Prospective Randomized Clinical Trial of Wide Area Circumferential Pulmonary Vein Ablation versus Segmental Pulmonary Vein Ablation for Pulmonary Vein Isolation as a Treatment for Short-Duration Paroxysmal Atrial Fibrillation

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Abstract

Background: Previous studies suggest that wide area circumferential pulmonary vein ablation (WACA) is more effective than segmental pulmonary vein ablation (SPVA) for pulmonary vein isolation (PVI) for treatment of atrial fibrillation. Whether this is true in patients (pts) with very short duration paroxysmal atrial fibrillation (PAF) is unknown. **Objective:** To compare WACA to SPVA in pts with PAF lasting <48 hours. **Methods:** One hundred pts with PAF <48 hours were randomized to either WACA vs SPVA (45 and 53 pts respectively, with 2 withdrawals), and followed up for 24 months with 14-day ECGs every 6 months. **Results:** Among 97 pts at an average of 22.1±4.8 months followup, 26 (57.8%) remained free of any atrial arrhythmias after WACA versus 29 (55.86%) after SPVA (p=0.64). Sixteen pts (35.6%) had recurrent PAF after WACA versus 20 pts (38.5%) after SPVA (p=0.79). Seven pts (15.6%) had atrial flutter after WACA versus 5 pts (9.64%) after SPVA (p=0.376) and 1 pt (2.2%) had atrial tachycardia after WACA vs 1 pt (1.9%) after SPVA (p=0.918). Total procedure time was lower for SPVA vs WACA (242.9 vs 271.1 minutes, p= 0.047), and fluoroscopy time similar for WACA vs SPVA (50.8 vs 53.4 minutes, p=0.555). **Conclusions:** As an initial ablation approach in pts with PAF <48 hours, SPVA was similarly effective to WACA with respect to arrhythmia recurrence, supporting the central role of the pulmonary veins for maintaining AF in these pts. Future therapies using alternative ablation energies may incorporate these insights to reduce risk to gastroesophageal structures.

Condensed Abstract

Previous studies suggest that wide area circumferential pulmonary vein ablation (WACA) is more effective than segmental pulmonary vein ablation (SPVA) for treatment of atrial fibrillation. We studied 100 pts with PAF <48 hours, randomized to WACA vs SPVA and followed for 24 months. At an average of 22.1±4.8 months, 26 (57.8%) remained free of any atrial arrhythmias after WACA versus 29 (55.86%) after SPVA (p=0.64). Sixteen pts recurrent PAF after WACA versus 20 pts after SPVA (p=0.79), seven pts had atrial flutter after WACA versus 5 pts after SPVA (p=0.376), and 1 pt had atrial tachycardia after WACA vs 1 pt after SPVA (p=0.918). Total procedure time was lower for SPVA vs WACA (p= 0.047), and fluoroscopy time similar for WACA vs SPVA (p=0.555). In pts with PAF <48 hours, SPVA was similarly effective to WACA, supporting the central role of the pulmonary veins for maintaining AF in these pts.

Introduction

Catheter ablation is often the preferred treatment for patients (pts) with symptomatic paroxysmal atrial fibrillation (PAF), with or without prior failure of antiarrhythmic drugs.[1,2,3] Since the discovery that ectopic activity from the pulmonary veins (PVs) initiates the majority of AF episodes, ablation strategies have focused on their electrical isolation.[4] Currently, the two most commonly performed ablation strategies for pulmonary vein isolation (PVI) are wide area circumferential pulmonary vein ablation (WACA) using radiofrequency catheter ablation (RFCA) and circumferential ostial pulmonary vein ablation using the cryoballoon[5,6]. An alternative approach, segmental pulmonary vein ablation (SPVA) is less commonly used, but may have the advantages of decreased ablation time, lower total procedure time, and decreased risk of damage to gastroesophageal structures in selected patients.

Early randomized studies comparing WACA and SPVA produced conflicting results,[7,8] but WACA resulted in significantly higher success rates and shorter fluoroscopy time compared to SPVA[9]. That study however, included pts with both paroxysmal AF and persistent AF, which may differ both mechanistically and in the location of the pro-arrhythmic substrate, thus potentially accounting for the apparent advantage of WACA.[9]

In a meta-analysis[10], Proietti, et.al. compared WACA to SPVA and concluded that WACA was the superior approach for all AF patients, with less recurrence of AF at long-term follow-up. In a subanalysis of seven studies in pts with only PAF, the authors also concluded that WACA was a superior method. However, not all analyzed studies were randomized and in general were heterogeneous in research design. In contrast, a randomized trial comparing WACA + left atrial linear ablation (LALA) versus SPVA in pts with only PAF did not show a significant difference in overall recurrence of PAF.[11]

We hypothesized that patients with short-duration PAF (i.e. episodes lasting <48 hours) may have limited left atrial substrate remodeling and triggers primarily confiined to the pulmonary veins, and respond equivalently well to either SPVA or WACA. We therefore conducted this prospective, randomized trial of WACA versus SPVA to evaluate the safety and efficacy of both approaches in pts with short-duration PAF.

Methods

Study Population:

Participation in the study was voluntarily and all participants provided written informed consent. The study was approved by the UCSD Institutional Review Board and registered on clinicaltrials.gov (IRB#110531, CT.GOV#NCT02106663). This study was approved by the IRB to continue until a total of 100 patients were randomized. Eligible patients included those with PAF episodes lasting <48 hours in duration who were eligible to undergo catheter ablation, were at least 18 years old, and could provide informed consent. Exclusion criteria included conditions that would limit participation for the entire duration of the study, a previous AF ablation, PAF lasting >48 hours, refusal to provide informed consent, contraindication to anticoagulation, myocardial infarction or cardiac surgery within 3 months of enrollment, intra-cardiac thrombus, or pregnancy. The duration of AF episodes was determined in each pt by either 24-hour Holter monitoring, extended event monitoring (7-30 days), or clinical history.

Patients who were eligible for the study and agreed to be enrolled were randomized to either the WACA or SPVA group. All pts enrolled underwent a standard-of-care pre-procedure evaluation including a comprehensive medical history and physical examination, standard pre-procedural laboratory testing, 12-lead ECG, and a pre-ablation chest CT or MRI. In those pts already on oral anticoagulation (OAC) threapy, it was either continued or held for

1-3 days before ablation (at the operator's discretion). If OAC was discontinued before ablation, pts were bridged with enoxaparin 1mg/kg SQ bid up to the night before ablation. All antiarrhythmic drugs (AADs) were held for five half-lives before ablation, except for amiodarone which was not stopped prior to the procedure. Randomization numbers were computer generated in blocks of 4 and placed in sealed envelopes containing a note identifying which group the participant was to be enrolled in before ablation. The operating physicians were given the randomization envelopes in a single-blinded fashion (pts blinded) after obtaining signed consent from the pts participating in the study. Pre- and post-procedure care was standard and the same for both groups.

Ablation procedure:

Catheter placement for ablation: The femoral veins were accessed bilaterally using standard Seldinger technique with or without ultrasound guidance. Trans-septal catheterization was performed using standard Brokenbrough technique guided by intra-cardiac ultrasound (ICE) and fluoroscopy. Two 8.0 or 8.5 French SL1 sheaths (Abbott Cardiovascular, St. Paul, MN, USA), or a single SL1 sheath and a deflectable 10 French Agilis™ sheath (Abbott Cardiovascular, St. Paul, MN, USA), were positioned in the left atrium (LA). Prior to trans-septal puncture, unfractionated heparin (150-300 Units/kg body weight) was administered as a bolus, followed by a continuous intravenous infusion (1,000-3,000 Units/hr), to maintain activated clotting time (ACT) between 350-400 seconds throughout the procedure. The ACT was measured every 15 minutes.

The ablation catheters used in this study were either a Thermocool Classic® or ST/SF® coupled with the Stockert RF generator (Biosense Webster, Inc., Diamond Bar, CA, USA) titrated to a maximum power of 30-40 watts with a temperature cutoff of 42º C and an irrigation flow rate of 17-30 cc/min, or a Boston Scientific Blazer™ (Boston Scientific, Inc., Natick MA) or St. Jude Safire™ (Abbott Cardiovascular, St. Paul, MN, USA) 8 mm solid-tip

catheter coupled with an EPT 3000 (Boston Scientific, Inc., Natick MA, USA) or IBI generator (Abbott Cardiovascular, St. Paul, MN, USA) respectively, titrated to a maximum power of 50 watts and maximum tempterature of 55º C. The power and duration of energy application at each location depended on elimination of local electrograms and esophageal temperature. Pulmonary vein mapping was performed with a circular twenty-pole Lasso™ catheter (Biosense Webster, Inc., Diamond Bar, CA).

Esophageal Temperature Monitoring During Ablation: Esophageal position and temperature were monitored during all left atrial ablations using a Circa S-Cath™ temperature probe (Circa Scientific, Inc, Englewood, CO, USA), positioned so as to span the left atrium from the roof to the mitral valve annulus. When ablating on the posterior wall of the left atrium the power and duration of energy application was adjusted depending on luminal esophageal temperature (LET). Ablation was terminated in the event of a rapid temperature rise (>0.2Cº/sec or any temperature rise above 39ºC). If ablation could not be completed due to an unacceptable rise in LET, the esophagus was moved using an endoscope (positioned by an interventional gastroenterologist).

Pacing was performed with the ablation catheter at all locations prior to ablation in the anterior right PVs at 10 mA output and 10 msec pulse duration to ensure lack of phrenic nerve capture.

Method for WACA: For WACA (Figure 1) the two left and right PVs were encircled by contiguous ablation lesions at least 10 mm proximal to the PV ostia, guided by 3-D electroanatomic mapping (Carto™, Biosense Webster, Inc. Diamond Bar, CA, USA or Ensite NavX™ or Precision™, Abbott Cardiovascular, St. Paul, MN, USA) with a 3-D LA geometry created using a roving mapping catheter (Lasso™, Boston Scientific, Inc., Natick MA, USA or Biosense Webster, Inc. Diamond Bar, CA, USA) or by importing a pre-recorded 3-D CT image which was registered to the 3-D LA geometry. Radiofrequency

energy was applied at each location around the PVs until the maximum local electrogram amplitude was < 0.5 mV. When the WACA was completed, PV isolation was confirmed using the circular mapping catheter. Additional focal ablation was performed at the PV antra or ostia as required until the mapping catheter showed no sign of PV potentials indicating entrance block. Identification of exit block by pacing within the PV ostia, or pacing on the circumferential ablation line to demonstrate loss of capture, was performed per operator preference.

Method for SPVA: For SPVA (Figure 2) each pulmonary vein was mapped using the circular Lasso™ catheter placed at the PV ostium, using fluoroscopy, 3-D mapping (Carto™, Biosense Webster, Inc., Diamond Bar, CA or Ensite NavX™ or Precision™, Abbott Cardiovascular, St. Paul, MN, USA) and intra-cardiac echo (ICE) guidance (Accunav™, Biosense Webster, Inc., Diamond Bar, CA) to record PV potentials (during distal coronary sinus pacing for the left PVs and during sinus rhythm for the right PVs). PVI was performed by sequential application of radiofrequency energy at multiple sites, 1-2 mm proximal to the Lasso™ catheter, where the earliest bipolar PV potentials were recorded, until all PV potentials were eliminated (entrance block).

For both methods, PVI was re-confirmed by demonstrating entrance block with the Lasso™ catheter at least 30 min after the last ablation. The presence of any PV ectopy triggering AF, suggesting the need for further ablation, was also assessed 30 minutes after ablation by administering isoproterenol intravenously (20 mcg/min for up to 30 minutes or until heart rate increased at least 25% from baseline). If PV reconnection was confirmed after 30 minutes, further focal ablation was performed at the sites where reconnection was suspected until all PV potentials were eliminated, again for up to 30 minutes after the last ablation and during repeated pharmacological stimulation.

For either group (i.e. WACA vs. SPVA) additional linear ablation or ablation of clinically significant ectopic foci outside the PVs identified after PV isolation, was permitted per protocol.

Post-ablation Care: After ablation, intravenous protamine (40-50 mg) was administered to reverse heparin, after which sheaths were pulled when the ACT was <180 seconds. Subsequently all pts were hospitalized overnight. Approximately 6 hours after ablation, pts received intravenous heparin (1.5-2 unit/kg/hr) overnight. Pts were then restarted on OAC (with sub-cutaneous heparin injections in the case of warfarin until the INR was therapeutic) and on any AAD regimen they had been on prior to ablation. They were maintained on this medication regimen for up to 90 days, after which AADs were discontinued, but OAC was continued at the discretion of their physician (typically if CHA_2DS_2VASc score was ≥2).

Study endpoints:

Follow-up was performed per standard-of-care, as suggested by current consensus documents.[1] Pts were seen in clinic at 1, 6, 12 and 24 months following ablation, and prior to their 6, 12 and 24 month follow-up visits they underwent 14-day continuous ECG monitoring to evaluate for recurrence of symptomatic or asymptomatic atrial arrhythmias. At each visit, a review of symptoms, complete physical examination, 12-lead ECG, and appropriate laboratory tests were performed. Additional event monitoring was done in the event of symptoms suggesting recurrent arrhythmia. During ablation, total procedure and fluoroscopy times were recorded, as well as the total duration of radiofrequency energy application. Safety endpoints included major complicatioins (tamponade, prolonged hospitalization, hospital readmission, severe bleeding requiring transfusion) and minor complications (other bleeding, hematoma, deep vein thrombosis, chest pain), which were compared between groups.

Data was collected from pts' records in the Perminova™ database (San Diego, CA, USA) and Epic Hyperspace™ (Verona, WI, USA) software. The primary outcome measure in this study was recurrence of any atrial arrhythmia, including atrial fibrillation (AF), atrial flutter (AFL) and atrial tachycardia (AT), as recommended by the current consensus statement.[1] This was defined as any ECG documented asymptomatic or symptomatic arrhythmia episode lasting more than 30 seconds on ECG or continuous monitoring, off class I and III AAD therapy. Since recurrence early after ablation can be transient, all atrial arrhythmias occurring before the blanking period of 90 days were not included in the statistical analysis, as recommended by current consensus statements.[1] Secondary outcome measures of ablation, fluoroscopy and procedure time between the two procedures types were compared. Post-procedural adverse events were also reported and compared.

Statistical analysis:

Continuous variables are expressed as the mean ± standard deviation, and statistical significance was calculated using Student's t-test. Categorical variables are expressed as absolute numbers or percentages, and statistical significance was calculated using the Chi-squared test or Fisher's exact test when expected values were ≤5. Freedom from recurrence of atrial arrhythmias was determined by Kaplan-Meier analysis with the Log Rank test. A p value <0.05 was considered statistically significant. For power calculation, assuming a 2-year follow-up enrolling over 5 years, a nominal survival of 60%, and a PVI survival of 67%[7], setting a non-inferiority lower limit of 50%, with alpha=0.05 and beta=0.2 (one-sided), yields a required sample size of 50 in each arm of the trial to demonstrate non-inferiority. Statistical analysis and power calculation were performed using R statistical software (R foundation, Vienna, Austria).

Results

Patient characteristics:

The study population initially consisted of 100 pts with paroxysmal AF lasting <48 hours in duration having their first ablation for PAF between November 2012 and November 2018. Two patients were withdrawn from the study after randomization but before ablation due to the presence of persistent AF, with the remaining pts randomized to WACA (n=45) or SPVA (n=53). Analysis of freedom from recurrence of any atrial arrhythmia was performed in all pts who had at least one follow-up visit at 6 months and at least one mobile cardiac outpatient telemetry (MCOT) monitor performed during followup available for analysis (97 of 98 patients, 99%). The average follow-up time was 22.1±4.9 months for the WACA and 22.2±4.8 months for the SPVA groups (p=0.730).

Baseline pts characteristics are shown in Table 1. There was no statistically significant difference between groups in relevant baseline characteristics. The mean age was 62.1±10.1 years, mean duration of AF 3.9±4.0 years, and mean ejection fraction 63.4±8.1%. Hypertension was seen in 45 pts (45.9%), 59 were male and 39 female.

Efficacy analysis:

During followup 26 (57.8%) in the WACA group and 29 (55.8%) in the SPVA group remained free from all atrial arrhythmias. Kaplan-Meier analysis of freedom from recurrent AF revealed no significant difference between ablation groups (Figure 3, log-rank p=0.79). Kaplan-Meier analysis of freedom from recurrent AF, AFL and AT combined also revealed no significant difference between groups (Figure 4, log-rank p=0.64). Analysis of recurrence rates of AF, AFL and AT separately also found no significant difference between ablation groups (Table 2).

During followup, among those who developed recurrence of AF (either paroxysmal or persistent) or atypical AFL, 20 underwent repeat ablation. Of these 20 pts, there were 10 in

both the SPVA and WACA groups (p=NS), and the number of PVs reconnected at repeat EP study was not statistically different between groups (3.2±0.9 in the SPVA group versus 2.4±1.4 in the WACA group, p=0.09).

Procedural data:

Ablation, flouroscopy and procedure times are shown in Table 4. Procedure time (defined as the total time from start to completion of each case) was significantly shorter (p=0.047) in the SPVA group (242.9±70.5 min) compared to the WACA group (271.1±63.9 min), as was the ablation time (55.0±56.3 min for SPVA versus 105.9±62.3 min for WACA, p=0.00005). When comparing flouroscopy time, there was no significant difference (p=0.555) between the SPVA group (53.4±17.7 min) and the WACA group (50.8±23.8 min). While additional linear ablation or ablation of clinically significant ectopic foci outside the PVs identified after PV isolation was not required or performed in any patient.

Adverse events:

One (2.2%) case of left atrial perforation and hemopericardium occured in the WACA group (n=45) requiring emergent pericardiocentesis, and the pt stayed an additional 4 days in the hospital before discharge without further complications. One case of post-procedural pericarditis (1.9%) occured in the SPVA group, leading to an additional day in the hospital before discharge. Two cases of deep vein thrombosis (DVT) (4.4%) occurred in the WACA group and one (1.9%) in the SPVA group. One pt in the WACA group presented to the ED post-ablation with chest pain (2.2%), where a small pericardial effusion not requiring pericardiocentesis was found on echocardiogram.

Four (8.9%) pts in the WACA group and three (5.7%) in the SPVA group developed post-procedural groin hematomas or bruising. One pt in the WACA group was readmitted to the hospital and one pt (also in the WACA group) had bilateral DVTs and bilateral

hematomas and was therefore readmitted to the hospital for four days. One pt in the SPVA group that developed a hematoma was kept an extra day in the hospital before discharge.

In summary, two pts (4.4%) in the WACA group and one pt (1.9%) in the SPVA group had major complications (p=0.464). No cases of atrioesophageal fistula, cerebrovascular accident, PV stenosis or phrenic nerve injury occurred. There was no significant difference between groups in any of the reported adverse events.

Discussion

The main finding of this study was that freedom from recurrence of atrial arrhythmias was similar between SPVA and WACA for PVI as a treatment for PAF lasting <48 hours. Notably, total ablation and procedure times were shorter when using the SPVA approach. These findings may provide important mechanistic insight regarding the potential location of AF triggers in short-duration PAF and provide a rationale for more targeted therapy in this group of patients.

Freedom from recurrence of atrial arrhythmias:

Two-year freedom from recurrence of atrial arrhythmias in our study is comparable to that reported in other studies, which range from 66-86%, although most prior studies only followed patients to 6 months or 1 year.[1] Notably, the benefit of ablation was durable with SPVA in our study population, with no significant drop-off over time compared with WACA.

Previous randomized studies by Karch, Sawhney, Fiala, and a recent study published by Gula, et. al., did not show a difference in AF recurrence following WACA or SPVA,[8,11,12,13] similar to our current study. In contrast, studies by Oral, et. al. and Nilsson, et. al. did find that WACA was superior to SPVA.[7,14] Notably, when evaluating pts with PAF only, Nilsson, et. al.[14] did not find any significant differences in outcome. A potential explanation for these divergent results is that PAF may encompass a diverse group of patients with different distributions of triggers and/or substrate. No prior studies focused on the PAF

subgroup with AF duration <48 hours, which may represent a distinct population with remodeling primarily within the PVs.

Interestingly, longer follow-up time is another common denominator of the studies where no significant difference in efficacy could be shown. In the study by Oral, et. al., follow up was 6 months, whereas in the study by Sawhney, et. al. follow up was 16.4±6.3 months, and in the study by Fiala, et. al. follow up was 48 months.[7,11,12] Similar to the study by Oral, et. al. however, follow-up time for the primary end point in the study by Karch, et. al. was 6 months.[9] Based upon these observations, our study design specified a 24 month follow-up. Notably, the survival curves for WACA and SPVA show no evidence of divergence with time, with the effect of both ablation approaches remaining stable out to 2 years.

When comparing the development of other atrial arrhythmias post-ablation, there was no significant difference observed between the groups in this study, although previous studies have shown an increased risk of developing atypical atrial flutter in pts undergoing WACA (with or without additional left atrial linear ablation) compared to SPVA.[11]

Differences in ablation, flouroscopy and total procedure time:

Regarding the secondary outcome measures, this study showed no significant difference in flouroscopy time, but significantly shorter ablation and procedure times in the SPVA group. In concordance with the results of the studies included in the review article by Prioretti, et. al., ablation time was significantly shorter in the SPVA group[10]. When perfoming WACA, a larger number of ablation lesions are created and thereby ablation times were longer. Looking at individual previous studies, such as the recent study by Gula, et. al., differences in total procedure time are mixed.[13] A reason for this could again be due to the level of experience at the center performing the study. For example, the average difference in procedure time of 41.3 min is longer than the average difference presented in the review

article by Proietti, et. al.[10] Unfortunately, the absolute values for average procedure time for WACA and SPVA, respectively, are not presented in the review.

Adverse events:

Similar to the results compiled in the review articles by Proietti, et. al. and Feld, et. al., this study showed no significant difference in the frequency of any adverse events when comparing the two methods.[10,11] Our frequency of major complications was higher than the average obtained by Proietti, et. al. for the WACA group (3.1%), while it was lower for the SPVA group (4.4%).[10]

Mechanistic Implications of Study Results:

Overall, the success of SPVA in patients with PAF <48 hours supports the concept that such patients represent an important AF sub-population in whom AF triggers and/or arrhythmia-sustaining substrate exist primarily within the pulmonary veins and who may respond to more focused ablation therapy. In contrast, in patients with PAF episodes lasting >48 hours duration or persistent AF, triggering of AF may occur as a result of atrial premature beats originating in the pulmonary veins but also possibly from other sources (e.g. superior vena cava, coronary sinus, appendages), and AF may then be sustained by atrial substrate abnormalities located outside the PVs (e.g. areas of atrial scarring creating functional and/or anatomical barriers to conduction) that require more extensive ablation strategies to encompass (e.g. posterior atrial wall isolation, left atrial appendage isolation, linear atrial ablation).

This may have important therapeutic implications for future therapies. One possible implication is that patients with short duration PAF may be reasonable candidates for stereotactic ablative radiotherapy (SAbR) for AF, with radiation directed at the pulmonary veins to avoid radiation-sensitive gastroesophageal structures adjacent to the posterior LA wall.[15] Additional studies of this approach are required to assess feasibility.

Clinical Implications:

Given the conclusions drawn from this study, either WACA or SPVA can be performed in pts with short duration PAF, without any significant difference in recurrence rates of atrial arrhythmias or frequency of adverse events. Furthermore, considering the significantly shorter ablation and total procedure times for SPVA achieved in this study, we believe that SPVA (i.e. or a similar procedure such as ostial cryoballoon ablation) can be performed in pts with short duration PAF lasting <48 hours and still produce similar outcomes to the more complex and time consuming WACA procedure, reducing potential risks associated with procedural anesthesia and more extensive atrial tissue ablation.[16]

Limitations:

There are several limitations to this study. First, the total time of monitoring done before ablation was limited, which makes it possible that some PAF episodes >48 hours duration, particularly asymtomatic ones, could have been missed. Second, during the long course of this study, ablation platforms evolved significantly, which could have impacted outcomes. However, since pts were randomized in this study to both types of ablation procedure thoughout the course of the study, impacts from these and other factors should be equally distributed in the two groups. Third, our study included a majority of male, Caucasian patients with a mean age of 62.1 years, similar to prior work. Future trials are required to determine if gender, age or ethnicity have any effect on the efficacy of ablation treatment of PAF. Fourth, post-procedure AF monitoring was performed using then state-of-the-art outpatient ECG monitoring, which is limited in duration and may miss asymptomatic events. Future studies incorporating wearable electronics which may provide greater sensitivity for recurrent AF events, are required.[17]

Conclusions

In conclusion, SPVA and WACA provide similar long-term freedom from AF and all

atrial arrhythmias in pts with short duration PAF <48 hours in duration. SPVA is also associated with lower ablation time and decreased procedure time. These results may help guide future mechanistically-targeted approaches such as SAbR to improve arrhythmia treatment delivery and safety.

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Tables

Table 1. Baseline Characteristics

Characteristics	Total (N=98)	WACA (N=45)	SPVA (N=53)	P value
Age (years)	62.1 ± 10.1	60.2 ± 10.4	63.7 ± 9.7	0.097
Female Gender	39 (39.8%)	18 (40.0%)	21 (39.6%)	0.970
Congestive Heart Failure	4 (4.1%)	3 (6.7%)	1 (1.9%)	0.233
Hypertension	45 (45.9%)	20 (44.4%)	25 (47.2%)	0.787
Anti-arrhythmic Therapy	80 (81.6%)	39 (86.7%)	41 (77.4%)	0.236
CHA_2DS_2-VASc	1.5 ± 1.5	1.5 ± 1.5	1.5 ± 1.4	0.844
Ejection Fraction (%)	63.4 ± 8.1	61.8 ± 9.7	64.9 ± 6.1	0.077
AF Duration (years)	3.9 ± 4.0	3.5 ± 3.7	4.1 ± 4.3	0.474

Table 2. Recurrence Analysis

Recurrence of	Total (N=97)	WACA (N=45)	SPVA (N=52)	P value
Atrial Fibrillation	35 (36.8%)	16 (35.6%)	20 (38.5%)	0.79
Atrial Flutter	12 (12.6%)	7 (15.6%)	5 (9.6%)	0.38
Atrial Tachycardia	2 (2.1%)	1 (2.2%)	1 (1.9%)	0.92
All Atrial Arrhythmias	42 (43.3%)	19 (42.2%)	23 (44.2%)	0.64

One pt in the SPVA group was not included as they did not have at least one follow-up visit at 6 months

Table 3. Time Analysis

Times	Total (N=98)	WACA (N=45)	SPVA (N=53)	P value
Ablation time	78.3 ± 64.1	105.9 ± 62.3	55.0 ± 56.3	0.00005
Fluoroscopy time	52.2 ± 20.6	50.8 ± 23.8	53.4 ± 17.7	0.555
Procedure time	255.7 ± 68.6	271.1 ± 63.9	242.9 ± 70.5	0.047

All times in minutes

Figure Legends

Figure 1. An example of WACA ablation is shown in this figure of the left atrium. The left panel (left-anterior oblique view) shows the left pulmonary vein WACA lesions and the right panel (right anterior oblique view) shows the right pulmonary vein WACA lesions. In this pt WACA lesions resulted in complete electrical isolation of the pulmonary veins. LAA = left atrial appendage, LLPV = left lower pulmonary vein, LUPV = left upper pulmonary vein, RLPV = right lower pulmonary vein, and RUPV = right upper pulmonary vein.

Figure 2. An example SPVA ablation (guided by a circular multi-electrode catheter in the pulmonary veins) is shown in this figure (antero-posterior view). As is typical for SPVA ablation lesions are positioned at the ostium of the pulmonary veins versus outside the pulmonary veins for WACA. Abbreviations same as in Figure 1.

Figure 3. Kaplan-Meier survival curve comparing freedom from atrial fibrillation for wide area circumferential ablation (WACA, red line) versus segmental pulmonary vein ablation (SPVA, black line) during study follow-up (p=0.79).

Figure 4. Kaplan-Meier survival curve comparing freedom from all atrial arrhythmias (including atrial fibrillation, atrial flutter, and atrial tachycardia) during study follow-up for wide area circumferential ablation (WACA, red line) versus segmental pulmonary vein ablation (SPVA, black line) pulmonary vein isolation (p=0.64).