Received: 4 October 2016 | Revised: 6 June 2017 | Accepted: 19 June 2017

DOI: 10.1111/chd.12512

ORIGINAL ARTICLE

WILEY Congenital Heart Disease

Stenting the vertical ductus arteriosus via axillary artery access using "wire-target" technique

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Abstract

Objectives: To retrospectively review the outcome of stent placement in neonates with a vertical ductus, present a technique of ductal stenting via the axillary artery and compare it to ductal stening via the femoral venous access.

Design: Nineteen patients with duct-dependent pulmonary circulations through a vertical ductus arteriosus were treated with stent implantation. Those patients were retrospectively included in the study. In the first nine of these cases, stent delivery was done transvenously. In the latter ten cases, we favored the axillary artery access to the transvenous approach for stenting the vertical ductus arteriosus. Wire-target technique was used to attain access to axillary artery.

Results: PDA stenting was successful in six out of nine cases in whom the procedure was done anterogradely via the femoral vein and in all cases in whom the procedure was done via axillary artery ($P = .047$). Wire-target technique was used successfully in all ten cases in whom the procedure was done via axillary artery. Fluoroscopy time and total procedure time were significantly shorter in patients in whom the procedure was done via axillary artery ($P < .001$)

Conclusions: Stenting of a vertical ductus arteriosus via the axillary artery using wire-target technique is feasible and safe in selected patients

KEYWORDS
axillary artery access, pulmonary atresia, stenting, vertical ductus arteriosus, wire-target technique

1 | INTRODUCTION

Ductal stenting (DS) has undergone an extraordinary evolution during the last two decades. With recent advances in stent, wire, and balloon technology, satisfactory success rates have been reported by several investigators. However, the morphology of the ductus arteriosus (DA) still predicts the technical difficulty of stenting, the risk of restenosis and necessity for reintervention.[1–7]

In the normal heart with a left-sided aortic arch, the DA connects the left pulmonary artery to the descending aorta just distal to the origin of the left subclavian artery and has a short, straight course. Such DA is also typically observed in patients who develop pulmonary stenosis or atresia late in fetal life and is at the easy end of the therapeutic spectrum.[3,4]

However, the DA in neonates with severe right heart obstructive lesions early in fetal life has a very different anatomy: the DA in these patients is longer, considerably more tortuous in different planes and mostly has a vertical origin from the aortic arch.[5–7]

This type of vertical DA generally is not amenable to stenting via the retrograde femoral artery route as it is very difficult to engage the ampulla, and even more so, securing a stable guidewire position for tracking of the balloon-stent ensemble. Stenting of this type of DA may be achieved by the transvenous route in patients with single-ventricle physiology.

However, this route makes catheter control more difficult and may cause hemodynamic instability in small neonates by keeping the atrioventricular and semilunar valves open.[8,9]

Access via the axillary artery may be the preferred route when a vertical DA is targeted. In this setting, one major disadvantage with the access of the axillary artery is that there are no other anatomical landmarks available for a blind puncture, if the axillary artery is not well palpable. Therefore, when the axillary artery is not palpable, puncturing by

Doppler guidance or an axillary artery cutdown may be the only realistic alternative for a successful intervention. However, both these methods are not the practice of pediatric cardiology and require other disciplines.[6,9,10] In two preliminary studies, percutaneous carotid access seems to be feasible in ductal stenting.[11,12] These initial experiences suggest that percutaneous carotid artery access in early infancy is safe and feasible with preserved vascular patency and no neurological adverse events.

The aim of this *study* was to retrospectively analyze the data of patients with vertical ductuses to determine the outcome of stent placement at our institution, as well as to present a technique that we have used in the catheterization laboratory to perform DS via axillary artery.

2 | MATERIALS AND METHODS

Between April 2013 and June 2016, 49 patients presented with duct-dependent congenital heart disease underwent cardiac catheterization and angiography with the intent of stenting the DA as first-stage palliation at Kemerburgaz University Medical Park Bahcelievler Hospital.

The detailed diagnoses were first established by two dimensional and Doppler echocardiography, categorizing the patients as having either single-ventricle or two ventricle physiology. Prior to DS, the exact DA morphology and its relationship to the aortic arch was also defined by echocardiography.

All procedures were performed under general anesthesia. All patients were discussed beforehand with the cardiothoracic team and surgical standby was routinely available. It was preferable to have a mildly constricted duct where the stent could find adequate grip. Therefore, prostaglandin infusion was stopped 6–12 hours before the procedure. However, in patients with inadequate PDA flow (oxygen saturation $<$70%), intravenous prostaglandin administration was continued, but titrated down to the lowest dose required to maintain ductal patency. All patients received intravenous heparin sodium (50–100 U/Kg) and routine prophylactic antibiotic therapy.

In all cases, primary vascular access was obtained using the femoral artery. Aortic arch angiography, mainly in anteroposterior, lateral, and four-chamber views, was performed to evaluate the ductal size, length, and morphology.

Ductal anatomy was defined as tortuous vertical (arising from the inner curvature of the proximal aortic arch with multiple bends) or tubular vertical (arising from the inner curvature of the proximal aortic arch with straight or slightly curved course). Nineteen patients with tubular or tortuous vertical DAs were retrospectively included in the study.

The protocol for the research project has been approved by a suitably constituted Ethics Committee of our institution within which the work was carried out and that it conforms to the provisions of the Declaration of Helsinki in 1995. Written informed consent was obtained from all parents or other surrogates for publication of this study and any accompanying images.

In the first 9 cases (Group 1), all of them with TOF-PA except two with complete AVSD-PA, stent delivery was done transvenously using 5F right Judkins catheter or cut pigtail catheter (Cordis Corp., Johnson & Johnson, New Brunswick, NJ), which was passed through the VSD and anterogradely into the ascending aorta. Next, a 0.014-inch floppy guidewire (Runthrough, Terumo Corporation, Tokyo, Japan) was passed through the DA and carefully placed in the left or right branch pulmonary arteries. Care was taken not to induce vessel trauma or ductal spasm when trying to advance guidewire into the duct. Then, a coronary stent (REBEL Platinum Chromium Coronary Bare Stent, Boston Scientific, Natick, MA) was delivered *bare* over the wire and implanted into the ductus arteriosus.

In the latter 10 cases (Group 2), we used the axillary artery access to the transvenous approach for stenting the vertical DA. Wire-target technique[13] was used in all 10 cases to attain access to axillary artery. In this technique, initial access was attained in right or left femoral artery via the modified Seldinger technique. We determined ductal anatomy and head-neck arteries by aortic arch-angiogram. Right or left axillary access was decided according to anatomical relationship of duct insertion to head-neck arteries. Left axillary artery was used when ductus arose from the underside of the arch opposite the origin of the left subclavian artery and right axillary artery was used when ductus arose from the underside of the arch opposite the origin of the right subclavian artery. Then, A 5F right Judkins (Cordis Corp., Johnson & Johnson) was used to position a 0.014-inch floppy guidewire (Runthrough) in the left or right axillary artery. After the wire was appropriately positioned in the axillary artery, anterior–posterior and lateral fluoroscopic views are used to align the percutaneous needle with the target wire. The needle was carefully advanced toward the target wire until its tip was observed in both projections to have engaged the target wire. A blood flash was usually seen. Finally, a wire was inserted into the needle, and it tracked the target wire. A 5Fr sheath (Radifocus Introducer II Pediatric Kit) was inserted and gently advanced approximately 3 cm into the axillary artery. Next, DA was engaged for guide wire anchoring with the 5F Judkins right coronary catheter (Medtronic, Inc., Minneapolis, MN, USA). A 0.014-inch floppy guidewire (Runthrough) was passed through the DA and carefully placed in the left or right branch pulmonary arteries. Care was taken not to induce vessel trauma or ductal spasm when trying to advance guidewire into the duct. Then, a coronary stent (REBEL Platinum Chromium Coronary Bare Stent) was delivered *bare* over the wire and implanted into the ductus arteriosus. At the time of DS, repeat descending aortagram with access via the femoral artery was used to evaluate the position of the stent, to exclude stent related pulmonary artery or aortic stenosis, and to reveal if the duct was completely covered (Figure 1).

In most DAs, the stent was implanted so that 2–3 mm of the stent protruded into the main pulmonary artery and the whole length of the DA was covered up to the ductal-aortic junction. The length of the stent chosen was 1 to 2 mm longer than the ductal length between the aortic and pulmonary end, with the guidewire across (as the guide wire tends to straighten a tortuous DA).

The diameter of the stent was chosen depending on the weight of the patient. The stent was inflated to a diameter of between 3 mm and 3.5 mm in patients weighing less than 3 kg and to a diameter of

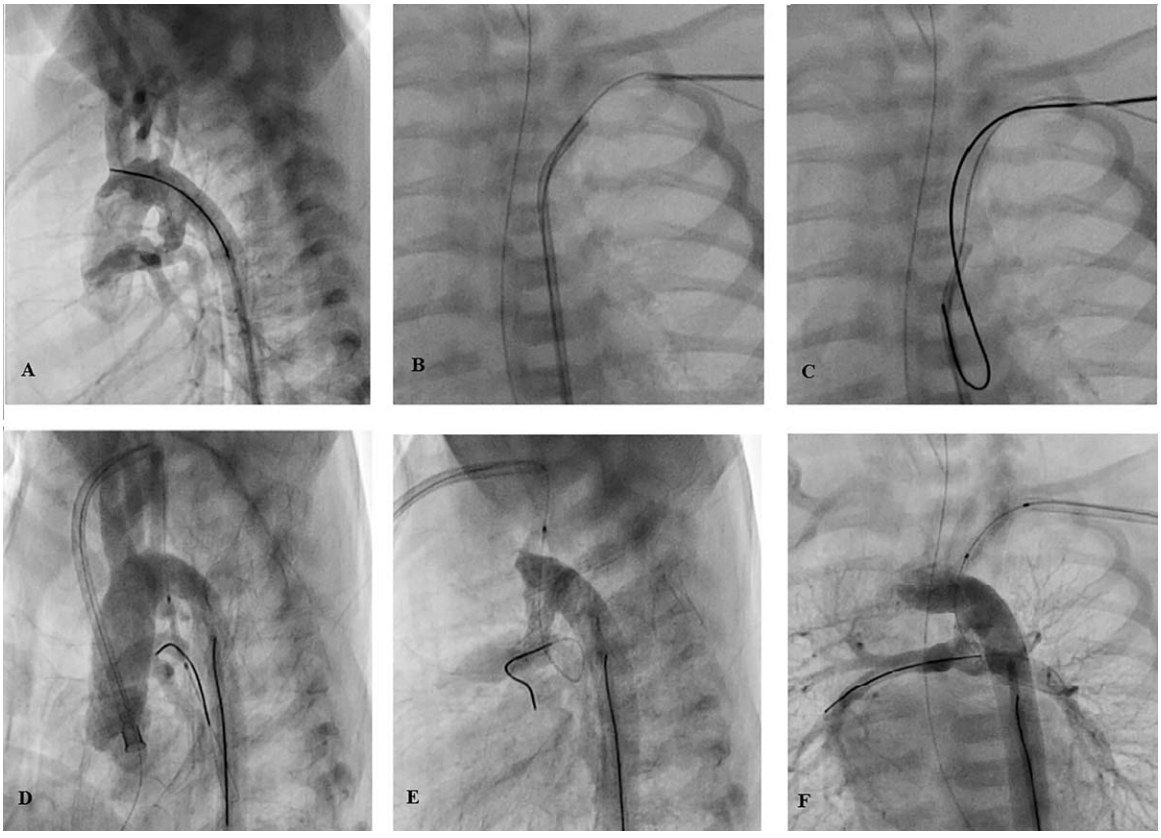

FIGURE 1 Wire-target technique to attain access to axillary artery. (A) Aortic arch angiography was performed to evaluate the ductal morphology in lateral fluoroscopic view. (B) A 5F right Judkins was used to position a 0.014-inch floppy guidewire in the left axillary artery and the needle was carefully advanced toward the 0.014-inch floppy guidewire. (C) A wire was inserted into the needle and tracked the target wire over which a 5F sheath was placed in the axillary artery about 3 cm inch. (D) Ductus arteriosus was engaged for guide wire anchoring with the 5F Judkins right coronary catheter and descending aortagram with access via the femoral artery was performed to evaluate the position of the wire. (E) 4 mm in diameter and 14 mm in length coronary stent was implanted (lateral fluoroscopic view). (F) stent in anterior–posterior fluoroscopic view

between between 4 and 4.5 mm diameter in patients weighing between 3 and 4 kg.

2.1 | Follow-up

All patients underwent Doppler ultrasound scanning to rule out axillary and femoral artery injuries the day after procedure. Anticoagulation, using intravenous heparin (20 units/kg/hour), was changed to acetylsalicylic acid (3–5 mg/kg/day) for as long as stent patency was required. The minimal duration of heparin therapy was 24 hour.

During follow-up, patients were evaluated by clinical examination, electrocardiography, echocardiography, and angiography. Angiography was planned to perform to evaluate stent patency if clinically indicated. Patients' medium term outcome was tracked.

2.2 | Statistical analysis

Continuous variables were summarized as mean (SD) or median (range) as appropriate, depending on normality of distribution. Categorical variables are represented by frequencies and percentages. Pearson chi-square test or Fisher's exact tests were used for comparison of categorical variables. Continuous variables were compared using the Student's *t*-test or Mann-Whitney U test, when appropriate. A P value $< .05$ was considered statistically significant. All statistical analyses were performed using SPSS 13.0 software package for Windows (SPSS, Inc, Chicago, IL).

3 | RESULTS

Stenting of the vertical DA was attempted in 19 patients, all of whom received prostaglandin infusion. The median age at the time of the procedure was 18 days (range 8 days to 2 months) and median weight was 3.2 kg (range 2.5–3.6 kg). All patients were full term infants except one who was preterm and followed for 2 months before procedure.

Clinical and hemodynamic characteristics of patients are shown in Table 1.

Eleven patients had two ventricle physiology (63%), and the great majority of them had TOF with PA (84%) whereas 8 had single-ventricle physiology (37%), and the majority had unbalanced AVSD with PA (71%).

The median DA diameter at its narrowest part was 2.1 mm (range 1.5–2.8 mm) and median ductal length was 16 mm (range 10 to 19 mm). PDA stenting was successful in 16 out of 19 cases. The great

TABLE 1 Clinical characteristics of 19 patients undergoing ductal stenting and comparison between *patients* with stent implantation via the femoral vena (Group 1) and via the axillary artery (Group 2)

	Total (n = 19)	Group 1 (n = 9)	Group 2 (n = 10)	*P*
Age, days	18 (8–60)	17.5 (8–27)	20 (10–60)	.51
Weight, grams	3.2 (2.5–3.6)	3.1 (2.8–3.6)	3.2 (2.5–3.4)	.13
Male, n(%)	9 (47)	4 (44)	5 (50)	.81
Physiology				
Biventricular, n (%)	11 (63)	5 (67)	6 (60)	.84
Single, n (%)	8 (37)	4 (33)	4 (40)	.84
Ductal anatomy				
Tortuous vertical	7 (37)	3 (33)	4 (40)	.76
Tubular vertical	12 (63)	6 (67)	6 (60)	.76
Duct narrowest diameter, mm	2.1 (1.5–2.8)	2 (1.5–2.6)	2.1 (1.6–2.8)	.46
Duct length, mm	16 (10–19)	16 (10–18)	15 (12–19)	.55
Stent length, mm	17 (12–20)	18 (12–20)	16 (14–20)	.81
Stent diameter, mm	4 (3–4.5)	4 (3–4.5)	4 (3–4.5)	.77
Fluoroscopy time, minutes	24 (13–44)	35 (24–44)	15.5 (13–18)	<.001
Procedure time, minutes	68 (44–118)	102 (86–118)	51 (44–68)	<.001
Procedural success rate	16 (84)	6 (66)	10 (100)	.047
Reintervention, n (%)[a]	2 (12.5)	1 (16.6)	1 (10)	.69
Complication rate, n (%)	6 (31)	5 (55)	1 (10)	.033
Oxygen saturation at last follow-up, %	75.6 (63–84)	76.2 (63–84)	75.2 (66–83)	.51
Follow-up, months	14 (2–22)	18 (15–22)	9 (2–15)	.001

Values are expressed as medians with range shown in parentheses.
[a]PDA flow became inadequate (oxygen saturation <70%) in both at three months postprocedure.

majority of stents implanted were of 4.0 mm and 4.5 mm diameter (82%). The median stent length was 17 mm (range 12–20 mm). The median procedure time was 68 min (range 44–118 min) and median fluoroscopy time was 24 min (range 13–44 min).

The procedure was done anterogradely via the femoral vein in nine patients (Group 1) and via axillary artery in remaining ten (Group 2). Patient characteristics, stent data, and clinical outcome of 19 patients are shown in Table 2.

PDA stenting was successful in six out of nine cases in Group 1 and in all cases in Group 2 ($P = .047$). PDA was tortuous in 7 out of 19 cases. Of those 3 were in Group 1 and 4 in Group 2. Stenting failed in all 3 patients in Group 1 with tortuous ductus morphology (Case 3, 7, and 9), but was successful in all 4 patients with tortuous PDAs in Group 2. The median procedure time was 102 min in Group 1 vs 52 min in Group 2 ($P < .001$) and median fluoroscopy time was 35 min in Group 1 vs 15.5 minutes in Group 2 ($P < .001$).

3.1 | Mortality and complications

There was no procedure related mortality. A total of six procedure-related complications, including five in Group 1 and one in Group 2 ($P = .033$), occurred in 19 cases (31%). Transient complete heart block, due presumably to the stiff catheter pressing on the atrioventricular node, occurred in Case 2. Stent migrated distally acutely in Case 6, resulting in the distal margin of the complex of stents protruding into the left LPA without obstructing flow into any of the LPA branches. Stent migrated and protruded into the aorta during balloon withdrawal in Case 8. This patient did not show any signs of hemolysis on urinalysis and obstructing flow in duct during follow-up. Case 3 and 7 *in whom* stenting failed, were also complicated by acidosis and hypothermia due to prolonged procedure times. Finally, Case 15 with stent diameter of 4.5 mm initially required antifailure treatment for two months due to increased pulmonary blood flow.

3.2 | Follow-up

None of the patients lost their femoral or axillary pulses after procedure and Doppler ultrasound scanning remained normal in all cases. The median duration of follow-up was 14 months (range 2 months to 2.2 years). Freedom from reintervention for the 14 patients was 74% during follow-up. The median oxygen saturation at last follow-up was 75.6% (range 72%–85%). Three patients in whom stenting failed were managed by surgical placement of a modified Blalock–Taussig (BT) shunt soon after procedures. Two patients in whom the PDA stenting was successful needed reintervention for inadequate ductal flow (oxygen saturation <70%) at three months postprocedure and received

TABLE 2 Patient characteristics, stent data, and clinical outcome

Case No		Sex	Age, days	Weight, kg	Vascular access for intervention	Ductal anatomy	Duct narrowest diameter, mm	Duct length, mm	Stent length, mm	Stent diameter, mm	Immediate result	FU, months	Reintervention	Outcome
1	PA-VSD	M	16	3.4	Femoral vein	Vertical, tubular	1.7	16	18	4	Adequate flow, no decompensation	22	-	VSD closure, and RV to pulmonary artery conduit at 14 months
2	Unbalanced complete, AVSD-PA, trisomy 21	F	14	2.8	Femoral vein	Vertical, tubular	2.1	12	14	3.5	Adequate flow but transient complete heart block	20	Balloon dilation of stent at three months postproce-dure	mBT shunt soon after reintervention
3	PA-VSD	F	8	3.2	Femoral vein	Vertical, tortuous	1.7	19	-	-	Unsuccessful stenting	18		mBT shunt after 5 days follow-up
4	PA-VSD, right aortic arch	M	12	3.1	Femoral vein	Vertical, tubular	2.2	16	18	4	Adequate flow, no decompensation	18		Adequate ductal flow
5	RV hipoplasia-PA-VSD	F	27	3.4	Femoral vein	Vertical, tubular	2.6	12	14	4.5	Adequate flow no decompensation	16		CPS shunt at 10 months
6	PA-VSD	F	24	3.6	Femoral vein	Vertical, tubular	1.6	16	18	4.5	Adequate flow but stent protruded into the LPA	15		Adequate ductal flow
7	Unbalanced Complete, AVSD-PA, trisomy 21	F	22	3.3	Femoral vein	Vertical, tortuous	1.5	15	-	-	Unsuccessful stenting complicated by acidosis	14		mBT shunt after 2 weeks follow-up,CPS shunt at 9 months
8	PA-VSD	M	23	3.2	Femoral vein	Vertical, tubular	2.3	17	18	4	Adequate flow, but stent protruded into the aorta	12		Adequate ductal flow
9	PA-VSD	F	20	3.2	Femoral vein	Vertical, tortuous	2.1	16	-	-	Unsuccessful stenting complicated by hy-pothermia	12		mBT shunt after 2 weeks follow-up
10	Unbalanced complete, AVSD-PA, trisomy 21	F	11	3.1	Left axillary artery	Vertical, tortuous	1.8	15	16	4	Adequate flow, no decompensation	11		CPS shunt at 7 months
11	PA-VSD	M	16	2.8	Left axillary artery	Vertical, tubular	2.1	15	16	3	Adequate flow, no decompensation	11		Adequate ductal flow
12	Right atrial isomersm-unbalanced AVSD-PA	F	17	2.5	Left axillary artery	Vertical, tortuous	1.9	16	18	3	Adequate flow, no decompensation	10		CPS shunt at 6.5 months
13	PA-VSD, right aortic arch	M	20	3.2	Right axillary artery	Vertical, tortuous	2.6	18	20	4.5	Adequate flow, no decompensation	9	Balloon dilation of stent at three months postproce-dure	mBT shunt soon after reintervention

(Continues)

TABLE 2 (Continued)

Case No		Sex	Age, days	Weight, kg	Vascular access for intervention	Ductal anatomy	Duct narrowest diameter, mm	Duct length, mm	Stent length, mm	Stent diameter, mm	Immediate result	FU, months	Reintervention	Outcome
14	RV hipoplasia-DTGA, severe PS	F	12	3.1	Left axillary artery	Vertical, tubular	2.8	15	16	4	Adequate flow, no decompensation	9		CPS shunt at 6 months
15	Balanced AVSD-PA	M	60	3.4	Left axillary artery	Vertical, tortuous	1.6	15	16	4.5	Adequate flow, mild decompensation	8		Adequate ductal flow
16	Dextrocardia-unbalanced AVSD-PA	F	10	3.1	Right axillary artery	Vertical, tubular	1.9	16	18	4	Adequate flow, no decompensation	7		Adequate ductal flow
17	PA-VSD	M	18	3.4	Left axillary artery	Vertical, tubular	2.3	17	18	4.5	Adequate flow, no decompensation	4		Adequate ductal flow
18	Balanced AVSD-PA	F	19	3	Left axillary artery	Vertical, tubular	2.2	10	12	4	Adequate flow, no decompensation	4		Adequate ductal flow
19	PA-VSD	M	20	3.2	Left axillary artery	Vertical, tubular	1.8	15	16	4	Adequate flow, no decompensation	2		Adequate ductal flow

PA-VSD, pulmonary atresia with ventricular septal defect; AVSD, atrioventricular septal defect, RV, right ventricle; mBT modified Blalock-Taussig; CPS, cavo pulmonary shunt; interventricular septal; FT, fluoroscopy time; PT, procedure time; FU, follow-up.

balloon dilation of stents. One of these patient had received a 3.5 mm stent that was redilated with a 3 mm × 15 mm coronary; the other patient who had received 4.5 mm stent underwent redilatation with a 4.5 mm × 20 mm coronary balloon (non-compliant Trek. NC balloon, Abbott Vascular, Santa Clara, CA, USA). Significant stent reexpansion could be obtained at 16 atm in both patients and oxygen saturation improved to >70% within 3–4 minutes. However, both were diagnosed as early intimal proliferation and cyanosis became more severe soon after reintervention. All were managed by surgical placement of a modified BT shunt three weeks after reintervention. At the last follow-up, two patients completed biventricular repair and eight received bidirectional Glenn's shunt. The remaining 9 patients had two-ventricle physiology and are waiting biventricular repair.

4 | DISCUSSION

Patent ductus arteriosus stenting seems to be a reasonable alternative to a modified BT shunt as it is less invasive and offers the possibility of adapting to clinical needs in the individual patient. Since the first report by Gibbs et al. in 1992, the success and outcome of DS has improved due to advances in technique and equipment. However, DS was still not successful in 7%–20% of the cases. [5,6,8,14]

According to studies, DA morphology was a major determinant for success of DS.

DA located along the inner curvature of the aortic arch were seen more often in patients in whom DS failed. Most of these vertical DAs have a certain degree of tortuosity and may be found in patients with complex congenital heart disease such as single ventricle morphology and PAVSD.[2,4,7,9]

In this study, DS was successful in six out of nine cases with vertical ducts in whom the procedure was done anterogradely via the femoral vein. DS failed in 3 patients with similar ductal morphology. All their ducts had a very tortuous course with multiple sharp, acute angle bends, making it impossible to pass and anchor the guide wire. This study suggests that a vertical and tortuous duct was technically challenging using the femoral approach.

In this context, the site for vascular access and applied techniques seem to be an important issue in patients with a vertical ductus particularly those that are additionally tortuous. *According to some studies*, axillary access on the ipsilateral side just opposite to the duct insertion is the preferred route for stenting vertical ductus arteriosus.[3,8,9] Also for vertical PDA stenting, the angle of approach from the carotid artery is much straighter than a femoral approach and this facilitates wire and stent passage across tortuous anatomy and provides more back up support when needed. There is a paucity of information regarding percutaneous carotid artery access in ductal stenting.[11,12] However, certain precautions must be observed when percutaneous carotid access is being considered and more studies should be powered to address this issue.

The most important advantage of this access is that the axillary artery is not an end-artery and therefore does not have the disadvantage of cannulating such an artery. While using the axillary artery, the

arm continues to be perfused by the second intercostal artery as well as by the acromial artery.[3,15]

The axillary access approach was demonstrated in latter ten cases in this study and was successful in all ($P = .047$). Positioning the wire via axillary approach was simple and more straight as compared to the anterograde approach via femoral vein which involves an additional curve during DS. As a result, we found that stenting the vertical ductus using the axillary approach has shorter fluoroscopy and total procedure time when compared with the femoral approach ($P < .001$).

The axillary artery access for demanding interventions in newborns is rarely described,[8,9,15] despite its many obvious advantages. Experience with axillary artery access is limited in pediatric cardiology practice. Success and complication rates are not well established in observational studies. However, vascular access is an extremely important issue for successful interventional therapy in critical congenital heart diseases, particularly in the newborns. Although the axillary artery is better felt in the smaller patients, including the premature newborns, potential complications of the axillary approach such as an arterial dissection, formation of a hematoma, excessive bleeding may occur as a result of blind arterial access.[9,15]

In the pediatric population, Schwemmer et al. [16] found that the use of ultrasound for arterial cannulation substantially improved the success rate, while Ganesh et al. [17] did not find a benefit. The operators in the latter investigation had minimal experience with ultrasound. Real-time imaging of the needle entering the vessel requires hand eye coordination, where the US probe needs to be kept steady with one hand while the needle is advanced with the other. This is a skill that can only be developed by practice and maintained by continued and frequent use.[18]Additional care needs to be taken for infection control while using ultrasound equipment to aid in procedural guidance. The introduction of an additional piece of equipment adds complexity to keeping these procedures sterile. Sterile probe covers should be readily available with all equipment. An additional person is often required to assist with sterile preparation of the ultrasound probe and machine operation.[19,20]

In this study, "wire-target" technique was successful in the latter ten cases to facilitate axillary arterial access safely and effectively. In patients who have communications at the atrial, ventricular, or great arterial level, wire-target technique has been used to position a wire from a vein or artery across the communications into an artery or vein, or from one vein to another. The wire-target technique affords the operator a reasonably simple method to provide safe and *effective* vascular access, in the process perhaps sparing the patient multiple needle punctures or a surgical cutdown.[11] This technique requires a standard directional catheter, wire and customary catheterization techniques. Accordingly, the operator needs no other methods, devices or new skill sets. With wire-target technique, we did not see any complications related to axillary approach. The procedures were uneventful in all patients.

Two patients in whom the PDA stenting was successful received balloon dilation of stents at early follow-up. However, intimal proliferation kept growing through the stents after reintervention. Both *underwent* palliation with modified Blalock-Taussig shunt due to low oxygen saturation soon after intervention. Duct patency after stenting is limited by in-stent restenosis, which occurs due to neointimal proliferation and/or peal formation. Vessel stenting incites a robust reaction of excessive extracellular matrix production and intimal hyperplasia. In this respect, similarity exists between the mechanisms of ductal closure and in-stent stenosis.[3,8,21,22] This study suggests that redilatation of stents may not be a good option particularly if stent stenosis occurs in the early period of stent implantation.

The major limitations of this study include its retrospective design, single-centre site, small sample size in each group. However, data on DS indication, cardiac diagnosis, technical features, materials, duct morphology and patency were complete in most patients.

5 | CONCLUSIONS

The axillary arterial access is an effective approach to stent the vertical and particularly tortuous arterial duct in newborns with duct-dependent pulmonary circulation. Compared with anterograde approach via the femoral vein, positioning the wire into the vertical duct via the axillary artery is much more feasible. This increases success rates as well as shortens the duration of procedure and reduces complications. The wire-target technique is safe and effective ancillary method that offers the possibility of adapting to establish precise axillary arterial access in the individual patient in pediatric cardiac catheterization laboratory.

ACKNOWLEDGMENT

The authors have no financial relationships or other conflicts of interest relevant to this article to disclose.

CONFLICT OF INTEREST

None.

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How to cite this article: Polat TB. Stenting the vertical ductus arteriosus via axillary artery access using "wire-target" technique. *Congenital Heart Disease*. 2017;12:800–807. https://doi.org/10.1111/chd.12512