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RAPID COMMUNICATION

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Four typical pulmonary venous pressure curves displaying the level of occlusion during atrial fibrillation ablation by cryoballoon

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Abstract

Background: Cryoballoon ablation is safe and effective for pulmonary vein isolation in patients with symptomatic drug-refractory paroxysmal atrial fibrillation. To monitor adhesion between the balloon and the pulmonary vein, an alternative technique to pulmonary venography is to analyze changes in the pressure curve.

Methods: We have described the adhesion level characterized by four types of pressure waveforms.

Results: These correlated with the extent of contrast agent leakage (Cohen's kappa of 0.81 [IC 95%: 0.63–0.99]).

Conclusion: Monitoring the venous pressure curve is easy to perform and has the advantage of being able to detect balloon movement during the first few seconds of treatment.

KEYWORDS

atrial fibrillation, catheter ablation, cryotherapy, pulmonary vein, venography

1 | INTRODUCTION

Cryoballoon ablation for atrial fibrillation is performed under fluoroscopy and involves isolating the pulmonary vein in a single shot by creating circumferential lesions between the balloon and the antral part of the pulmonary vein. Before starting cryotherapy, perfect adhesion between the two must be checked as blood flow over the balloon during ablation would prevent sufficient lesion formation. The conventional technique consists of injecting a few milliliters of contrast media into the pulmonary vein, distal to the balloon.[1] An alternative technique consists in analyzing the changes in the pressure curve obtained in the pulmonary vein, distal to the balloon.[2–5] More specifically than just the previously described loss of the A wave with a simultaneous increase in slope and V amplitude indicating occlusion, four typical profiles of pulmonary venous pressure curves can be observed. We aim at describing them and their meaning in terms of adhesion success between the balloon and the pulmonary vein.

2 | METHODS

We retrieved data from patients referred for a paroxysmal or persistent atrial fibrillation ablation procedure, for which balloon cryoablation was performed and pulmonary venous pressure curves were recorded. Procedures consisted in the placement of

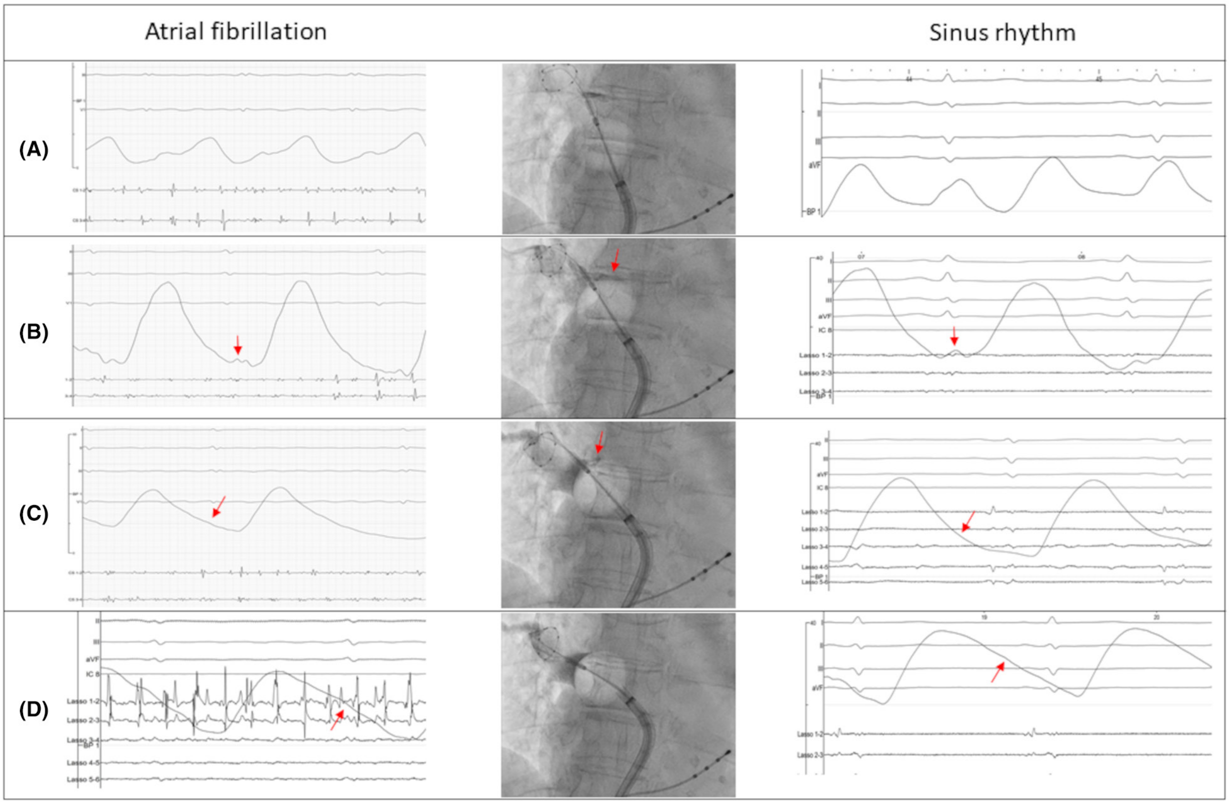

FIGURE 1 Pictures of the four pulmonary venous pressure curves representative of the level of adhesion between the balloon and the pulmonary vein antrum in atrial fibrillation (left pictures) and sinus rhythm (right pictures). (A) Type-1 curve: the sizes of atrial and ventricular waves are similar (no adhesion); (B) type-2 curve: the atrial wave is still visible, which indicates a wrong position of the balloon; (C) type-3 curve: exclusive ventricular wave with pressure drop (inward-curving slope) indicating an imperfect balloon position; (D) type-4 curve: exclusive ventricular wave with a slow decrease in pressure (outward-curving slope) indicating perfect adhesion. The so-called A (atrial) wave is in fact observed in the same way in sinus rhythm as in fibrillation and therefore does not correspond to atrial contraction.

steerable sheath (Flexcath R, Medtronic) in the left atrium through trans-septal access after a right femoral venous puncture. A 28-mm double-coated cryoballoon (Arctic Front, Medtronic) was used. Pulmonary vein potentials were continuously monitored by a mapping catheter (Achieve, Medtronic) deployed through the cryoballoon catheter family guide wire lumen. The cryoballoon was placed at the pulmonary vein antrum by pushing or turning it slightly in order to obtain a type-4 curve. Four distinct pulmonary vein pressure curves displayed different levels of adhesion between the balloon and the pulmonary vein antrum (Figure 1). (a) Type-1 curve was observed when there was no contact and was defined by two ample ventricular and atrial components. (b) Type-2 curve was observed when the contact was incomplete and was characterized by a ventricular wave and a micro-atrial wave. (c) Type-3 curve indicated imperfect adhesion and was defined as a single ventricular wave with a concave downslope. An inward-curving slope indicates a loss of pressure due to a leak at the ostium of the pulmonary vein. (d) Type-4 curve indicated perfect adhesion and the downslope of the ventricular wave was convex. An outwardly curved slope means that there is no loss of pressure during systole, and therefore no leakage. The operator had 3 min to position the balloon and obtain a type-4 curve. Once obtained or if the time was exceeded, contrast was injected to check the adhesion level (no adhesion, leakage, micro-leakage, and adhesion).[5] The operator initiated the cryotherapy ablation and monitored the disconnection either during the application or after the application by pacing maneuver.

3 | RESULTS

All patients were in sinus rhythm except one who had atrial fibrillation (Table 1). The procedures lasted from 71 to 161 min, and the recorded fluoroscopy times ranged from 9 to 39 min with an irradiation dose ranging from 35 to 193 mGy. For the 39 treated pulmonary veins of the 10 included patients, 60 shots for isolation were guided by pressure curves and contrast fluid injections. All the veins were isolated. A type-4 curve was obtained in 48 cases (80%) with an average isolation time of 37.5 s. A type-3 curve was observed in 8 cases (13%), and with pull-down maneuver, the mean isolation time was 51.3 s. A type 2 was observed in 4 cases (7%), one in five applications achieved isolation at 75 s after pull-down maneuver. No type 1 curve was observed. The level of adhesion based on pressure waveform has been correlated with the extent of contrast agent leakage (Figure 2), and the calculated Cohen's kappa was 0.81 [IC 95%: 0.63–0.99].

TABLE 1 Demographics, clinical characteristics, and procedural parameters of the patients.

	Patients ($n = 10$)	
Demographics		
Age, years	58.2	(±12.8)
Female	7	(70%)
Clinical characteristics		
Body mass index, kg/m^2	26.9	(±2.8)
Hypertension	3	(30%)
Diabetes mellitus	2	(20%)
Ischemic heart diseases	1	(10%)
Previous ablation	3	(30%)
$CHADS_2$ score	0.6	(±0.5)
$CHADS_2$-VASc score	1.8	(±1.0)
Creatinine, mg/dL	1	(±0.2)
Fibrillation		
Paroxysmal	9	(90%)
Persistent	1	(10%)
Procedures		
Procedure time	112.8	(±29.3)
Fluoroscopic time, min	19.4	(±8.4)
Fluoroscopy dose, mGy	72.9	(±44.7)
Total treated pulmonary veins	39	–
Total adhesion monitoring data	60	–
Number of applications per vein		
Left superior pulmonary vein	1.3	(±0.7)
Left inferior pulmonary vein	1.6	(±0.7)
Right superior pulmonary vein	1.4	(±0.5)
Right inferior pulmonary vein	1.6	(±0.5)
Available venous potentials	22	–
Time before isolation	39.7	(±19.6)

4 | DISCUSSION

We described a classification of the pulmonary vein pressure curves into four types corresponding to different levels of adhesion between the balloon and the pulmonary vein antrum, which was in good agreement with the contrast agent leakage monitoring. The main contribution of this classification was to describe the aspect of the pressure curve corresponding to minimal leak between the venous antrum and the balloon. As described by Safavi-Naeini et al. the simple disappearance of the A wave on the pressure curve does not allow identification of perfect venous occlusions.[5] The convexity of the descending portion of the curve is the most important factor in confirming the absence of pressure loss in the vein and the absence of leak. Sharma et al. showed a good success rates of acute and long-term ablation after using disappearance of the A wave for occlusion monitoring with no systematic comparison with venography.[3] We may expect a similar or even better procedural success rate with the proposed classification.

The advantages of the venous pressure method are that it does not require contrast injection and it allows continuous monitoring of the occlusion even during the first seconds of cryotherapy. When the application is started, the pressure in the balloon increases and the resulting slight increase in balloon volume may lead to a slight displacement and the appearance of a leak that was not initially noticed. Pressure curve analysis is possible during the first 15–20s of cryotherapy application. Afterward, the curve disappears as the fluid in the lumen of the balloon freezes. Stimulation of the phrenic nerve is generally initiated as soon as the pressure curve is lost during application to the right pulmonary veins.

The main drawback of the technique is the lack of localization of the leak. Nevertheless, in our experience, the location of the leak is

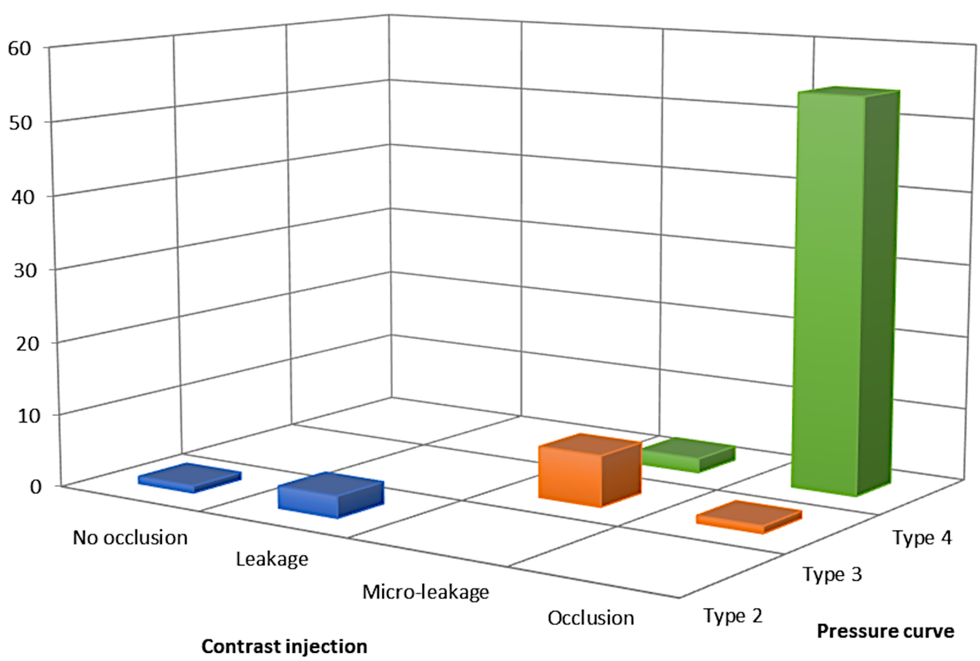

FIGURE 2 Agreement between the results of the conventional contrast injection approach and the pulmonary venous pressure curves.

fairly standardized and correlates with the classic sites of venous reconnection.[6] Occlusion is usually obtained after discreet deflection of the balloon toward the front for the left superior pulmonary vein, or toward the bottom for the other veins.

5 | CONCLUSION

Pulmonary vein pressure is easy to monitor, is in good correlation with venography, and has the advantage that balloon movement can be detected during the first few seconds of atrial fibrillation ablation by cryoballoon.

FUNDING INFORMATION

No funding source.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, AM, upon reasonable request.

ETHICS STATEMENT

The local ethics committee approved the study on January 10, 2019 (N°190110).

INFORMED CONSENT

In accordance with the Data Protection Act (Loi Informatique et Liberté), an information letter was sent to patients with all the necessary information about the study and their rights regarding the use of their data.

REGISTRY AND THE REGISTRATION NO. OF THE STUDY/TRIAL

N/A (study on retrospective data).

ANIMAL STUDIES

N/A.

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