



A tale of two balloons: technical and procedural difference between cryoballoon systems

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Purpose of review

The cryoballoon catheter has been an option for the treatment of atrial fibrillation for over a decade. The most widely used device is the Medtronic Arctic Advance cryoballoon catheter. Recently, Boston Scientific has released the POLARx cryoballoon catheter. Here we review the major changes in the catheter system's design and its implications for procedural practice.

Recent findings

The POLARx cryoballoon catheter has been approved for use in Europe. Some studies have been published detailing the first clinical experiences in vivo with this newest technology.

Summary

The changes to the POLARx cryoballoon catheter, particularly its ability to maintain balloon size and pressure, will improve occlusion and theoretically improve procedural outcomes.

Keywords

atrial fibrillation, cryoballoon ablation, POLARx

INTRODUCTION

Atrial fibrillation (AF) is the most common arrhythmia with an estimated incidence of 46.3 million individuals worldwide, and the incidence is expected to increase worldwide as large portions of the population age [1,2]. Cryoballoon catheters for the ablation of the pulmonary veins (PV) in the treatment of AF have been commercially available since the first-generation Medtronic Arctic Advance (Minneapolis, USA) was released in 2010, and has undergone four generations of cryoballoon modifications [3]. Recent data showing the benefit of cryoballoon ablation compared to drug therapy [4^{••},5^{••}] has allowed for its use as a first-line treatment for AF without prior use of antiarrhythmics, further expanding its use.

Recently, Boston Scientific's POLARx cryoablation balloon catheter has been approved for use in the European Union, and data from early clinical experience is being obtained. It is currently undergoing FDA IDE trial in the US. Although the overall design of the cryoballoon in dimension appears to be similar to that of the Medtronic Arctic Front system, the POLARx system has several important differences that may alter both ablation technique, as well as dosing.

CRYOBALLOON BASICS

The cryoballoon catheter was originally designed as an alternative to traditional radiofrequency (RF) ablation for pulmonary vein isolation (PVI). Although RF ablation requires point-by-point connection to achieve PVI, the cryoballoon was designed to provide a 'one-shot' circumferential lesion to improve rates of PVI, and hopefully procedural outcomes as well. Following transeptal puncture, the cryoballoon catheter is inflated and placed against any of the PV antrums. Refrigerant is then delivered to the balloon, and delivered via eight

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KEY POINTS

- Multiple changes have been made to the cryoablation system design in hopes of simplifying cryoballoon ablation procedures for operators and improving safety and outcomes.
- Changes to the design of the cryoballoon catheter made in the latest POLARx balloon should improve occlusion, simplifying ablation procedures and possibly improving procedural success and outcomes.
- Further study is needed to determine whether the changes to the Boston Scientific cryoablation system translates to increased procedural success.

injection ports. With good contact, the cryoballoon then adheres to the tissue, keeping the balloon in contact with the tissue despite the active motion of the heart. The large-scale randomized trial FIRE & ICE showed the second-generation cryoballoon was noninferior to RF ablation with similar success rates of 65.4% in the cryoballoon group and 64.1% in the RF group [6].

Similar to many other contact-based catheter technologies, close contact between the balloon and atrial tissue circumferentially, especially during cryoablation, is the key determinant to ensure transmural lesions. In addition to the force that applies to the balloon, a few factors impact greatly on the contact:

- (1) The balloon has a spherical design that ideally fits best to a circular antrum. In many patients, the PV ostium or the antrum is oval in shape but not circular as we expect. So the compliance or the deformability of the balloon will facilitate the engagement of the balloon catheter to the atrial wall when force is applied. One should remember that the deformability of a balloon when it is inflated is different from that when cryoablation starts. Both the solidity of the balloon and the myocardial tissue compliance will change when the temperature drops. This explains why a perfect PV occlusion on angiogram does not necessarily translate into good contact during cryoablation [7]. The material that the balloon is made of and the inflating pressure at different temperatures determine optimal compliance of the balloon which should allow a certain extent of deformability for better balloon-tissue contact without sacrificing safety and force transmission ability.
- (2) As a physical principle, when refrigerant injection initializes one should expect a counterforce to the wall of the balloon from balloon-tissue

interface and an expansion of balloon size. This will occasionally cause balloon dislodgement from the PV ostium (so-called pop-out phenomenon) that may or may not be compensated by applying additional force to the balloon and sheath [8]. Although we don't have data on how the injection force and balloon extensibility will affect balloon-tissue contact, it seems that the POLARx cryoballoon performs better than the Arctic Advance balloon in this aspect due to changes in the balloon design.

THE BOSTON SCIENTIFIC POLARx VS. MEDTRONIC ARCTIC FRONT ADVANCE

The Boston Scientific POLARx cryoballoon system, currently undergoing IDE trial in the US, contains the same toolset as the Arctic Front but with several major design changes to the system as a whole in the hopes of resolving previously documented procedural limitations. Changes to the ablation catheter itself include a new thermoplastic balloon material and a pressure sensor, changes that alter how ablation energy is delivered. Its accompanying toolset, including the sheath, mapping catheter, and console have been altered as well.

The POLARSheath and POLARMAP mapping catheter

Both the FlexCath Advance and the POLARSheath are unidirectional, deflectable sheaths. The FlexCath measures at 12 Fr, whereas the POLARSheath is slightly larger at 15.9 Fr. The POLARSheath has been designed to smooth common procedural difficulties. The POLARSheath has no step-up in the transition from the dilator to the sheath. It is also designed with a 155-degree angle deflection, compared to the FlexCath's 135 degrees. This should increase maneuverability for patients with challenging anatomy and improve access to the RIPV. The adjustable stiffness in the POLARSheath also provides more support. This interplay of sheath angle and cryoballoon axial force determines the cryoballoon-PV tissue contact. The increased angle of deflection may better engage the balloon in the inferior portion of the pulmonary vein antrum. This may also reduce the need for a more inferior transeptal puncture to establish the angle of engagement [10]. This will improve the balloon-sheath interplay to establish the concentric engagement with the target vein.

The Medtronic Achieve Advance mapping catheter is a 25 mm loop attached to the distal end of the balloon. The Boston Scientific POLARMAP catheter has a continuous nitinol core, and all of its electrode wires are individually insulated. The few studies conducted in and published by operators in Europe

suggest time-to-effect (TTI) per vein was higher than as reported with Achieve. In combination with the changes to the POLARx balloon, the POLARMAP can be withdrawn toward the ostium without sacrificing stability.

The balloon

The POLARx balloon itself differs in several ways from the Arctic Front Advance. Both balloons are available in a 28 mm size. The Arctic Front Advance also comes with a 23 mm option, which is less frequently utilized clinically. The Arctic Front Advance balloon does not actually reach its 28 mm diameter until after freezing has commenced [11]. The POLARx balloon is now equipped with a pressure sensor that controls the internal pressure of the balloon to keep the balloon size, shape, and stiffness the same throughout the ablation. The POLARx is also made of a proprietary thermoplastic material which may make the balloon more compliant when engaging the PV antrum and easier to retract into the sheath.

There are also changes in preparing the balloon for ablation. The Arctic Front balloon only inflates once it has reached human body temperature. The POLARx is prepared by inflating outside the body for debubbling, to void air in the fold of the balloon before insertion into the sheath. The slider switch on the handle to the POLARx cryocatheter deflates and elongates the balloon, putting the control of the balloon deflation in the hands of the operator, rather than a console operator. Both balloons automatically deflate postablation upon reaching 20 degrees Celsius.

In practice, the cryoballoon does not always provide a 'one-shot' lesion. Following inflation of the Arctic Front Advance cryoballoon, balloon occlusion is then assessed with imaging such as ICE, fluoroscopy, and use of contrast [12]. When good contact cannot be achieved, it is common practice to apply multiple lesions in a segmental technique to ensure transmural lesions. However, this occlusion may change as the balloon can be dislodged following pressure changes resulting from ablation. It is important to know that both the stability of pressure at initiation of cryoablation and the average pressure maintained during cryoablation have an influence on the balloon-tissue contact and subsequently on the efficacy of ablation. The Medtronic balloon is pressurized to about 20 psi as the refrigerant flow rises suddenly to provide therapeutic cooling [13], however, the POLARx balloon is pressurized to a constant 20 psi throughout inflation and ablation (Fig. 1). A higher in-balloon pressure during ablation facilitates force transmission applied by the operator, but it is associated with less

compliance. A lower in-balloon pressure during cryoablation gives more deformability to the balloon, however, the external force can be dispersed. The relook angiography technique has been proposed to assess this shift. The changes made to the design of the cryoballoon catheter in Boston Scientific's POLARx balloon may prevent the need for such accommodations, whereas providing greater efficacy in producing permanent PVI prior to ablation throughout the application of the balloon. It maintains a uniform size from the inflation state to the ablation state, because the system is continuously monitoring and adjusting internal balloon pressure (Fig. 2). The POLARx balloon did not result in the pop-out phenomenon in a study of 25 cases, but 4/22 cases performed with Arctic Advance were observed [9**]. The compliant balloon should improve contact and maintain occlusion achieved, which theoretically can improve cryoballoon lesion size and potentially translate to the improved circumferential lesion.

The SmartFreeze console and mapping

The Boston Scientific cryoballoon console was altered with both safety and efficacy in mind. A diaphragm movement sensor (DMS) is placed on the skin to measure abdominal movement as an additional method of monitoring phrenic nerve activity. This provides more sensitive, objective feedback than the operator placing their hand on the abdomen, a common practice when ablating with the Arctic Advance. Furthermore, the console has been designed with ablation timers to automatically adjust ablation based on when time-to-isolation (TTI) is marked. This, paired with the POLARMAP catheter, has significant implications for dosing.

Dosing

Cryoballoon dosing, that is, the amount of time the cryoballoon is applied to the lumen of the PV, has evolved over time. Initial dosing recommendations were suggested at 240-s freezes per the STOP AF trial protocol [14], however, following increased instances of dose-dependent complications such as phrenic nerve injury, this was reduced, particularly following the changes to the design of the catheter in the second-generation balloon [15]. Dosing varies widely by center, but based on the FIRE & ICE trial, balloon dosing is generally reduced to 180-s freezes or less [6]. Operators may apply the balloon and freeze. Following a period that allows the balloon to defrost and re-warm, a second application is usually performed.

The European trial for the POLARx utilized dosing protocols of 180 s with TTI \leq 60 s or else a 240-s

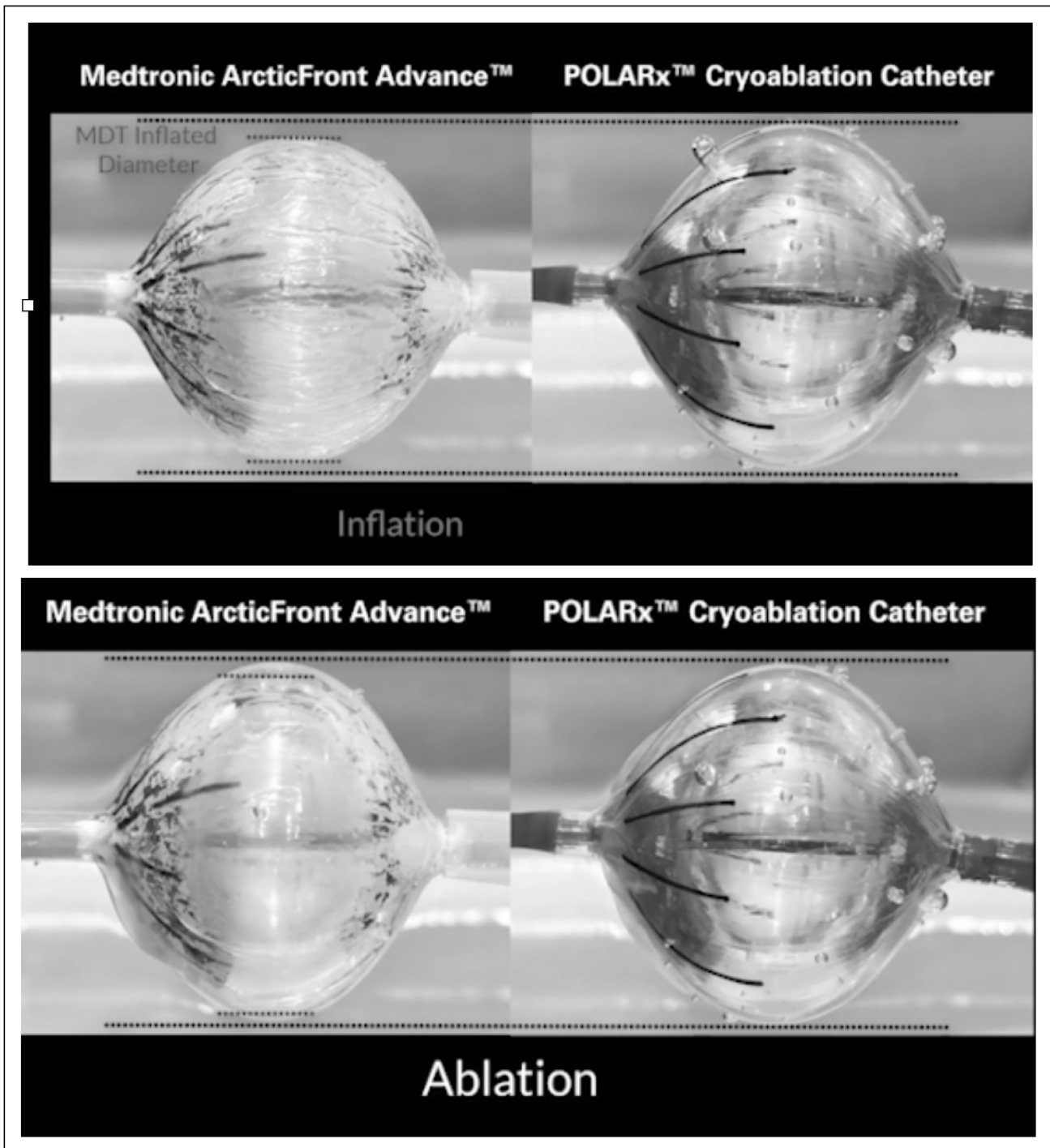


FIGURE 1. A comparison of the POLARx versus the Arctic Advance when inflated versus during ablation (Permission obtained from Boston Scientific).

freeze per PV. This dosing is questionable, as it has not been applicable to clinical practice for over a decade. In theory, the increased compliance of the POLARx balloon should improve balloon-to-tissue contact. Dosing requirements, therefore, should be reduced rather than increased. Resuming prior 240-s dosing protocols may result in a greater incidence of

dosing-dependent complications such as phrenic nerve palsy, which was commonly observed with the first-generation cryoballoon [16].

Preliminary data shows the POLARx balloon reaches lower nadir temperatures than the Arctic Advance balloon [17]. The POLARx balloon also takes longer to thaw, which may reduce early re-

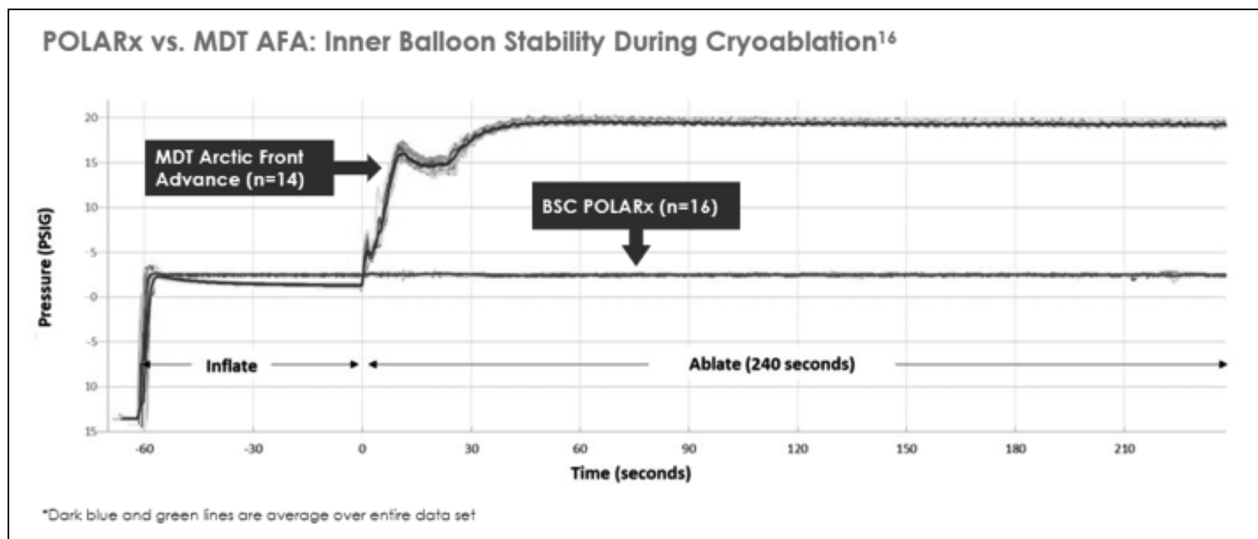


FIGURE 2. A graph of the pressure within both models of cryoballoon (Permission for image obtained from Boston Scientific).

ablation of PVI before concomitant tissues are sufficiently warmed and therefore reduce the incidence of dose-dependent complications such as esophageal injury. As with the dosing changes between the first and second-generation Medtronic balloon, dosing will be an important consideration in the clinical use of the POLARx balloon. The consistent, reproducible freeze path in combination with improved balloon contact should reduce TTI and therefore lower dosing requirements. Clinical data will ultimately be the determining factor driving changes to dosing practice.

Clinical data

Have these changes to the cryoablation system translated to clinical results? The European IDE trial showed 89/120 PV were isolated with a single freeze, allowing for one-third of patients to receive a single freeze per vein. This trial reports 71% freedom from arrhythmia after 1 year [18[■]]. One comparative study comparing Arctic Advance and POLARx demonstrated shorter TTI in the POLARx group (44.8 s vs 39 s) [19]. Another study by Creta *et al.* suggested increased ablation time in the right-sided PV, contradicting the assumption the more maneuverable POLARSHEATH would ease access to these veins [20[■]]. This early clinical data also shows some increased procedural time, LA dwell time, and increased fluoroscopy when using the POLARx system, which could be attributed to operators adapted to the use of new devices.

On other hand, the more compliant POLARx balloon could make it easier for the balloon to be deeply seated, a risk factor for PV stenosis. Of course,

poor balloon positioning could prevent optimal wide antral circumferential ablation. The prolonged dosing may also increase risk for phrenic nerve injury, which may be mitigated by the phrenic nerve safety notifications on the ablation console and DMS. The European IDE trial reported only one incidence of transient phrenic nerve palsy and no other major complications [18[■]]. A review of the few European studies on the POLARx did not demonstrate significant incidents of PNP compared to the Arctic Front Advance [17], despite the addition of the DMS.

CONCLUSION

Improved balloon compliance and prevention of balloon dislodgement theoretically should take the cryoballoon one step closer to a true 'one-shot' device. Data is currently sparse and data may be inconsistent as operators adapt to the changes to technology and ablation technique. We look forward to the results of the US-based FROZEN-AF trial.

The new cryoballoon platform, along with future capabilities such as variable balloon size, will improve ease of the procedure and the adoption of the single-shot device to provide a safer and more effective procedure. Although the changes to the cryoballoon catheter are promising, it is vital to consider appropriate dosing. The excitement in the potential to improve procedural outcomes for long-lasting freedom from AF is hampered by safety concerns. Following FDA approval of this new cryoballoon catheter, dosing studies will be necessary to maximize the safety profile.

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Conflicts of interest

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