Techniques in
Vascular and
Interventional
Radiology

Pediatric Arterial Interventions

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The spectrum of pediatric vascular pathology differs from the adult population and it varies greatly to include congenital and acquired disorders. Although catheter-directed angiography remains the gold standard, most vascular conditions in the child can be adequately diagnosed with magnetic resonance angiography, computed tomographic angiography, or duplex/Doppler ultrasonography with only a few exceptions, such as intrarenal arterial stenosis, small vessel vasculitides, and visceral vascular malformations. The advancement of catheter and wire technology has made it increasingly possible for complex arterial interventions to be performed in children, including embolization, angioplasty with stent insertion, thrombolysis, and endovascular neurological procedures. More angiographic procedures are being performed with the aim of also being therapeutic. Special considerations in children include the use of appropriate equipment and adequate dosing of contrast and of the various medications used during angiography, particularly in patients less than 15 kg in weight. This article will focus on the management of renovascular hypertension, liver transplant hepatic arterial intervention, and the use of carbon dioxide gas as a contrast agent in the child.
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Angiography

Angiography has largely been replaced by imaging modalities such as computed tomographic angiography (CTA), magnetic resonance angiography (MRA), and Doppler ultrasonography (US) for diagnosis with the exceptions of a few conditions, such as the detection of intrarenal arterial pathology and certain vascular anomalies. Technological advancement has now made it possible to perform complex percutaneous arterial interventions in the very small patient. The most common indications for angiography in the child include renovascular hypertension, gastrointestinal disorders, trauma, and neurological disorders. Relative contraindications include contrast allergy, coagulopathy, renal failure, sepsis, severe congestive heart failure, severe poorly controlled hypertension, and active vasculitis resulting in increased risk of vessel injury.

Appropriate values for preprocedure laboratory examinations include platelet count >50,000, prothrombin time (PT) <32, and international normalized ratio (INR) <1.2–1.5. It is important to note that, although neonates will have prolonged values, they are essentially hypercoagulable. In fact, one can argue that, if there is no history of easy bleeding or bruising, preprocedure laboratory studies do not have to be obtained.

Low osmolar contrast material (300-350 mg iodine/mL) is most commonly used for pediatric angiography. Contrast volume should not exceed 4-5 mL/kg in neonates or 6-8 mL/kg outside the neonatal age group.[1] In patients <15 kg in weight, performing hand injections and contrast dilution will ensure that the maximum contrast volume is not exceeded. Generally, power contrast injection can be performed at adults rates when the patient is >50 kg. For patients <50 kg, injection parameters can be reduced up to half of the adult injection parameters. Hand injection of contrast is generally performed in patients <15 kg in weight. Image acquisition (digital subtraction angiography) can be obtained at 3-6 frames/second in the arterial phase and 1 frame/second in the venous phase. Suggested injection parameters have been published elsewhere.[1]

Intravenous heparin (75-100 U/kg) is usually administered after arterial access is obtained in patients <15 kg to prevent femoral artery thrombosis. Nitroglycerin (1-2 μg/kg) can be administered intrarterially to treat arterial spasm before crossing a stenotic artery or before an intervention. The dose of 1% lidocaine (without epinephrine) should not ex-

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ceed 0.5 mL/kg when used as a local anesthetic. Glucagon (20 μg/kg, max. 1 mg) can be used intravenously to decrease subtraction artifact due to increased bowel peristalsis.

Published vascular complications from angiography have been as high as 7%-10% of pediatric patients primarily in those younger than 1 year of age and in patients under 15 kg in weight.[1] However, observed complication rates are significantly less due to technological advancements and the increased use of US guidance for arterial access.

Renovascular Hypertension

Hypertension occurs in 1%-2% of children. Of these patients, up to 25% have a renovascular etiology with the most common cause being fibromuscular dysplasia (FMD) in 70% of cases. Other causes include Neurofibromatosis type 1, Williams syndrome, Takayasu's arteritis, middle aortic syndrome, trauma, tumor encasement, and post radiation effects. Noninvasive imaging (Doppler US, nuclear renal scan, MRA, and CTA) continue to be a vital part of the diagnostic evaluation of renal artery stenosis. To date, with current technological advances, noninvasive imaging has become more sensitive in the detection of main renal artery stenosis but still falls short in the evaluation of intraparenchymal renal arterial branches. The gold standard continues to be catheter-directed angiography. Indications for renal angiography include persistent hypertension (>99th percentile for age), failure to control hypertension with a single medication, planned angioplasty, and to avoid or delay complex revascularization surgery in a patient known to have renal artery stenosis.[2,3]

Renal Angiography

General anesthesia may be used for patients <12 years of age with moderate sedation for older patients with certain exceptions (eg, patients who are developmentally delayed will require general anesthesia). Suspended respirations will ensure that the images obtained will be of good quality. Intravenous glucagon (20 μk/kg, max. 1 mg) can be given to minimize artifacts from bowel peristalsis. Percutaneous access can be achieved by palpation or US guidance. US guidance is preferred because it will allow access quickly, thereby lessening the risk of arterial thrombosis or spasm primarily in smaller patients. In general, a 0.018-inch/21-gauge or 0.035-inch/18-gauge needle/guidewire system can be used. The 21-gauge system is preferred in smaller patients or when the brachial or axillary artery needs to be accessed. Depending on patient size, a 4- to 5-Fr vascular sheath is placed especially if multiple catheter manipulations or an intervention is expected. Once arterial access is achieved, intravenous heparin (100 U/kg) is administered routinely if the patient is <15 kg in weight due to the increased risk of femoral artery thrombosis. Once the vascular sheath is placed, its sidearm is flushed and then connected to a pressurized and heparinized saline flush bag. In smaller patients and for patients on fluid restriction, a flow-limiting valve can be attached to sidearm of the vascular sheath to limit fluid rate to 2-4 mL/h, thereby avoiding fluid overload. Intermittent hand flushes are also recommended.

Flush aortography can be performed in posterior–anterior and lateral projections to evaluate for middle aortic syndrome and to evaluate the origins of the visceral arteries. Imaging the thoracic aorta and great vessels is useful in Takayasu's syndrome and Williams syndrome, especially if there are neurological symptoms. Typically, a 3- to 5-Fr pigtail or a 4- to 5-Fr Omniflush catheter (Angiodynamics, Queensbury, NY) can be used. The advantage of the Omniflush catheter is that it can be used to select the contralateral common iliac artery facilitating the formation of a reverse curve type catheter before selecting the renal arteries. Selective renal angiography can be accomplished using a Cobra 2 catheter or SOS 2 selective catheter (Angiodynamics). The SOS 1 catheter (Angiodynamics) is better for use in the smaller caliber aorta. All main and accessory vessels are selected and evaluated in bilateral oblique projections. Care must be taken to select only the orifice of the vessels and not advance the catheter into the main renal artery, which would result in arterial spasm which, in turn, will mimic arterial stenosis. Manometric evaluation of the aorta and renal artery is warranted when a stenosis is demonstrated. In small patients, most catheters will be occlusive, making pressure measurements difficult to obtain. Typically, a systolic gradient across the stenosis of 10 mm Hg is significant. Fibromuscular disease may be detected as a "string of beads" (Fig. 1), focal web (Fig. 2), diffuse stenosis (Fig. 3), or a stenosis with an associated aneurysm or arterial occlusion (Fig. 4). Manometric evaluation may not be needed if the findings are classic. When findings are equivocal, there is a role for renal vein renin (RVR) sampling with the goal of localizing the location of renin production. A renin ratio (R/Rc) of >1.5 between the affected (R) and normal kidney (Rc) and a ratio (Rc/P) of <1.3 between the

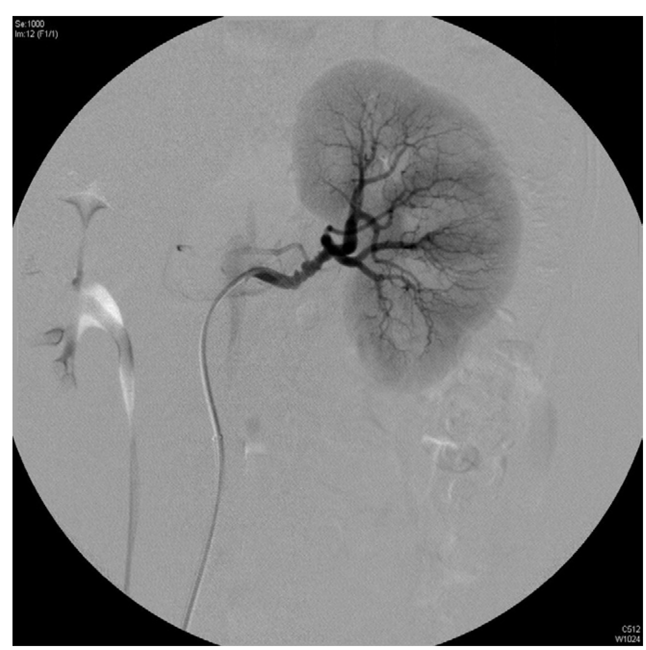

Figure 1 Classic "string of beads" appearance of fibromuscular dysplasia.