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Improved durable pulmonary vein isolation with shorter procedure times and lower energy levels using RF ablation with ablation index and a stringent lesion contiguity

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ABSTRACT

Background: The single procedure success rates of durable pulmonary vein isolation (PVI) for paroxysmal atrial fibrillation (PAF) varies between 80 and 90%. Ablation index, incorporating contact force, stability, time and power is a more profound parameter of significant lesion size and has been established. Equally important is a stringent contiguity of the lesion set.

Methods and results: A total number of 100 consecutive patients undergoing de-novo catheter ablation for paroxysmal atrial fibrillation (PAF) were analyzed between 2016 and 2019. In the first 50 patients (group A) PVI was performed using a surround flow, contact force catheter (Biosense Webster Thermocool STSF, Biosense Webster, USA) with a drag-and-ablate technique to encircle the PVs. In the following 50 patients (group B), PVI was performed using ablation index and a stringent lesion contiguity with an interlesion distance (ILD) of <5 mm. The baseline characteristics showed no significant differences between both groups. During a mean follow-up of 18 ± 3 months after a single procedure, 36 (72%) patients of group A were free of arrhythmia recurrence versus 43 (86%) patients in group B ($p = 0.047$). A total of 14 patients (group A: 10 (20%), group B: 4 (8%); underwent a redo-procedure. 7 patients of group A (14%) and 2 patients of group B (4%) showed recovered veins. In 3 patients of group A and 2 patients of group B the PVs were durably isolated. In these patients persistent AF recurrence was caused by extra-PV AF sources. Four patients of group A and three patients of group B had continued paroxysmal or persistent AF but did not undergo redo-procedure. With regard to the procedural data, the procedure time, the total energy and the fluoroscopy time were significantly lower in group B (AI and ILD <5 mm) (128.86 ± 18.19 versus 115.35 ± 15.38 ; $p < 0.05$; 1619.16 ± 988.56 versus 1186.26 ± 756.34 ; $p < 0.05$; 11.49 ± 3.20 versus 9.66 ± 3.86 ; $p = 0.04$). Both procedures were performed with a low number of complications, no pericardial effusion was seen in either group.

Conclusions: PVI using ablation index in combination with a stringent lesion contiguity improves clinical outcome after first-time PVI with lower PVI recovery, shorter procedure times, lower total energy and shorter fluoroscopy times and therefore, is more efficient.

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1. Introduction

Pulmonary vein isolation (PVI) has become the cornerstone of the interventional treatment of paroxysmal Atrial fibrillation (PAF).

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Durable PVI is necessary to prevent arrhythmia recurrence. Despite, intensive research during the past 15 years in the field of catheter ablation for PAF, recurrence rates after pulmonary vein isolation (PVI) remain as high as 10–25% after a single procedure even in highly experienced centers [1–3]. The main reason for recurrence of AF after PVI is a recovery of initially isolated PVs. Thus, efforts to overcome these limitations have been focused on techniques to enhance the durability of PV isolation. The recent introduction of contact force catheters and point-by-point ablation to encircle the PVs has been established to improve the contiguity of the lesions

and lesion size and therefore, an enhanced PVI [4].

In addition, ablation index (AI), a novel marker incorporating contact force (CF), time and power in a weighted formula and stability has been reported useful to improve durable PVI [5]. The CLOSE protocol, which comprises in addition to AI, an inter-lesion distance of <6 mm, is a novel approach aiming to enclose the PVs with optimized, contiguous RF lesions [6,7].

The aim of this observational analysis was to compare CF-based encircling of the PVs with a PVI using ablation index and an ILD of <5 mm.

2. Methods

2.1. Study population

This observational analysis comprised a total of 100 patients with symptomatic PAF. The mean age was 68.30 ± 11.17 years in group A and 65.25 ± 9.08 in group B. All patients were referred for an interventional treatment of PAF. A detailed diagnostic work-up was performed in our outpatient department prior to admission. All antiarrhythmic drugs, with the exception of amiodarone, were ceased at least five half-lives prior to the procedure.

2.2. Study protocol

Paroxysmal AF was defined according to the current guidelines. However, patients with AF episodes lasting >48 h or requiring electrical cardioversion were excluded from the study. All patients were characterized by self-terminating episodes with at least one documentation in Holter-ECG.

2.3. Ablation procedure

The procedures were performed under sedation with propofol infusion. The presence of left atrial thrombi was excluded by transesophageal echocardiography in the electrophysiological laboratory directly before the procedure. All patients underwent a standardized PVI procedure. The following catheters were introduced via a right femoral vein access: (1) A steerable decapolar catheter (Biosense Webster, Diamond Bar, CA, USA) was positioned within the coronary sinus; (2) a circumferential decapolar diagnostic catheter (Lasso NAV 15 or 20 mm, Biosense-Webster, Diamond Bar, CA, USA) for mapping of the pulmonary vein ostia; and (3) a 3.5 mm externally irrigated-tip, surround flow ablation catheter with contact force measurement (Thermocool STSF, Biosense-Webster, Diamond Bar, CA, USA). Access to left atrium was achieved by a single transeptal puncture with the two catheters placed into the left atrium via the same puncture. A single bolus of 5000 IU of heparin was administered before transeptal puncture. After transeptal puncture an additional bolus of 5.000–10.000 IU of heparin was added, according to the patient's body weight. The activated clotting time was assessed every 30 min and maintained within a range of 250–350 s. A temperature probe (S-CATH M, Circa Scientific, Englewood, CO, USA) was positioned in the esophagus and the endoluminal temperature was monitored throughout the procedure. For anatomical guidance, a 3-dimensional reconstruction of the left atrium and the PVs was created using the CARTO 3 system (Biosense Webster, USA).

Group A: a drag-and-ablate technique was used to encircle the PVs. During ablation, each point was deployed using the VISITAG™ module (settings: stability: 3 mm for 8 s, CF: 30% > 4 gr) to encircle the ipsilateral PVs in order to achieve simultaneous isolation.

Group B: point-by-point RF delivery was performed to achieve a contiguous circle enclosing the ipsilateral veins. Real-time automated display of RF applications (VISTAG™, CARTO 3, Biosense Webster,

USA) was used with predefined settings of catheter stability (3 mm for 8 s) and minimum CF (30% of time >4 g). RF application was continued until an ablation index (AI) of 380 at the posterior wall and 480 at the anterior wall was reached. An interlesion distance of less than 5 mm was achieved between the points. The ablation index was determined by a tailored approach for the operator.

In the absence of first pass PVI after completion of the ipsilateral circle, PVI was accomplished with additional RF applications upon the discretion of the operator. No substrate modification was performed as the patients showed a paroxysmal pathology.

PVI was confirmed by entrance- and exit-block of the PVs using a circular mapping catheter. RF was delivered in a power-controlled mode without ramping with 30 W (irrigation flow: 8 ml/min) with the SmartAblate generator and pump (Biosense Webster, USA) in both groups.

In case of esophageal temperature rise above 39 °C, ablation at the posterior wall was stopped immediately. To achieve complete isolation the circle resp. energy levels were modified to avoid esophageal temperature rise. Acute PVI was achieved in every patient. After PVI a waiting period of 20 min was obtained. Early reconnection was treated with touch-up ablation until PVI was reached. In case of pre-documented typical atrial flutter cavotricuspid isthmus (CTI) ablation was performed.

2.4. Follow-up

In all patients two 48 h Holter-ECGs were performed every 3 months. A detailed history of the patients' symptoms suggestive for potential arrhythmia recurrences was taken. In case of undocumented symptoms suspicious for arrhythmia recurrences, documentation by additional external ECG event recordings was performed. A documented symptomatic or asymptomatic arrhythmia episode lasting >30 s was defined as recurrence.

An initial blanking period of 3 months was accepted. The antiarrhythmic drug treatment was not re-initiated after ablation. If patients experienced an early recurrence within the initial three months after the procedure, antiarrhythmic drugs were re-initiated for the remaining time of the blanking period. In the absence of structural heart disease Flecainid was used, if structural heart disease was present Amiodaron was used. However, all antiarrhythmic drugs were ceased at the end of the blanking period. Patients with an arrhythmia recurrence after the blanking period were considered procedural failure.

The primary study endpoint was freedom from any atrial tachyarrhythmia occurring after the blanking period during a follow-up of at least 12 months. Secondary endpoints were procedural complications and PV recovery during redo procedures.

2.5. Statistical analysis

All continuous variables are reported as mean \pm SD and/or medians with ranges, while categorical variables were summarized as proportions. Categorical variables were compared using the chi square test. Comparison between groups were performed with either Student's *t*-test or the chi square test. Statistical significance was established at *p*-value < 0.05. Time to arrhythmia recurrence was estimated using the Kaplan-Meier method and compared by the log-rank test. Statistical analysis was performed with a statistical software package (SPSS, version 27, IBM, Armonk, NY, USA).

3. Results

A total number of 100 consecutive patients undergoing de-novo catheter ablation for paroxysmal AF were analyzed. Patient characteristics were well-balanced and are displayed in Table 1.

3.1. Procedural results

A total of 11 patients presented with spontaneous AF to the procedure (group A: 5, group B: 6). Electrical isolation of the PVs was achieved in all patients. In both groups 5 patients received an additional cavotricuspid isthmus ablation. The mean procedure duration was 128.86 ± 18.19 in group A vs 115.35 ± 15.38 min in group B ($p < 0.05$). The procedures were performed by a single operator with the same set-up and staff. Mean fluoroscopy time of 11.49 ± 3.20 vs 9.66 ± 3.86 min ($p < 0.05$), mean total energy application of 1619.16 vs. 1186.26 s, ($p < 0.05$) and total ablation time (group A: 56.62 ± 20.45 min versus 40.16 ± 16.25 min in group B) were significantly lower in group B (Table 2). The first pass isolation of the PVs was higher in group B (Group A: 38 (76%) versus group B: 46 (92%), $p < 0.05$).

3.2. Primary endpoint: freedom from any atrial arrhythmia

All patients completed the per protocol endpoint of a 12-month follow-up. The Kaplan-Meier 1-year arrhythmia-free survival estimation revealed a significantly better outcome in group B than in group A patients (86% vs. 72%, $p = 0.047$ (Fig. 1). In group-A, arrhythmia recurrences were characterized as paroxysmal AF in 10 and persistent AF in 4 patients. Recurrences occurred in group-B patients as paroxysmal AF in 3 patients and persistent AF in 4 patients.

3.3. Secondary endpoints: electrophysiological findings during redo procedure and complications

A total of 14 patients underwent repeat ablation (group A: 10 (20%) patients, group B: 4 (8%) patients). The rate of PV recovery during repeat procedures showed a higher trend in group A (group A: 7 (14%) versus group B: 2 (4%); $p = 0.08$ (Table 3).

In both groups re-isolation of the pulmonary veins was performed if PV recovery was seen. If the PVs were still isolated at the time of the repeat-procedure a substrate modification resp. electrogram-guided ablation was performed in order to terminate AF.

In a total of 5 patients (group A: 3, group B: 2) showed persistent isolated PVs and had extra-PV sources as cause of the AF recurrence.

No pericardial effusions, thromboembolic events or atrio-esophageal fistula occurred. One patient in group A suffered from an aneurysma spurium in the groin with conservative treatment. Mean hospital stay was 24 ± 6 h.

4. Discussion

4.1. Main findings

The presented study revealed the following key findings: 1) The arrhythmia-free survival is significantly higher using AI and an ILD of less than 5 mm. 2) The procedural time, total energy application and fluoroscopy time is significantly lower using the AI and ILD of less than 5 mm.

4.2. Strategies to achieve durable PV isolation

The PVs are the predominant source of PAF and electrical PV isolation is the cornerstone of catheter ablation for PAF [8,9]. Arrhythmia recurrences after ablation are mainly attributed to electrical PV reconnection with a strong correlation between the clinical magnitude of arrhythmia recurrences and the number and atrial-to-vein conduction recovery of the PVs [10]. Thus, significant efforts were made to develop techniques and tools that may help to enhance the durability of PVI after a single procedure. In this attempt, several different strategies were investigated, such as elimination of dormant conduction induced by adenosine [14], the implementation of a waiting period after PVI [11], contact force-guided ablation (TOCCATA) [12] and implementing AI following the CLOSE protocol respectively.

Since the introduction of CF-sensing technology, several studies suggested an improved durability of PVI and therefore, long term freedom of AF [13]. In addition, CF technology was associated with a reduced incidence of dormant conduction and lower rates of pericardial effusions [14]. The improved outcomes by using CF-technology are due to a better tissue contact and catheter stability, leading to an enhanced lesion depth, width and volume increase.

However, data on CF-guided PVI are not consistent across all studies. In addition to these conflicting results, still approximately 20% of the patients require a repeat procedure due to arrhythmia recurrence. Those conflicting results indicates that CF alone cannot preclude the presence of gaps in the ablation line. Therefore, the distance between the lesions seems to be equally important.

Previous studies showed the importance of contiguous, overlapping lesions to achieve durable PVI. Interlesion distance of more than 5 mm was linked to a lower acute success, despite CF of more than 10 gr [15].

The CLOSE protocol describes a method to obtain PVI with objective and reproducible criteria, including ablation index and an interlesion distance of less than 6 mm [16]. AI optimizes the RF delivery by building a force/time integral in conjunction to the predefined power settings. Thus, higher power settings can safely

Table 1
Baseline characteristics.

	Contact force (Group A)	Ablation index and ILD <5 mm (Group B)	p-value
Age (y)	68.30 ± 11.17	65.25 ± 9.08	ns
Male (%)	25 (62,5%)	28 (70%)	ns
BMI	27.19 ± 3.78	27.17 ± 4.26	ns
AHT (n)	26 (65%)	29 (72,5%)	ns
EF (%)	55.74 ± 4.46	56.4 ± 5.38	ns
valv HD (n)	2 (5%)	3 (7,5%)	ns
CHD (n)	5 (12,5%)	4 (10%)	ns
Stroke (n)	3 (7,5%)	2 (5%)	ns
CHADS-Vasc-Score	2.03 ± 1.58	2.15 ± 1.74	ns
NOAK (n)	34 (85%)	35 (87,5%)	ns
Marcumar (n)	6 (15%)	5 (12,5%)	ns

Table 2
Procedural data.

	Contact force (Group A)	Ablation Index and ILD <5 mm (Group B)	p-value
Procedural time (min)	128.86 ± 18.19	115.35 ± 15.38	<0.05
Fluoroscopy time (min)	11.49 ± 3.20	9.66 ± 3.86	<0.05
Total energy (J)	1619.16	1186.26	<0.05
Total average power (W)	1105.51 ± 778.71	1163.25 ± 832.93	0.64

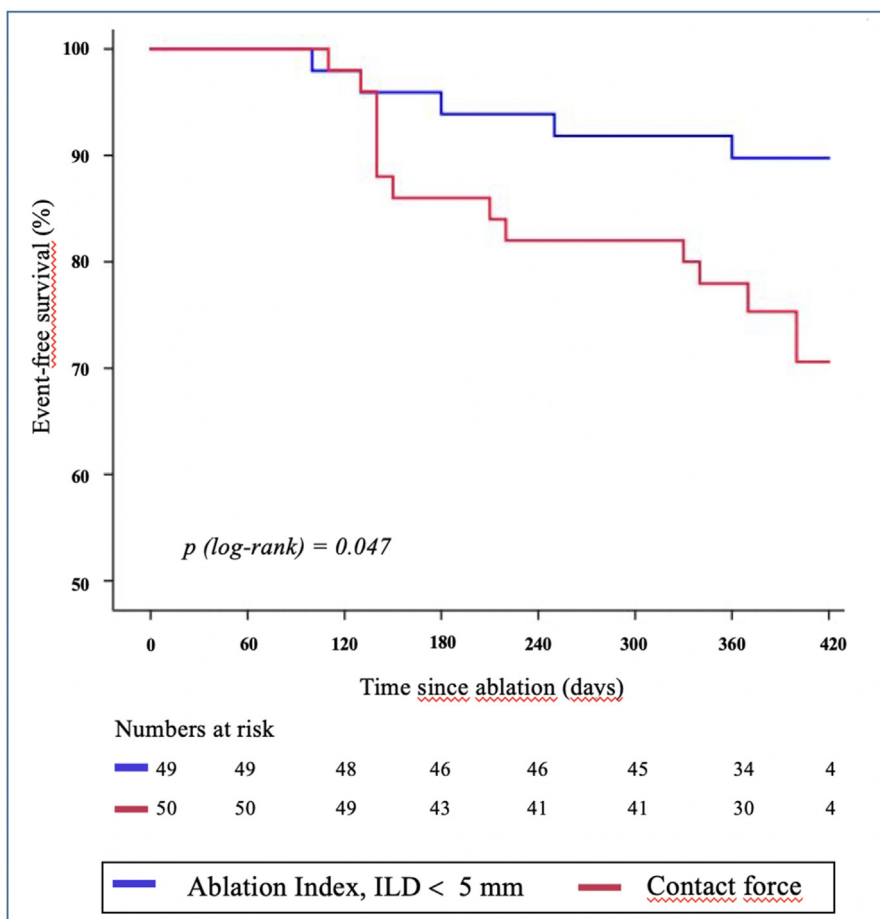


Fig. 1. Kaplan-Meier arrhythmia-free survival estimation during an overall mean follow-up of 18 ± 3 months after a single procedure. The vertical line indicates a follow-up duration. Patients of group B had a significantly better outcome as compared to group A patients (p = 0.047 based on the follow-up of 14 months).

Table 3
Recurrence rates and repeat procedures.

	Contact force (Group A)	Ablation Index and ILD <5 mm (Group B)	p-value
Recurrence at 3 months (n)	3 (6%)	4 (8%)	ns
Recurrence at 6 months (n)	14 (28%)	7 (14%)	0.047
Paroxysmal AF at 6 months (n)	10 (20%)	3 (6%)	0.09
Persistent AF at 6 months (n)	4 (8%)	4 (8%)	ns
Repeat procedures (n)	10 (20%)	4 (8%)	0.09
PV recovery (n)	7 (14%)	2 (4%)	0.08

be used to shorten application time, resulting in fewer dislocations. Even at sites with a lower catheter stability effective lesions can be achieved. The RF circle and the lesion size are expected to be similar when all parameters are met and to be reproducible across different centers [17].

Our findings support the use of AI, the CLOSE protocol and a stringent contiguity of the lesion set to achieve a significantly

higher rate of durable PVI in conjunction with a shorter procedure time and lower total energy application.

Additionally, we found a higher first pass isolation of the right PVs as compared to the left PVs. Most likely due to the anatomy of the right PVs as well as probably less epicardial PV connections and presumably a higher stability of the catheter.

Although, there some reports on higher complication rates with

the STSF catheter, it showed in our study a good safety and efficacy profile. Its architecture results in larger ablation lesions with an immediate delivery of the predefined power and no temperature rise during ablation. In our study the STSF catheter showed a good safety profile with no pericardial tamponade and no clinical apparent esophageal fistula.

5. Conclusions

PVI using ablation index in combination with a stringent lesion contiguity (ILD <5 mm) improves clinical outcome after first-time PVI with lower PVI recovery, shorter procedure times, lower total energy and shorter fluoroscopy times and therefore, is more efficient.

5.1. Limitations

The presented study has some limitations that may have impacted the study findings. First, in the presented study is a monocentric, observational analysis. Second, despite 24-h Holter ECG the recurrence of AF can be underestimated during follow-up. However, the design using 50 consecutive patients with one technique and the next 50 consecutive patients with another technique is very similar to a randomized approach.

Conflicts of interest

There are no conflicts of interest related to the manuscript.

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