Presence of a Left Common Pulmonary Vein and Pulmonary Vein Anatomical Characteristics as Predictors of Outcome Following Cryoballoon Ablation for Paroxysmal Atrial Fibrillation

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Abstract

Introduction: Pulmonary vein (PV) isolation using cryoballoon ablation (CBA) is a common therapy for patients with drug refractory paroxysmal atrial fibrillation (PAF). However, initial CBA is successful in only 70-80% of patients. The role of an atypical left common PV (LCPV) and PV anatomical indices on CBA outcomes remains unclear. *Methods and Results:* We followed 80 patients (age 60.7 ± 9.7, 31 % women) with PAF undergoing CBA for one-year post-procedure for the development of recurrent atrial arrhythmias (AA). Recurrence was assessed by documented AA on EKG or any form of long-term cardiac rhythm monitoring. The presence of an LCPV and individual PV diameters were evaluated using cardiac CT. Based on the maximum and minimum PV ostial diameters, the eccentricity index (EI), ovality index (OI), and PV ostial area (PVA) were calculated for all the veins. A multivariable cox-proportional hazard model assessed whether the presence of an LCPV or PV anatomic indices (EI, OI and PVA) predicted recurrence of AA following CBA. After one year follow up, 19 (23.7%) participants developed recurrence of AA. On multivariable regression, the presence of an LCPV did not predict the recurrence of AA ($p = 0.38$). Among the PV anatomical indices, on univariate analysis, only the area of the left inferior PV showed a trend towards predicting recurrence, though this result was not significant on multivariate analysis ($p = 0.09$). *Conclusion:* In patients with PAF, neither the presence of an LCPV nor individual PV anatomical indices predicted recurrence of AA following CBA.

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ABSTRACT

Introduction:

Pulmonary vein (PV) isolation using cryoballoon ablation (CBA) is a common therapy for patients with drug refractory paroxysmal atrial fibrillation (PAF). However, initial CBA is successful in only 70-80% of patients. The role of an atypical left common PV (LCPV) and PV anatomical indices on CBA outcomes remains unclear.

Methods and Results:

We followed 80 patients (age 60.7 ± 9.7, 31 % women) with PAF undergoing CBA for one-year post-procedure for the development of recurrent atrial arrhythmias (AA). Recurrence was assessed by documented AA on EKG or any form of long-term cardiac rhythm monitoring. The presence of an LCPV and individual PV diameters were evaluated using cardiac CT. Based on the maximum and minimum PV ostial diameters, the eccentricity index (EI), ovality index (OI), and PV ostial area (PVA) were calculated for all the veins. A multivariable cox-proportional hazard model assessed whether the presence of an LCPV or PV anatomic indices (EI, OI and PVA) predicted recurrence of AA following CBA. After one year follow up, 19 (23.7%) participants developed recurrence of AA. On multivariable regression, the presence of an LCPV did not predict the recurrence of AA ($p = 0.38$). Among the PV anatomical indices, on univariate analysis, only the area of the left inferior PV showed a trend towards predicting recurrence, though this result was not significant on multivariate analysis ($p = 0.09$).

Conclusion:

In patients with PAF, neither the presence of an LCPV nor individual PV anatomical indices predicted recurrence of AA following CBA.

Key words: Paroxysmal atrial fibrillation, cryoballoon ablation, left common pulmonary vein, pulmonary vein anatomy

Introduction:

Pulmonary vein isolation (PVI) with radiofrequency (RF) or cryoballoon ablation (CBA) is a common therapy for patients with drug refractory paroxysmal atrial fibrillation (AF).[1] However, studies have reported the success rate of ablation to be around 70-80% after one year of follow-up.[2-4] The exact etiology for certain patients not benefiting from this procedure remains unclear but likely includes pulmonary vein anatomy, underlying cardiovascular disease, valvular heart disease (VHD), older age, dilated left atrium (LA), obesity, undiagnosed sleep apnea and the procedure being performed at less experienced centers.[5-11] Since CBA requires circumferential adhesion of the ablation catheter to the PV ostium, the role of PV anatomy influencing the success of CBA has always been debated.[12,13]Isolation of a left common pulmonary vein (LCPV) can be particularly challenging as complete circumferential occlusion with a cryoballoon catheter is often not possible given the large size or ovality of the ostia. Furthermore, studies evaluating the presence of an LCPV affecting CBA outcomes have shown variable results.[5,14,15]A number of single-center studies have also assessed the role of PV anatomical indices such as eccentricity index (EI), area of vein (PVA) and ovality index (OI) in relation to CBA outcomes.[12,13,16]However, these studies were limited by a small sample size and the inclusion of a mixed population of both paroxysmal and persistent AF patients.

To date, the influence of PV anatomical characteristics on mid-term outcomes in a select patient population of paroxysmal AF patients only has never been systematically investigated. We sought to evaluate whether the presence of an LCPV or individual PV characteristics such as PVA, OI and EI serve as predictors of success following CBA for paroxysmal AF patients.

Methods:

Patient Population:

A retrospective chart analysis was performed for all patients with a known diagnosis of paroxysmal AF undergoing CBA as a first or repeat procedure between the dates of January 2015 and April 2018. The study population was following at the Reliant Medical Group Cardiology Clinic at Saint Vincent Hospital in Worcester, Massachusetts. Prior to chart review and data collection, the study protocol was approved by the institutional review boards at both the Reliant Medical Group and Saint Vincent Hospital. Patients over the age of 18 with a diagnosis of paroxysmal AF were selected for review while those with a diagnosis of persistent or permanent AF were excluded. Based on our initial screening, 103 patients met the study inclusion criteria. We subsequently excluded 23 patients who did not undergo cardiac computed tomography (cCT) imaging prior to the procedure or, due to technical issues, images could not be retrieved from the radiology archives. The final analysis included 80 patients who underwent a detailed chart review for baseline demographics, underlying comorbidities, medication use and CBA procedural data. In addition, analysis with measurements of the PV anatomy on cCT was performed for all patients.

Cryoballoon Ablation Procedure:

All procedures were performed under general anesthesia. Briefly, utilizing a femoral venous approach, two sheaths (7Fr and 9Fr) were placed in the left femoral vein. Via these sheaths, a Livewire decapolar catheter and an Intracardiac Echocardiography (ICE) catheter (both St. Jude Medical, St. Paul, MN) were advanced into the right atrium (RA) and subsequently positioned under fluoroscopic guidance in the coronary sinus and RA, respectively. A transseptal sheath was placed in the right femoral vein. Using ICE and fluoroscopy guidance, trans-septal access to the LA was obtained. A heparin bolus was given prior to trans-septal puncture and then as needed to maintain the activated clotting time (ACT) greater than 300 seconds during the procedure. The transseptal sheath was then exchanged for a 12 Fr Flexcath sheath through which a 28 mm Artic Front Advance Cryoballoon ablation catheter (both Medtronic, Inc., Minneapolis, MN) along with an inner lumen Achieve spiral mapping catheter (Medtronic, Inc.) were placed in the LA. Using the St. Jude Medical Ensite Velocity NAVX software, guided by a three dimensional CT recreation of the LA, electroanatomic mapping was performed in the LA to identify all the PVs. Each of the PVs were then sequentially isolated using cryoballoon insufflations after ensuring tight contact with their respective antrums. During cryoablation of the right-sided PVs, the livewire catheter was used to stimulate the phrenic nerve from the SVC to monitor for phrenic nerve injury. Following cryoablation, a bidirectional conduction block was demonstrated from all veins, and a post-ablation voltage map was created using the NAVX software. For areas noted to have incomplete PV isolation with electrical gaps, additional touch up freezes with the cryoablation catheter or, if necessary, a RF ablation catheter was performed. For LCPVs with large ostiums, a segmental approach was utilized with multiple cryoablation applications delivered around the circumference of the PV antrum in order to achieve antral isolation of the common vein. Additional cryoablation applications or additional RF ablation was performed as needed until complete PV isolation was achieved from all veins.

Cardiac CT acquisition and image analysis:

All cCT scans were performed on a 256 slice scanner (Seimens Somatom) with a retrospective electrocardiogram (ECG) gating technique. Helical scanning was performed after bolus administration of 100 cc Isovue 370 (Bracco) with a region of interest (ROI) on the ascending aorta at the level of the carina. The scanning parameters included a 128 x 0.6 mm collimation, a rotation time of 0.28 sec, and a pitch of 0.23. Scans were performed with a heart rate of 75 beats per minute or lower.

Images with a reconstruction interval of 0.6 mm were transferred to a workstation with 3D software capabilities (Vitrea, Vital), and 3D volume rendered images of the left atrium and pulmonary veins were acquired. 3D volume rendered images were primarily used for global assessment of atriopulmonary anatomy, evaluation of PV anatomic variants, and branching patterns and not used for quantitative analysis. Thin slice 0.6 mm acquisitions were used at the picture archive and communication system (PACS) workstation (McKesson) to manually obtain Multiplanar Reconstructed images (MPR) of each PV in cross-section at its ostium. The maximum and minimum diameter measurements of each PV ostium were then obtained manually using a caliper tool **(Figure 1)** . An LCPV ostium was defined when the superior and inferior left PV carina joined at a distance greater than 5 mm prior to entering the LA. The length of this common trunk was then measured. Anatomic variants recorded were accessory PVs such as the right middle pulmonary vein (RMPV) draining the middle lobe to an isolated ostium on the left atrium (LA). All cases were retrospectively analyzed by an American Board of Radiology certified attending Cardiac Radiologist with four years of experience blinded to the outcomes of the CBA procedure.

Pulmonary Vein Measurements:

The following indices were calculated for each of the PVs once the PV maximum diameter (PVmaxD) and minimum diameter (PVminD) were obtained from MPR images on cCT at the level of the ostium: (1) EI=PVmaxD/PVminD,[16] (2) OI = 2 x (PVmaxD-PVminD/PVmaxD+PVminD)[16]and (3) PVA= π x PVmaxD x PVminD. PV EI values between 1.2-1.4 were representative of ovality while <1.2 were circular and > 1.4 considered as flat. For the OI, higher values were more representative of ovality.

Follow up for Ablation success:

Patients were followed for a period of one year after the CBA procedure for the development of any form of atrial arrhythmias (AA). AA were confirmed on chart review by self-reported patient symptom and documented by EKG's or any form of long-term cardiac rhythm monitoring such as a holter or event monitor. A three month blanking period was followed to allow for recurrence of AA after the initial procedure except for symptomatic patients with early recurrence requiring a repeat procedure such as an electrical cardioversion or repeat ablation.

Statistical Analysis:

Categorical variables were reported as frequency and percentage, whereas continuous variables were reported as mean ± standard deviation. Statistical significance for categorical variables was tested using the chi-square method, while for continuous variables, the Student's t-test method was employed. A multivariable Cox proportional regression analysis was used to calculate the hazard ratio (HR) and 95% confidence intervals (CI) for the association between the presence of a LCPV and recurrence of AA. The models were adjusted as follows: model 1 was adjusted for age and sex; model 2 was adjusted for model 1 along with coronary artery disease (CAD), congestive heart failure (CHF), diabetes mellitus (DM), chronic kidney disease (CKD), hypertension, hyperlipidemia, and VHD; model 3 was further adjusted for model 2 along with the use of beta-blockers, calcium channel blockers, and anti-arrhythmic drugs; and finally model 4 was adjusted for model 3 along with $CHADS_2VASC_2$ score, total cryoablation time, total fluoroscopy time, baseline heart rate, LA volume index and left ventricular ejection fraction (LVEF). A univariate analysis was performed for all the anatomic indices (EI, OI and AV) for each of the PVs to evaluate if they predicted recurrence of AA. A step-wise approach was utilized, and anatomic indices with a p-value <0.1 on univariate analysis were subsequently included in a multivariate model. Survival curves were constructed using the Kaplan-Meir method and compared using the log-rank test. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc, Cary, NC), and p-values < 0.05 were considered significant.

Results:

Baseline Characteristics:

A total of 80 patients who underwent CBA for paroxysmal AF were included in our analysis. Their baseline characteristics (**Table 1**) were as follows: age 60.7 ± 9.7 years, males 68.8% (n=55), body mass index (BMI)

31.5 ± 6.9 kg/m^2, baseline LVEF 57 ± 8 % and recurrence of AA 23.8% (n=19). The majority of the study group (82.5%, n=66) had a typical PV anatomy with four distinct PVs, while atypical anatomy with an LCPV was seen in 17.5% (n=14) patients. Other atypical combinations of RMPV with LCPV (n=3) and RMPV with the four distinct PVs (n=5) were also present. The study population demographics and clinical data by the presence or absence of the LCPV are shown in **Table 2** . Additional touch up with RF ablation was necessary for 14% (n=2) versus 6% (n=4) of patients in the LCPV versus typical PV anatomy group, respectively. The baseline characteristics were similar between the two groups except for the longer duration of total fluoroscopic time (TFT) for the LCPV group.

Recurrence of AA by the presence of LCPV:

On multivariable Cox regression analysis, the presence of an LCPV had no impact on the recurrence of AA(HR 1.78; 95% CI, 0.38-8.29; p=0.46;**Table 3**). On Kaplan-Meir survival curves, the presence of an LCPV did not predict time to first recurrence of AA (**Figure 2,**p=0.21).

Recurrence of AA by anatomic characteristics of PVs:

The anatomic indices for each of the PVs based on the presence or absence of recurrence of AA showed no significant difference between the two groups (**Table 3**). On comparing the anatomic indices for the left versus right-sided PVs (**Table 4**), the left inferior PV (LIPV) was more oval compared to the right inferior PV (RIPV), and there was a strong trend for the left superior PV (LSPV) being more oval compared to the right superior PV (RSPV). However, the ostial PVA was greater for the right-sided PVs. Furthermore, on univariate analysis, only the PVA of the LIPV was a significant predictor for recurrence of AA. This association was no longer significant once the LIPV ostial area was adjusted further in a multivariate model (**Table 5**).

Discussion:

Our study demonstrated that in this population of patients with paroxysmal AF, the presence of an atypical PV anatomy with an LCPV had no effect on CBA outcomes and event-free survival. In addition, our study findings revealed that among the anatomical indices, only the ostial area of the LIPV showed a trend towards being a predictor of recurrence of AA following CBA.

A few studies have suggested that atypical PV anatomy is associated with a higher incidence of AF.[17,18]In our study participants the incidence of typical PV anatomy was 82.5% which is slightly higher compared to previous studies which suggest the incidence to be around 70-75%.[19-21]Nonetheless, the presence of an atypical anatomic pattern did not have a significant influence on CBA outcomes. Circumferential isolation of the LCPV can be technically challenging with cryoablation given its larger sized ostia. Thus, the presence of an atypical PV anatomy affecting CBA outcomes has been an ongoing source of discussion. To date, studies evaluating the presence of an LCPV affecting ablation success have shown variable results.[5,6,14,15,22]However, these studies were limited by a small sample size, a mixed population of both paroxysmal and persistent AF, and a majority of them employed the RF ablation technique. On reviewing the existing literature, we identified only one small single-center study which exclusively looked at paroxysmal AF patients undergoing CBA.[23] Our findings are in agreement with this study wherein the presence of a variant PV anatomy had no influence on outcomes.

Another area of interest in CBA outcomes involves an assessment of the ovality of the individual PVs. Successful CBA requires optimal circumferential adhesion of the cryoballoon catheter at the level of the PV ostium. Excessive ovality can limit catheter adhesion leading to sub-optimal tissue contact, thereby affecting CBA outcomes. To assess whether ovality affected outcomes, we specifically looked at measures of ovality, which included the EI and OI of individual PVs. As an extension for evaluating measures of ovality, we decided to assess if the PVA at the level of the ostium influences CBA results. For our study population, the ovality of the LIPV was greater compared to the RIPV, and there was a strong trend towards the LSPV being more oval than the RSPV. This is partially in agreement with prior studies, which indicated that left-sided veins were more oval compared to their right-sided counterparts.[12,24,25]On further stratifying

our results by the presence or absence of AA recurrence, no significant difference was observed for all the measures of PV ovality. Moreover, on univariate followed by multivariate analysis, none of the anatomical indices were predictors of recurrence of AA.

Prior studies have evaluated the role of PV anatomy in influencing mid-term outcomes following CBA.[13,26]Schmidt and colleagues studied a mixed population of drug refractory paroxysmal and persistent AF patients undergoing CBA. Their finding revealed that in patients with post-procedure AF recurrence, left-sided PVs were more oval compared to patients without recurrence, but no significant association was noted for the right-sided PVs.[13] Our study results were contrary to these findings, and none of the anatomical PV indices showed any significant correlation to mid-term CBA success. One possible explanation for this finding could be the small sample size in the present study, and well as our study population of exclusively paroxysmal AF patients. Furthermore, in a similar study population of paroxysmal AF patients undergoing CBA, other anatomic parameters such as a sharp left lateral ridge between the left PVs and LA appendage and a sharp carina between the LSPV and LIPV predicted acute and mid-term failure. Additionally, for the RIPV, this study concluded that parameters such as a non-perpendicular angle between the axis of the PV and ostial plane and an early branching PV with a change in axis angle predicted failure.[26]While our study focused on mid-term outcomes following CBA, other studies have evaluated parameters of acute procedural success such as degree of occlusion and nadir balloon temperature in relation to PV diameters, ostial area and ovality indices.[12,16,27]

Our study is a first of its kind evaluating whether the presence of an atypical PV anatomy or PV anatomic characteristics predict mid-term outcomes exclusively in paroxysmal AF patients. Although constrained by a small sample size, our results did not show any particular association between PV anatomy and CBA failure in paroxysmal AF patients. In addition, though our study population had a fair percentage of atypical PV anatomy and oval left-sided PVs, procedural difficulties could have been negated by a segmental, non-occlusive, approach to ablation, as well as by additional CBA applications as needed until durable PV isolation was achieved. Finally, pre-procedural imaging with cCT or cardiac MRI continues to play an important role in defining PV anatomy to help guide electroanatomical mapping and PVI during the CBA procedure.

Study limitations:

Our results should be interpreted in the context of the inherent limitations of our study design. Firstly, ours is a retrospective single-center study predominantly consisting of a Caucasian population, limiting the generalizability of the outcomes. Secondly, we documented recurrence by patient-reported symptoms supplemented by EKG's and long-term cardiac rhythm monitoring. It is certainly possible that patients with asymptomatic recurrence of AF could have been missed. Thirdly, we did not specifically look at parameters of acute success such as nadir balloon temperature and degree of occlusion of the cryoballoon ablation catheter. Finally, other parameters of PV and LA anatomy such as the orientation of PV ostia and angulation in relation to the LA, length of PV trunks from ostium to bifurcation, and thickness of the left lateral ridge between the left PVs and LA appendage were not evaluated in our study.

Conclusion:

In patients with paroxysmal AF undergoing CBA, the presence of an atypical anatomy with an LCPV had no effect on outcomes. In addition, PVA and anatomic indices of PV ovality were not predictive of recurrence of AA. Despite significant technological advancements in CBA therapy, the reasons for procedural failure are still incompletely understood. Pre-procedural anatomic assessment of the PV and LA continues to be an important tool to help guide successful CBA results. To fully understand the reasons for CBA procedural failure, larger controlled trials will be necessary.

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FIGURES

Figure 1: Freedom from atrial arrhythmia recurrence by the presence (1) or absence (0) of a left common pulmonary vein

Figure 2: Cardiac CT images with multiplanar reconstruction showing ostial measurement at the left common pulmonary vein (A-C) and right superior pulmonary vein (D-F) ostium

TABLES

Table 1 : Baseline characteristics of the study population

Table 2 : Baseline characteristics of the study population based on the presence or absence of a left common pulmonary vein

Table 3: Multivariate adjusted Cox-proportional hazard model of atrial arrhythmia recurrence after cryoablation by left common pulmonary vein status

Table 4: Comparison of anatomic indices for left-sided versus right-sided pulmonary veins

Table 5: Predictors of atrial arrhythmia recurrence by pulmonary vein anatomical indices on univariate and multivariate cox regression analysis

Figure 1:

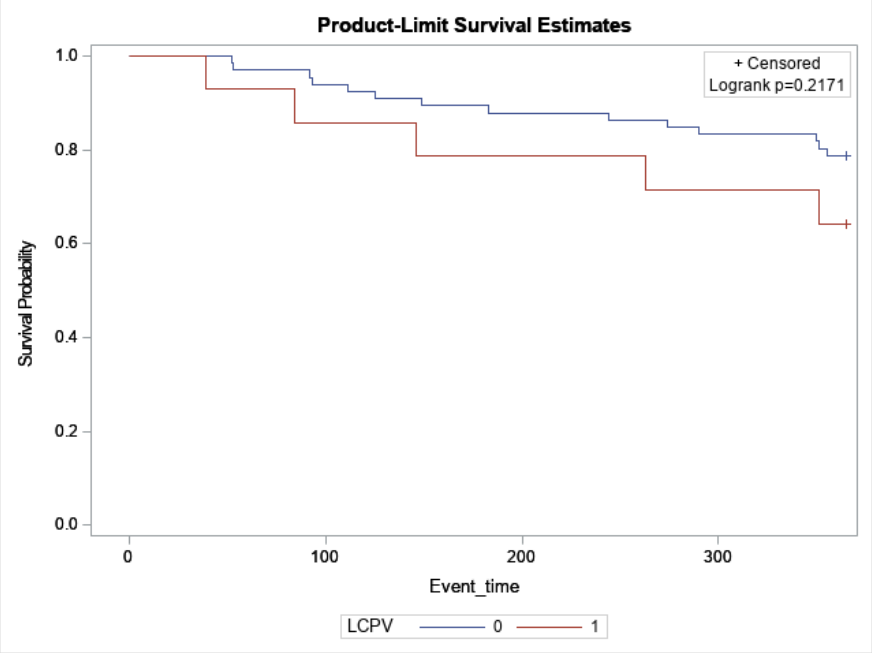

Figure 2:

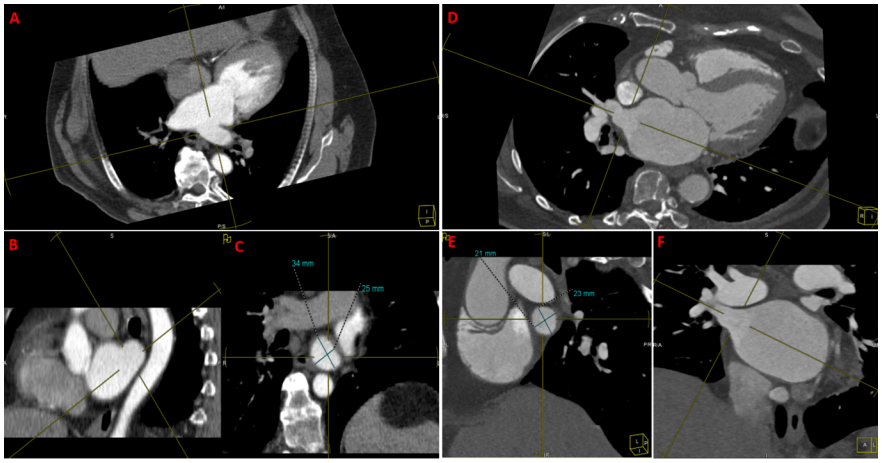

Table 1:

Baseline Characteristics Total N = 80	Mean± SD or n (%)
Age (years)	60.7 ± 9.7
Male (%)	55 (68.8)
Baseline Heart Rate	67.6 ± 16.8
Body Mass Index	31.5 ± 6.9
Coronary artery disease	14 (17.5)
Congestive heart failure	12 (15.0)
Diabetes mellitus	16 (20.0)
Hypertension	53 (66.3)
Valvular heart disease	31 (38.8)
Hyperlipidemia	55 (68.8)
Chronic Kidney Disease	7 (8.8)
Obstructive Sleep Apnea	26 (32.5)
Beta Blocker Use	57 (71.3)
Calcium Channel Blocker Use	10 (12.5)
Anti-Arrhythmic Drug Use	26 (32.5)
CHADS2VASC score	1.8 ± 1.4
LVEF (%)	57 ± 8
Left Atrium Volume Index	31.3 ± 10.7
Total Fluoroscopy Time (min)	54 ± 181
Total Cryoablation Time (min)	1678 ± 342
Presence of LCPV	14 (17.5)
LCPV Maximum Diameter (mm)	28.9 ± 3.9
LCPV Minimum Diameter (mm)	18.6 ± 4.9
LSPV Maximum Diameter (mm)	16.4 ± 8.0
LSPV Minimum Diameter (mm)	11.8 ± 6.1
LIPV Maximum Diameter (mm)	15.8 ± 7.8
LIPV Minimum Diameter (mm)	10.9 ± 5.6
RSPV Maximum Diameter (mm)	21.6 ± 3.6
RSPV Minimum Diameter (mm)	17.4 ± 4.0
RIPV Maximum Diameter (mm)	19.6 ± 3.4
RIPV Minimum Diameter (mm)	16.4 ± 3.1
Recurrence of AA	19 (23.8)

Baseline Characteristics Total N = 80	Mean± SD or n (%)
LVEF, Left ventricular ejection fraction; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LIPV, Left Inferior Pulmonary Vein; RSPV, Right Superior Pulmonary Vein; RIPV, Right Inferior Pulmonary Vein; AA, Atrial Arrhythmia	LVEF, Left ventricular ejection fraction; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LIPV, Left Inferior Pulmonary Vein; RSPV, Right Superior Pulmonary Vein; RIPV, Right Inferior Pulmonary Vein; AA, Atrial Arrhythmia

Table 2:

Baseline Characteristics Mean± SD or n (%)	LCPV Absent N=66	LCPV Present N=14	P-Value+
Age (years)	61 ± 10	58.9 ± 8	0.41
Male	46 (69.7)	9 (64.3)	0.69
Baseline Heart Rate	66.5 ± 17	72.6 ± 15.9	0.21
Body Mass Index	31.7 ± 7.3	30.4 ± 4.4	0.51
Coronary artery disease	11 (16.7)	3 (21.4)	0.67
Congestive heart failure	11 (16.7)	1 (7.1)	0.36
Diabetes mellitus	14 (21.2)	2 (14.3)	0.56
Hypertension	44 (66.7)	9 (64.3)	0.86
Valvular heart disease	24 (36.4)	7 (50)	0.34
Hyperlipidemia	46 (69.7)	9 (64.3)	0.69
Chronic Kidney Disease	6 (9.1)	1 (7.1)	0.81
Obstructive Sleep Apnea	21 (31.8)	5 (35.7)	0.78
Beta Blocker Use	48 (72.7)	9 (64.3)	0.52
Calcium Channel Blocker Use	8 (12.1)	2 (14.3)	0.82
Anti-Arrhythmic Drug Use	22 (33.3)	4 (28.6)	0.73
CHADS2VASC score	1.9 ± 1.5	1.4 ± 1	0.25
LVEF (%)	58 ± 7	55 ± 11	0.20
Left Atrium Volume Index	32 ± 11.2	28 ± 7.1	0.11
Total Fluoroscopy Time (min)	32.9 ± 14.8	150.8 ± 428.7	0.026*
Total Cryoablation Time (sec)	1653 ± 286	1797 ± 533	0.15
RFA Need	4(6)	2(14.3)	0.29
RSPV Maximum Diameter (mm)	22 ± 3.6	20 ± 3.2	0.06
RSPV Minimum Diameter (mm)	17.7 ± 4.1	16.1 ± 3.5	0.19
RIPV Maximum Diameter (mm)	19.7 ± 3.4	19.1 ± 3.7	0.64
RIPV Minimum Diameter (mm)	16.5 ± 3.1	15.9 ± 2.8	0.54
Recurrence of AA	14 (21.2)	5 (35.7)	0.40

Baseline Characteristics Mean± SD or n (%)	LCPV Absent N=66	LCPV Present N=14	P-Value+
+p-value as calculated by t-test for continuous and chi^2 for categorical variables; *significant LVEF, Left ventricular ejection fraction; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LIPV, Left Inferior Pulmonary Vein; RSPV, Right Superior Pulmonary Vein; RIPV, Right Inferior Pulmonary Vein; AA, Atrial Arrhythmia; RFA, Radio frequency ablation	+p-value as calculated by t-test for continuous and chi^2 for categorical variables; *significant LVEF, Left ventricular ejection fraction; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LIPV, Left Inferior Pulmonary Vein; RSPV, Right Superior Pulmonary Vein; RIPV, Right Inferior Pulmonary Vein; AA, Atrial Arrhythmia; RFA, Radio frequency ablation	+p-value as calculated by t-test for continuous and chi^2 for categorical variables; *significant LVEF, Left ventricular ejection fraction; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LIPV, Left Inferior Pulmonary Vein; RSPV, Right Superior Pulmonary Vein; RIPV, Right Inferior Pulmonary Vein; AA, Atrial Arrhythmia; RFA, Radio frequency ablation	+p-value as calculated by t-test for continuous and chi^2 for categorical variables; *significant LVEF, Left ventricular ejection fraction; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LIPV, Left Inferior Pulmonary Vein; RSPV, Right Superior Pulmonary Vein; RIPV, Right Inferior Pulmonary Vein; AA, Atrial Arrhythmia; RFA, Radio frequency ablation

Table 3:

Outcome of interest	LCPV Present HR (95% CI)	LCPV Absent HR (95% CI)	p-value
Recurrence of AA		Ref	
Model 1[a]	1.92 (0.68 – 5.42)	1.00	0.22
Model 2[b]	1.86 (0.63 – 5.53)	1.00	0.26
Model 3[c]	1.73 (0.51 – 5.79)	1.00	0.38
Model 4[d]	1.98 (0.42 – 9.26)	1.00	0.38

Outcome of interest	LCPV Present HR (95% CI)	LCPV Absent HR (95% CI)	p-value
AA, Atrial arrhythmia; LCPV, Left Common Pulmonary vein; HR, Hazard Ratio; CI, Confidence Interval [a]Model 1 adjusted for age and sex [b]Model 2 adjusted for Model 1 + Coronary artery disease, Congestive heart failure, Diabetes mellitus, Chronic kidney disease, Hypertension, Hyperlipidemia and Valvular heart disease [c]Model 3 adjusted for Model 2 + Beta-blocker medications, Calcium channel blocker medications and Anti-arrhythmic medications [d]Model 4 adjusted for Model 3 + CHADS2VASC score, Total fluoroscopy time, Total cryoablation time, baseline heart rate, Left atrial volume index and Left ventricular ejection fraction	AA, Atrial arrhythmia; LCPV, Left Common Pulmonary vein; HR, Hazard Ratio; CI, Confidence Interval [a]Model 1 adjusted for age and sex [b]Model 2 adjusted for Model 1 + Coronary artery disease, Congestive heart failure, Diabetes mellitus, Chronic kidney disease, Hypertension, Hyperlipidemia and Valvular heart disease [c]Model 3 adjusted for Model 2 + Beta-blocker medications, Calcium channel blocker medications and Anti-arrhythmic medications [d]Model 4 adjusted for Model 3 + CHADS2VASC score, Total fluoroscopy time, Total cryoablation time, baseline heart rate, Left atrial volume index and Left ventricular ejection fraction	AA, Atrial arrhythmia; LCPV, Left Common Pulmonary vein; HR, Hazard Ratio; CI, Confidence Interval [a]Model 1 adjusted for age and sex [b]Model 2 adjusted for Model 1 + Coronary artery disease, Congestive heart failure, Diabetes mellitus, Chronic kidney disease, Hypertension, Hyperlipidemia and Valvular heart disease [c]Model 3 adjusted for Model 2 + Beta-blocker medications, Calcium channel blocker medications and Anti-arrhythmic medications [d]Model 4 adjusted for Model 3 + CHADS2VASC score, Total fluoroscopy time, Total cryoablation time, baseline heart rate, Left atrial volume index and Left ventricular ejection fraction	AA, Atrial arrhythmia; LCPV, Left Common Pulmonary vein; HR, Hazard Ratio; CI, Confidence Interval [a]Model 1 adjusted for age and sex [b]Model 2 adjusted for Model 1 + Coronary artery disease, Congestive heart failure, Diabetes mellitus, Chronic kidney disease, Hypertension, Hyperlipidemia and Valvular heart disease [c]Model 3 adjusted for Model 2 + Beta-blocker medications, Calcium channel blocker medications and Anti-arrhythmic medications [d]Model 4 adjusted for Model 3 + CHADS2VASC score, Total fluoroscopy time, Total cryoablation time, baseline heart rate, Left atrial volume index and Left ventricular ejection fraction

Table 4:

	Left-sided Veins Mean± SD	Right-sided Veins Mean± SD	*P*-Value+
Ovality index SPV	0.28±0.21	0.22±0.14	0.05
Ovality index IPV	0.31±0.22	0.18±0.12	<0.0001*
Area of vein SPV	1.86±1.07	3.04±1.30	<0.0001*
Area of vein IPV	1.67±0.96	2.58±0.93	<0.0001*
Eccentricity Index SPV	1.19±0.63	1.27±0.18	0.11
Eccentricity Index IPV	1.23±0.63	1.21±0.15	0.76

	Left-sided Veins Mean± SD	Right-sided Veins Mean± SD	*P*-Value+
SPV, Superior Pulmonary Vein; IPV, Inferior Pulmonary Vein; +p-value as calculated by paired t-test for continuous variables;*significant	SPV, Superior Pulmonary Vein; IPV, Inferior Pulmonary Vein; +p-value as calculated by paired t-test for continuous variables;*significant	SPV, Superior Pulmonary Vein; IPV, Inferior Pulmonary Vein; +p-value as calculated by paired t-test for continuous variables;*significant	SPV, Superior Pulmonary Vein; IPV, Inferior Pulmonary Vein; +p-value as calculated by paired t-test for continuous variables;*significant

Table 5:

Univariate analysis
Ovality index LCPV
Ovality index LSPV
Ovality index LIPV
Ovality index RSPV
Ovality index RIPV
Area of vein LCPV
Area of vein LSPV
Area of vein LIPV
Area of vein RSPV
Area of vein RIPV
Eccentricity Index LCPV
Eccentricity Index LSPV
Eccentricity Index LIPV
Eccentricity Index RSPV
Eccentricity Index RIPV
Multivariate analysis
Area of vein LIPV
HR, Hazard ratio; CI, Confidence interval; LCPV, Left Common Pulmonary Vein; LSPV, Left Superior Pulmonary Vein; LI