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Microcatheter-assisted stenting of the tortuous vertical ductus arteriosus via femoral access in a duct-dependent pulmonary circulation

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ABSTRACT

Background: Stenting of the patent ductus arteriosus (PDA) has been accepted as alternative option to surgical shunting to enable additional pulmonary blood flow or for palliation of patients with a truly duct-dependent pulmonary circulation. The procedure can be challenging given the variable and often tortuous anatomy of the PDA and various technical approaches are reported.
Objective: To report an alternative technique to treat tortuous ducts with microcatheter assistance and by transfemoral approach.
Methods: We applied this technique of PDA stenting in 5 consecutive patients (4/5 age < 1 week, weight 2,7–3,2 kg; 1/5 re-do PDA stenting at 6,5 month and 5,9 kg). A soft coronary guidewire was advanced by microcatheter assistance into the branch pulmonary arteries and thereafter replaced by an extrastiff guidewire to enable the placement of long coronary stents.
Results: Successful PDA stenting with this stepwise approach and with femoral access only could be achieved in all patients ($n = 5/5$). A single stent was used in 2 patients (one with re-do stenting and previous stents). 3/5 patients had 2 stents implanted by telescopic technique. Stent sizes used were 4,5 × 15 mm ($n = 2$) and 4,5 × 18 mm ($n = 6$). No guide wire or stent dislodgement appeared through all procedures with microcatheter assistance.
Conclusions: This technique enables PDA stenting via transfemoral approach in complex and tortuous ducts and thereby offers an attractive addition to the interventional management of truly duct-dependent pulmonary circulation.

1. Introduction

Stenting of the patent ductus arteriosus (PDA) has been performed as alternative option to surgical shunting for many years. Promising results were shown in neonates as well as older patients who were in need of additional pulmonary blood flow or in patients with a truly duct-dependent pulmonary circulation [1–5]. In a recent multicenter comparison of 106 patients with PDA stenting and 251 patients with a Blalock-Taussig (BT) shunt insertion, there was no difference in the primary end point "death" or "unplanned re-intervention" to treat cyanosis. These encouraging findings are supporting PDA stenting as a reasonable alternative to BT shunt in selected patients [6]. The overall positive reports led to the acceptance of PDA stenting in current guidelines for selected patients and with selected congenital heart defects [7,8].

Variable technical approaches to PDA stenting are reported. However, the procedure can be challenging given the variable anatomy of the PDA [9]. In order to overcome the often tortuous anatomy with multiple windings and a vertical origin of the PDA, various access sites such as carotid access and axillary access from the left or right side are recommended as well as introduction of a delivery catheter or long sheath to enable the final stent placement [5,9–12].

In this paper we describe the results of a microcatheter-assisted technique to facilitate PDA stenting with a tortuous and vertical anatomy in patients with duct-dependent pulmonary blood flow via a simple transfemoral approach.

2. Material and methods

2.1. Patients and management

Medical records of all subsequent patients with a tortuous and vertical ductus arteriosus who required PDA stenting for true ductal dependent pulmonary perfusion in our institution from June 1st 2016 until December 31st 2017 were analyzed. Patients with an otherwise straight ductus arteriosus (left-sided obstructive lesions, Tetralogy of

Abbreviations: ACT, activated clotting time; BT Shunt, Blalock-Taussig shunt; LPA, left pulmonary artery; PDA, patent ductus arteriosus; PTCA, percutaneous transluminal coronary intervention; RPA, right pulmonary artery; VSD, ventricular septal defect.

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Fallot etc.) who received PDA stenting were not included. Parental informed written consent for the catheter investigation and treatment was obtained. Due to the retrospective and descriptive character of this report, additional consent by the ethical committee was waived.

The prostaglandin infusion was reduced to 10 ηg/kg/min before and during the procedure and stopped after the final stent was implanted. Thereafter the patients were anticoagulated with low dose Aspirin. After a 4 F arterial femoral access was achieved, 100 IU heparin/kgbw was administered and no activated clotting time (ACT) measured. All patients were investigated under deep conscious sedation and without general anesthesia as by our institutional protocol [13].

2.2. Catheter technique

After delineation of the anatomy of the ductus arteriosus in an a.p. and strictly lateral view, the origin of the ductus was intubated with either a 4 F IM diagnostic catheter (Cordis, REF No. 538-460, Johnson&Johnson Company, Miami Lakes FL, United States of America) or a modified (edges cut manually according to the anatomy) 4 F pigtail catheter (Terumo Outlook, REF RQ-4SPSO4GM, Terumo Europe N.V., Leuven, Belgium). Thereafter a soft PTCA guide wire (ASAHI SION blue, REF AHW14R004S, ASAHI Intec Co Ltd., Aichi Japan) was advanced to the branch pulmonary arteries supported by a microcatheter wherever necessary (Renegade™ STC 18, REF M001181310, Boston Scientific, Cork, Ireland).

Whenever the soft end of the guide wire could not be advanced easily to the periphery, a stepwise approach by using successive advancement of the microcatheter and the tip of the guidewire was used to reach the branch pulmonary arteries. The end of the microcatheter was thereafter passed to the far periphery of the pulmonary artery. Then the soft guide wire was removed and a stiff guidewire with microglide coating was advanced to the periphery (HI TORQUE IRON MAN, Abbott Vascular, REF 1001309, Diegem, Belgium). Based on the anatomy, the distal 10 cm of this guidewire were manually bended to achieve a soft curve across the arch and the ductus to the pulmonary artery. By this measure the tortuous ducts were straightened (see Fig. 1). Thereafter a premounted drug eluting coronary stent (18 mm × 4.5 mm, Resolute Onyx ™, REF No. RONXY45018X, Medtronic, Galway, Ireland) was deployed within the PDA. Repeat angiography was performed and if necessary a second stent of the same company was inserted at 18, 15 or 12 mm length and 4.5 mm diameter in a telescopic way so that the proximal end of the second stent slightly protruded into the aorta and covered the complete length of the straightened duct (see Fig. 2B). After another angiography the stiff wire was slowly removed and a final angiography was performed to document the result.

3. Results

3.1. Patient details

The patient details and details of the ductal anatomy are described in Table 1. Deep sedation with spontaneous breathing was used in 4 patients, one patient (patient 5) was transferred to our institution and the catheter was performed on the day of admission whilst the patient was intubated due to severe cyanosis. In 1 patient transfemoral PDA stenting was necessary as a second procedure (patient 1). Due to the former size and weight of the patient (1500 g) and to reduce the potential vascular damage, this patient had undergone primary transcarotid stenting at neonatal age.

All stents were implanted without long sheath or delivery catheter but with a short 4 F arterial access sheath only. There was no arterial compromise after the implantation. In 4 patients oxygen saturations stabilized and the patients could be discharged. 1 patient underwent a Glenn procedure 7 months later and 3 patients are awaiting further management with stable oxygen saturation at home. In one patient with severe left and right pulmonary artery stenosis (LPA and RPA) stenosis (patient 5) balloon dilatation of the stenosed LPA and RPA origin was necessary. This patient however showed severe inadequate RPA perfusion at the end of the procedure and went for surgery. A patch plasty of the pulmonary artery bifurcation and surgical shunt insertion was performed.

3.2. Catheter technique

The vertical origin of the PDA can be best expressed by the angles measured in relation to the descending aorta. This measurements revealed a mean angle of 316° in the a.p. projection and a 320° angle in the lateral projection indicating an almost full turn necessary for all catheters and wires to access the PDA from a transfemoral route. In two patients the first guide wire could be advanced without additional support, in the remaining three a microcatheter assisted stepwise placement of the guidewire to the branch pulmonary arteries was used. Replacing the soft by a stiff guidewire was possible in all patients without dislodgement of the microcatheter. Due to the support of the stiff preshaped guidewire, the placement of the long premounted coronary stents was possible without any wire displacement. A single stent was used in 1 patient only and 2 stents were necessary in the remaining 4 patients, implanted by telescopic technique.

The successive implantation steps are illustrated in Fig. 1 (patient 4). The ductal anatomy and procedural details of all other patients are shown in Fig. 2A–D.

4. Discussion

In contrast to left-sided obstructive cardiac lesions, special attention has to be paid to the morphology of the PDA in patients with duct dependent pulmonary circulation. In these cases the PDA often shows a vertical origin and a tortuous course, making transcatheter intervention more difficult. Additionally, stenoses of the main pulmonary branches are an important issue in the interventional management of these patients, increasing the complexity of this procedure.

Failure of ductal stenting has been associated with PA/VSD or univentricular physiology [14]. In order to overcome such a challenging ductal anatomy with multiple windings and a vertical origin of the PDA, carotid access and axillary access from the left or right side are recommended as well as introduction of a delivery catheter or long sheath to enable the final stent placement [3,5,9–12]. Currently available low profile, flexible, premounted stents with scaffolding may prevent complications of ductal stenting such as ductal spasm or the inability to enter the PDA with the stent. Longer stents (i.e. >12 mm), necessary to treat longer ducts, may however cause difficulties to allow manoevering around sharp angles in vertical ducts. These obstacles can be overcome by using guiding catheters [15]. Michel-Behnke et al. used predilation of stenosed areas in 8/21 patients to enable stent placement. They placed the stents via assistance of a long sheath close to the PDA origin [5]. A long sheath to support stent placement was also described as method of choice by Alwi et al. in 69 consecutive patients [1]; a similar approach by using a guiding catheter or long sheath was used by Francis et al. in 15 older pediatric patients [2]. Schranz et al. described a two-wire technique and various access sites to enable crossing tortuous ducts for PDA stenting in 27 patients with truly PDA dependent pulmonary circulation [3]. The authors also describe, that based on the origin and shape of the PDA, vascular access was attempted from the femoral vein, femoral artery, and right or left axillary artery favoring the straightest course towards the ductal take off from the aorta. The stiffer wire was advanced besides the floppy wire thereby enabling a safe advancement of the stiff wire, preventing perforation or creation of a false lumen. Polat described a wire-target technique to gain axillary access and with this approach suggest improved handling of vertical ducts [16].

In our case series we could show, that even in complex ducts with an almost 360° turn off the aortic arch, stenting via a transfemoral access is possible with no complications or wire and stent dislodgement. We were able to advance the initial floppy wire in all patients; in two without microcatheter assistance and in three by using a stepwise microcatheter supported propagation of the floppy guide wire to the branch pulmonary arteries. Successful stent deployment could be achieved in all patients with premounted coronary stents.

Percutaneous carotid access will require general anesthesia and intubation in most centers worldwide but has been shown as a safe alternative for ductal stenting especially in complex anatomy [6,10,17]. In patient 1 we had initially performed PDA stenting using a double-stent Y-technique via a carotid access; intubation was required at this

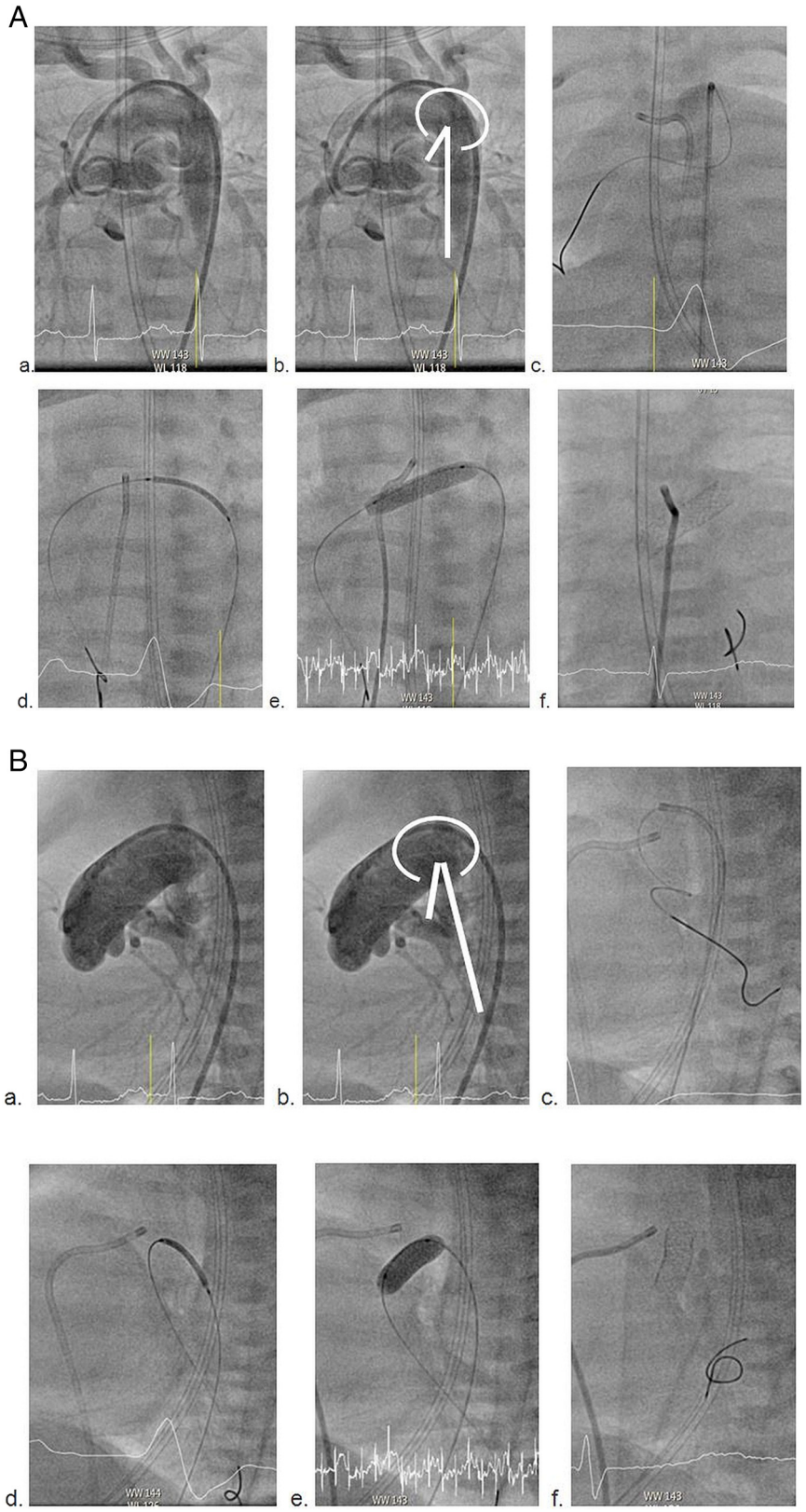

Fig. 1. Angiographic documentation of the stepwise stent implantation in patient 4. A (anterior-posterior), B (lateral): (a) Initial assessment of the anatomy; (b) indicating the angle between descending aorta and ductal route which has to be passed by catheter and guide wire; (c) insertion of the floppy guide wire; (d) after changing to the stiff guide wire straightening the duct; (e) stent inflation; (f) final result.

time due to prematurity and apnea-bradycardia syndrome. The subsequent stent placement was performed in the way presented herein from a transfemoral access and without general anesthesia.

As mentioned by Michel-Behnke et al., the insertion of the stiff implantation wire straightens the PDA, changing the initial ductal course. Its elongation can necessitate the insertion of multiple stents

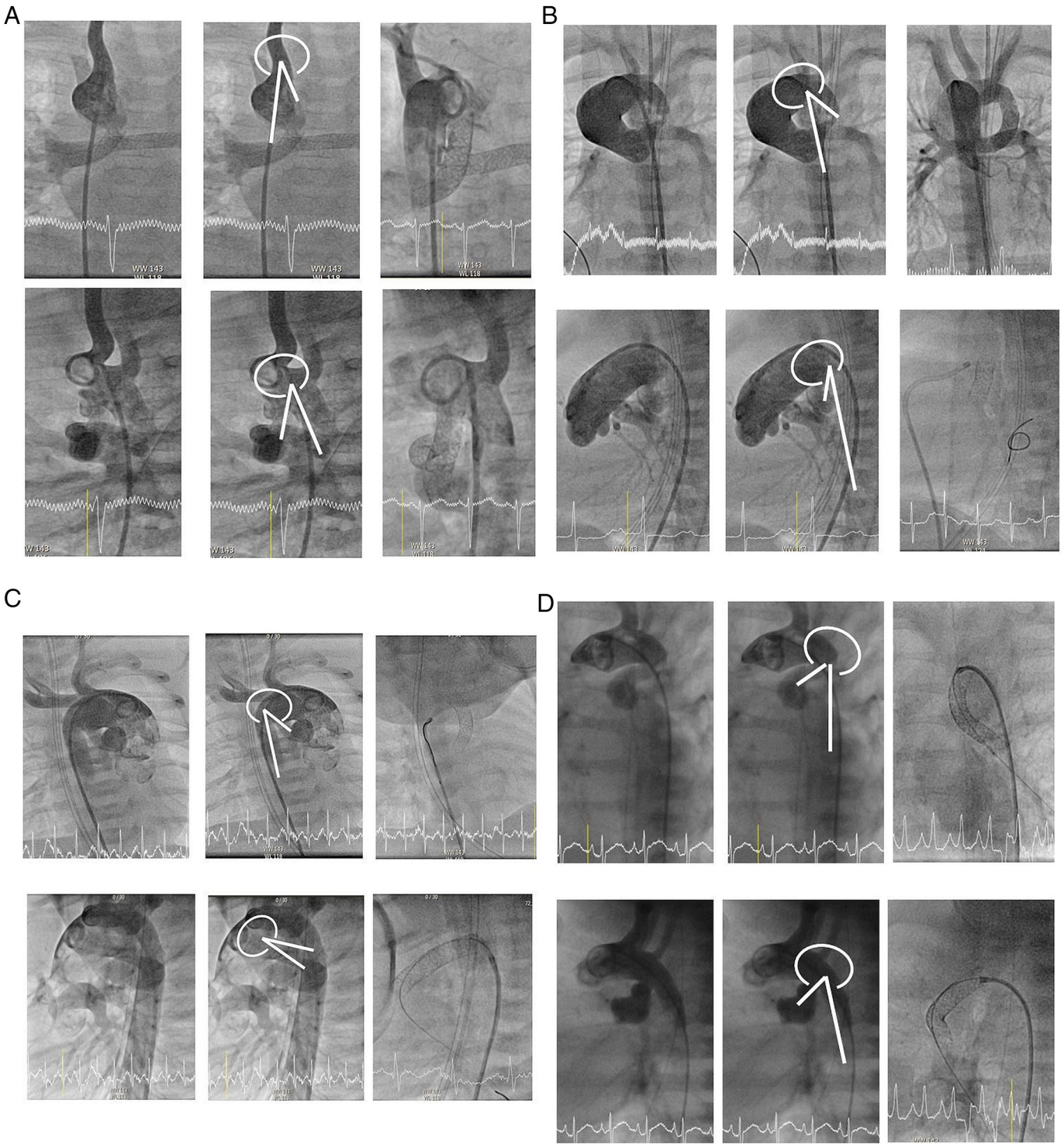

Fig. 2. A–D: Angiographic documentation of the remaining patients 1, 2, 3 and 5. The upper three pictures show (from left to right) the baseline angiography, then the description of the angle of the PDA origin to the descending aorta and then the final result after stent implantation in anterior-posterior projection. The lower three pictures show the same result in a strict lateral projection. A. Patient 1 with previous 2 stents in the LPA and RPA. Re-Do PDA-stenting with one coronary stent. B. Patient 2: Implantation of two coronary stents with predominant flow to the RPA. C. Patient 3: Implantation of two coronary stents. D. Patient 5: Implantation of 2 coronary stents straightening the duct (for detailed patient characteristics see Table 1).

by telescopic technique [5]. This had to be performed in 3 out of 5 patients in this case series and in patient 1 during the primary procedure at neonatal age. By covering the whole ductal length, pulmonary blood flow could be assured in all patients. A protrusion of the aortic end of the ductus stent is known to be uncritical [5].

This case series did not involve a long-term follow-up course and therefore stent performance and long-term durability cannot be addressed. The use of drug eluting stents (zotarolimus in our cases) might have positive implications on restenosis rates [18,19] but has to be evaluated in future studies.

5. Conclusion

In this paper we describe the initial results of our microcatheter assisted technique to facilitate PDA stenting in patients with a tortuous and vertical PDA anatomy and via standard transfemoral approach. This

Table 1
Patient characteristics: PA = pulmonary artery; DORV = Double outlet right ventricle; AVSD = Atrioventricular septal defect; VSD = Ventricular septal defect; TGA = Transposition of the great arteries; DILV = Double inlet left ventricle.

Patient	Diagnosis	Age	Weight	Deep conscious sedation	Aortic arch	Angle descending aorta to ductal course		Stents implanted
		(weeks)	(kg)			a.p.	lateral	
1	PA, DORV, AVSD, Levocardia, Isomerism	26	5,9	yes	right	320	320	4,5 x 15 mm previous 2 stents
2	PA, VSD, d-TGA	1	2,8	yes	right	310	330	4,5 x 18 mm, 4,5 x 15 mm
3	PA, DILV, L-TGA	1	3,2	yes	right	330	340	4,5 x 18 mm, 4,5 x 18
4	PA, VSD, sinusoids	1	2,7	yes	left	320	320	4,5 x 18 mm
5	PA, VSD, sinusoids	1	3,1	no	left	300	300	4,5 x 18 mm, 4,5 x 18 mm

novel technique may offer an attractive addition to the interventional management of truly duct-dependent pulmonary circulation.

5.1. Perspectives

5.1.1. Competency in medical knowledge

Stenting of the PDA has been performed as alternative to BT-Shunt surgery in patients with duct-dependent pulmonary circulation for many years.

5.1.2. Competency in patient care

Overall positive reports led to the acceptance of interventional PDA stenting in current guidelines for selected patients and with selected congenital heart defects. However, this procedure can be challenging given the variable and often tortuous anatomy of the PDA and various technical approaches are reported.

5.1.3. Translational outlook 1

The herein reported microcatheter assisted technique enables stenting of complex and tortuous ducts via transfemoral approach and thereby may be an attractive addition to the interventionist's armamentarium.

5.1.4. Translational outlook 2

This case series did not involve a follow-up course and therefore stent performance and durability cannot be addressed. The use of drug eluting stents (zotarolimus in our cases) might have positive implications on restenosis rates but has to be evaluated in future studies.

Conflict of interest

There is no conflict of interest by any of the authors regarding this report.

Grants

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Authors' statement

All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

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