potentials were identified and ablated followed by ablation of complex fractionated atrial electrograms and deployment of linear lesion sets in case of conversion to an AT.23

Follow-up

Patients completed outpatient clinic visits at 3, 6, 12, and months and in 6-months intervals thereafter, including 12-lead surface ECG and 24-hour Holter ECGs. In addition, regular telephonic

Figure 3  Cryoballoon-based pulmonary vein isolation in a patient with left common pulmonary vein (LCPV). Sequential ablation approach. A, B: Angiography of LA and LCPV in left anterior oblique (LAO) 40° and right anterior oblique (RAO) 30° view. C: Application of contrast medium through the CB2 into the superior branch (sup) of the LCPV (RAO 30°). D: Application of contrast medium through the CB2 into the inferior branch (inf) of the LCPV (LAO 40°). E, F: Schematic images of panels C and D. Note complete occlusion of the LCPV ostium; therefore a sequential strategy was used. CB = cryoballoon; CS = coronary sinus catheter; LA = left atrium; TP = temperature probe; TSS = transseptal sheath.
interviews were performed. Additional outpatient clinic visits were immediately initiated in case of symptoms suggestive of recurrent AF/AT.1,3,18 The primary endpoint was defined as recurrence of any symptomatic or documented atrial arrhythmia >30 seconds after a blanking period of 3 months. Secondary endpoints were defined as procedure-related major complications.

Statistical analysis
Continuous data are given as mean (SD) if variables were normally distributed; otherwise the median, minimum, first and third quartiles, and maximum are reported. Categorical data are described with absolute and relative frequencies.

For the matched control group, propensity score matching was performed. It was based on a logistic regression model that included age, gender, AF type, hypertension, LA size, and follow-up duration. Recurrence-free survival was estimated by the Kaplan–Meier method. Follow-up between the 2 groups was compared using the Wilcoxon test. All statistical tests were 2-sided, and \( P \leq 0.05 \) was considered significant. All calculations were performed using R (version 3.3.1; www.r-project.org).1,3,18

Results
Baseline characteristics
Between June 2012 and June 2016, a total of 670 consecutive patients underwent CB2-based PVI at 3 experienced electrophysiology centers. In 74 of 670 patients (11%), an LCPV was identified. The control group was matched from among \( n = 167 \) patients with CB2-based PVI and normal PV anatomy.1,2,18,22,24 A total of \( n = 74 \) patients were identified. No differences in patient baseline characteristics were detected (Table 1).

Acute ablation results
Procedural parameters are given in Table 2 and Supplementary Table 1. In patients with LCPV 221 of 222 PVs (99%) and in patients in the control group 294/296 (99%) PVs were successfully isolated. Three right superior pulmonary veins (RSPVs) were not targeted due to PNP during treatment of the right inferior pulmonary vein (RIPV) (LCPV group: \( n = 1 \); control group: \( n = 2 \)).

Standard ablation approach vs sequential ablation approach
To further evaluate and compare the efficacy, safety, and clinical outcomes of the standard ablation approach (group I) and the sequential ablation approach (group II), a subgroup analysis of patients with an LCPV was conducted. A total of 37 of 74 patients (50%) with antral CB2 occlusion of the LCPV were treated by the standard ablation approach (group I). In 37 of 74 patients (50%), antral LCPV occlusion with the CB2 could not be obtained, and the sequential ablation approach was performed (group II). Mean minimal CB2 temperature was \(-52.6^\circ C \pm 7.3^\circ C\) in group I and \(-47.7^\circ C \pm 5.9^\circ C\) in group II (\( P = .0018 \)). Mean LCPV diameter verified by fluoroscopy was 27.1 ± 3 mm in group I and 33.5 ± 5 mm in group II. Maximum LCPV diameter measured 32.0 mm in group I and 48.9 mm in group II. All LCPVs could be successfully isolated. Mean number of applications was 2.0 ± 1 in group I and 2.4 ± 0.7 in group II.

Complications
Periprocedural complications are listed in Table 2. PNP occurred in 1 of 74 patients (1.4%) of the LCPV group and in 2 of 74 patients (2.8%) of the control group during ablation along the RIPV (\( P = .378 \)). All PNP recovered within a maximum of 10 months. No further major complications occurred. In 2 of 148 patients (1.4%) (1 in LCPV group: 1 in control group), an aneurysm spurious of the right femoral vein not requiring transfusion or surgical intervention was observed.

Clinical results
Clinical follow-up was obtained in 147 of 148 patients (99.3%); 1 of 148 patients (0.7%) of the LCPV group was lost to follow-up. Mean follow-up duration was 1.9 ± 0.9 years (LCPV group: 2.0 ± 1.0; control group: 1.8 ± 0.8; \( P = .820 \)). A total of 47 of 73 patients (64%) of LCPV group and 49 of 74 patients (66%) of the control group remained in sinus rhythm (\( P = .820 \) (Figure 4). In the LCPV group, 26 of 73 patients (36%) suffered from recurrence of AF/AT: 8 (31%) had PAF, 12 (46%) had PersAF, and 2 (8%) had an AT as the mode of recurrence. Among patients with PAF at the time of inclusion, 27 of 38 (71%) remained in sinus rhythm [median: 2.1 (1.5, 3.3) years], whereas among patients with previous PersAF, 21 of 35 (60%) presented in sinus rhythm after a median of 1.8 (1.1, 2.4) years.

Clinical results: Sequential ablation approach vs standard ablation approach
A total of 23 of 37 patients (62%) in group I and 24 of 36 patients (67%) in group II remained in sinus rhythm after a median of 2.0 years (1.3, 3.2) in group I and 2.0 years (1.2, 3.2) in group II.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Baseline characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
</tr>
<tr>
<td>No. of patients</td>
<td>148</td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.8 ± 9</td>
</tr>
<tr>
<td>Female gender [n (%)]</td>
<td>71 (48)</td>
</tr>
<tr>
<td>Paroxysmal AF [n (%)]</td>
<td>82 (55)</td>
</tr>
<tr>
<td>Persistent AF [n (%)]</td>
<td>66 (45)</td>
</tr>
<tr>
<td>Duration of AF (months)</td>
<td>24 (11, 36)</td>
</tr>
<tr>
<td>LA diameter (mm)</td>
<td>44 ± 6</td>
</tr>
<tr>
<td>Congestive heart failure [n (%)]</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Arterial hypertension [n (%)]</td>
<td>96 (65)</td>
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<tr>
<td>Diabetes mellitus type II [n (%)]</td>
<td>14 (9)</td>
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<tr>
<td>Coronary artery disease [n (%)]</td>
<td>20 (14)</td>
</tr>
<tr>
<td>Prior stroke [n (%)]</td>
<td>10 (7)</td>
</tr>
<tr>
<td>Mean CHA2DS2-VASc score</td>
<td>2 (1, 3)</td>
</tr>
</tbody>
</table>

Chi-square test of no regression predicting LCPV group presented no statistical differences compared to the control group (\( P = .820 \)). Values are given as mean and SD if data were normally distributed or as median (1st, 3rd quartiles).

AF = atrial fibrillation; LA = left atrium; LCPV = left common pulmonary vein.
2.5) in group II) \( (P = .309) \) (Figure 5). Supplementary Figure 1 depicts the outcome after multiple procedures for each group. No differences were found between the groups.

### Findings during reablation procedures

A total of 18 of 26 patients (69%) in the LCPV group suffering from recurrences of AF/AT underwent a second ablation procedure using RF energy 295±154 days after the index procedure. Three of 18 patients (17%) presented with persistent isolation of all PVs. In 15 of 18 patients (83%) and in 26 of 54 patients with (48%) previously isolated PVs, LA-to-PV reconduction was demonstrated. A total of 10 of 18 LCPVs (56%), 12 of 8 RSPVs (67%), and 6 of 18 RIPVs (33%) were found to be persistently isolated. A total of 22 of 25 control group patients (88%) underwent a second RF-based ablation procedure 544±318 days after the index procedure. Four of 22 patients (18%) presented with persistent isolation of all PVs. In 18 of 22 patients (82%) and in 35 of 88 previously isolated PVs (40%), LA-to-PV reconduction was demonstrated. A total of 27 of 44 left-sided PVs (61%) were found to be persistently isolated. No difference was found regarding the number of persistently isolated LCPVs and left-sided PVs in control group patients \( (P = .801) \). A total of 17 of 22 RSPVs (77%) and 13 of 22 RIPVs (59%) were found to be persistently isolated, and no difference between the groups was found regarding the number of persistently isolated right-sided PVs \( (P = .139) \).

Of 10 persistently isolated LCPVs, 8 were treated with the standard ablation approach (group I), and 2 were treated with the sequential ablation approach (group II). For the subgroup analysis between the groups, no differences were identified with regard to persistency of isolated LCPVs \( (P = .321) \). A total of 16 reconduction gaps were identified and distributed as shown in Figure 6. In 6 patients (33%) with LA-to-PV reconduction, no specific location of reconduction gaps was identified, and reisolation of PVs was conducted by performing a complete wide area circumferential ablation around the ipsilateral PVs. Reisolation of all PVs was successfully

### Table 2  Procedural data

<table>
<thead>
<tr>
<th>Procedural data</th>
<th>All</th>
<th>LCPV</th>
<th>Control</th>
<th>( P ) value</th>
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<tbody>
<tr>
<td>No. of PVs</td>
<td>518</td>
<td>222</td>
<td>296</td>
<td>—</td>
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<tr>
<td>Total CB2 cycles per PV</td>
<td>1 (1, 2)</td>
<td>1 (1, 2)</td>
<td>1 (1, 2)</td>
<td>.198</td>
</tr>
<tr>
<td>Total CB2 cycles per PV until PVI</td>
<td>1 (1, 1)</td>
<td>1 (1, 1)</td>
<td>1 (1, 1)</td>
<td>.439</td>
</tr>
<tr>
<td>No. of isolated PVs [n (%)]</td>
<td>515/518 (99)</td>
<td>222/221 (99)</td>
<td>294/296</td>
<td>.421</td>
</tr>
<tr>
<td>Minimal CB2 temperature (°C)</td>
<td>–48±6</td>
<td>–48±6</td>
<td>–48±6</td>
<td>.587</td>
</tr>
<tr>
<td>Minimal esophageal temperature (°C)</td>
<td>35 (33, 36)</td>
<td>35 (34, 36)</td>
<td>35 (33, 36)</td>
<td>.520</td>
</tr>
<tr>
<td>Time to PVI (seconds)</td>
<td>41 (30, 60)</td>
<td>40 (25, 63)</td>
<td>42 (30, 60)</td>
<td>.933</td>
</tr>
<tr>
<td>Procedure time (minutes)</td>
<td>105 (80, 135)</td>
<td>105 (85, 140)</td>
<td>105 (80, 135)</td>
<td>.468</td>
</tr>
<tr>
<td>Fluoroscopy time (minutes)</td>
<td>19 (14, 25)</td>
<td>21 (15, 26)</td>
<td>19 (14, 23)</td>
<td>.093</td>
</tr>
<tr>
<td>Amount of contrast medium (mL)</td>
<td>100 (70, 150)</td>
<td>100 (88, 150)</td>
<td>100 (16, 153)</td>
<td>.160</td>
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<td>Phrenic nerve palsy [n (%)]</td>
<td>3 (2.0)</td>
<td>1 (1.4)</td>
<td>2 (2.7)</td>
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<tr>
<td>Pericardial tamponade [n (%)]</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>.999</td>
</tr>
<tr>
<td>Aneurysm spurium [n (%)]</td>
<td>2 (1.4)</td>
<td>1 (1.4)</td>
<td>1 (1.4)</td>
<td>.503</td>
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<tr>
<td>Periprocedural stroke/TIA [n (%)]</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>.999</td>
</tr>
</tbody>
</table>

Values are given as mean and SD if data were normally distributed or as median (1st, 3rd quartiles). CB2 = second-generation 28-mm cryoballoon; LCPV = left common pulmonary vein; PV = pulmonary vein; PVI = pulmonary vein isolation; TIA = transient ischemic attack.

![](image1.png)

Figure 4  Long-term clinical results. Kaplan–Meier curve demonstrates the relative proportion of patients in stable sinus rhythm after index PVI using the second-generation cryoballoon. A total of 64% (LCPV group) and 66% (control group) patients remained in sinus rhythm after mean follow-up of 1.9±0.9 years \( (P = .820) \). LCPV = left common pulmonary vein; PVI = pulmonary vein isolation.

![](image2.png)

Figure 5  Subgroup analysis. Long-term clinical results in group I vs group II. With regard to long-term clinical results, 14 of 37 patients (62%) in group I and 12 of 36 patients (67%) in group II remained in sinus rhythm after a median of 2.0 years (1.3, 3.2) in group I and 2.0 years (1.2, 2.5) in group II \( (P = .309) \). Group I = standard ablation approach; group II = sequential ablation approach.
performed. In addition, ablation of ostial potentials along previously performed ablation lesions was conducted in 7 of 18 patients (39%), additional ablation of complex fractionated atrial electrogram in 2 of 18 patients (11%), and ablation of linear lesion ablation in 2 of 18 patients (11%) (1 [6%] mitral isthmus line, 1 [6%] anterior line). No periprocedural complications occurred, and no PV stenosis was found during reablation procedures.

**Discussion**

The current study is the first to report on the acute efficacy, safety, and long-term clinical results of patients with LCPV and CB2-based PVI. The study demonstrates high acute success rates and procedural safety for treatment of LCPVs. Freedom from AF/AT recurrence was 64% after 2 years of follow-up, with no statistical difference compared to patients in the control group with normal PV anatomy (66%).

Anatomic variants of LA geometry and the PVs may pose technical challenges during AF ablation procedures, thus potentially compromising effective lesion formation and acute efficacy, increasing periprocedural complications, and affecting clinical outcomes. The current study analyzed the impact of LCPV in CB2-based PVI.

In the current study, no preprocedural imaging was performed except for transesophageal echocardiography. Therefore, no preprocedural screening of anatomic variants was conducted, and no patient was categorically excluded from PVI. In our patient cohort, we assessed LCPV in 11% of patients and thus in a considerably high proportion of patients scheduled for PVI.

To the best of our knowledge, no data for CB2-based PVI focusing on patients with LCPV and assessing systematically acute efficacy, safety, and clinical results have yet been published. Only 2 studies have reported on acute efficacy and clinical follow-up of PVI with the first-generation CB in patients with LCPV. Kubala et al demonstrated superior clinical outcomes in patients with 4 separate PVs compared to patients with LCPV (67% vs 50%; P = .02) after 13 months of follow-up. In contrast, Sorgente et al found no differences in long-term clinical efficacy between patients with LCPV and those with 4 separate PVs. For conventional RF-based PVI in conjunction with 3-dimensional electroanatomic mapping, no negative impact on clinical outcomes in the presence of LCPV was demonstrated, and no correlation between PV diameters and long-term clinical failure of PVI was found in 2 clinical studies. However, when remote magnetic navigation was applied, variant PV anatomy including LCPV as assessed by preprocedural evaluation via multidetector computed tomography was found to be a predictor of AF recurrence after PVI. Another study analyzing long-term outcomes after multielectrode PV ablation catheter–based PVI also found no significant correlation between PV anatomy and the efficacy of PVI. In our current study, patients with LCPV demonstrated a 64% rate of sinus rhythm after a single CB2-based PVI after 2 years of follow-up. Compared to patients in the matched control group, no statistical difference was identified (66%). These findings are comparable to recently published 2-year clinical results of patients treated with the CB2 without subanalysis of anatomic PV variants (67%–69%). In patients with previous PAF, a 71% stable sinus rhythm rate was detected after 2-year follow-up in the presence of LCPV, which is comparable to the latest data from unselected patients (73%). With a stable sinus rhythm rate of 60% in patients with previous PersAF and LCPV, our findings are comparable to recent 2-year data rate of 56% reported by Tscholl et al.

Recently, the CB2 proved noninferiority to RF in conjunction with 3-dimensional electroanatomic mapping in PVI for the treatment of PAF and demonstrated significant advantages with regard to the postprocedural necessity for rehospitalization, cardiovascular, and repeat ablation procedures.

One potential explanation for these encouraging success rates might be a high rate of durable PVI over time as demonstrated in studies analyzing repeat ablation procedures after previous CB2-based PVI. In patients in the current study undergoing repeat procedures due to recurrence of AF/AT, we demonstrated no significant difference regarding persistently isolated PVs between the groups. A persistent isolation was found in 56% of LCPVs and 61% of left-sided PVs (P = .801). Although these findings are comparable to recently published results of patients treated with the CB2 without subanalysis of anatomic PV variants, further studies are needed to evaluate the value of PV reconnection and clinical success.

The 2 different ablation approaches used for PVI in LCPVs revealed equal findings with regard to efficacy, safety, and clinical outcomes. We could demonstrate that even LCPVs with a large diameter >48 mm can be targeted for reablation procedures.
using the sequential ablation approach. Applying this strategy, we might spare the potentially arrhythmogenic antral tissue of the LCPV. However, clinical outcomes of both approaches are comparable. Alternatively, a consecutive ablation approach (ablation of a continuous antral lesion by consecutive overlapping applications at each quadrant of the PV ostium) was previously suggested rather than the sequential ablation approach in the setting of large PV diameters. However, the efficacy of the consecutive ablation approach might be questionable due to the limited temperature drop caused by incomplete antral occlusions, consecutively less minimal CB2 temperatures, and thus less effective freeze cycles and lesion formation.  

Study limitations

The data are based on a retrospective analysis with a matched control group. The follow-up was limited to 24-hour Holter ECGs. These limitations might overestimate the overall clinical success rate after CB2-based PVI. Different ablation protocols were used in the patient cohort. However, in recent studies no differences were found in clinical outcomes when different CB2-based ablation protocols were applied.  

Conclusion

Patients with LCPV undergoing CB2-based PVI demonstrated a high acute success and a low complication rate. Compared to a matched control group with normal PV anatomy, no significant differences were identified with regard to clinical success and the rate of persistently isolated PVs. Therefore, CB2-based PVI seems to be a suitable option for patients with LCPV.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.hrthm.2017.05.003.

References