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ORIGINAL ARTICLE

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Perforation of the atretic pulmonary valve using chronic total occlusion (CTO) wire and coronary microcatheter

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Abstract

Background and objective: Chronic total occlusion (CTO) guidewire have been recently reported as an alternative to radiofrequency for perforating atretic pulmonary valve. Since procedure failures or perforation of the right ventricle still occurred with CTO, we tried to enhance the stability, steering, and pushability of the wire using a microcatheter in order to improve the safety and efficacy of the procedure.

Methods: We performed pulmonary valve perforation with CTO guidewire and microcatheter in five consecutive newborns with pulmonary atresia with intact ventricular septum (PA-IVS) under fluoroscopic and echocardiographic control.

Results: The valve was easily perforated at the first attempt for all patients. After perforation, the microcatheter positioned in the main pulmonary artery allowed the exchange of the CTO guidewire for a more flexible wire, avoiding lesion and facilitating manipulation in the distal pulmonary branch arteries. The pulmonary valve was then dilated with balloons of increasing size as usually performed. We did not experience any procedural or early complications. Blalock-Taussig shunt was performed in 2 children because of a persistent cyanosis, 4 and 10 days after perforation.

Conclusions: The combined use of a CTO guide and a microcatheter appears to be a safe and reliable technique for perforating the pulmonary valve of newborns with PA-IVS. Further procedures with this approach are needed to confirm this first experience.

KEYWORDS

catheterization, children, CTO guidewire, microcatheter, pulmonary atresia with intact ventricular septum, pulmonary valve

1 | INTRODUCTION

Radiofrequency is a well-established method for perforating the pulmonary valve in case of pulmonary atresia with intact ventricular septum (PA-IVS).[1-3] However, considering the high cost and the low availability of radiofrequency generator and wires, many perforations of the atretic valve are performed with a mechanical procedure using the stiff end of a coronary guidewire,[4,5] and more recently using chronic total occlusion (CTO) guidewire.[6-8] Yet, the mismatch between the diameter of the 5-French Judkins right (JR 5F) usually used for the procedure and the 0.014 inch CTO wire could diminish stability, steering, and pushability of the wire, resulting in failures[6] or right ventricular outflow tract (RVOT) perforation.[8] Moreover, the stiffness of the CTO wire could impair the manipulation into a distal pulmonary branch artery[6] and expose to distal vessels perforation.

Hence, we developed a new strategy for the perforation and dilatation of an atretic pulmonary valve. We used a coronary microcatheter to increase the stability of the CTO guide wire that could facilitate

the valve perforation, and allow the CTO to be exchanged in the main pulmonary artery with a more flexible wire easily and safely positioned in a distal pulmonary artery branch or in the descending aorta through the ductus arteriosus. We hypothesized this new strategy would prevent failure or complications of the procedures.

2 | METHOD

Between November 2013 and October 2017, all newborns with PA-IVS eligible for valve perforation were included. Criteria for perforation comprised the membranous atresia of the pulmonary valve, a well-developed bipartite or tripartite RV according to the classification of Bull et al.,[9] and the absence of RV-dependent coronary perfusion.

Informed consent was obtained from the parents before catheterization. The study was approved by the local Ethic Committee (approval number 2018 049).

2.1 | Perforation procedure

All procedures were performed under general anesthesia and intratracheal intubation. A 5F sheath was introduced in the right femoral vein, and a femoral arterial access was also obtained before injection of 100 UI/kg heparin.

Right ventricle (RV) angiogram in lateral projection was first performed to exclude RV-dependent circulation of the right coronary artery and to evaluate the RV volume. Then, a second angiogram in lateral projection was performed with the catheter placed in the infundibulum to measure the pulmonary valve annulus size.

The tip of a 5F JR catheter, 2.5-3.5 curve (Cordis, Hialeah, Florida) was then gently placed just below the center of the atretic valve, under fluoroscopic and transthoracic echocardiography (TTE) control (long and short axis of RVOT to check the correct position of the catheter in the center of the valve, Figure 1). Once the position of the JR was optimal, a stiff end 0.014″ CTO guidewire mounted on a 2.6 to 2.9F coronary microcatheter was introduced in the 5F JR, and the pulmonary valve was perforated pushing forward both the microcatheter and the CTO guidewire, the tip of the CTO was placed at the end of the microcatheter. After perforation, the microcatheter was positioned in the main pulmonary trunk, controlled with TTE. The CTO guidewire was then exchanged with a more flexible soft end wire (BMW, Abbott, Chicago, Illinois) easier for manipulation, gently placed in a distal branch of the right or the left pulmonary artery or in the descending aorta through the ductus arteriosus, avoiding perforation of distal vessels with the hard tip of the CTO. The valve was then dilated with balloons (coronary balloons 2-5 mm (Trek, Abbott), and TYSHAK balloons (Numed, Hopkinton, New York) 6 or 8 mm) of increasing size up to 125%-150% of the pulmonary valve annulus diameter. The main steps of the procedure are depicted in Figure 2.

3 | RESULTS

Over 4 years, five patients were included. Clinical and interventional characteristics are listed in Table 1. Median age at perforation was 5 days (3-6) and median weight 3120 g (2610-3735). Procedure time ranged from 94 to 191 minutes (median 148). All procedures were successful and we did not experience any per procedural or early complication. Three CTO wires (Confianza Pro (Abbott), Progress 200T (Abbott), Hornet (Boston Scientific, Natick, Massachusetts)) and three microcatheters (Finecross (Terumo, Shibuya, Japan), Corsair (Asahi Intecc, Tustin, California), Turnpike LP (Teleflex, Limerick, Pennsylvania)) were used consecutively depending on availability, without modification in the success rate of the procedures. However, since the lower profile and the hydrophilic coat of the Turnpike LP microcatheter would facilitate the atretic valve perforation, this microcatheter was preferred for the three last procedures. Three patients (patients 1, 2, and 5) were free of PGE1 8, 10, and 4 days after perforation, respectively. Patient 1 is now 4 years old. He remained free of reintervention. At last TTE, he had no residual pulmonary valve stenosis, but the regurgitation was considerable resulting in a moderate RV dilatation (RV/RV ratio 0.78). The valvular and subvalvular pulmonary stenosis progressively increased in patient 2, without efficacy of a new percutaneous pulmonary valve dilatation 3 months after perforation. A surgical right ventricular outflow tract enlargement with a transvalvular patch was finally performed 5 months after perforation. Patient 5 is now 4 months old. He had no residual pulmonary valve stenosis and a mild pulmonary valve regurgitation at last evaluation. Patients 3 and 4 required a surgical Blalock-Taussig shunt 11 and 4 days after

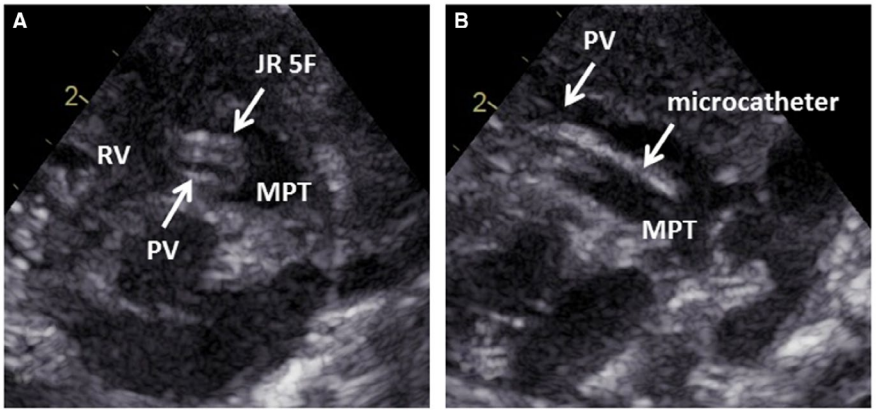

FIGURE 1 Transthoracic echocardiography analysis of the valve perforation. A: The right ventricle (RV) outflow tract long-axis view assesses the position of the 5F Judkins right (JR) catheter in the center of the atretic pulmonary valve (PV) before perforation. B: The valve is perforated and the microcatheter is positioned in the main pulmonary trunk (MPT) before exchanging the CTO wire for a flexible wire

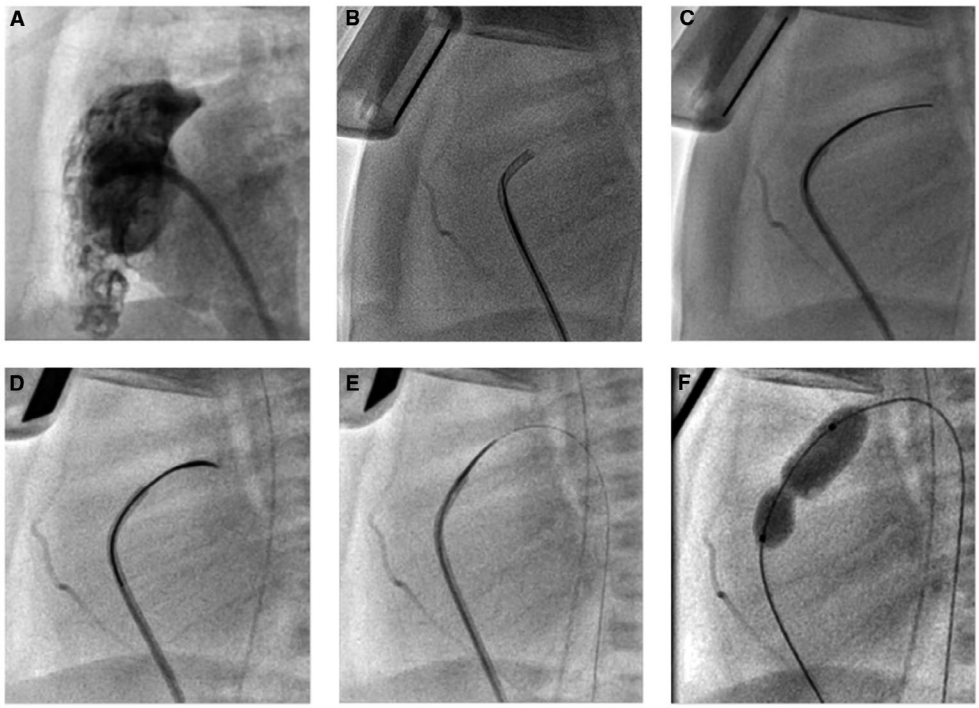

FIGURE 2 Fluoroscopic acquisitions of the main steps of the perforation procedure. A: Right ventricle angiogram in lateral projection assessing RV volume and pulmonary annulus size. B: Correct positioning of a 5F Judkins right (JR) catheter just below the center of the atretic valve under transthoracic echocardiography and fluoroscopic control. C: Perforation of the pulmonary valve pushing both the CTO guidewire and the microcatheter over the JR. D: Positioning of the microcatheter in the main pulmonary artery. E: Exchange of the CTO guidewire for a flexible wire over the microcatheter, which is positioned in the descending aorta through the ductus arteriosus. F: final dilatation of the valve with 8 mm TYSHAK balloon

perforation, respectively, because of duct-dependency. Patient 3 is now 1.5 years old. She did not need further reintervention. At last TTE, she had no residual pulmonary valve stenosis, a mild regurgitation, and a well-developed RV. A percutaneous closure of the BT shunt is planned. The RV of Patient 4 did not grow despite the pulmonary valve perforation, leading to a univentricular repair strategy. Thus, he underwent a partial cavopulmonary shunt at 1 year and is waiting for totalization.

4 | DISCUSSION

Percutaneous valve perforation and dilatation is the treatment of choice for PA-IVS without RV hypoplasia or RV-dependent coronary perfusion. Various techniques have been developed to perforate the pulmonary valve before dilatation, including radio frequency,[10] laser,[11] or using the hard tip of a coronary guidewire.[4] Since a laser is very expensive and requires preventive measures to protect staff, and the results of perforation with the stiff end of a wire are unpredictable, radio frequency is currently the most preferred method for pulmonary valvotomy. However, since the emergence of CTO guidewire in the last decade, various publications have demonstrated the efficacy of this wire to perforate the pulmonary valve instead of the costlier and less available radiofrequency. However, failure of perforation or pericardial effusion secondary to RV perforation still persists.[6,7] These complications may be attributed to the mismatch between diameters of the 0.014″ CTO wire and the 5F catheter usually used for the procedure that could lead to (1) a decrease in pushability of the wire preventing the perforation, and (2) the possibility of a slip of the CTO between the tip of the catheter and the pulmonary valve favoring RV perforation. Moreover, the stiffness of the CTO guidewire impaired its mobilization in pulmonary branch and may promote distal vessel perforation.

Coronary microcatheters have been recently developed to treat coronary chronic total occlusion.[12] Since microcatheters have been reported to increase the stability of the guide wire, to enhance the penetrating power, and to allow guide exchange, microcatheters have seemed useful for the atretic pulmonary valve perforation. In our experience, the creation of a "telescopic" system using a 0.014″ CTO guide wire, within a 2.6 to 2.9F microcatheter, within a 5F catheter increased stability and pushability of the system resulting in a 100% successful rate of the procedures, without any complication. This telescopic system has been recently reported in one case of PA-IVS perforation with success.[13] According to the authors, microcatheter facilitated the central perforation of the pulmonary valve that would preserve valve function with much lower risk of progressive pulmonary regurgitation. In our study, pulmonary valve outcome was assessed for only 3 out of the 5 patients. Two of them had a mild pulmonary regurgitation without RV dilatation, but one displayed a more severe regurgitation with a moderate RV dilatation. None had

TABLE 1 Clinical and interventional characteristics of the five children

	Age at perforation (day)	Weight (gram)	Pulmonary valve annulus (mm)	CTO	Microcatheter	Maximum diameter of balloon (mm)	Days post on PGE1	Days post on ICU
1	5	3735	8	Confianza (Asahi Intecc)	Finecross, 2.6F (Terumo)	10	8	6
2	3	2610	5	Progress 200T (Abbott)	Corsair, 2.6F (Asahi Intecc)	8	10	11
3	3	3700	6	Progress 200T (Abbott)	Turnpike LP, 2.9F (Teleflex medical)	8	Duct-dependency	3
4	5	3120	4	Confianza (Asahi Intecc)	Turnpike LP, 2.9F (Teleflex medical)	6	Duct-dependency	NA
5	6	2880	6	Hornet (Boston scientific)	Turnpike LP, 2.9F (Teleflex medical)	8	4	6

a significant pulmonary valve stenosis. Further evaluation of pulmonary valve outcome will be interesting.

Such a telescopic system using a standard coronary wire, a microcatheter, and a 4F JR coronary catheter was also recently tested[14], but with a major difference since radiofrequency energy using a standard electrosurgical system delivered to the wire was done to perforate the pulmonary valve instead of our CTO guidewire. The authors reported an increased stability of the wire with the microcatheter resulting in a 100% success rate in 5 patients, but the guidewire entered pericardial space twice in one patient. No pericardial effusion occurred as the system was switched to coagulation mode during guidewire retraction. In our point of view, the major safety option to prevent RV perforation remains the transthoracic echocardiography (TTE) assessment during all the critical steps of the perforation. TTE should be performed by a confirmed sonographer, familiar with newborn cardiac ultrasound. Long axis and short axis of the pulmonary valve confirm the correct position of the JR in the center of the atretic valve before pushing the microcatheter and CTO wire. Then, TTE to check that the microcatheter and CTO wire are situated in the main pulmonary trunk before the exchange of the wire. Procedures using a fluoroscopic control only should be avoided because of the increased risk of RV perforation.

In conclusion, perforation of the atretic pulmonary valve in newborns with PA-IVS with a co-axial telescopic system consisting of a 0.014 CTO guidewire inside a microcatheter that passed in a 5F JR coronary catheter appears to be a safe, effective, simple, and in addition an available and low-cost alternative of radiofrequency. Further procedures are needed to confirm this first experience.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

AUTHOR CONTRIBUTIONS

Bruno Lefort wrote the manuscript, performed the catheterizations, and analyzed the data. Christophe Saint-Etienne performed the catheterizations and approved the manuscript.

Iris Ma revised the manuscript.

Nathalie Soulé performed the catheterizations and approved the manuscript.

Fanny Dion revised the manuscript.

Alain Chantepie conceptualized the study, performed the catheterizations, and approved the manuscript.

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