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RESEARCH

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Comparison of pulmonary vein isolation between two commercially available cryoballoon systems

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Abstract

Background Pulmonary vein isolation (PVI) using cryoballoon (CB) ablation has comparable efficacy and safety to the gold standard of radiofrequency ablation in the treatment of symptomatic atrial fibrillation (AF). Initial randomized control trials were performed using Arctic Front Advance Pro™ (AFr) (Medtronic, Dublin, Ireland) CB system. Novel CB systems have recently become available, including the POLARx™ (Px) (Boston Scientific, Marlborough, Massachusetts, USA) system. We aimed to compare PVI using the Px and the AFr CB systems in our patient population in terms of efficacy, safety and procedure characteristics in a routine clinical setting.

Methods We performed a retrospective analysis of our internal AF ablation registry, containing 452 consecutive patients (pts) that underwent first procedure cryo-PVI for symptomatic AF. Primary endpoints were AF recurrence after 3 and 12 months, complication rate, procedure duration, fluoroscopy time and fluoroscopy dose. Secondary endpoints were minimal freeze temperature, time to isolation (TTI) and temperature at TTI for each of the pulmonary veins as well as minimal esophageal temperature during the procedure.

Results The primary efficacy endpoints of AF recurrence after 3 and 12 months were similar between the AFr and the Px systems (25.5% vs 21.3%, $p=0.416$ and 22.2% vs 20.6%, $p=0.794$, respectively). Complication rates were similar (3.9% vs 6.8%, $p=0.18$) between groups and consisted mostly of mild vascular complications. The AFr group showed a significantly shorter procedural duration (68 (55–77) vs 73 (60–80) min, $p=0.002$), and lower fluoroscopy dose compared to the Px system. Fluoroscopy times remained similar, however. Minimal freeze temperatures and temperatures at time of isolation were significantly lower in the Px group. However, the time to isolation and minimal procedural esophageal temperature were similar in both groups.

Conclusion PVI using the AFr and the Px systems showed comparable safety and efficacy. Procedural times were longer for the Px system. The Px system showed lower freeze temperature measurements but seemed to have a comparable biological effect.

Background

Initial randomized controlled trials (RCTs) showed comparable efficacy and safety and significantly shorter procedural times for pulmonary vein isolation (PVI) using cryoballoon ablation (CBA) compared to the gold standard of radiofrequency ablation (RFA) in the treatment of symptomatic atrial fibrillation (AF) [1–3].

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A recent metanalysis based on 14 randomized controlled trials (RCTs) and 34 observational studies showed a reduced incidence of AF recurrence for CBA compared with RFA, a difference that was not dependent on study design [4]. Although complication rates were higher in the CBA group, the difference was driven by (mostly transient) phrenic nerve palsy [4]. The rates of pericardial effusion, cardiac tamponade and vascular complications were lower in the CBA group [4]. In conclusion, CBA presents a favorable method for first procedure pulmonary vein isolation, with possible improvements to be made in prevention of phrenic nerve palsy.

Initial RCTs were performed using Arctic Front Advance ™ (Medtronic, Dublin, Ireland) CB system [1]. Meanwhile, the fourth-generation Arctic Front Advance Pro™ (AFr) system is being routinely used, allowing for better real-time capture of PV potentials due to a shorter tip size [5].

Novel CB systems have recently become available, including the POLARx™ (Px) (Boston Scientific, Marlborough, Massachusetts, USA) system [6]. Several observational studies showed comparable efficacy and safety between the AFr and the Px systems [7–11]. Randomized studies are underway [12].

We aimed to compare PVI using the Px and the AFr CB systems in our patient population in terms of efficacy, safety and procedure characteristics in a routine clinical setting. The rationale is providing data specific for our population and setting, as well as data on rare complications like phrenic nerve palsy and cardiac tamponade which can be pooled by future research efforts.

Methods

We performed a retrospective analysis of our internal AF ablation registry, containing 452 consecutive patients that underwent first procedure cryo-PVI for symptomatic AF from October 2020 to February 2024. The new Px CB system was acquired by our center in October 2020. The AFr System has been in routine use for more than 5 years. The comparison of characteristics of the two systems can be found in Table 1. Esophageal temperature measurement and phrenic nerve stimulation for prevention of phrenic nerve palsy were performed in all patients.

Procedural sedation and analgesia were performed using a combination of propofol, fentanyl and midazolam. A steerable decapolar catheter was placed in the coronary sinus by femoral access and was used as a landmark to perform a single trans-septal puncture (TSP). Routine administration of unfractionated heparin was performed immediately after TSP with an initial bolus of 160 IU/kg and with a target activated clotting time of > 300 s.

During ablation of the right pulmonary veins, the decapolar catheter was positioned in the superior vena cava to perform phrenic nerve stimulation. Diaphragmatic action was monitored using modified ECG leads in both systems, and with an additional integrated diaphragm movement sensor using the Px system.

AF recurrence was defined as a documented episode of AF or atrial tachycardia (AT) > 30 s. Patients underwent follow-ups at 3 months and 12 months, either as part of a prescheduled visit or via telephone call to the primary care provider or to the patient. Recurrence during the first 3 months after ablation was excluded at 12 months of follow-up. Most of the patients received at least one Holter ECG over at least 24 h during each follow-up period or AF recurrence was determined using an implanted device interrogation. AF recurrence in the remaining patients was assessed based on symptoms and occasional ECGs.

Primary endpoints were AF recurrence after 3 and 12 months, complication rate, procedure duration, fluoroscopy time and fluoroscopy dose. Secondary endpoints were minimal freeze temperature, time to isolation (TTI) and temperature at TTI for each of the pulmonary veins as well as minimal esophageal temperature during the procedure.

Statistical analysis

Continuous variables are presented as mean ± standard deviation or median and interquartile range as appropriate and categorical variables are summarized as absolute and relative frequencies. The Kolmogorov–Smirnov

Table 1 Balloon characteristics

	Arctic Front Advance Pro™ (4. generation)	**POLARx™**
Balloon	28 mm or 23 mm diameter, 8-mm tip	28 mm diameter, 5-mm tip (short tip) or 12-mm tip (long tip)
Steerable sheath	FlexCath, 15-F, max. 135° deflection	POLARSHEATH, 15.9-F, max. 155° deflection
Detection of phrenic nerve stimulation	Compound motor action potential/palpation	Diaphragmatic Movement sensor and compound motor action potential/palpation
Other	Increase in pressure/size during freeze	Constant pressure/size during freeze

test was used to test normality. Continuous variables were compared using the Student's *t*-test or the Mann–Whitney *U* test. Pearson's chi-square test was used for categorical variables. A two-sided *p* value of <0.05 was considered statistically significant.

The data for the procedural times of the Px system were analyzed to evaluate the learning curve. The dataset was divided into two groups: early procedures and late procedures, with the split point set at the midpoint of the dataset. A *t*-test was performed to compare the mean procedural times between the early and late groups.

Analyses were performed using the SPSS software, version 26.0 (IBM Corporation, Armonk, NY, USA).

Results

Baseline characteristics

We included 452 consecutive patients who underwent CBA from October 2020 to February 2024. Of the initial population ($n=452$, 61% male, mean age 65.0 ± 12.7 years, BMI 27.8 ± 4.5 kg/m^2, LA 38.5 ± 5.9 mm), 51% had paroxysmal AF (Table 2). A total of 306 Patients received CBA with the AFr system versus 146 patients with the Px System. There were significantly more patients with paroxysmal AF in the AFr group (55.9% vs 42.1%, $p=0.006$), and the mean LA diameter was slightly larger in the Px group (37.9 ± 5.7 vs 39.7 ± 6.3, $p=0.005$) (Table 2). At discharge, 26% of patients were on class Ic or III antiarrhythmic drugs and 75% were on beta blockers.

Primary endpoints (Table 3)

Acute PVI of all veins was achieved in all patients. The primary efficacy endpoints of AF recurrence after 3 and 12 months were similar between the AFr and the Px systems (25.5% vs 21.3%, $p=0.416$ and 22.2% vs 20.6%, $p=0.794$, respectively) (Fig. 1) (Table 3). Complication rates were similar (3.9% vs 6.8%, $p=0.18$) between groups and consisted mostly of mild haematoma (0.9% vs 3.5%, $p=0.066$) (Table 3). One patient in the Px group needed vascular surgery for arteriovenous fistula (0.7%). There was one case (0.7%) of suspected right coronary artery air embolism without sequelae in the Px group, as well as one case of stroke (0.3%) and one case of transient ischemic attack (0.3%), both occurring postprocedurally, in the AFr group. Phrenic nerve palsy occurred in 2.4% of patients in the AFr group compared to 2.1% in the Px group ($p=0.799$).

The AFr group showed a significantly shorter procedural duration (68 (55–77) vs 73 (60–80) min, $p=0.002$) and lower fluoroscopy dose (2209 (1298–4600) vs 2997 (1584–6938) mGycm2, $p=0.021$) compared to the Px system. Fluoroscopy times remained similar (10.3 (8.1–14.2) vs 10.6 (8.1–14.7) min, $p=0.851$), however (Table 3). The analysis of the learning curve for the Px system showed no significant difference in procedural duration between the early and the late procedures ($p=0.417$) (Fig. 2).

Table 2 Baseline characteristics

	Baseline population ($n=452$)	Cryoballoon system used		*p* value
		Arctic Front™ ($n=306$)	PolarX™ ($n=146$)	
Age (years), mean ± SD	65.0 ± 12.7	64.5 ± 12.6	66.0 ± 13.0	0.215
Male gender, *n* (%)	276 (61.1)	182 (59.5)	94 (64.4)	0.317
Patients with paroxysmal atrial fibrillation, *n* (%)	232 (51.4)	171 (55.9)	61 (42.1)	**0.006**
Arterial hypertension, *n* (%)	310 (68.6)	210 (68.6)	100 (63.5)	0.614
Chronic heart failure history, *n* (%)	82 (18.1)	53 (17.3)	29 (19.9)	0.512
Coronary heart disease, *n* (%)	107 (23.7)	71 (23.2)	36 (24.7)	0.069
Diabetes, *n* (%)	67 (14.8)	41 (13.4)	26 (17.8)	0.178
History of stroke/TIA, *n* (%)	43 (9.5)	28 (9.2)	15 (10.3)	0.703
Glomerular filtration rate (mL/min), mean ± SD	77.2 ± 64.5	76.6 ± 56.3	78.7 ± 79.3	0.746
BMI (kg/m^2), mean ± SD	27.8 ± 4.5	27.7 ± 4.5	27.9 ± 4.4	0.604
Group Ic and group III antiarrhythmic medication use on discharge, *n* (%)	114 (25.9)	77 (25.7)	37 (26.4)	0.865
Beta blocker use, *n* (%)	337 (74.6)	234 (76.5)	103 (70.5)	0.286
LA diameter, mm, mean ± SD	38.5 ± 5.9	37.9 ± 5.7	39.7 ± 6.3	**0.005**

Bold = p<0.05 (statistically significant)

SD, standard deviation; TIA, transient ischemic attack; BMI, body mass index; LA, left atrium

Table 3 Primary endpoints

	Arctic Front™ (*n* = 306)	PolarX™ (*n* = 146)	*p* value
AF recurrence after 3 months (%)	25.5%	21.3%	0.416
AF recurrence after 12 months (not including the first three months) (%)	22.2%	20.6%	0.794
Complication rate (%)			
Total	3.9%	6.8%	0.18
Mild haematoma	0.9%	3.5%	0.066
Vascular complications needing intervention, surgery or transfusion	0%	0.7%	NA
Air embolism	0%	0.7%	NA
TIA	0.3%	0%	NA
Stroke	0.3%	0%	NA
Phrenic nerve palsy	2.4%	2.1%	0.799
Procedure duration (min, median, interquartile range)	68.0 (55–77)	73 (60–80)	**0.002**
Fluoroscopy time (min, median, interquartile range)	10.3 (8.1–14.2)	10.6 (8.1–14.7)	0.851
Fluoroscopy dose (mGycm2, median, interquartile range)	2209 (1298–4600)	2997 (1584–6938)	**0.021**

Bold = p<0.05 (statistically significant)

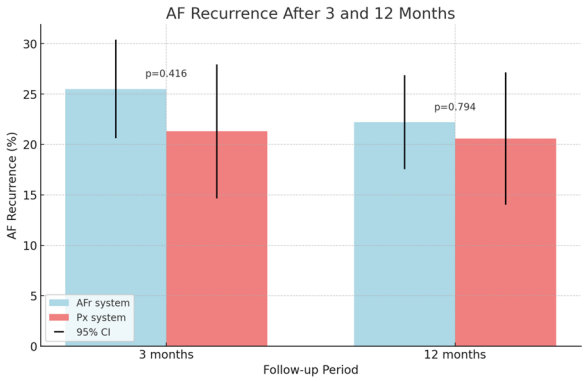

Fig. 1 Primary efficacy endpoints

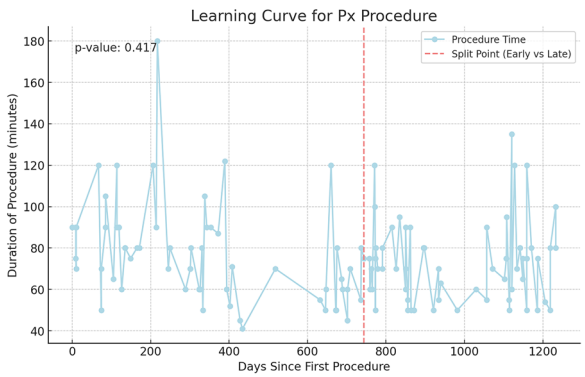

Fig. 2 Learning curve for the Px procedure

Secondary endpoints (Tables 4, 5)

Minimal freeze temperatures (− 52, − 48, − 54 and − 51 °C vs − 56.5, − 53, − 60, and − 57 °C for LSPV, LIPV, RSPV and RIPV, respectively, $p < 0.001$ for all PVs) and temperatures at time of isolation (− 40, − 37, − 39.5 and − 40 vs − 48.5, − 42.5, − 42.5 and − 43 °C for LSPV, LIPV, RSPV and RIPV, respectively, $p < 0.001$ for all PVs) were significantly lower in the Px group (Table 4). However, the time to isolation (49 (37–64), 39 (25–74), 40 (28–66) and 52.5 (36–90) vs 60 (38–74), 56.5 (35–87), 44.5 (25–79), 47.5 (31–100) s, $p = 0.819$, 0.218, 0.424, and 0.062, for LSPV, LIPV, RSPV and RIPV, respectively) and minimal procedural esophageal temperature (26.2 (17.0–29.8) vs 29.8 (14.6–33.7), $p = 0.465$) were similar in both groups.

Discussion

This study aimed to compare efficacy, safety and procedure characteristics of PVI using the Px and the AFr CB systems in our patient population. We found similar efficacy in terms of AF recurrence after 3 and 12 months. The complication rate was comparable between the groups. The numerical difference in complication rate was driven by higher rates of mild hematoma in the Px group, which could be explained by a slight difference in sheath size (15.9 F for Px vs 15 F for AFr).

Rates of phrenic nerve palsy were comparable between the two systems. We observed one case of RCA air embolism without sequelae using the Px system as well as one case of stroke (0.5%) and one case of transient ischemic attack (0.5%), both occurring postprocedurally, in the AFr group—the event rate is too low to reach statistical significance. Larger studies and pooled analyses might elucidate whether there is a difference in rare complications between the two technologies.

Our study is largely comparable to previously published data: past observational studies showed comparable

Table 4 Secondary endpoints—freeze parameters

	Minimal temperature (°C, median, interquartile range)			Temperature at TTI (°C, median, interquartile range)			TTI (s, median, interquartile range)		
	Arctic Front™ (*n* = 306)	PolarX™ (*n* = 146)	*p* value	Arctic Front™ (*n* = 306)	PolarX™ (*n* = 146)	*p* value	Arctic Front (*n* = 306)	PolarX™ (*n* = 146)	*p* value
LSPV	−52 (−55 to −47)	−56.5 (−60 to −55)	**< 0.001**	−40 (−45 to −33)	−48.5 (−50 to −44)	**< 0.001**	49 (37–64)	60 (38–74)	0.819
LIPV	−48 (−52 to −47)	−53 (−56 to −51)	**< 0.001**	−37 (−42 to −27)	−42.5 (−47 to −40)	**< 0.001**	39 (25–74)	56.5 (35–87)	0.218
RSPV	−54 (−57 to −51)	−60 (−64 to −53)	**< 0.001**	−39.5 (−43 to −32)	−42.5 (−50 to −35.0)	**< 0.001**	40(28–66)	44.5 (25–79)	0.424
RIPV	−51 (−54 to −46)	−57 (−65 to −53)	**< 0.001**	−40 (−42 to −35)	−43 (−49 to −34)	**< 0.001**	52.5 (36–90)	47.5 (31–100)	0.062

Bold = p<0.05 (statistically significant)

TTI, time to isolation; LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein

Table 5 Secondary endpoints—minimal esophageal temperature

	Arctic Front™ (*n* = 306)	PolarX™ (*n* = 146)	*p* value
Minimal esophageal temperature (°C, median, interquartile range)	26.2 (17.0–29.8)	29.8 (14.6–33.7)	*p* = 0.465

efficacy between the AFr and the Px systems [7–10]. One small observational study showed a trend toward a higher rate of phrenic nerve palsy in the Px group (15% vs 7%, $p = 0.05$) [11], whereas other studies showed similar safety [7–10]. Larger studies or pooled data analysis will be necessary to determine whether there are differences in very rare complications like TIA, stroke, cardiac tamponade or atrioesophageal fistula.

The Px system showed lower minimal freeze temperatures as well as temperatures at TTI. However, the TTI and minimal esophageal temperature were similar between systems.

Our results are consistent with earlier research—in small observational studies, minimal freeze temperatures and temperatures at time to isolation (TTI) were significantly lower for the Px system, whereas time to isolation (TTI) was similar [7, 8, 11]. This points to a difference in temperature measurement due to differences in the design of the systems, as opposed to a stronger biological effect of the Px system.

The procedural times were longer in the Px group. This is consistent with earlier studies [7, 8] and might be explained by inexperience using the new system or by a difference in handling of the systems. The analysis of the learning curve for the Px system showed no significant difference in procedural duration between the early and the late procedures (Fig. 2). However, the study might be underpowered to find a difference in this highly variable endpoint.

Study limitations

This was a small observational retrospective single center study with associated limitations. Holter ECG or device interrogation data were available for 55.1% patients. In the remaining patients, recurrence was assessed solely on the basis of symptoms and occasional ECGs. This might have led to some asymptomatic AF recurrence events being missed, but should not alter the relative procedural success between both systems.

Conclusion

PVI using the AFr and the Px systems showed comparable safety and efficacy. Procedural times were longer for the Px system. The Px system showed lower freeze temperature measurements but seemed to have a comparable biological effect.

Author contributions

J-H van den B, JW, CS, J-H S, SD and KF were involved in data collection. KF and DS performed data analysis and interpretation and wrote the manuscript. AS and JL contributed to data interpretation. All authors contributed to the writing of the final version of the manuscript, read and approved the final version.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the local ethical committee.

Consent for publication
Not applicable (none required from the local ethical committee).

Competing interests
D. Steven reports receiving grants from Biosense Webster and Abbott as well as lecture fees from Medtronic, Pfizer, Biosense and Abbott. J. Lüker reports having received lecture fees from Boston Scientific, Johnson&Johnson and Abbott. J. Wörmann reports having received lecture fees from Abbott and Boston Scientific and educational fees from Boston Scientific and Johnson&Johnson. Other authors report having no conflicts of interest.

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