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Evaluation of the luminal esophageal temperature behavior during left atrium posterior wall ablation by means of second-generation cryoballoon

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Abstract

Purpose The purpose of this study was to clarify the behavior of the luminal esophageal temperature (LET) in a cohort of patients undergoing second-generation cryoballoon (CB-A) for pulmonary vein isolation (PVI) and additional left atrium posterior wall (LAPW) ablation by means of CB-A.

Methods Thirty patients with symptomatic persistent AF (PersAF), having undergone PVI + LAPW cryoballoon ablation with LET monitoring.

Results Interruption of the application due to a LET below 15 °C occurred in 5 patients (16.6%), 2 at the LIPV and 3 in the LAPW. The 5 patients underwent gastroscopy the day after ablation. In all individuals, esophageal thermal lesion (ETL) was absent.

Conclusion The evaluation of LET might be an additional tool in helping to prevent damage to the esophagus during the LAPW ablation with the CB-A by stopping the freeze application when temperature reaches values of < 15 °C.

Keywords Luminal esophageal temperature · Left atrium posterior wall · Esophageal thermal lesion · Atrial fibrillation · Pulmonary vein isolation

1 Introduction

The second-generation cryoballoon (CB-A; Arctic Front Advance, Medtronic, Minneapolis, MN, USA) has proven to be highly effective for the treatment of atrial fibrillation (AF) [1] and has gained rapid acceptance in recent years, and the pulmonary veins (PVs) and the left atrium posterior wall (LAPW) have been shown to play a significant role in the genesis and maintenance of AF [2–4]. The lesions created by second-generation balloons are wider and more homogeneous than those produced with first-generation balloons [5, 6]. Although a recent article conclude that LAPW isolation (LAPWI) can be successfully performed with the CB-A [7], damage to the esophagus might occur when ablating on the posterior wall.

In this setting, esophageal damage has been shown to be tightly related to the LAPW and with the luminal esophageal temperature (LET).

In this study, we sought to enroll consecutive patients who underwent for pulmonary vein isolation (PVI) and additional LAPWI ablation by means of CB-A, with LET monitoring, to clarify the behavior of the esophageal temperature.

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2 Methods

2.1 Patient population

Consecutive patients with drug-resistant persistent AF (PersAF), having undergone PVI and additional LAPWI ablation strategy by means of CB-A, from March to August

2018, were consecutively included in the study. The exclusion criteria were any contraindications for the procedure, including the presence of an intracavitary thrombus, uncontrolled heart failure, contraindications to general anesthesia, and prior AF ablation. All patients signed informed consent to the procedure. The study was approved by the ethical committee of our institution. The protocol was carried out in accordance with the ethical principles for medical research involving human subjects established by the Declaration of Helsinki, protecting the privacy of all participants as well as the confidentiality of their personal information.

2.2 Pre-procedural management

A transthoracic echocardiogram was performed within 1 week prior to ablation enabling assessment of structural heart disease. To exclude the presence of thrombi, trans-esophageal echocardiography was performed the day before the procedure. All patients underwent a pre-procedural computed tomography (CT) scan to assess detailed left atrial (LA) and pulmonary vein (PV) anatomy. All antiarrhythmic drugs (AAD) were discontinued at least 3 days before ablation, apart from amiodarone that was stopped 1 month before.

2.3 Index procedure

Through a single transseptal puncture, an inner-lumen mapping catheter (Achieve®, Medtronic©) was advanced to each PV ostium through a steerable 15 Fr sheath (FlexCath Advance®, Medtronic©, Minneapolis, MN, USA). Baseline electrical information was gathered in each PV ostium. A 28-mm CB-A (Arctic Front AdvanceTM, Medtronic©) was advanced, inflated, and positioned at each PV ostium. Optimal vessel occlusion was defined by selective contrast injection showing total contrast retention with no backflow into the left atrium. The ablation sequence was treating the left superior PV (LSPV) first, followed by the left inferior PV (LIPV), right inferior PV (RIPV), and right superior PV (RSPV). Once vessel occlusion was deemed satisfactory, delivery of cryoenergy to allow freezing was commenced. Standard cryothermal applications lasted 180 s. Our target temperature was − 40 °C within the first 60 s. If the temperature did not attain this value, an extra freeze was delivered. Successful PVI was defined as an absence of all PV potentials or their dissociation from an atrial activity. During the entire procedure, activated clotting time was maintained over 250 s by supplementing heparin infusion as required.

Subsequently, ablation of the LAPW was performed in all patients. In order to achieve the latter, the Achieve catheter was placed deeply in the LSPV to stabilize the cryoballoon, with the distal balloon freezing surface oriented towards the LAPW. The first cryoenergy application was performed close to the balloon position during isolation of the LSPV to generate continuous lesions at the LAPW. By slight clockwise rotation and incremental advancement of the cryoballoon, consecutive freezes were applied along the LAPW in an overlapping manner, until the original balloon position for isolation of the RSPV was reached. The same maneuver was performed between the LIPV and RIPV with the goal of accomplishing complete LAPWI.

After ablation, in order to evaluate LAPWI, pacing maneuvers to test entrance and exit block were performed by placing the Achieve catheter (Medtronic, Minneapolis, USA) on the posterior wall. Also, a high-density 3D electroanatomical map (CARTO 3, Biosense Webster) was created with a multielectrode mapping catheter (Pentaray, Biosense Webster, USA). Areas of low voltage were defined as < 0.15 mV (Fig. 1).

2.4 Luminal esophageal temperature

The CIRCA's S-CATH™ Esophageal Temperature Monitoring System was used for every procedure. The S-CATH deploys an array of 12 temperature sensors throughout the length and width of the esophagus, positioning sensors near the source of temperature changes. The CIRCA system incorporates a monitor that displays the data from all 12 sensors. If required, the location of the esophageal probe was modified to the suitable position according to the CB-A position during freezing for a precise measurement of the LET, under fluoroscopic guidance. Fürnkranz A. et al. reported an association of low LET with ETL. They demonstrated that a LET value of < 12 °C predicted lesions with highest sensitivity and specificity (100% and 92%, respectively) [8], and based on that, for safety, if the LET reached 15 °C, the application was instantly suspended with a "double stop technique." The behavior of the LET during each CB-A application was recorded.

2.5 Phrenic nerve monitoring

Prior to ablation of the right-sided PVs, a standard decapolar catheter was placed in the superior vena cava cranial to the RSPV, or in the right subclavian vein in order to pace the right phrenic nerve during ablation. Phrenic nerve pacing started once the temperature reached − 20 °C in order to avoid balloon dislodgement due to diaphragmatic contraction in the first phase of cryoenergy application. Pacing was continued throughout the entire duration of cryoenergy delivery. In cases of phrenic nerve palsy (PNP), the freeze was immediately aborted and observed for recovery. Moreover, as from December 2013, an immediate deflation technique was performed in cases of PNP as described by Ghosh et al. [9]

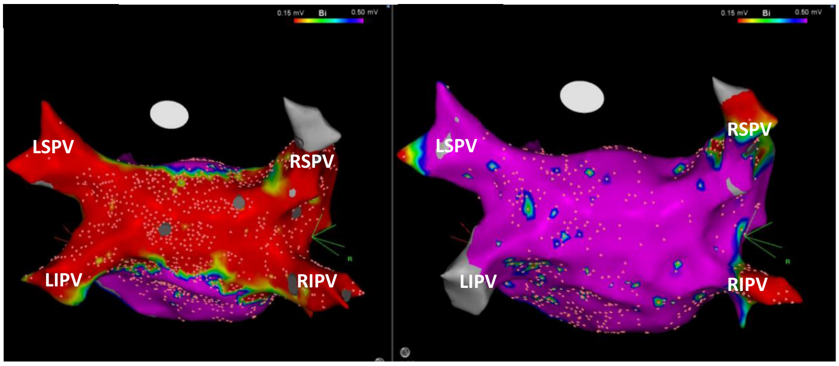

Fig. 1 Post- and pre-ablation images recorded with the 3D mapping system. The red region represents voltage < 0.15 mV, and the purple region represents voltage > 0.50 mV. Left: shows LAPW post-ablation. Right: LAPW pre-ablation. LAPW, left atrium posterior wall; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein

2.6 Post-procedural management

After the procedure, patients were continuously monitored via telemetry for at least 18 h. Before discharge, a transthoracic echocardiogram was performed in all patients in order to exclude post-procedural complications. Patients were discharged on the following day and were instructed to continue AAD and anticoagulation therapy for at least 3 months.

3 Results

3.1 Baseline population characteristics

A total of 30 patients [20 males (66.67%); mean age 69.07 ± 7.24 years] having undergone PVI and additional LAPW ablation strategy by means of CB-A were taken into consideration for our analysis. All patients had failed ≥ 1 class I or III anti arrhythmic drugs. Baseline clinical and demographic characteristics of the index procedure are listed in Table 1 .

3.2 Procedural characteristics

Main procedure parameters are summarized in Table 2. A total of 118 PVs were identified and successfully isolated with the CB-A. No patient was excluded on the basis of anatomical findings. The mean number of CB-A applications was 1.01 ± 0.4 in the LSPV, 1.05 ± 0.4 in the LIPV, 1.22 ± 0.3 in the RSPV, and 1.12 ± 0.3 in the RIPV.

The LAPW was successfully isolated solely by CB-A ablation in 28 out of 30 (93.3%) patients, and in the remaining 2 patients, isolation of the LAPW was completed by focal tip irrigated RF ablation. The mean numbers of CB-A applications required for the superior portion of the LAPW and the inferior portion of the LAPW creation were 4.13 ± 0.41 and 4.03 ± 0.39, respectively.

The total procedural time and fluoroscopy time were 95.07 ± 23.12 min and 25.26 ± 13.99 min respectively to complete the PVI + LAPW ablation.

3.3 LET behavior during ablation

The coldest LET values throughout each CB-A ablation were 33.52 ± 3.1 °C for the LSPV, 30.83 ± 5.18 °C for the LIPV, 32.11 ± 3.87 °C for the RSPV, 35.18 ± 0.42 °C for the RIPV, 31.71 ± 1.04 °C for the superior portion of the LAPW, and 31.69 ± 1.80 °C for the inferior portion of the LAPW, respectively (Table 2). Interruption of the application due to a LET below 15 °C occurred in 5 patients (16.6%), 2 at the LIPV (120 s and 170 s from the beginning of freeze) and 3 in the

Table 1 Baseline characteristics of the study population ($n = 30$)

	$N = 30$
Age (years)	69.07 ± 7.24
Male gender (%)	20 (66.67)
Body mass index (kg/m^2)	29.39 ± 4.68
Hypertension (%)	17 (56.67)
Diabetes mellitus (%)	7 (23.33)
Heart failure (%)	4 (13.33)
Coronary artery disease (%)	2 (6.67)
Chronic kidney disease (%)	4 (13.33)

Table 2 Procedural characteristics

Procedure time, minute	95.07 ± 23.12
Fluoroscopy time, minute	25.26 ± 13.99
Minimum LET left superior PV, °C	33,52 ± 3,1
Minimum LET left inferior PV, °C	30,83 ± 5,18
Minimum LET right inferior PV, °C	32,11 ± 3,87
Minimum LET right superior PV, °C	35,18 ± 0,42
Minimum LET superior portion of the LAPW, °C	31,71 ± 1,04
Minimum LET inferior portion of the LAPW, °C	31,69 ± 1,80

°C, degree Celsius, *PV* pulmonary veins, *LET* luminal esophageal temperature, *LAPW* left atrium posterior wall superior portion of the LAPW (in 1 patient at 134 s from the beginning of freeze proximally to the RSPV and in 2 patients at 100 s and 124 s, respectively, from the beginning of freeze proximally to the LSPV) Fig. 2.

The 5 patients underwent gastroscopy the day after ablation. In all individuals, esophageal thermal lesion (ETL) was absent. Of note, in both cases of cryoenergy interruption during ablation in the LIPV, electrical isolation could be documented in early phases of the freeze. We did not identify predictors of lower LET in the baseline clinical characteristics like age, gender, or body mass index (BMI) of the patient population.

3.4 Complications

Transient phrenic nerve palsy was observed in two patients (6%) during the RSPV ablation, and phrenic nerve function recovered in both patient before the end of the procedure.

4 Discussion

4.1 LAPW ablation

Isolation of the LAPW is becoming more common nowadays with the rationale that this region possesses unique structural, molecular, and electrophysiological characteristics, all of which appear to contribute to triggering and driving AF [10–13]. The modification of the subtracts in the LAPW is a potential strategy to improve outcomes in patients with persistent or permanent AF, but it needs to be noted that the evidence is not conclusive [14].

The lesions created by second-generation balloons are wider and more homogeneous than those produced with first-generation balloons [5, 6]. Kenigsberg et al. [15] characterized lesions and ablation area during PV isolation in 43 patients treated with the second-generation balloon. The authors found that lesion placement created a wide antral area that left only 27% of the LAPW unablated. These characteristics raise the possibility of adapting cryoballoon ablation techniques to achieve PLAW isolation. A recent study by Kuniss et al. showed that a significant amount of the posterior wall could be ablated following PVI + roof line ablation with the CB-A. Electroanatomical mapping after completion of the lesion set showed that a surprising portion of the posterior wall was electrically isolated. In a multicenter study, Aryana et al. recently described the feasibility of adding an inferior line between the inferior pulmonary veins to the roof line in order to accomplish a complete posterior wall isolation. The study examined 222 and 168 patients, who underwent a first-time cryoballoon ablation procedure using PVI + LAPW or PVI retrospectively. The goals of the study were the procedural safety, efficacy, and short- and long-term outcomes in those 390 consecutive patients with PersAF. They accomplished acute isolation in more than 99% of all pulmonary veins in both groups. The acute isolation of the LAPW was achieved in 77.2% of the PVI + LAPW group using 13.7 ± 3.2 applications and 34 ± 10 min of cryoablation [7]. In our study, acute LAPWI occurred in 93.3% of patients with CB-A. In 2 patients, focal RF was needed to achieve LAPWI. Of note, the difference observed between Aryana et al. observations and our findings in terms of rate of LAPWI with the CB-A might be related to the significantly larger size and the multicentric nature of the study of the aforementioned article.

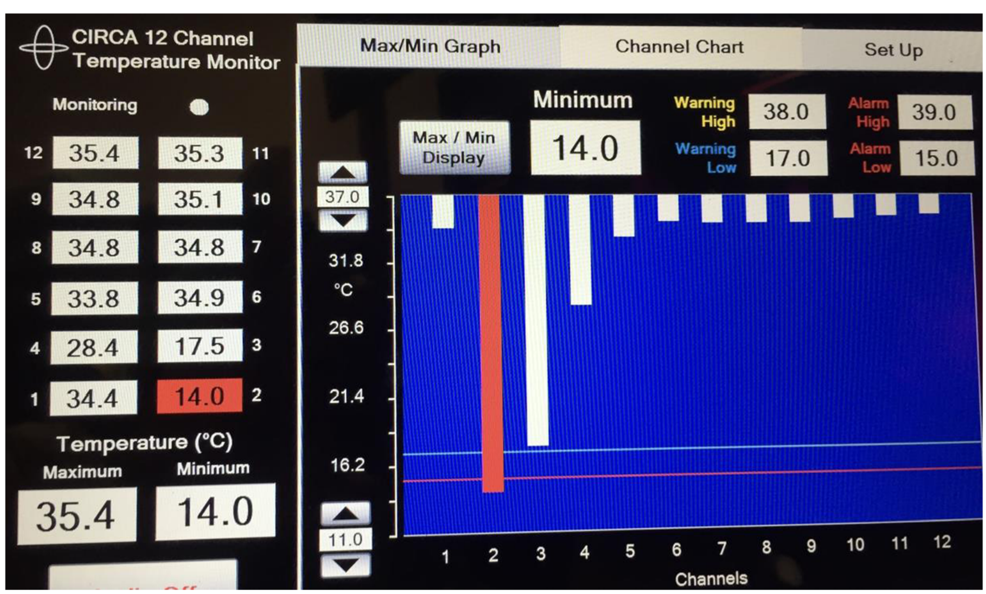

Fig. 2 Circa temperature monitor showing a low LET in the channel 2

4.2 LET and esophageal injury

Damage to the esophagus is a potential collateral effect of AF ablation. In the last years, a considerable amount of articles have addressed this issue. Among all possible lesions to the esophagus, atrio-esophageal fistula (AEF) is the most fearsome. In fact, although rare, atrio-esophageal fistula is associated with a devastatingly high overall mortality rate [16, 17].

This complication was first described by Pappone et al. [16] and has mainly been studied in the setting of AF ablation with RF since its first description. The first report of AEF as a consequence of cryoballoon (CB) ablation was published by Stöckigt et al [18] The authors reported an unusually low temperature in proximity of the LIPV when delivering an application with the first-generation device. The CT scan following ablation showed air trapped in the LIPV wall confirming the hypothesis of an AEF. Kawasaki et al. [19] and Lim et al. [20], further reported on AEF in the setting of cryothermal ablation with the cryoballoon. Interestingly, Lim et al. reviewed the current best practices that may reduce the risk of AEF such as PPI administration, imaging modalities to visualize the esophagus, and importantly LET measurement. Lately, John et al. [21] reported 11 AEF out 120,000 when analyzing the MAUDE database as from 2011. The authors concluded that proximity of the esophagus to the LIPV and evidence of very low LET might enhance the risk of AEF when ablating in the LIPV.

In the last years, clinical studies, specific regarding LET monitoring during PVI in the settings of CB ablation, have been published. Fürnkranz A et al. [8] recently reported a significant association between low LET with ETL. Specifically, the authors demonstrated that a LET value of < 12 °C predicted lesions with the highest sensitivity and specificity (100% and 92%, respectively). In a similarly designed study, Metzner A.et al. reported no ELs if the nadir LET was higher than 3.0 °C [22]. Interestingly, Miyazaki S et al. reported that the use of esophageal temperature probe itself increased the incidence of ELs by causing mechanical abrasions. However, this analysis was performed in the setting of AF ablation with irrigated RF energy.

We believe that evaluation of the esophageal temperature might be an additional tool in helping to prevent damage to the esophagus [19, 20]. In fact, although atrio-esophageal fistula is rare, it is the most fearsome complication of any AF ablation procedure, with devastatingly high overall mortality rate [16, 17].

In our study, we had to interrupt the freezing in three cases (10%) during the LAPW ablation, more precisely in the superior division of the LAPW (in 1 patient at 134 s from the beginning of freeze proximally to the RSPV and in 2 patients at 100 s and 124 s, respectively from the beginning of freeze proximally to the LSPV). The 3 patients underwent gastroscopy the day after ablation. In all individuals, ETL was absent.

4.3 Limitations

This was a single-center non-randomized trial; a larger number of patients is required to confirm our results. Subclinical manifestation of esophageal injuries could not be excluded since routine diagnostic studies were not performed to investigate for such adverse events. Prospective studies are warranted in order to evaluate the total incidence of esophageal damage in the setting of posterior box isolation with the CB.

5 Conclusion

The evaluation of LET might be an additional tool in helping to prevent damage to the esophagus during the LAPW ablation with the CB-A by stopping the freeze application when temperature reaches values of < 15 °C.

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