Use of percutaneous carotid artery access for performing pediatric cardiac interventions: Single-center study

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ABSTRACT

Background	:	Carotid artery (CA) access allows a more straight route for many left heart lesions. This has previously been achieved via a surgical cut-down approach in certain pediatric cardiac interventions. However, there are little data considering CA access in pediatric cases, percutaneously.
Aim	:	We hypothesized that there would be notable improvements in efficiency as well as overall success when using the CA for access in selected cases.
Methods	:	Between November 2016 and January 2019, records of patients undergoing attempted percutaneous CA access under ultrasound guidance for cardiac catheterization were reviewed.
Results	:	Thirty patients underwent 36 catheterizations; median age 17 days (range, 6 days–9 months) and median weight 3.2 kg (1.2–7.8). Procedures performed were stenting or stent redilatation of the patent ductus arteriosus in 23, stenting or angioplasty of modified Blalock–Taussig shunts in four, aortic valvuloplasty in three, angioplasty for coarctation of the aorta in four, renal angioplasty in one, and diagnostic catheterization in one case. The intended intervention was unsuccessful in two patients despite successful CA access. Follow-up imaging showed a normal carotid in 28 of 30 (94%), with mild luminal narrowing with normal Doppler velocities in two instances. No patient had clinically apparent neurological sequelae attributable to CA access.
Conclusions	:	Our data indicate that CA access should be employed when dealing with a select group of infants requiring vertical approach for left-sided cardiac lesions. Percutaneous CA access, even in very small preterm infants, is safe and feasible with negligible vascular injury and no neurological adverse events.
Keywords	:	Carotid artery, percutaneous, pediatric cardiac intervention

INTRODUCTION

Carotid artery (CA) route achieved via surgical cutdown is rarely preferred for cardiac catheterization by pediatric interventional cardiologists because of concerns for vascular injury or potential risk for cerebrovascular accidents.[1-4]

However, recent studies have shown that percutaneous CA access has a low rate of vascular complications during interventions and excellent rate of carotid patency on follow-up imaging. Moreover, there was no clinical evidence of neurological adverse events in these papers.

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Thus, this data exhibit encouraging safety profile of percutaneous CA access for transcatheter pediatric cardiac interventions.[5-7]

The CA may be a choice in selected cases because of the vertical angle of approach for many left heart lesions including aortic stenosis, aortic arch pathologies, modified Blalock–Taussig (mBT) shunt, and vertical patent ductus arteriosus (PDA). Considering the fact that caliber of the CA is larger in diameter than the femoral artery (FA), CA access can be performed with low risk of vascular complications in small infants.[2,6,8]

In this study, we initially adopted a percutaneous CA access in only small infants in order to reduce the vascular complications and unsuccessful cardiac interventions using femoral or axillary arterial access due to the vertical angle of cardiac lesions. Thereafter, we performed percutaneous CA in most aforementioned interventions that provided the ability to maneuver the catheter directly to left-sided cardiac lesions. We hypothesized that there would be notable improvements in efficiency as well as overall success when using the CA for access in selected cases.

METHODS

Between November 2016 and January 2019, records of patients undergoing attempted percutaneous CA for cardiac catheterization were reviewed. The retrospective review was approved by the Institutional Review Board of Altinbas University School of Medicine.

The primary indication for initial CA approach included infants weighing <2500 g at increased risk for vessel trauma from FA catheterization,[8,9] failed interventions via femoral or axillary arterial route due to vertical angle of cardiac lesions, stenting the vertical PDA, mBT shunt interventions, and vertical PDA stent redilatations.

Procedure

All catheterizations were performed under general anesthesia with endotracheal intubation. Heart rate, respiratory rate, saturations, and blood pressure were monitored during the procedure. Percutaneous access was obtained using a 22G needle (Radifocus® Micro puncture metallic entry needle) under ultrasound guidance (12 L linear array vascular probe, GE Medical Systems, Milwaukee, WI, USA) into the CA in all cases. We attempted to access the CA via a single puncture through the anterior wall of the vessel in the anterior triangle of the neck. The bifurcation of the common CA into the internal and external branches was visualized, and a suitable location sufficiently caudal from the bifurcation was identified (typically approximately halfway between the clavicle and the edge of the mandible). Choice of which carotid was used for access was based on intervention; we elected whichever carotid seemed more

directly aligned with the structure of interest based on previous noninvasive imaging (usually echocardiography) or patient's particular anatomy as demonstrated by angiography using FA. A 0.018″ soft-tipped wire was advanced once blood return was seen in the needle hub or confirmation of needle entry into the lumen was seen on ultrasound. Fluoroscopy was then used to advance the wire into the ascending aorta and a 4 or 5 Fr sheath (Radifocus® Introducer II Pediatric Kit) was inserted and gently advanced approximately 3 cm into the CA.

All patients received intravenous 100 U/kg heparin sodium immediately after sheath placement, with redosing as needed to maintain an activated clotting time (ACT) of >200 s. Protamine was not administered to reverse heparin effect, even in the setting of supratherapeutic ACT. Hemostasis was obtained by manual compression in all cases.

All patients received routine prophylactic antibiotic therapy (cefazolin, 25 mg/kg, intravenously) during the procedure, followed by two more doses post-procedure.

Following the procedure, the infants were transferred back to cardiac intensive care unit for monitoring. An echocardiogram was performed following the procedure in all infants.

Demographic, procedural, and postprocedural variables were assessed with particular emphasis on technical success in obtaining vascular access and postprocedural vessel patency and neurologic complications.

Statistics

All data are expressed as the median (range) and n (%).

RESULTS

Thirty patients underwent 36 catheterizations via percutaneous carotid access (PCA). Thirty-five procedures were interventional, and the remaining one was diagnostic catheterization. Two patients experienced a second and two patients experienced third interventional catheterization at later times via the same vessel. The median age at catheterization was 17 days (range, 6 days–9 months) and weight was 3.2 kg (1.2–7.8) Procedure demographics are shown in Table 1.

Carotid arterial access was eventually achieved in all patients [Table 2]. A total of 34 catheterizations were successfully accomplished via percutaneous CA. Interventional catheterizations were performed in 33 patients, including the most common being stenting PDA or stent redilatation [n = 21 patients, Figure 1], balloon aortic valvuloplasty (n = 3) and stenting or angioplasty of mBT shunts [n = 4, Figure 2], percutaneous transluminal renal angioplasty (n = 1), and balloon angioplasty for coarctation of the aorta (n = 4). Diagnostic catheterization was performed in only one

patient. The intended intervention was unsuccessful in two patients referred for ductal stenting despite successful percutaneous CA (Cases 6.2 and 9).

Initial access was attained via a different vascular access site in nine patients, including eight via FA and one via axillary artery. CA sheath placement procedures were technically successful in all. Time to complete sheath placement was 3.7 ± 1.7 min. The right carotid arteries were chosen in 13/36 catheterizations (36%). Sheath size used was a 4 Fr in 5 and 5 Fr in 31 cases.

Sheaths remained in the CA for a median of 41 min (range, 17–95 min). The median ACT after sheath placement and heparin administration was 243 s (220–440, n = 36).

Table 1: Clinical characteristics of thirty patients undergoing percutaneous carotid artery access for performing pediatric interventional cardiac catheterization

Number of catheterizations	36
Age, days	17 days (6 days-9 months)
Weight, g	3.2 kg (1.2-7.8)
Female/male, n	14/16
Access site, right/left	13/23
Sheath size, 4 Fr/5 Fr	5/31
Access success rate, n (%)	36 (100)
Duration of sheath in carotid artery, min (range)	40 (17-95)
Duration of manual pressure on sheath removal, min (range)	9 (5-22)
Intervention success rate, n (%)	33/35 (94)
Interventions performed via carotid sheath	
Stenting or stent redilatation of the PDA	23
Stenting or angioplasty of BT shunts	4
Balloon aortic valvuloplasty	3
Balloon angioplasty for coarctation of the aorta	4
Percutaneous transluminal renal angioplasty	1
Diagnostic catheterization	1
Postprocedure CA patency	30 (100)
Complications related to CA access n (%)	7 (19)
Complications related to CA access at last FU n (%)	2 (5)
FU, months	13

Values are expressed as medians. PDA: Patent ductus arteriosus, CA: Carotid artery, BT: Blalock-Taussig, FU: Follow-up
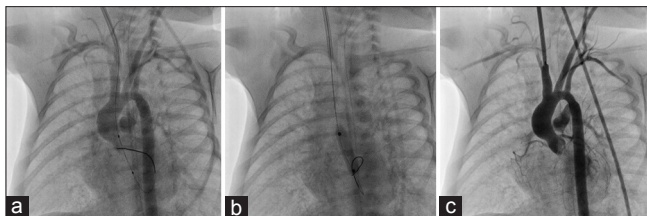

Figure 1: Aortic valvuloplasty in a 6-day-old neonate with a weight of 1300 g, access via the carotid artery (Case 3). (a) Left anterior oblique projection direct visualization of the balloon dilatation catheter by contrast injection via introducer sheath (b) Aortic valvuloplasty (c) Postprocedural mild aortic regurgitation

There were no instances of thrombus formation around the external portion of the sheath and within the catheter sheath after removal.

After the catheterization, sheaths were removed, and hemostasis was achieved by manual compression for a median duration of 9 min (range, 5–22 min).

In all cases, two-dimensional and Doppler ultrasound examination was performed within 24 h of the catheterization. Seven patients having detectable abnormalities: Two had nonocclusive thrombus (Cases 7 and 17), one had mild luminal narrowing caused by a small tissue flap at the arterial puncture site (Case 11.1), one had carotid pseudoaneurysm (Case 14), two patients had mild hematomas at the puncture site without evidence of carotid flow disturbance (Cases 2 and 8), and finally one patient with large hematoma developed at the puncture site causing respiratory distress because of upper airway compromise (Case 12).

These two patients with nonocclusive thrombus were treated with therapeutic doses of subcutaneous low-molecular-weight heparin twice daily. Case 7 with nonocclusive thrombus had restored flow and only mild luminal narrowing with normal Doppler velocities by 2 weeks, and anticoagulation was discontinued. Case 17 had nonocclusive thrombus at 24 h with restoration of flow and mild focal narrowing documented at 7 days and again anticoagulation was discontinued.

Case 11.1 had mild luminal narrowing on the ultrasound performed within 24 h, with a normal carotid by 15 days.
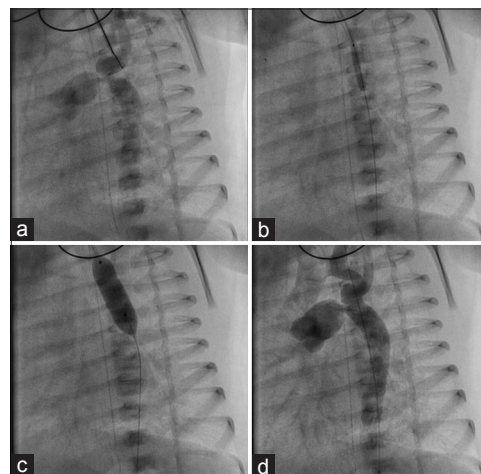

Figure 2: Balloon angioplasty of coarctation of the aorta in a 10-day-old neonate. (a) Lateral view of aortogram, access via the carotid artery. Preductal coarctation clarifies the failed retrograde access despite multiple attempts, retrogradely. (b) Predilatation with a 2 mm × 16 mm coronary balloon was applied to the coarctation segment. (c) 6 mm × 20 mm Thysack II balloon was positioned across the coarctation region and dilated. (d) A final aortogram shows diameter of the coarctation region and patent ductus arteriosus (prostaglandin E1 infusion could be discontinued, and the ductus arteriosus closed 2 days later, but the coarctation did not recur with a systolic gradient of 10 mmHg)

Table 2: Patient characteristics, stent data, and clinical outcome

Case number	Diagnosis	Sex	Age, days	Weight, kg	First access site	CA used	Procedures performed via carotid sheath	Sheath size (Fr)	Duration of sheath in place, min	Duration of manual pressure on sheath removal, min	Immediate result/ complication	FU, months	Reintervention/last echocardiography at FU
1	Critical aortic stenosis	Male	6	1.4	CA	Right	Balloon aortic valvuloplasty	4	32	10	Initial mean gradient of 75 mmHg was reduced to 24 mmHg	27	Mean gradient 38 mmHg at 24 months
2	CoA-left ventricular dysfunction	Male	10	1.3	CA	Left	CoA balloon angioplasty	5	17	11	Initial gradient of 82 mmHg was reduced to 14 mmHg/mild hematoma	27	Recoarctation occurred at 5 months of age, surgically corrected, absence of a gradient at 24 months of age
3	Critical aortic stenosis, BAV	Male	6	1.3	CA	Right	Balloon aortic valvuloplasty	4	35	8	Initial mean gradient of 60 mmHg was reduced to 22 mmHg	25	Mean gradient 34 mmHg at 24 months of age
4.1	PA-VSD	Female	16	3.4	FA	Left	PDA stent	5	58	8	Adequate flow/no decompensation	25	Reintervention at 3 months of age
4.2	PA-VSD-PDA stent stenosis	Female	92	6.2	CA	Left	PDA stent redilatation	5	30	5	Inadequate flow/ modified BT shunt	22	Right mBT shunt stenosis at 6 months of age
4.3	PA-VSD-mBT stent stenosis	Female	272	7.8	FA	Left	mBT shunt angioplasty and stent	5	17	5	Adequate flow, no decompensation	22	VSD closure and RV to pulmonary artery conduit at 15 months of age
5	PA-VSD	Female	14	2.9	FA	Left	PDA stent	5	56	10	Adequate flow/stent protruded into the aorta	22	VSD closure and RV to pulmonary artery conduit at 16 months of age
6.1	PA-VSD-right aortic arch	Male	12	3.2	Left AX	Right	PDA stent	5	45	12	Adequate flow/no decompensation	21	Reintervention at 2 months of age
6.2	PA-VSD-PDA stent stenosis, -Right aortic arch	Male	65	4.8	CA	Right	Unsuccessful ductal Stent redilatation	5	95	16	Inadequate flow/ modified BT shunt	19	Right mBT shunt stenosis at 8 months of age
6.3	PA-VSD-mBT shunt stenosis, right aortic arch	Male	242	7.6	FA	Right	mBT shunt angioplasty and stenting	5	33	11	Adequate flow/no decompensation	18	VSD closure and RV to pulmonary artery conduit at 19 months of age
7	RV hipoplasia -PA-VSD-MAPCA	Female	27	3.4	FA	Right	MAPCA stent	5	40	14	Adequate flow/ nonocclusive thrombus	18	CPS shunt at 10 months of age, Fontan completion at 24 months of age/mild luminal narrowing
8	CoA-left ventricular dysfunction	Male	10	2.8	FA	Left	CoA balloon angioplasty	5	26	10	Initial gradient of 40 mmHg was reduced to 16 mmHg/mild hematoma	16	Recoarctation occurred at 5 months of age, surgically corrected, absence of a gradient at 24 months of age

Contd...

Table 2: Contd...

Case number	Diagnosis	Sex	Age, days	Weight, kg	First access site	CA used	Procedures performed via carotid sheath	Sheath size (Fr)	Duration of sheath in place, min	Duration of manual pressure on sheath removal, min	Immediate result/ complication	FU, months	Reintervention/last echocardiography at FU
9	Unbalanced complete, AVSD-PA-trisomy 21	Female	10	3.2	CA	Left	PDA stent	5	85	16	Stent migration/ inadequate flow/no decompensation	-	Right mBT shunt following intervention/ died postoperative day 2
10	PA-VSD-right mBT shunt stenosis	Male	120	7	FA	Right	mBT shunt stenting	5	56	12	Adequate flow/no decompensation	15	VSD closure and RV to pulmonary artery conduit at 13 months of age
11.1	PA-VSD	Female	20	2.8	AX	Left	PDA stent	5	44	8	Adequate flow/mild luminal narrowing	14	Reintervention at 6 months
11.2	PA-VSD PDA stent stenosis	Female	195	6.8	CA	Left	PDA stent redilatation	5	28	6	Adequate flow, no decompensation	8	VSD closure and RV to pulmonary artery conduit at 13 months of age
12	Interrupted aortic arch-right aortic arch-restrictive PDA?	Male	25	3.4	FA	Right	Diagnostic	5	56	22	Aortoaortic-dependent distal systemic circulation/large hematoma	14	Surgical correction with placement of an interpositional graft at 1 month of age
13	Right atrial isomersm -unbalanced AVSD-PA	Female	15	2.9	CA	Left	PDA stent	5	40	12	Adequate flow/no decompensation	14	CPS shunt at 7 months of age
14	Tricuspid atresia-severe PS-PDA	Male	13	3.2	FA	Left	PDA stent	5	55	10	Adequate flow/carotid pseudoaneurysm	14	CPS shunt at 9 months of age
15.1	PA-VSD	Female	14	2.8	CA	Left	PDA stent	5	42	12	Adequate flow/no decompensation	13	Reintervention at 5 months (case 22)
15.2	PA-VSD PDA stent	Female	168	6.6	CA	Left	PDA stent redilatation	5	45	6	Adequate flow, mild decompensation	8	VSD closure, and RV to pulmonary artery conduit at 14 months of age
16	CoA-left ventricular dysfunction	Male	17	1.3	CA	Left	Balloon angioplasty	4	19	12	Initial gradient of 46 mmHg was reduced to 14 mmHg	13	Recoarctation at 3 months operated, absence of a gradient at 9 months of age
17	PA-VSD	Female	18	3.4	CA	Left	PDA stent	5	42	12	Adequate flow/ nonocclusive thrombus	12	Adequate ductal flow, scheduled for complete repair/mild luminal narrowing
18	Left renal artery stenosis	Male	95	5.1	FA	Left	Percutaneous transluminal angioplasty	5	32	8	Stenotic segment decreased from 80% to 30%	12	Systemic blood pressure remained within the normal range at 12 months of age
19	PA-VSD PDA	Female	20	2.8	CA	Left	Angioplasty and restent	5	44	8	Adequate flow/no decompensation	12	VSD closure and RV to pulmonary artery conduit at 13 months of age

Table 2: Contd...

Case number	Diagnosis	Sex	Age, days	Weight, kg	First access site	CA used	Procedures performed via carotid sheath	Sheath size (Fr)	Duration of sheath in place, min	Duration of manual pressure on sheath removal, min	Immediate result/ complication	FU, months	Reintervention/last echocardiography at FU
20	PA-VSD mBT shunt stenosis	Male	90	5.4	FA	Right	mBT shunt angioplasty and stent	5	40	8	Adequate flow/no decompensation	12	Adequate ductal flow, scheduled for complete repair
21	PA-VSD	Female	18	3.4	CA	Left	PDA stent	5	42	12	Adequate flow/no decompensation	11	Adequate ductal flow, scheduled for complete repair
22	Critical aortic stenosis, BAV	Male	14	1.1	CA	Right	Balloon aortic valvuloplasty	4	22	8	Initial mean gradient of 78 mmHg was reduced to 20 mmHg	11	Mean gradient 28 mmHg at 9 months of age
23	PA-VSD	Female	22	2.8	CA	Left	PDA stent	5	52	12	Adequate flow/no decompensation	11	Adequate ductal flow, scheduled for complete repair
24	Dextrocardia -unbalanced AVSD-PA	Female	10	3.1	CA	Right	PDA stent	5	42	10	Adequate flow/mild decompensation	8	Adequate ductal flow, scheduled for CPS shunt
25	PA-VSD ductal stent via AX artery access	Female	12	3.1	CA	Left	Angioplasty and restent	5	48	8	Adequate flow/no decompensation	8	Adequate ductal flow, scheduled for complete repair
26	PA-VSD ductal stent via AX artery access	Male	15	2.9	CA	Left	Angioplasty and restent	5	36	8	Adequate flow/no decompensation	8	Adequate ductal flow, scheduled for complete repair
27	Tricuspid atresia, restrictive VSD-PDA	Male	14	3.2	CA	Right	PDA stent	5	24	7	Adequate flow/no decompensation	6	Adequate ductal flow, scheduled for CPS shunt
28	CoA-left ventricular dysfunction	Male	10	1.4	CA	Left	Balloon angioplasty	4	38	14	Initial gradient of 42 mmHg was reduced to 12 mmHg	5	CoA pressure gradient 24 mmHg at 2 months of age
29	Unbalanced AVSD-PA	Male	22	2.8	CA	Right	PDA stent	5	42	8	Adequate flow/no decompensation	3	Adequate ductal flow, scheduled for CPS shunt
30	PA-VSD	Female	11	3.1	CA	Left	PDA stent	5	38	10	Adequate flow/no decompensation	1	Adequate ductal flow, scheduled for complete repair

CA: Carotid artery, PA-VSD: Pulmonary atresia with ventricular septal defect, AVSD: Atrioventricular septal defect, RV: Right ventricle, mBT: Modified Bialock-Taussig, CPS: cavopulmonary shunt please erase interventricular septal, CoA: Coarctation of aorta, BAV: Bicuspid aortic valve, FT: Fluoroscopy time, FU: Follow-up, PT: Procedure time, PDA: Patent ductus arteriosus, MAPCA: Major aortopulmonary CA, PS: Pulmonary stenosis, FA: femoral artery, AX: Axillary artery

Two patients (Cases 2 and 8) had hematomas at the puncture site without evidence of carotid flow disturbance that resolved without incident; both patients underwent balloon angioplasty for coarctation of the aorta through a 5F sheath. Both had normal CA ultrasounds at 2 weeks follow-up.

Remaining two cases (Cases 12 and 14) required surgical intervention because of a vascular access complication: Case 14 with CA pseudoaneurysm was successfully treated by ligation and Doppler ultrasound scanning showed normal flow pattern during follow-up. Case 12 had the longest time to achieve hemostasis after diagnostic catheterization of the interrupted aortic arch and collateral arteries that arising from the ascending aorta and supply blood to the descending aorta. Pressure was maintained on the carotid puncture site for 22 min, followed by use of a pressure dressing for 3 h. However, a large hematoma developed at the site. In the course of the diagnostic workup, the hematoma enlarged, thereby causing respiratory distress because of upper airway compromise. The endotracheal intubation was lifesaving. Later, contrast-enhanced computed tomography revealed hematoma in the region of the right common CA. Emergency surgery evacuated the hematoma and repaired a pinpoint defect of the left common carotid 1 cm before bifurcation. Blood loss was minimal, and surgical control of bleeding was not required in all remaining cases.

All patients were evaluated by Doppler ultrasound scanning that encompassed the CA up to last available follow-up, ranging from 1 to 27 months after percutaneous CA (median 13 months). Carotid follow-up imaging showed a normal carotid in 28 of 30 (94%), with mild luminal narrowing with normal Doppler velocities in two instances (patients 7 and 17, described above). No patient had clinically apparent neurological sequelae attributable to PCA at any time.

DISCUSSION

It is recognized that access via the CA provides a more direct route for many pediatric left heart interventions. There have been few articles published on the safety of percutaneous puncture of the CA without surgical cutdown.[6,7,10] Vida *et al.* reported forty infants <3 months of age, who underwent primary percutaneous balloon dilatation with a transcarotid approach by direct puncture of the right CA for severe aortic valve stenosis. No complications were related to the transcarotid approach, and a right CA Doppler at discharge was normal in all patients.[5] Recently, Justino and Petit reported 42 patients underwent 47 catheterizations during which ultrasound-guided percutaneous CA access was attempted, with five patients undergoing a second percutaneous catheterization at a later time via the same

vessel. At follow-up, 40 of 42 patients (95%) had a normal CA, with two instances of mild stenosis. There were no neurological sequelae attributable to percutaneous CA.[6]

In our series, we performed preliminary percutaneous CA cautiously, at first only in small neonates who have the highest risk of femoral arterial injury (Cases 1, 2, and 3). Given that the neonatal CA is larger in diameter than the FA, CA access may play an important role in preventing the complications of FA thrombosis when applied to this higher risk infant population. After this initial encouraging experience, we began to use percutaneous CA after failure of the FA or axillary arterial approach in older children. Finally, we performed percutaneous CA in all interventions that provided the ability to maneuver the catheter directly to left heart structures with potentially less technical difficulty.

In this context, balloon aortic valvuloplasty was performed in three cases via right CA (Cases 1, 3, and 22). All these three cases were preterm infants weighted <1500 g. Furthermore, the potential benefit of the carotid approach is the ability to maneuver the catheter directly to the left ventricle. Particularly in very small preterm infants, because of close proximity and relatively straight course of the sheath while performing balloon aortic valvuloplasty, direct visualization of the aortic valve by contrast injection via introducer sheath and over the wire ballooning may be achieved possibly shortening cardiac catheterization time and reducing catheter-based complications [Case 22, Figure 1].

Similarly, we opted for the left CA access in three neonates with severe aortic coarctation. All four cases were hemodynamically frail at the time of the coarctation intervention. The interventions were performed within 5 min in three very low birth preterm after direct visualization of lesion via sheath placed in the left CA (Cases 2, 16, and 28). In the remaining cases, severe coarctation lesson could not be accessed retrogradely due to preductal location (Case 8). In this case, guidewire was always accessed across the PDA despite multiple attempts. Thus, coarctation dilatation procedures were performed via left CA [Figure 2].

It is shown that access via the CA allows a more straight route for interventions targeting at some mBT shunts, specifically those mBT shunt that arise from the common CA itself.[2,6,10] Similarly, mBT shunt arose from the common CA in three of four cases, the decision was made to intervene on the mBT shunt using the CA after multiple attempts were made through FA access (Cases 6.3, 10, and 20) [Figure 3]. In the remaining cases, mBT shunt arose from the innominate artery (Case 4.3). However, directing the stent through the mBT shunt was impossible via FA approach because of the tight angle between the shunt and the innominate artery. In all cases, access was obtained from the CA approach during the same

catheterization. Subsequent successful mBT intervention was achieved in all.

Among the nonconventional vascular sites, carotid and axillary arteries are the most expedient routes for stenting PDA with complex morphology. Axillary artery route was the favored approach in our earliest cases.[11] However, it is a slightly less direct route to the PDA and the puncture site at the apex of the axilla is little distance away from the pleural cavity. For the PDA morphology in question, the most direct approach that would eliminate acute curves of the guidewire for stent delivery is via the common CA. The angle of approach from the CA is much straighter than a FA or axillary artery approach and this facilitates wire and stent passage across tortuous anatomy and provides more back up support when needed. Stenting or stent redilatation of the ductus arteriosus was the most common intervention in our series [*n* = 23 patients, Figure 4]. The intended intervention was unsuccessful in two patients despite successful percutaneous CA. Reintervention was performed in Case 6.2 due to extreme ductal stent stenosis, but the stent could not be accessed. In Case 9, stent migration occurred while retrieving the guidewire. Additional manipulation intended to improve the stent apposition, but migrated stent could not be accessed. Thus, inadequate flow occurred soon after the procedure, due to incomplete stent coverage of the ductus. In both cases, the right-sided mBT shunt was performed soon after intervention. Case 9 died 2 days after operation due to cardiac decompensation (low cardiac output state).

Case 18 has the left renal artery stenosis diagnosed with digital subtraction angiography. The patient has malignant systemic hypertension being measured in all the four limbs. Levels of rennin, human atrial natriuretic peptide, and brain natriuretic peptide were all markedly elevated in the plasma. At an initial attempt to perform percutaneous transluminal angioplasty of the stenotic artery through the right FA. Through a 5F Judkins right-guiding catheter, the stenotic lesion could not be crossed with a 0.014-inch floppy wire because of the steep angle of branching of the renal artery from the descending aorta. Thus, the second attempt at transluminal angioplasty was performed via the left CA. A 0.014 floppy guidewire was easily inserted into the narrowed left renal artery. Balloon dilatation was then performed using 1.5-mm fixed balloon [Figure 5]. The use of an antegrade approach for renal artery interventions overcome most of the problems, particularly the small size of the renal arteries, and their steep angle of branching from the descending aorta, faced when attempting percutaneous transluminal angioplasty in small infants with renovascular hypertension.[12,13] Hence, percutaneous renal artery angioplasty is reasonable via CA access in
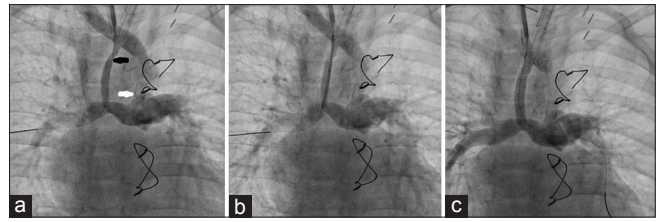

Figure 3: Modified Blalock–Taussig shunt stenting in an infant with pulmonary atresia-ventricular septal defect and cyanosis. Ductal stenting and stent redilatation were performed previously (a) The right carotid artery was used for angiography (Case 4), demonstrating the region of narrowing at the systemic arterial end of the modified Blalock–Taussig shunt (black arrow) and occluded ductal stent (white arrow) (b) The stent was passed across the site of stenosis and positioned along the length of modified Blalock–Taussig shunt (c) Postexpansion angiogram, resolution of the shunt stenosis required only 12 min
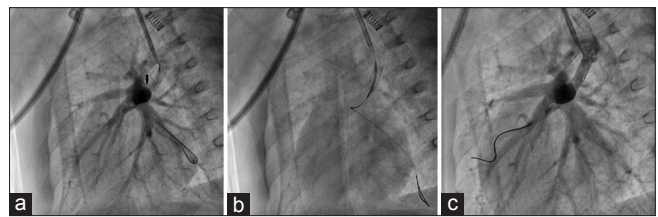

Figure 4: Ductal stent redilatation in an infant with pulmonary atresia with ventricular septal defect and cyanosis (Case 11) of the ductus arteriosus. (a) In-stent stenosis: layer of neointimal proliferation (black arrow); (b) stenosis of unstented segment of a long vertical ductus arising from the left subclavian artery; (c) Postexpansion angiogram
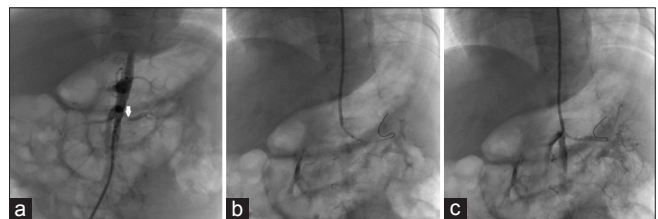

Figure 5: Percutaneous transluminal angioplasty in a 3-month-old infant with left renal artery and malignant systemic hypertension (Case 18) (a) The right femoral artery was used demonstrating the short stenotic lesion, almost complete (95%) when compared to the diameter of the adjacent healthy segment of the left renal artery (white arrow) and steep angle of branching of the artery from the descending aorta. (b) The catheter advanced from the right carotid artery, mounting a 1.5 mm balloon, was passed across the site of stenosis and inflated until the waist of the balloon disappeared. (c) After the angioplasty, the ratio of stenosis was reduced from 95% to 30%

infants. This approach provides a more direct route to the renal artery.

Removal of a percutaneously placed sheath with manual compression of the carotid puncture site is safe and successful at achieving hemostasis, and this occurred without reversal of heparin. Only two cases including one with pseudoaneurysm and the other with a large hematoma required surgical intervention. Both patients had high blood pressures during catheterization. Doppler

ultrasound scanning showed normal flow pattern during follow-up. There were no documented neurologic sequelae attributed to CA access in the immediate postprocedure period; however, a detailed evaluation has not been performed.

Limitations

Ultrasound-guided vascular access is not a method of choice for many pediatric heart centers. As with any new practice, there was a learning period where these new methods required more time to be performed. In our clinic, ultrasound guidance has been used for FA access in most cases for 4 years. This provided for this study a practical experience in the arterial access. This is a small cohort from a retrospective single-center study. Thus, the results may not be necessarily generalizable to every Pediatric Heart Center. In addition, it would be early to state that CA access is safe in the absence of data looking at long-term outcomes, including subtle changes such as cognitive functions. Nevertheless, potential occlusion of CA by the arterial cannula does not appear to increase the risk of neurologic injury in infants undergoing venoarterial extracorporeal membrane oxygenation in recent studies.[14,15]

CONCLUSIONS

Ultrasound-guided percutaneous CA, access even in very small preterm infants, is feasible and should be employed when dealing with a select group of cases required vertical approach for left-sided cardiac lesions. Carotid follow-up imaging showed a normal flow velocity in all cases and negligible vascular injuries in few cases.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Robinson BV, Brzezinska-Rajszys G, Weber HS, Ksiazyk J, Fricker FJ, Fischer DR, *et al.* Balloon aortic valvotomy through a carotid cutdown in infants with severe aortic stenosis: Results of the multi-centric registry. Cardiol Young 2000;10:225-32.

2. Davenport JJ, Lam L, Whalen-Glass R, Nykanen DG, Burke RP, Hannan R, *et al.* The successful use of alternative routes of vascular access for performing pediatric interventional cardiac catheterization. Catheter Cardiovasc Interv 2008;72:392-8.

3. Fischer DR, Ettedgui JA, Park SC, Siewers RD, del Nido PJ. Carotid artery approach for balloon dilation of aortic valve stenosis in the neonate: A preliminary report. J Am Coll Cardiol 1990;15:1633-6.

4. Maeno Y, Akagi T, Hashino K, Ishii M, Sugimura T, Takagi J, *et al.* Carotid artery approach to balloon aortic valvuloplasty in infants with critical aortic valve stenosis. Pediatr Cardiol 1997;18:288-91.

5. Vida VL, Bottio T, Milanesi O, Reffo E, Biffanti R, Bonato R, *et al.* Critical aortic stenosis in early infancy: Surgical treatment for residual lesions after balloon dilation. Ann Thorac Surg 2005;79:47-51.

6. Justino H, Petit CJ. Percutaneous common carotid artery access for pediatric interventional cardiac catheterization. Circ Cardiovasc Interv 2016;9:e003003.

7. Choudhry S, Balzer D, Murphy J, Nicolas R, Shahanavaz S. Percutaneous carotid artery access in infants <3 months of age. Catheter Cardiovasc Interv 2016;87:757-61.

8. Glatz AC, Shah SS, McCarthy AL, Geisser D, Daniels K, Xie D, *et al.* Prevalence of and risk factors for acute occlusive arterial injury following pediatric cardiac catheterization: A large single-center cohort study. Catheter Cardiovasc Interv 2013;82:454-62.

9. McMahon CJ, Price JF, Salerno JC, El-Said H, Taylor M, Vargo TA, *et al.* Cardiac catheterisation in infants weighing less than 2500 grams. Cardiol Young 2003;13:117-22.

10. Ligon RA, Ooi YK, Kim DW, Vincent RN, Petit CJ. Intervention on surgical systemic-to-pulmonary artery shunts: Carotid versus femoral access. JACC Cardiovasc Interv 2017;10:1738-44.

11. Polat TB. Stenting the vertical ductus arteriosus via axillary artery access using "wire-target" technique. Congenit Heart Dis 2017;12:800-7.

12. Takigiku K, Satomi G, Yasukochi S. Successful transluminal angioplasty of renal arterial stenosis using the transcarotid approach. Cardiol Young 2002;12:589-91.

13. Courtel JV, Soto B, Niaudet P, Gagnadoux MF, Carteret M, Quignodon JF, *et al.* Percutaneous transluminal angioplasty of renal artery stenosis in children. Pediatr Radiol 1998;28:59-63.

14. Lamers LJ, Rowland DG, Seguin JH, Rosenberg EM, Reber KM. The effect of common origin of the carotid arteries in neurologic outcome after neonatal ECMO. J Pediatr Surg 2004;39:532-6.

15. Wagner K, Risnes I, Berntsen T, Skarbø AB, Ramberg B, Vandvik IH, *et al.* Clinical and psychosocial follow-up study of children treated with extracorporeal membrane oxygenation. Ann Thorac Surg 2007;84:1349-55.