Title:

Arterial recanalization for access for arterial intervention in children: Technique and outcomes

Abstract

Purpose: To assess the technical success of arterial recanalization in the children requiring arterial access and intervention.

Materials and Methods: Over 14 years, 41 attempts to cross 30 arterial occlusions were made in 22 patients (13 male, 9 female). Median patient age was 12 months (15 days-14 years) and weight was 7.6 kg (3.0–77.3 kg). Technique used and outcome were recorded.

Results: 25 of 41 (61%) attempts at crossing an arterial occlusion were successful. 19 / 30 (63%) of first attempts to cross occlusions were successful and 6 / 11 (55%) of repeat attempts were successful. Occlusions were combinations of common femoral artery (CFA) (4), external iliac artery (EIA) (36), common iliac artery (CIA) (11) and aorta (1). Complications occurred in 5 of 41(12%) attempts: 3 minor (hematoma, extravasation, transient leg ischemia) and 2 major (rupture, thrombosis).

Conclusion: Arterial access by recanalization of occluded segments is technically feasible in children, with a low complication rate.

Introduction

Repeated arterial access is required in some neonates, such as those with vein of Galen malformations (1) and for older children such as those with renovascular hypertension (2). Obtaining arterial access is sometimes challenging (3) and access site complications are the most common adverse event following pediatric arteriography (3). Thrombosis is one of these risks and the rate in children is reported to be as high as 8%–10%, and up to 16% in those smaller than 15 kg (3,4). This may prevent access for subsequent arteriography and intervention unless the resulting arterial occlusion can be recanalized. In our experience it is possible to recanalize occluded arteries in children. The purpose of this study was to assess the technical success and associated complication rate of arterial recanalization for immediate arterial access for diagnostic arteriography or endovascular intervention in the pediatric population.

Materials and Methods

This single-center retrospective study was exempted from institutional review board approval. Patients were identified by conducting searches of the prospectively maintained interventional radiology database. Inclusion criteria were all consecutive patients, 0 – 18 years of age, who underwent an attempt at recanalization of a complete arterial occlusion for the purpose of performing diagnostic arteriography or endovascular intervention between 2002 and 2015. There were no exclusion criteria.

Data Sources and Collection

Data sources included the Radiology Information System (RIS), Picture Archiving Communication System (PACS), prospectively collected dedicated interventional radiology databases and electronic patient charts.

Definitions and Criteria

Arterial occlusions were identified by intra-procedural ultrasound or absent opacification of a segment of artery on arteriography. A procedure was defined as the endovascular treatment for which arterial access was required. An attempt was defined as using one more of the techniques described to cross an arterial occlusion on one side at a procedure whether successful or not. At any one procedure a patient could have had one attempt to cross an occlusion, or two attempts to cross occlusions (if there were bilateral occlusions). Technical success was defined as successful passage of a guidewire across the occlusion and subsequent performance of the intended arteriography or endovascular intervention. Complications were graded according to the Society of Interventional Radiology classification of complications (5). Occluded segments were analyzed separately.

Technique

The common femoral artery below the level of occlusion was accessed percutaneously using a micropuncture technique (21-gauge needle and 0.018-inch guidewire) with ultrasound guidance. The occlusions were crossed using either a blunt only or a sharp technique depending on operator preference. The blunt technique used forceful advancement of a 0.018-inch nitinol guidewire (Cope Mandril Wire Guide, Cook Medical LLC, Bloomington, IN), a 0.018- or 0.035-inch hydrophilic guidewire (Radifocus® Guidewire, Terumo,

Somerset, NJ) or a stiff guidewire (Amplatz Extra-Stiff Wire Guide, Cook Medical LLC, Bloomington, IN)) under fluoroscopy and/or ultrasound control with guide wire support provided by a 3- or 4-French vascular dilator (3Fr 0.018 or 4Fr 0.018 Standard Dilator, Cook Medical LLC, Bloomington, IN) or blunt metal needle (the 15cm rigid catheter introduction stiffening cannula from an 8.5-French pigtail drain set (Dawson-Muller, Cook Medical, Limerick, Ireland)) or diagnostic 4-French catheter until patent lumen was reached. The sharp technique involved passage of a 21-gauge needle (21-gauge One-Part Percutaneous Entry Needle, Cook Medical LLC, Bloomington, IN) under ultrasound guidance along the obliterated lumen until patent lumen was reached. Following passage of a guidewire a 4- or 5-French arterial sheath (Performer™ Introducer, Cook Medical LLC, Bloomington, IN) was placed and the intended procedure carried out. Patients were heparinized (80 units/kg) only if the subsequent procedure required this. All procedures were carried out by one of five of pediatric interventional or pediatric neurointerventional radiologists with a between five and 19 years (mean 9 years) experience in their specialty.

Statistical Tests

Statistical analyses were performed by using Microsoft® Excel Version 15.35 (Microsoft Corporation, Redmond, Washington, United States). We used χ^2 square analyses to compare outcome between first and repeat attempts. A P value of <0.05 was considered significant. 95% confidence intervals were calculated for the proportion of successful attempts and proportion of complications.

Results

Patient Population

Over 14 years, 2690 arteriograms were performed on patients aged from 0 days to 20 years (mean 7.2 years). 41 attempts to cross 30 arterial occlusions were made in 22 patients. Characteristics of the patient population and indications for arterial access are summarized in Table 1.

Recanalization Attempts

The 30 occluded segments were combinations of common femoral artery (CFA) (4), external iliac artery (EIA) (36), common iliac artery (CIA) (11) and aorta (1). 25 / 41 (61%) attempted crossings were performed on the right side. 30 / 41 (73%) of the attempts to cross occlusions were first attempts. Median age at first arterial access was 22 days (range 1 day – 4.1 months) and median time from last successful access in the occluded vessel was 5.4 months (range 7 days – 2.8 years).

11 / 41 attempts to cross occlusions were repeat attempts (10 were second attempts and one was a third attempt). Repeat attempts were for repeat arteriography. For 20 / 30 (67%) occluded segments one attempt to cross was made, for 9 / 30 (30%) occluded segments two attempts, and for 1 / 30 (3%) occluded segment. In the 11 repeat attempts to cross occlusions for arterial access, median time since the previous attempt to cross these segments was 5.7 months (range 1.8 months – 1.2 years).

Outcomes

25 of 41 attempts to cross occlusions and achieve arterial access were successful, giving a technical success rate (per attempt) of 61.0% (95% CI 46.0% – 75.9%). 19 / 30 (63%) of first attempts to cross occlusions were successful and 6 / 11 (55%) of repeat attempts were successful. This difference was not statistically significant ($P = 0.8809$). Analysis outcome by age is presented in Table 2. As can be noted from Table 2, older patients had a higher success rate than younger patients, but the difference was not statistically significant. In one of the successful repeat attempts the occlusion was crossed with wire and vascular dilator but a 4-French sheath could not be passed. In this patient, the long vascular dilator was used to perform angiography as guidance for transvenous embolization of a vein of Galen malformation. Following the 16 / 41 failed attempts, an attempt was made to use the contralateral side in 7, the left axillary artery was accessed in 5 and the whole procedure was abandoned in 4.

A blunt technique was used in 38 / 41 (93%) of attempts to cross occluded segments. Of 38 blunt attempts 24 (63%) were successful. Of 38 blunt attempts, 27 were first attempts and 18 of these (67%) were successful. All except one were retrograde crossings. There were 3 / 41 (7%) attempts made to cross occluded segments using a sharp technique with a 21-gauge needle under ultrasound guidance. 1 / 3 (33%) of these sharp recanalization attempts were successful. In addition to recanalization for immediate arterial access, angioplasty was performed in an attempt to preserve vessel patency and make future access easier in 2 / 41 (5%). One of these patients also had a stent placed in the EIA.

Complications

There were five complications in the 41 attempts to cross an arterial occlusion in 22 patients giving a procedural complication rate of 12% (95% CI 2.2% - 22.2%) and patient complication rate of 22.7% (95% CI 5.2% - 40.2%). According to SIR reporting standards (5) three were minor complications requiring nominal therapy with no consequence: one groin hematoma, one extravasation which was conservatively managed and one episode of transient leg ischemia. Two were major complications requiring therapy: vessel rupture in one patient and immediate stent thrombosis in another (Fig 1). In both cases (early in the series) an angioplasty was performed and stent insertion in one in order to preserve patency. There were no long-term sequelae from these complications.

Discussion

Although arteriography and arterial intervention in children are not as common as in adult practice however there are pediatric diseases for which repeated arterial access is required. In this series 18 of 22 patients had neurological disease and of these, 14 had a vein of Galen malformation. This is an example of a condition where repeated arterial access is required, usually starting in the neonatal period. In a series published by Berenstein et al. (1) patients with vein of Galen malformation whose endovascular treatments started in the neonatal period required an average of 4.2 procedures to achieve a cure.

The median age at first arterial access in this cohort was 22 days. Compared to adults, vessels in children are more superficial, straighter and have little or no vascular disease (3), making intra-arterial navigation easier. However, obtaining arterial access in small arteries can be difficult, and they tend to occlude more easily (3,6). This is thought to be related to the larger catheter-to-vessel ratio in children (3) and possibly to a higher incidence of dissection and

vasospasm at the access site (3). This problem of large catheter-to-vessel ratio increases with decreasing patient size. The rate of thrombosis following arterial access is 16% in those smaller than 15 kg (7) and may be as high as 39% when arterial interventions are performed with larger sheaths (3,8). In a study in which Doppler ultrasound assessment was performed 24 hours after arterial access, the incidence of arterial occlusion was shown to be significantly higher in patients weighing less than 10 kg (16%) than in as compared with patients weighing more than l0 kg (7). Beside the catheter-to-vessel ratio there are several potential risk factors for arterial occlusion after vascular catheterization, including the puncture technique (experience of the operator), the duration of the procedure and in particular failure to heparinization.

When a small child with bilateral iliac artery arterial occlusion requires arteriography, standard techniques can not be used. Axillary artery access is an alternative. Axillary access has been demonstrated to be feasible in a series of 25 successful procedures with a complication rate of 8% (9). In neonates less than five days old, umbilical arterial access is another option (3), but at this age, the patient is unlikely to have had previous arterial access resulting in occlusions. Umbilical access may reduce rate of occlusion at the groin, but occlusion of the common iliac artery may still occur. Small children with occlusions of the EIA may develop collateral pathways to perfuse the lower limb (Fig. 1) although impaired growth or claudication of the affected limb may result (6,10). These collateral vessels are often small and tortuous and are unlikely to be suitable for arterial access. This study demonstrates that recanalization is technically successful in more than 60% of attempts therefore may present another option in these challenging cases.

In this cohort, a retrograde blunt technique with a guidewire supported by a vascular dilator or catheter was most often successful. There are numerous devices available which are

specifically designed for chronic total occlusions in the lower extremities in adults (11). Whilst these could be considered for use in the children, this approach would be outside the intended use for the product, and significantly costlier, and the devices are too large for use in very small children.

In this series, angioplasty was performed in two patients following successful crossing of an occluded arterial segment, with the intention of facilitating future arterial access. Both cases resulted in complications, one vessel rupture and one thrombosis (Fig. 1) and both were performed early in the series. Adult lower limb arteries which commonly become occluded are frequently treated by either angioplasty or stent placement. Even those which are completely occluded (for example iliac arteries) can have good patency following angioplasty or stenting (12). Arterial occlusions in adults are usually due to atherosclerosis, which develops after the vessel has grown to full size. At 19 years of age mean femoral artery diameter is 14.2 mm (95% CI 9.6 – 18.8mm) (13). In children in this cohort the vessels had become occluded following prior arterial access at an early age and were consequently very small. At two years of age mean femoral artery diameter is 6.3 mm (95% CI 2.5 - 10.0mm) (13). We postulate that following occlusion the vessel does not continue to grow and for this reason at angioplasty may result in vessel rupture (Fig 1). These children often have well-developed collateral pathways, but there is a risk of these thrombosing due to reduced flow if patency is established in the previously occluded artery. Based upon this reasoning and our experience of successful repeated passage across arterial occlusions to achieve arterial access in 55% we no longer perform any intervention to maintain vessel patency for subsequent arterial access.

Although in this cohort recanalization was useful, there are some considerations regarding how generalizable the results are. Centers performing a lower volume of pediatric and more

specifically neonatal arteriography and arterial intervention are unlikely to face the clinical problem of needing to obtain arterial access across an occluded segment. Additionally, such centers may not have the necessary equipment, experience and access to surgical support to deal with complications should they arise. For these reasons, the results presented here may be generalizable only to institutions with a similar referral base and experience.

This study has some other limitations that must be acknowledged. The cohort of children is small and data is incomplete for some patients (Table 1). Moreover, the study is limited by the fact that it is a retrospective review. Each attempted crossing of an arterial occlusion was undertaken for performance of another endovascular procedure and as a result often there was no specific entry of this component of the procedure on RIS or PACS. However, information was also obtained from the Interventional Radiology database which is prospectively maintained with procedural details. The final limitation which must be acknowledged is the lack of clinical follow up data regarding outcomes of the accessed limb, especially longitudinal growth. However, this is not a study of the frequency or causes of occlusion following arterial access in children.

The data presented shows that when arterial access in children can be achieved by recanalization of occluded segments in over 60% of cases. However, there is a complication rate of between 2 and 22%. Recanalization can be performed more than once.

References

1. Berenstein A, Fifi JT, Niimi Y, Presti S, Ortiz R, Ghatan S, et al. Vein of Galen malformations in neonates: new management paradigms for improving outcomes. Neurosurgery. 2012 May;70(5):1207–13; discussion 1213-1214.

2. Shroff R, Roebuck DJ, Gordon I, Davies R, Stephens S, Marks S, et al. Angioplasty for Renovascular Hypertension in Children: 20-Year Experience. PEDIATRICS. 2006 Jul 1;118(1):268–75.

3. Heran MKS, Marshalleck F, Temple M, Grassi CJ, Connolly B, Towbin RB, et al. Joint Quality Improvement Guidelines for Pediatric Arterial Access and Arteriography: From the Societies of Interventional Radiology and Pediatric Radiology. J Vasc Interv Radiol. 2010 Jan;21(1):32–43.

4. Ding L, Pockett C, Moore J, El-Said H. Long sheath use in femoral artery catheterizations in infants <15 kg is associated with a higher thrombosis rate: Proposed Protocol for Detection and Management. Catheter Cardiovasc Interv Off J Soc Card Angiogr Interv. 2016 Aug 16;

5. Omary RA, Bettmann MA, Cardella JF, Bakal CW, Schwartzberg MS, Sacks D, et al. Quality Improvement Guidelines for the Reporting and Archiving of Interventional Radiology Procedures. J Vasc Interv Radiol. 2003 Sep;14(9):S293–5.

6. Burrows PE, Benson LN, Babyn P, MacDonald C. Magnetic resonance imaging of the iliofemoral arteries after balloon dilation angioplasty of aortic arch obstructions in children. Circulation. 1994 Aug;90(2):915–20.

7. Kulkarni S, Naidu R. Vascular ultrasound imaging to study immediate postcatheterization vascular complications in children. Catheter Cardiovasc Interv. 2006 Sep 1;68(3):450–5.

8. Wessel DL, Keane JF, Fellows KE, Robichaud H, Lock JE. Fibrinolytic therapy for femoral arterial thrombosis after cardiac catheterization in infants and children. Am J Cardiol. 1986 Aug 1;58(3):347–51.

9. Roebuck DJ, Vendhan K, Barnacle AM, Brew S, McLaren CA. Ultrasound-guided Transaxillary Access for Diagnostic and Interventional Arteriography in Children. J Vasc Interv Radiol. 2010 Jun;21(6):842–7.

10. Burrows PE, Benson LN, Williams WG, Trusler GA, Coles J, Smallhorn JF, et al. Iliofemoral arterial complications of balloon angioplasty for systemic obstructions in infants and children. Circulation. 1990 Nov;82(5):1697–704.

11. Endovascular therapy for critical limb ischemia. Expert Rev Cardiovasc Ther. 2015 Apr 3;13(4):429–44.

12. Goode SD, Cleveland TJ, Gaines PA, STAG trial collaborators. Randomized clinical trial of stents versus angioplasty for the treatment of iliac artery occlusions (STAG trial). Br J Surg. 2013 Aug;100(9):1148–53.

13. Steinberg C, Weinstock DJ, Gold JP, Notterman DA. Measurements of central blood vessels in infants and children: normal values. Cathet Cardiovasc Diagn. 1992 Nov;27(3):197–201.

Figure Legends

Fig. 1

15-month-old, 7.8 kg child with a vein of Galen malformation with known left and right iliac artery occlusions, requiring arterial access for embolization. (**a)** Digital subtraction arteriogram following puncture of the right CFA showing retrograde filling of collateral pathways *(arrows)* and the CIA and right EIA occlusion *(asterisks)*. Following passage of wire across and a 4-French catheter with some difficulty across a right EIA occlusion **(b)**. Following arteriogram and embolization of the vein of Galen malformation a 4-French sheath was passed with some difficulty into the distal aorta and right CIA and EIA angioplasty performed. (**c, d)** Digital subtraction arteriograms demonstrating extravasation from EIA into the retroperitoneum *(arrow)* **(c)** and filling of a false aneurysm *(arrow)* **(d)**. (**e)** Coil embolization was performed above and below the site of extravasation.

Table Legends

Table 1. Patient Characteristics

Table 2. Outcome in different age groups

Table 1. Patient Characteristics

Patients, n	22
Age, median (range)	12 months (15 days - 14.9 years)
Weight*, kg, median (range)	7.6 (3.0 – 77.3)
Male, n (%)	13 (59)
Number of arteriograms prior to diagnosis of occlusion, mean +/-SD	1.4 +/- 0.8
Diagnosis	
Vein of Galen malformation	14 (64)
Dural arteriovenous fistula	2 (9)
Other cerebral arteriovenous malformation	1 (4)
Choroid plexus tumor	1 (4)
Congenital heart disease	1 (4)
Aortic re-coarctation	2 (4)
Aortic thrombosis	1 (4)
Indication for arterial access	
Embolization	24 (59)
Arteriography	11 (27)
Angioplasty	5 (12)
Thrombolysis	1 (2)

* Weight data was missing for eight of the 34 procedures.

Table 2. Outcome in different age groups

	Age (y)		
	< 1 (n = 22)	**1 – 3 (n = 16)**	**>3 (n = 3)**
No. of successful attempts (%)	11 (50)	11 (69)	3 (100)
Comparison †	-	*P* = 0.4105	*P* = 0.3093

† Values listed for a group are those compared with the first group, i.e., each other age group compared v.s. age <1 y.