Indian Pacing and Electrophysiology Journal 19 (2019) 211–215

Contents lists available at ScienceDirect

Indian Pacing and Electrophysiology Journal

journal homepage: www.elsevier.com/locate/IPEJ

The assessment of pulmonary vein potentials using the new achieve advance during cryoballoon ablation of atrial fibrillation

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ARTICLE INFO

Article history:
Received 31 March 2019
Received in revised form
3 June 2019
Accepted 21 June 2019
Available online 22 June 2019

Keywords:
Atrial fibrillation
Achieve
Catheter ablation
Pulmonary vein isolation

ABSTRACT

Background: The new version of inner lumen mapping catheter (Achieve Advance™; Medtronic, Minnesota, USA) includes a new solid core which provides improved rotational response, as compared to the current Achieve Mapping Catheter. In the present study, we sought to analyze the rate of visualisation of real-time recordings using this new device comparing it with a large cohort of patients having undergone second generation cryoballoon (CB) ablation using the previous Achieve mapping catheter.
Methods: All patients having undergone CB ablation using the Achieve Advance and the last 150 consecutive patients having undergone CB ablation using the previous Achieve were analysed. Exclusion criteria were presence of an intracavitary thrombus, uncontrolled heart failure, moderate or severe valvular disease and contraindications to general anesthesia.
Results: A total of 200 consecutive patients (60.1 ± 9.5 years, 75% males) were evaluated (50 Achieve Advance and 150 old Achieve). Real-time recordings were significantly more prevalent in the "new Achieve Advance" population compared with the "old Achieve" group (73.5% vs 56.8%; $p = 0.0001$). Real-time recordings could be more frequently visualized in the "Achieve Advance" group in all veins except RIPV (LSPV: 86% vs 71.3%, $p = 0.04$; LIPV: 84% vs 62.7%, $p = 0.005$; RSPV: 78% vs 52%, $p < 0.0001$; RIPV: 46% vs 41.3%, $p = 0.3$).
Conclusions: The rate of visualisation of real-time recordings is significantly higher using the new Achieve Advance if compared to the previous Achieve mapping catheter in the setting of CB ablation. Real-time recordings can be visualized in approximately 73.5% of veins with this new device.

1. Introduction

Real-time (RT) recordings during cryoballoon (CB) ablation provide valuable information regarding time to isolation (TTI) of the pulmonary veins (PV) during cryoablation of atrial fibrillation (AF). Pulmonary vein potentials can be visualised by a dedicated inner lumen mapping catheter (ILMC) (Achieve, Medtronic, Minnesota, USA) which is used in combination with the CB. A new version of inner lumen mapping catheter (Achieve Advance™; Medtronic, Minnesota, USA) has been released on the market and currently implented for CB ablation. The latter includes a new solid core providing improved rotational response, as compared to the current version (Fig. 1). The greater flexibility and improved rotational response of the new device should provide a better positioning of this mapping catheter in the proximal portion of the pulmonary vein (PV) resulting in improved visualization of electrical activity in the PV itself. No modifications have been made neither the design of the distal segments nor in length and maximum catheter outer diameter.

The present study sought to analyse the rate of visualisation of RT recordings in our first series of 50 patients using the new Achieve Advance comparing it with a large cohort of patients having undergone second generation CB-A ablation using the old inner

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Peer review under responsibility of Indian Heart Rhythm Society.

https://doi.org/10.1016/j.ipej.2019.06.004

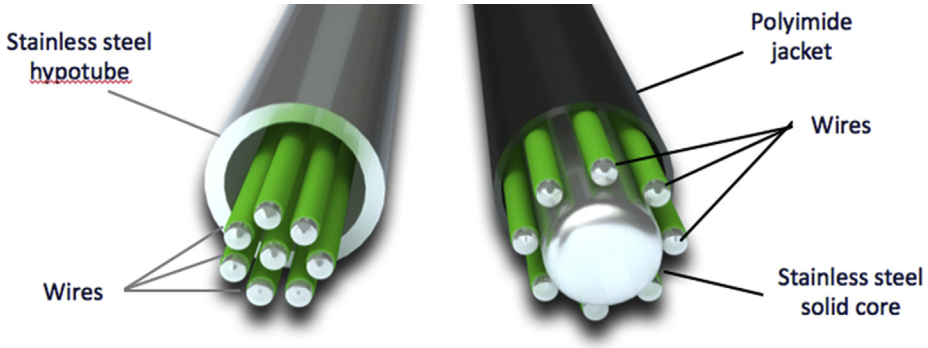

Fig. 1. On the left the current Achieve, whose shaft consists of a stainless steel hypotube (empty tube) into which the electrode wires are inserted. The proximal shaft is then bonded to the distal segment to allow distal control. This design required the user to carefully handle the catheter when taking it out of the package and during maneuvering. On the right, the new Achieve Advance is built on a solid core design platform. This consists of a solid stainless steel core with the electrode wires surrounding it and it is covered by a thin polyimide jacket.

lumen mapping catheter.

2. Methods

2.1. Study population

A total of 200 consecutive patients were included in our retrospective analysis. Since March the 1st 2017 a total of 50 consecutive patients having undergone CB ablation using the new ILMC (Achieve Advance™ 20 mm; Medtronic, Minnesota, USA) were enrolled. Procedural characteristics of this group were compared to the last 150 consecutive patients having undergone CB ablation using the previous Achieve Advance.

The main focus of the study was to compare the incidence of RT recordings visualisation between both devices. Other acute procedural results were also taken into consideration and compared. Exclusion criteria were: the presence of an intracavitary thrombus, uncontrolled heart failure, moderate or severe valvular disease, and contraindications to general anesthesia.

2.2. Pre-procedural management

All patients provided written informed consent to the procedure. All antiarrhythmic drugs were discontinued at least 3 days before ablation. For patients under anticoagulant therapy, our standard practice has been recently described[5]. A transthoracic echocardiogram (TTE) was performed within 1 week prior to ablation. To exclude the presence of intracavitary thrombi, all patients underwent transesophageal echocardiography (TEE) the day before the procedure. All patients underwent a pre-procedural computed tomography (CT)-scan to assess detailed left atrium (LA) and PV anatomy.

2.3. Cryoballoon ablation procedure

Briefly, after obtaining LA access, through a steerable 15 Fr sheath (FlexCath Advance, Medtronic©, Minneapolis, MN, USA), a ILMC (Achieve, Medtronic© or Achieve Advance, Medtronic©; 20 mm) was advanced in each PV ostium. A 28 mm Cryoballoon Advance (CB-A) (Arctic Front Advance™, Medtronic©) was advanced inflated and positioned in each PV ostium. Optimal vessel occlusion was considered as achieved when selective contrast injection showed total contrast retention with no backflow to the LA. Once occlusion was documented, cryoablation was started. Every cryo application lasted 180 s. Usually, the left superior PV (LSPV) was treated first, followed by the left inferior (LIPV), right inferior (RIPV) and right superior (RSPV). Pulmonary vein activity was recorded with the ILMC at a proximal site in the ostium prior to ablation in each vein. During ablation, if PV potentials (PVPs) were visible during energy delivery, time to isolation was recorded when PVPs completely disappeared or were dissociated from LA activity. Durable PV isolation was assessed at least 20 min after cryoablation. In the case of phrenic nerve palsy (PNP), recovery of diaphragmatic contraction was carefully monitored for 30 min.

Further additional applications were not applied when the veins were already isolated. If needed, pacing from the distal and/or proximal coronary sinus was performed to distinguish eventual farfield atrial signals from PV potentials
recorded on the mapping catheter, respectively, for left- and right-sided PVs. Moreover, after having retrieved the 15 Fr sheath to the right atrium while keeping the ILMC in the LSPV, a bipolar catheter was introduced through the transseptal access in the left atrial appendage (LAA), and pacing was performed in order to distinguish eventual farfield of left atrial electrical activity from PV potentials.

2.4. Phrenic nerve monitoring

Before ablation of right-sided PVs, a standard decapolar catheter was placed in the superior vena cava cranial to the RSPV or in the subclavian vein in order to pace the right phrenic nerve during ablation of the right-sided PVs. Phrenic nerve capture was achieved when contraction of the right hemidiaphragm could be observed both under fluoroscopic imaging and with manual palpation of the abdomen. Phrenic nerve pacing started when the temperature reached −20 °C in order to avoid balloon dislodgement due to diaphragmatic contraction in the first phase of cryoablation. Pacing was continued throughout the whole duration of the application. If loss of capture was observed, freeze was immediately aborted and observed for recovery. Additional applications were not necessary as all PVs were isolated at the time PNP occurred.

2.4.1. Post-ablation management

Patients were discharged the day following ablation if their clinical status was stable. After the intervention, the patients were continuously monitored with ECG telemetry for at least 18 h. Before hospital discharge, all patients underwent transthoracic echocardiography in order to exclude pericardial effusion and a chest X-ray. Oral anticoagulation was started the same evening of ablation and continued for at least 3 months.

2.4.2. Follow up

After discharge, patients were scheduled for follow-up visits

with baseline ECG and 24 h Holter recordings at 1, 3, 6 and 12 months. Any symptoms following ablation were deemed as deserving a Holter monitoring. All reports of Holter or ECG recordings having been performed in referring centers were sent to our centre for confirmation of the diagnosis of atrial tachycardia recurrence. Furthermore telephone calls were performed during the follow-up. A blanking period of 3 months was considered for the study. All documented episodes of atrial tachyarrhythmias lasting ≥30 s were considered as a recurrence.

2.5. Statistical analysis

Categorical variables are expressed as absolute and relative frequencies. Continuous variables are expressed as mean ± SD or median and range as appropriate. Comparisons of continuous variables were done with a t-student test and binomial variables with chi-square or Fisher test as appropriate. A 2-tailed probability value of <0.05 was deemed significant. Statistical analysis was performed using SPSS 20.0.0 (IBM Inc., Armonk, New York, USA).

3. Results

3.1. Baseline characteristics

A total 200 patients (60.1 ± 9.5 years, 75% males) with drug-resistant AF having undergone PV isolation by means of CB technology were taken into consideration for the analysis (Table 1). All had previously failed ≥1 Class I or III antiarrhythmic drugs. Mean time of AF was 34.5 ± 17.8 months. Mean left atrial diameter was 43.8 ± 5.8 mm. There were no statistical differences in the baseline characteristics between the 2 groups (Table 2). In particular, mean LA diameter were not significantly different between the 2 groups (p = 0.5).

3.2. Anatomical characteristics

No patient was excluded due to anatomical reasons based on the pre-procedural CT scan. A discrete left common ostium was observed in 12 patients (6%); among them, 10 were in the "old Achieve" group (6.7%) and 2 in the "new Achieve" group (4%; p = 0.7). In case of discrete common ostium, the standard approach was to address, sequentially, the superior and the inferior branches delivering a single cryo-application for each one. The mean LSPV diameter was 18.1 ± 1.9 mm (18.1 ± 1.8 mm in the "old Achieve" group vs 18.1 ± 2.1 mm in the "new Achieve" group, p = 0.8), mean LIPV diameter 17.2 ± 1.2 mm (17.3 ± 1.2 mm in the "old Achieve" group vs 17.0 ± 0.9 mm in the "new Achieve" group, p = 0.1), mean RIPV diameter 18.2 ± 1.0 mm (18.1 ± 1.1 mm in the "old Achieve" group vs 18.3 ± 0.7 mm in the "new Achieve" group, p = 0.1), mean RSPV diameter 19.9 ± 1.5 mm (19.9 ± 1.3 mm in the "old" group vs 19.8 ± 2.0 mm in the "new Achieve" group, p = 0.4).

Table 1
Baseline characteristics of the study population.

Number of patients	200
Age (years)	60.1 ± 9.5
Male gender	150 (75)
Duration of symptoms (months)	34.5 ± 17.8
Persistent AF	72 (36)
Hypertension	125 (62)
Diabetes mellitus	21 (10)
Coronary artery disease	11 (5)
Valvular heart disease	8 (4)
Left ventricular ejection fraction (%)	58.9 ± 6.5
Left atrial diameter (mm)	43.8 ± 5.8
CHA_2DS_2-VASc score	1.43 ± 1.22
Body mass index (kg/m^2)	26.9 ± 4.9
Oral anticoagulation	168 (84)
IC class antiarrhythmic drugs	128 (64)
Beta blockers	23 (11)
III class antiarrhythmic drugs	98 (49)
Calcium channel blockers	2 (1)

Categorical variables are expressed as absolute and percentage (in brackets). Continuous variables are expressed as mean ± SD. AF: atrial fibrillation.

3.3. Procedural data

In the total population, procedural and fluoroscopy time were, respectively, 104.2 ± 33.8 min and 16.7 ± 8.2 min. No significant differences in procedural and fluoroscopy time were found between the 2 groups (respectively, 105.0 ± 34.1 and 17.4 ± 8.5 min in the "old Achieve" group vs 101.8 ± 32.9 and 15.5 ± 6.8 min in the "new Achieve" group; p = 0.5 and p = 0.1). There was no statistical difference between the 2 groups in terms of number of freezes, minimal temperatures attained and time to PV isolation for each vein (Table 3).

In a total of 800 PVs, a grade 4 occlusion could be obtained in 759 (94.9%) and for the remaining PVs (n = 41; 5.1%) a grade 3 occlusion was documented. A grade 4 occlusion was obtained in the LSPV in 144 patients (96%) using the previous Achieve vs 47 patients with the new Achieve Advance (94%; p = 0.7); in the LIPV a grade 4 occlusion was attained for 144 patients (96%) in the "old Achieve" group compared with 44 (88%) in the "new Achieve" group (p = 0.08). The complete occlusion before RIPV ablation was also reached in 142 patients (94.7%) in the "old Achieve" group compared with 44 (88%) in the "new Achieve" group (p = 0.1); and finally, a grade 4 occlusion could be attained in the RSPV in 146 patients (97.3%) among the "old Achieve" group vs 48 (96%) in the "new Achieve" group (p = 0.6). At a mean follow up of 41.7 ± 17.2 months (median 40 months), the success rate without antiarrhythmic therapy was 82% (164/200). The rate of AF recurrence after the blanking period was 20.7% in the "old Achieve group" (31/150) and 10% in the "new Achieve group" (5/50; p = 0.1) with a significantly different follow up between the 2 groups (48.2 ± 14.9 months in the "old Achieve" group vs 22.2 ± 2.1 months in the "new Achieve" group; p < 0.001). In particular at 12 and 20 months, the freedom from AF was, respectively, 94% (47/50) in the "new Achieve group" vs 89% (178/200; p = 0.4) in the "old Achieve group" and 90% (45/50) in the "new Achieve group" vs 85.5% (171/200; p = 0.5) in the "old Achieve group".

3.3.1. Real time recordings

In the overall study population, real-time isolation recording could be observed in 61% of all the PVs. Real-time recordings were significantly more prevalent in the "new Achieve" population compared with "old Achieve" group (respectively, 73.5% vs 56.8%; p = 0.0001). During LSPV ablation, real-time recordings could be visualized in 86.0% of PVs in the "new Achieve" group vs 71.3% of PVs in the "old Achieve" group (p = 0.04), during LIPV ablation PV potentials were present in 84.0% of PVs in the "new Achieve" group vs 62.7% of PVs in the "old Achieve" group (p = 0.005). During RIPV ablation, PV potentials were visualized in 46.0% of PVs in the "new Achieve" group vs 41.3% of PVs in the "old Achieve" group (p = 0.3) and during RSPV ablation real-time recordings could be observed in 78.0% of PVs in the "new Achieve" group vs 52.0% of PVs in the "old Achieve" group (p < 0.0001).

3.3.2. Complications

In the overall study population no major complications occurred. Five PNPs (2.5%) were observed in the total study population; among them, 4 (2.7%) occurred in the "old" group and 1

Table 2
Comparison of clinical characteristics between patients having undergone 2nd generation CB using the novel Achieve vs the old one.

	New Achieve (n = 50)	Old Achieve (n = 150)	P-value
Age (years)	59.7 ± 10.3	60.2 ± 9.3	0.7
Male gender	38 (76)	112 (75)	1.0
Duration of symptoms (months)	36.7 ± 15.6	32.2 ± 18.5	0.1
Persistent AF	18 (36)	54 (36)	1.0
Hypertension	28 (56)	97 (65)	0.3
Diabetes mellitus	3 (6)	18 (12)	0.3
Coronary artery disease	3 (6)	8 (5)	1.0
Left ventricular ejection fraction (%)	59.4 ± 5.1	58.4 ± 7.9	0.4
Left atrial diameter (mm)	43.5 ± 5.8	44.2 ± 6.0	0.5
CHA_2DS_2-VASc score	1.25 ± 0.95	1.58 ± 1.35	0.1
Body mass index (kg/m^2)	27.5 ± 5.3	26.5 ± 2.9	0.1

Categorical variables are expressed as absolute and percentage (in brackets). Continuous variables are expressed as mean ± SD. AF: atrial fibrillation.

Table 3
Procedural characteristics.

	New Achieve (n = 50)	Old Achieve (n = 150)	P value
Procedural time(min)	101.8 ± 33.0	105.0 ± 34.1	0.9
Fluoroscopy time(min)	15.5 ± 6.8	18.4 ± 8.5	0.5
Freezes in LSPV	1.22 ± 0.46	1.36 ± 0.72	0.2
Freezes in LIPV	1.30 ± 0.64	1.28 ± 0.51	0.7
Freezes in RSPV	1.26 ± 0.48	1.28 ± 0.55	0.1
Freezes in RIPV	1.42 ± 0.73	1.32 ± 0.57	0.7
Min temp in LSPV	−49.5 ± 3.3	−47.7 ± 5.4	0.1
Min temp in LIPV	−43.9 ± 4.2	−44.6 ± 5.6	0.3
Min temp in RSPV	−50.4 ± 4.6	−48.5 ± 5.4	0.1
Min temp in RIPV	−45.5 ± 5.8	−45.1 ± 6.3	0.1
T_{PVI} in LSPV (sec)	51.0 ± 34.3	47.2 ± 26.3	0.4
T_{PVI} in LIPV (sec)	58.0 ± 48.1	37.9 ± 25.1	0.3
T_{PVI} in RSPV (sec)	42.0 ± 36.5	39.7 ± 26.5	0.3
T_{PVI} in RIPV (sec)	62.8 ± 39.1	52.4 ± 33.7	0.3

Continuous variables are expressed as mean ± SD. Min temp: minimal temperature. LSPV: left superior pulmonary vein. LIPV: left inferior pulmonary vein. RSPV: right superior pulmonary vein. RIPV: right inferior pulmonary vein. CB-A: Cryoballoon Advance device. CB-ST: Cryoballoon short-tip device. T_{PVI}: time from start of freezing to pulmonary vein isolation.

(2.0%) in the "new Achieve" group (p = 0.6). Two hematomas in the groin region with spontaneous resolution (1.0%) were observed, both in the "old Achieve" population (p = 0.6).

4. Discussion

To the best of our knowledge this is the first article focusing on the comparison between the new ILMC and the current one used in the setting of second-generation CB ablation of AF. The main findings of our study are 1) the rate of visualisation of real-time recordings of PVPs is significantly higher using the new Achieve Advance if compared to the previous Achieve mapping catheter during second generation CB ablation, 2) the new solid core and the greater flexibility do not significantly jeopardize the support and the grade of PV occlusion, 3) procedural times and characteristics are similar using both devices.

Real-time recordings during the cryoablation might provide valuable information on time to PV isolation and consequently on the conduction properties of the LA-PV junction [2,3]. Furthermore, previous studies have reported that shorter times to isolation are associated with sustained LA-PV disconnection [2,3]. Conversely, longer times to isolation tend to reliably predict early recovery of PV conduction [4]. Anatomically, the PV sleeves are often thicker and occupy more of the circumference at the atrial end, but they tend to become thinner as you progressively move more distally into the vein [5].

Recent publications reported a 50–60% rate of real-time recordings visualisation during CB ablation [1,6]. Given the above mentioned considerations, this percentage might appear deceiving. Although, the current strategy usually commences by recording baseline electrical activity at the PV ostium level before attempting occlusion and subsequently ablation, time to isolation might not only be crucial in offering valuable information on LA-PV conduction, but it might also guide the operator in tailoring the dosing strategy of the freeze-thaw cycle. In fact, recent data in the literature seem to indicate that shorter application times seem to offer similar clinical outcome if compared to the recommended "2 times 240 s" strategy [5,7,8]. However, although shortening the application duration has proven effective and might lead to shorter procedural times and fluoroscopy times these findings need to be confirmed in large and randomised trials.

In our study, real-time recordings could be visualised in approximately 73.5% of veins when using the Achieve Advance during CB ablation. This rate was found to be significantly higher if compared to the previous Achieve mapping catheter. This difference might be explained by the particular structure of the new device made by a new solid core which provides improved rotational response and greater flexibility.

This solid core design platform is constituted by a solid stainless steel core with the electrode wires surrounding it and it is covered by a thin polyimide jacket (Fig. 1). The distal segment, which is crucial for the support of CB during the PV occlusion and ablation, is unchanged and made of a nitinol core in both devices in order to make the loop soft and atraumatic. In fact the occlusion grade and procedural characteristics did not significantly differ between the 2 groups (Table 3) suggesting that support and, subsequently, stability of the CB is similar in both devices.

Similarly to previous reports real-time recordings were more frequently observed in the superior veins if compared to the lower PVs [1,11]. One potential explanation lies in fact that the CB tends to

be coaxial to the venous course when being positionned in the antra of both upper veins while more catheter manipulation is usually needed to occlude the inferior veins [9]. In fact when positionning the balloon in the lower veins the ILMC often needs to be positioned more distally in the vein in order to offer better catheter stability [10]. Moreover, the PV sleeves are typically shorter in the inferior veins compared to the superior ones [11]. Therefore, the chances of visualising real-time recordings might decrease drastically.

In the present study, the rate of PV potentials visualisation is significantly higher using the new Achieve Advance for all PVs except RIPV; of note, the frequency of RT recordings during RIPV ablation is considerably low in both groups (46% vs 41.3%; $p = 0.3$). As abovementioned, this might be probably related to the difficult anatomical position and orientation of the RIPV; during the ablation of this vein, the mapping catheter often needs to be placed more distally in the vein to achieve a stable support and a complete occlusion. This results in a lower chance to obtain electrical recordings on the ILMC during the ablation of this PV.

A previous study meticulously described specific maneuvers designed to maximize real-time recordings during second generation CB-Adv ablation [12]. The authors concluded that electrical information could be gathered in most PVs. However, the operator had to rely often on exit block verification during CB application. Although, unidirectional block is extremely rare during PV isolation [13] and therefore exit block may be an effective alternative to confirm PV, these maneuvers might be difficult to achieve in some cases on the ILMC. Moreover, direct disappearance or dissociation of PV potentials from LA activity might be significantly more easy to interpret.

The greater size of the new Achieve Advance (25 mm with 10 spaced electrodes) might hypothetically result in higher rates of PV recordings visualisation as a higher number of electrodes may possibly give more chances to get PV signals. This is already and preliminary confirmed by a small, recent work by Reissmann et al. [14] reporting the visualization of RT recordings in 80% of the PVs in a sample of 40 patients and 159 PVs having undergone CB ablation with the new 25-mm Achieve Advance. Of note, the authors reported that in 3 RIPV the ILMC had to be exchanged for a stiff guidewire because of insufficient mechanical support; however, the PV isolation exclusively using the new ILMC was achieved in 98% of the PVs.

5. Limitations

Although conducted on a large cohort of patients, this study bares the limitations of being retrospective and non randomized. We did not use a thermal esophageal probe. Therefore a certain amount of esophageal lesions might have gone unnoticed. We did not perform cMAP during right phrenic nerve pacing. The incidence of PNP might have been lower.

6. Conclusions

The rate of visualisation of real-time recordings of PVPs is significantly higher using the Achieve Advance mapping catheter if compared to the previous Achieve in the setting of second-generation CB ablation. Real time recordings can be visualized in approximately 73.5% of veins with this new cryoballoon. The new solid core and the greater flexibility do not significantly impair the support and the grade of PV occlusion. Procedural times and characteristics were found similar using both devices.

Conflicts of interest

GBC and CdA receive compensation for teaching purposes and proctoring from AF solutions, Medtronic. PB receives research grants on behalf of the centre from Biotronik, Medtronic, St. Jude Medical, Sorin, Boston Scientific and speakers fees from Biosense Webster, Biotronik, Medtronic. CdA is consultant for Daiichi Sankyo.

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