

Persistent Carina Conduction after Wide Area Circumferential Ablation is Associated with Inadequate Lesion Creation During Pulmonary Vein Isolation

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Abstract

Background: Ablation at the intervenous carina is often required for pulmonary vein isolation (PVI) after wide-area circumferential ablation (WACA). This might be a marker of lower lesion quality of WACA and influence the outcome of the procedure.

Methods: We reviewed PVI cases done after the introduction of the Ablation Index (AI), but before specific target values were implemented. In six segments around ipsilateral PVs mean and minimum contact force (CF), impedance drop (IPD) and AI were determined and correlated with the need for carina ablation.

Results: Twenty-five patients (age: 65±10 years), 2960 ablation lesions and 9428 parametric data were included. Ablation at the carina was required for PVI after 12/25 (48%) left WACA and 16/25 (64%) right WACA (p=0.39). The average and minimum AI, the minimum CF and average IPD were lower in the WACA lines where carina ablation was needed, compared to those resulting in “en bloc” PVI (p<0.02). The most consistent association was found between lesion quality in the anterior segments of left PVs and the requirement of left carina ablation. While there was no recurrence in the 7/25 (28%) patients with both left and right “en bloc” PVI by WACA, 1/8 (12.5%) of those with one and 7/10 (70%) of those with both carinas ablated experienced recurrent arrhythmia within one year (p<0.01).

Conclusions: Failure to isolate the PVs without carina ablation is associated with lower quality of the WACA line, especially at the left anterior ridge. This compromises the effectiveness of PVI.

Introduction

Pulmonary vein isolation (PVI) is the cornerstone of catheter ablation of atrial fibrillation (AF)¹. During point-by-point radiofrequency (RF) ablation PVI is attempted “en bloc”, encircling ipsilateral PVs by left and right, wide area circumferential ablation (WACA)². However, RF delivery between two ipsilateral veins, at the intervenous carina may be needed to achieve isolation in a considerable number of PV pairs^{3,4}. This may be the result of peculiar anatomy, but can also be caused by ineffective lesions in the WACA line sparing epicardial tissue^{5,6,7}. This latter may also increase the recurrence rate after PVI. Recent developments in technology have led to improved RF lesion delivery (by contact-force (CF) sensing) and provided a means to better characterize lesion quality (by the Ablation Index)⁸. Improvement in the quality of the WACA line likely contributes to diminishing rates of

“epicardial connections” necessitating carina ablation for PVI reported in the literature over the years^{5,6,7}. To confirm this, we examined a special population of patients undergoing PVI in whom lesion quality could be characterized retrospectively but was not used to guide RF delivery, resulting in a wide variation of lesions. Our aim was to explore the association between the need for ablation at the carina for PVI, lesion quality of the WACA line and the outcome of the procedure. We hypothesized that “en bloc” PVI, without the need for carina ablation might be a marker of better lesion quality of WACA and result in more favorable outcome.

Methods

We selected consecutive patients undergoing their first PVI for AF at a time when the Ablation Index (AI) was measured during the procedures, but specific target values were not established, resulting in greater variation of AI of individual lesions. Exclusion criteria were: presence of a common PV trunk (lack of a carina) and any gap in the WACA line (interlesion distance > 6 mm anywhere along the line).

The ablation strategy was to create antral WACA lines around

Key Words

Atrial Fibrillation, Box Isolation

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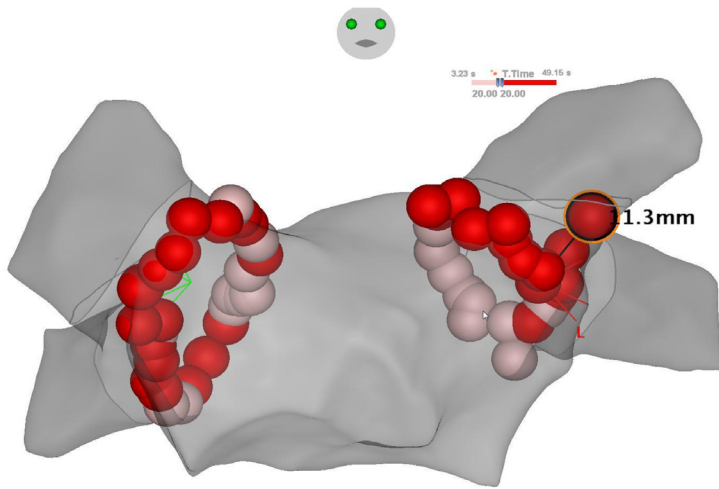


Figure 1:

Three dimensional reconstruction of the pulmonary veins (PVs) and posterior left atrium seen from an anteroposterior view. Ablation tags around ipsilateral PVs are colored according to ablation time (red: ≥ 20 s, white < 20 s). Ablation was also performed inside the left WACA ring, at the anterior PV carina, with the innermost tag being 11.3 mm inside the WACA ring.

ipsilateral PVs guided by electroanatomical mapping (CARTO, Biosense Webster, Irvine, CA), CF sensing (target value: 5-10 gram) and intracardiac echocardiography (ICE). Whenever PVI could not be achieved by RF delivery along the WACA line, ablation at the intervenous carina was undertaken until both PVs became electrically isolated. The RF energy was delivered in a point-by-point fashion using a 3.5 mm open irrigated-tip catheter with CF sensing (Thermo Cool Smart Touch, Biosense Webster) and power setting of 25-35 W. Power was reduced on the posterior wall, in the vicinity of the esophagus as seen on ICE. Automated ablation tag marking (Visi Tag) was used, set to the following annotation criteria: catheter stability range of motion ≤ 3 mm, duration ≥ 3 s, force over time: ≥ 2 g over $\geq 25\%$ and tag diameter 3 mm. The Ablation Index (AI) - a recently introduced marker of lesion depth that incorporates CF, ablation time, and power in a weighted formula - was available to the operator, but no specific targets were set.

The CARTO maps were reviewed retrospectively by an investigator blinded to clinical data. Any ablation tag at the intervenous carina region > 6 mm inside the WACA line delivered after completion of WACA was regarded as evidence for carina ablation (Figure 1.). Both left and right WACA lines were divided into six segments and the average and minimum CF, AI and impedance drop (IPD) determined in each segment. The perimeters of WACA lines were measured using proprietary tools of the CARTO software.

Patients were followed in the outpatient clinic at 3, 6 and 12 months after the procedure. Asymptomatic patients underwent 7-day Holter monitoring between 6 and 12 months post procedure, while any symptoms prompted event monitoring using transtelephonic ECG. Documented atrial arrhythmia ≥ 30 seconds in duration, after an 8-week blanking period was counted as a recurrence.

Statistics

Continuous variables are presented as mean \pm standard deviation and

compared using the independent samples t-test. Categorical variables are presented as percentages and compared by Fisher's exact test. A p-value < 0.05 was considered statistically significant.

Results

Twenty-five patients were studied, their clinical profiles are summarized in Table 1. The 50 WACA lines included 2960 ablation lesions, of which 9428 parametric data were analyzed. After 28 of 50 (56%) WACA PVI was not achieved and ablation at the intervenous carina was necessary. These included 12/25 (48%) left and 16/25 (64%) right WACA ($p=0.39$).

The average and minimum ablation index, the minimum CF and average IPD were lower in the WACA lines after which carina ablation was needed, compared to the ones resulting in "en bloc" PVI (353 ± 40 vs. 387 ± 40 , $p < 0.01$, 243 ± 46 vs. 282 ± 39 , $p < 0.01$, 2.6 ± 0.9 vs. 3.2 ± 0.9 grams, $p=0.02$, 8.4 ± 3.1 vs. 11.1 ± 3.3 Ohms, $p < 0.01$, respectively).

When analyzing the left sided WACA: the average and minimum AI were lower in those requiring carina ablation for PVI (339 ± 42 vs. 378 ± 35 , $p=0.02$ and 229 ± 48 vs. 283 ± 41 , $p=0.01$, respectively). There was no difference however in overall average or minimum CF and IPD ($p \geq 0.2$). The six-segment analysis showed the most consistent association between parameters of lesion quality and the need for left carina ablation in the anterior segments of left PVs. Average and minimum AI, as well as minimum CF in these segments showed a strong association with the requirement of carina ablation for PVI (Table 2.). When anteriorly the superior and inferior segments were averaged, all parameters of lesion quality showed lower values in patients with left carina ablation (mean CF: 5.6 ± 1.5 vs. 7.4 ± 2.6 grams, minimum CF: 3.4 ± 1.1 vs. 5.2 ± 2.2 grams, mean IPD: 8.8 ± 4.3 vs. 13.3 ± 4.4 Ohms, minimum IPD: 4.0 ± 3.5 vs. 9.8 ± 4.7 Ohms, mean AI: 409 ± 42 vs. 357 ± 59 , minimum AI: 302.8 ± 95.4 vs. 377.7 ± 63.2 , $p < 0.05$ for all).

Regarding the right sided WACA those without "en bloc" PVI tended to show lower average AI, IPD and minimum CF (365 ± 37 vs. 400 ± 45 , $p=0.05$ and 7.8 ± 2.2 vs. 11.4 ± 3.62 Ohms, $p=0.01$ and 2.6 ± 0.7 vs. 3.2 ± 0.5 grams, $p=0.04$, respectively). Segmental analysis did not identify a particular region with consistently lower values in those with carina ablation (Table 2.).

Left and/or right carina ablation was required for complete PVI in 18/25 (72%) patients. There was no difference in sex, BSA, echocardiographic parameters or total RF time between these patients

Table 1: Baseline parameters of patients. LAD=left atrial diameter, EDD=end - diastolic diameter, EF=ejection fraction

Age (years)	65 \pm 10
Women (%)	32
BSA (m ²)	1.96 \pm 0.22
Persistent AF (%)	36
LAD (mm)	45 \pm 6.6
EDD (mm)	52 \pm 3.6
EF (%)	63 \pm 8.3

Table 2: Ablation parameters of left and right WACA resulting in “en bloc” PVI vs. need for carina ablation. AI=Ablation Index, CF=contact force, IPD=impedance drop

	Left WACA			Right WACA		
	“En bloc” PVI	Carina ablation	p-value	“En bloc” PVI	Carina ablation	p-value
Perimeter (mm)	103±19	106±18	0.71	126±15	135±19	0.28
Overall avg. AI	378±35	339±42	0.02	400±45	365±37	0.05
Minimum AI	283±41	229±48	0.01	282±39	253±43	0.12
Overall avg. CF (g)	6.7±2.1	6.0±2.1	0.39	9.1±1.1	8.5±2.1	0.41
Minimum CF (g)	3.1±1.2	2.5±1.0	0.17	3.2±0.5	2.6±0.7	0.04
Overall avg. IPD (Ohms)	10.9±3.2	9.39	0.28	11.4±3.62	7.8±2.2	0.01
Minimum IPD (Ohms)	3.6±3.5	2.5±2.7	0.42	2.7±2.1	1.5±1.5	0.13
Avg. AI						
roof	406±37	362±47	0.02	416±59	380±48	0.11
sup ant	418±44	369±66	0.04	429±54	396±46	0.12
sup post	353±36	328±33	0.09	413±57	354±46	0.01
inf ant	400±44	345±66	0.02	420±60	393±49	0.22
inf post	333±35	304±28	0.03	338±40	321±26	0.22
inf	359±43	324±39	0.04	376±40	343±28	0.02
Min. AI						
roof	325±63	279±71	0.1	364±66	321±77	0.17
sup ant	378±63	303±95	0.03	381±68	356±57	0.34
sup post	337±39	304±35	0.04	369±70	321±58	0.08
inf ant	348±67	269±67	0.01	387±72	365±41	0.34
inf post	321±38	282±42	0.02	291±39	272±44	0.3
inf	306±43	268±55	0.06	336±40	289±39	0.01
Avg. CF						
roof	7.9±2.1	7.7±2.4	0.81	10.9±2.5	9.1±3.3	0.18
sup ant	7.4±2.6	5.6±1.5	0.04	11.2±2.5	10.4±3.5	0.53
sup post	6.2±2.2	6.4±2.6	0.85	8.3±2.4	7.4±4.4	0.6
inf ant	7.3±3.3	5.1±1.9	0.06	9±3.1	9.7±3.7	0.66
inf post	5.1±1.4	6.2±3.9	0.34	6.6±1.7	5.9±1.7	0.34
inf	6.5±2.8	5.1±2.9	0.22	8.6±1.8	8.3±3.5	0.8
Min. CF						
roof	4.6±1.8	3.4±1.7	0.09	5.9±2.6	4±2	0.05
sup ant	5.2±2.2	3.4±1.1	0.02	7.2±2.9	5.9±3.4	0.35
sup post	5.2±2.2	4.5±2	0.42	5.1±1.8	4.5±2.5	0.53
inf ant	5.6±2.3	3.3±1.7	0.01	5.7±2.1	5.4±2.6	0.72
inf post	3.9±1.3	4.9±3.9	0.34	4.5±1.6	3.6±1.5	0.14
inf	3.8±1.3	3.1±1.5	0.23	3.5±1	3.8±2	0.66
Avg. IPD						
roof	12.1±3.9	10.7± 3.9	0.34	13.7±4.8	8.5±2.9	0.01
sup ant	11.5± 3.4	10.7±3.1	0.55	13.8±3.6	10±2.5	0.01
sup post	8.9± 2.8	8.4±5.5	0.79	9.5±5.2	5.9±2.2	0.7
inf ant	13.3±4.4	8.8±4.4	0.02	12.4±4.3	9±2.5	0.02
inf post	8.9±3.6	8.1±5.1	0.65	8±3.7	5.7±2.1	0.12
inf	10.5±4.6	8.9±4.7	0.4	10.7±4.2	7.7±3.2	0.06
Min. IPD						
roof	5.9±3.7	4.1±3.2	0.21	6.8±5.3	3.8±3.3	0.09
sup ant	7.1±4.5	6.9±3	0.93	7.9±4	6±2.8	0.16
sup post	6.7±3.2	5.3±3.2	0.29	6.5±3.5	2.6±1.6	0.01
inf ant	9.8±4.7	4±3.5	0.01	8.5±3.9	5.6±2	0.02
inf post	6.5±3.4	5.3±3.7	0.4	4.1±3	2.9±2.1	0.26
inf	6.1±3.5	5.4±3.7	0.66	5.2±2	4.1±3.5	0.41

and those with bilateral “en bloc” PVI ($p \geq 0.13$).

While there was no recurrence in the seven patients with both left and right “en bloc” PVI by WACA, 1/8 (12.5%) of those with one and 7/10 (70%) of those with both carinas ablated experienced recurrent arrhythmia within one year ($p < 0.01$). There was no difference in any other parameter between patients with or without recurrence, including percentage of persistent AF, sex, BSA, echocardiographic measurements and average AI of left or right WACA ($p > 0.1$).

All 8 patients with recurrence underwent a repeat procedure. The one with only unilateral right carina ablation at the index procedure had reconnection of right PVs, the other 7 with bilateral carina ablation had reconnection of left in 2 (28.5%), right in 3 (43%) and both left and right PVs in 2 (28.5%) cases, respectively.

Discussion

The main findings of this study are:

1. The need for carina ablation to achieve PVI is related to the quality of the original WACA: several markers of lesion quality are lower in WACA lines without “en bloc” PVI
2. The most consistent relationship between poor lesion quality and failure of “en bloc” PVI is observed at the anterior segments of left PVs, i.e. the PV-left atrial appendage (LAA) ridge.
3. The requirement of carina ablation is associated with reduced effectiveness of PVI

Ablation between ipsilateral PVs, at the intervenous carina can be required to achieve PVI after creating a WACA line in up to 50 % of the cases^{3,4}. Although recent advances in technology likely decreased this percentage, it is nevertheless still reported in some contemporary series in more than 10% of cases^{6,9}.

The intervenous carina has long been recognized as the most common site to retain conduction after WACA^{3,4}. This has been attributed to its unique anatomical structure and thickness⁴. Cabrera et al. described crossing myocardial fibers in the intervenous carina, connecting the posterior wall of the superior PV with the anterior wall of the inferior PV or vice versa, in most hearts¹⁰. Early activation at the PV carina can be the result of sparing these - frequently epicardially located - crossing fibers along the insufficient WACA line. This may explain the frequent occurrence of carinal breakthrough after incomplete WACA.

However, recently it has been recognized that ablation at the anterior carina of the left PVs can lead to isolation even when the carina is not the earliest entrance site of activation^{6,9}. The postulated explanation of this finding is activation through the vein of Marshall (VOM), running in the left PV-LAA ridge. Our results corroborate this assumption by showing that left PV carina ablation was less frequently required when sufficiently deep lesions were delivered along the left PV-LAA ridge, likely eliminating VOM conduction.

Non-transmural ablation along the WACA line not only results in the requirement of carina ablation to achieve PVI, but also leaves some - likely epicardial - part of the PV antrum unablated. This may explain the observed higher recurrence rate in these patients. The unfavorable impact of residual carina conduction after circumferential ablation

on outcome was also shown in the international Minimax Study. In this randomized trial routine carinal ablation did not affect outcome, but the need for carina ablation in the group originally assigned to circumferential PVI-only was associated with an increased rate of recurrences¹¹.

Therefore, while carina ablation per se is not detrimental to the outcome of PVI, not being able to produce “en bloc” isolation of ipsilateral PVs is.

Technological improvements in RF lesion creation, including standardized lesion delivery based on the AI and higher power, short duration ablation have resulted in high rates of “en bloc” PVI, likely improving current success rates¹².

Limitations

Patient recruitment was limited to a period in the beginning of our experience with the use of the AI when standardized target values were not defined. Therefore, some of the ablation lesions may have been suboptimal to current standards. This period provided the opportunity to study the effect of differences in lesion quality on PVI effectiveness. Later, more standardized WACA resulted in less variation in lesion quality and less need for carina ablation. Limiting the study to procedures during this transitional period underlies the relatively low number of patients. However, a large number of ablation points were included and thousands of parametric data were analyzed.

Conclusions

Failure to isolate the PVs without carinal ablation is related to lower lesion quality of the WACA line, especially at the left PV-LAA ridge. It is likely the result of epicardial sparing by the not sufficiently deep lesions in the WACA ring. This compromises the therapeutic effectiveness of the procedure. The results suggest that in case of incomplete PVI by WACA reinforcement of the original ring rather than carinal ablation may be more effective.

Conflict of Interest

Dávid Tasnádi is an employee of Biosense Webster, Inc. The others have no conflicts of interests to disclose.

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