Interventional Cardiology

A focus on the remarkable add-on value of chronic total occlusion guidewires in the armamentarium of atretic pulmonary valve perforation

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Abstract

Continuous advances in the technology of Chronic Total Occlusion (CTO) hardware have led to the development of a wide range of specialty guidewires with increased maneuverability, tip support, torque force, and penetrating power. We and other congenital interventionists described the safe, efficient, and effective use of CTO wires in percutaneous Pulmonary Valve (PV) mechanical perforations. Consecutive reports highlighted the importance of these CTO wires in the armamentarium and discussed their high potential in substituting other methods of endovascular perforation. Herein, we will review the reported experiences with CTO wires and discuss the procedural advantages and technical aspects of these wires in transcatheter treatment of Pulmonary Atresia with Intact Ventricular Septum (PA/IVS).

Keywords: Congenital heart disease • Chronic total occlusion • Coronary wires • Transcatheter interventions • Valve perforation

Abbreviations: CHD: Congenital Heart Disease; CTO: Chronic Total Occlusion; PA/IVS: Pulmonary Atresia with Intact Ventricular Septum; PCI: Percutaneous Coronary Intervention; PV: Pulmonary Valve

Introduction

Multidisciplinary collaboration is essential to promote innovation, optimization of techniques, and development of medical devices for tailored patient care. In particular, close interaction between specialists in the catheter-based treatment of coronary, congenital, structural, and valvular heart disease has been extending the armamentarium over the years and widening the horizon. The examples are numerous and in both directions. Structural heart specialists were inspired by the Melody valve project, conceived by their colleagues, congenital interventionalists, in 2000, to implement the same idea in transcatheter aortic valve implantations [1,2]. Likewise, but in the other direction, congenital interventionalists used coronary stents to maintain the ductal patency in ductal dependent circulations [3]. More recently, there has been an introduction of CTO wires, originally designed for complex Percutaneous Coronary Interventions (PCIs), into the field of congenital heart interventions [4]. The CTO wires have evolved substantially over the past decade and became of paramount help for interventionists working in resource-limited countries to substitute the sophisticated radiofrequency systems. We and others reported successful and complication-low experiences in endovascular perforation, pushing interventionists in well-equipped centers to use these CTO wires as a first choice in their interventions [4-10]. In this mini review, we will go through the reported experiences with CTO wires and detail the technical aspects of these wires for congenital interventionalists dealing with atretic PVs.

Literature Review

General characteristics of CTO wires

A wide range of CTO wires with different tip angles, weights, and penetration forces are available and commonly employed in PCIs. These specialty CTO guidewires differ from other more common coronary guidewires by their heavy tips. They are placed into an exact area that is desired to be perforated and then they are pushed gently with drilling manoeuvers, which is sufficient to have successful results. Various terminologies are utilized when discussing CTO wires: penetrability, pushability, trackability, torquability, steerability, and lubricity [11]. According to these terminologies, the success of the process depends on the type of CTO wire, lateral support of the wire, and the resistance encountered in the lesion. When selecting a CTO wire, the penetration power is mainly taken into account (Table 1). The penetrability depends on the tip load, tapered tip design, wire support (microcatheter and anchoring techniques), and lateral support of the wire. Crossability is better with tapered tips than with straight tips, although the latter give a better tactile feeling feedback. According to the resistance encountered in the tissue, two types of CTO wires are currently available: polymer-coated (hydrophilic) wires and uncoated (hydrophobic) coil wires [11,12]. Hydrophilic wires attract very little resistance when they come in contact with tissue in the lumen. These wires move easily through soft tissue, follow the path of least resistance, and therefore have a potential risk to go extra-luminal. These wires are softer, offer good maneuverability, may find microchannels easier (especially with tapered tips), and are preferred mostly in tortuous clogged lesions. On the other hand, hydrophobic wires offer less maneuverability but provide a better tactile response with good resistance and torquability. These characteristics make hydrophobic wires preferable in hard and fully occluded lesions.

Table 1: CTO wires properties.

Guidewire	Manufacturer	Coating	Cover type or coils	Tip radiopacity (cm)	Tip stiffness (Load) (g)	Tip diameter (in)	Penetration Power (Kg/in²)
Shinobi	Cordis	Hydrophobic	Polymer wrapped	3	6.8	0.014	44
Shinobi Plus	Cordis	Hydrophobic	Polymer wrapped	3	7	0.014	45
MiracleBros 3	Asahi Intecc	Hydrophobic	Silicone coating	11	3	0.014	32
MiracleBros 6	Asahi Intecc	Hydrophobic	Silicone coating	11	6	0.014	72
MiracleBros 12	Asahi Intecc	Hydrophobic	Silicone coating	11	12	0.014	106
Conquest 9	Asahi Intecc	Hydrophobic	Silicone coating	20	9	0.009	135
Conquest Pro 9	Asahi Intecc	Hydrophilic	SLIP COAT coating, excluding the tip	20	9	0.009	146
Conquest Pro 12	Asahi Intecc	Hydrophilic	SLIP COAT coating, excluding the tip	20	12	0.009	195
Conquest Pro 8-20	Asahi Intecc	Hydrophilic	SLIP COAT coating, excluding the tip	17	20	0.008	
PILOT 150	Abbott Vascular	Hydrophilic	Full polymer cover	3	2.5	0.014	
PILOT 200	Abbott Vascular	Hydrophilic	Full polymer cover	3	3.9	0.014	
CROSS-IT 100XT	Abbott Vascular	Hydrophilic	Bare coils	3	1.6	0.0105	20
CROSS-IT 200XT	Abbott Vascular	Hydrophilic	Bare coils	3	4.4	0.0105	54
CROSS-IT 300XT	Abbott Vascular	Hydrophilic	Bare coils	3	7.1	0.0105	72
CROSS-IT 400XT	Abbott Vascular	Hydrophilic	Bare coils	3	10.9	0.0105	101
PROGRESS 40	Abbott Vascular	Hydrophilic	Intermediate polymer cover	3	5	0.012	40
PROGRESS 80	Abbott Vascular	Hydrophilic	Intermediate polymer cover	3	11.5	0.012	80
PROGRESS 120	Abbott Vascular	Hydrophilic	Intermediate polymer cover	3	17.5	0.012	120
PROGRESS 140 T	Abbott Vascular	Hydrophilic	Intermediate polymer cover	3	15.5	0.0105	140
PROGRESS 200 T	Abbott Vascular	Hydrophilic	Intermediate polymer cover	3	13.5	0.009	200

Introduction of CTO wires in transcatheter treatment of PA/IVS

In 1991, Qureshi, et al. and Parsons, et al. first used laser-heated wires to perforate atretic PVs and since then transcatheter interventions became the cornerstone of treatment of selected PA/IVS cases with suitable anatomy for biventricular circulation [13,14]. In the same year, Latson LA performed the first case of PV opening with the stiff-tip of a 0.014" coronary guidewire [15]. In 1993, Rosenthal, et al. reported that laser-assisted PV perforation might significantly lead to deadly heart misperforations [16]. Shortly after, the same team reported on the efficacy and safety of the radiofrequency-assisted PV perforation [17]. With cumulative experience, radiofrequency perforation became the most accepted method for dealing with this anomaly and has been routinely applied in most centers. However, cost and availability constraints of equipment limited its usage in resource-limited countries and motivated the search for different perforation techniques. In recent years, it turned out that stiff-tip wire perforation is risky and technically challenging due to less control on the perforating system [9]. Meanwhile, interventionists have been discussing the novel use of CTO wires as a safe and effective technique [4-10], and sometimes as a better performing alternative to radiofrequency perforation [5,10].

Discussion

Advantages and technical aspects of CTO wires for antegrade perforation in PA/IVS

The use of CTO wire for PV perforation is thought as a good alternative given its peculiar property called "penetration power." According to the literature, the reported procedural success rate with CTO wires were so far 77% [10], 80% [7], 87.5% [4], 89% [6], and 100% [8,9]. To achieve successful perforations, close, stable, and continuous contact of the catheter tip with the plane of the PV is mandatory so that the torque force of the CTO wire is directly transmitted forward to the target zone. Compared to 5-Fr catheters, 4-Fr catheters are softer, less bulky, and much easier to manipulate in neonatal hearts, particularly in patients with PA/IVS who present with tricuspid regurgitation, right ventricular hypertrophy, and/or hypoplasia. However, 5-Fr catheters offer better catheter support and improved wire torquability and have lower odds of pointing the perforation wire in a superior and anterior direction. Therefore, we recommend the use of 5-Fr JR coronary catheters and taking time in centering the catheters in front of the atretic PV thereby achieving the optimal coaxial alignment of catheters before perforation [6,9,18].

In comparison to radiofrequency wires and stiff-tip of classic coronary wires, the floppy tip of CTO wires will not displace the catheters when they are being pushed forward across the atretic PVs. This important advantage has been reported by Alwi, et al. and contributes to the controlled penetrability, augmented precision, and straight-forward pushability of CTO wires that significantly reduced perforation time [4]. After successful valve perforation, it is possible, due to advanced steerability, to guide some CTO wires directly into a descending aorta through the arterial duct and less commonly into a distal branch pulmonary artery without any snare assistance [10]. In our experience, we favored the use of highly penetrating CTO wires, and thereby we did not steer these wires into a distal vessel because the excessive penetration force of CTO wires, although assumed safe, could lead to the dissection or perforation of soft vessels in neonates. Some interventionists proceed by advancing the floppy tip of a classic coronary 0.014" guidewire alongside the CTO wire that is subsequently removed [10]. Other interventionists created a telescopic system with a CTO guidewire, a microcatheter, and a 5-Fr catheter, and reported that microcatheters can stabilize the catheter, increase wire support and perforation power, and finally allow easier wire exchanges [8]. In our experience, we always implemented snare assistance for several reasons [9]. A single-loop or even better a three-loop 4-FR snare catheter, retrogradely routed through the arterial duct and positioned just above the plane of the atretic valve, will first serve as a fixed target for drilling, reducing repetitive hand-contrast controls and the risk of inadvertent misperforations [6,9,18]. The snare will sit in the pulmonary sinus and courses into the posterior inferior plane of the main pulmonary artery and arterial duct preventing any blind perforation attempt. This snare catheter will also allow an immediate catch of the CTO floppy tip within the pulmonary artery lumen, confirming the perforation success, stabilizing the assembly, and assisting the safe advancement of the wire tip into the descending aorta, thereby creating an arteriovenous circuit. This arteriovenous circuit will allow fast and secure delivery of a single valvuloplasty balloon of target diameter into position avoiding unnecessary predilation with smaller coronary balloons [18].

In PA/IVS, the membranous atretic tissues consistency is different from the fibrous cap in coronary CTOs and the thickness might vary from one patient to another. The strategies involved in perforation include drilling, penetrating, and sliding. The drilling process implies a gradual step-up of the wire stiffness and relies on the visual as well as the tactile feedback information from the wire tip. It is very important to be patient and manipulate the CTO guidewires gently because perforation time varied from 1 minute up to 15 minutes in our experience. The comparison of different CTO wires is not reasonable given the limited number of recruited patients in the literature. Patil, et al. highlighted the utility of the tapered tip design that amplifies the capacity of the wire to lock and puncture while being submitted to a rotational movement with the support of a catheter next to the membrane which is going to be perforated [6]. Alwi, et al. successfully used the Conquest Pro CTO wires to perforate the PV in 7/8 cases without any complications [4]. Kamali, et al. reported the use of low-penetration wires and the rate of successful perforations was 77% [10]. Bakhru, et al. reported the use of high-penetration wires after unsuccessful perforation with low-penetration wires. They also concluded that the predictability of CTO wires with low-penetration power is uncertain while hydrophilic wires and those with higher tip load were associated with higher success rates [7]. On the other side, Patil, et al. discussed that hydrophilic wires may not be useful in PA/IVS and have an increased risk of causing misperforation because of less tactile feeling [6]. Their preferred guidewires were straight-tipped MiracleBros 12 or the tapered-tipped Conquest 9, CROSS-IT 400 XT, Conquest Pro 9, and Conquest Pro 12. The straight-tipped Miracle guidewires exhibit better torque, crushing force, and tactile feeling but lesser penetration force when compared to the tapered-tipped Conquest guidewires. In our experience, we achieved one successful perforation using a less powerful but thinner hydrophilic CROSS-IT 200 XT after the failure of the powerful hydrophobic MiracleBros 12 [9]. Wire tips, generally defined as the distal few centimetres, are the most complex assemblies in coronary wires and play the biggest role in determining the performance features discerned by interventionists [19]. For any given value of bending stiffness, reduced tip designs can generate higher penetrating pressure that can be exerted by the tip to penetrate soft tissue within an occlusion. When pushed against membranous pulmonary atresia, this property might improve the ability of the wire to pierce forward in a directed fashion and reduce the potential risk of severe pericardial effusion in the event of unintended misperforation [4]. Wire tip diameter might inherently play an important additional role in the presence of a tiny angiographically unidentified hole.

The risk of misperforations with CTO wires is not inexistent in published series. However, CTO wire misperforation is usually limited to a tiny hole while the radiofrequency wire has the capability of not only misperforating but also slicing the tissues, thus creating a sizable misperforation with rapid progression to tamponade. In our experience and recently reported experiences, the proper use of CTO wires for PV perforation is safe and complication-free [8,9]. The snare assistance technique increases the safety of the procedure. However, caution should always be taken, ensuring that coated stents and a surgery team are kept ready in case of life-threatening complications.

Potential use of CTO wires in congenital heart interventions

Indications of vascular perforations in CHD interventions are not infrequent. Nowadays, the most current indication is PV perforation in neonates with PA/IVS. Less common transcatheter indications include perforation of functionally interrupted aorta, occluded caval veins or caval baffles, and creation of cavopulmonary anastomosis or reverse Potts shunts [20]. To our knowledge, CTO wires have been applied so far in one case of perforation of a functionally interrupted aorta after the failure of radiofrequency wires [21]. CTO wires have been also used for the restoration of caval veins patency and in some challenging septal anatomies during patent foramen ovale closures (unpublished reports).

Conclusion

The introduction of affordable and accessible CTO wires with subsequent technique modifications revolutionized the PV perforation procedure in PA/IVS patients with safe outcomes and like high success rate in comparison to the one reported with radiofrequency or other techniques. Appropriate patient and hardware selection remains the cornerstone of the procedure. The application of CTO wires in the treatment of other stenotic and occluded vascular lesions is expected in congenital heart interventions and should be promoted.

Author Contributions

RH designed the manuscript and took the lead in writing it entirely. Both authors have critically read and approved the final version of the manuscript.

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Conflict of Interest

Z. Saliba is a proctor and consultant for Abbott Vascular and Lifetech. R. Haddad has no conflict of interest to declare.

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