A Discourse on Pediatric Vascular Trauma

Dawn Coleman, MD, describes the most common vascular injuries in pediatric patients, special considerations for this population, the implant longevity dilemmas, and more.

What are the most common mechanisms and locations of pediatric vascular injury?

Pediatric vascular trauma is rare and comprises only approximately 0.6% to 2% of all traumatic pediatric injuries.[1] The most common mechanisms include motor vehicle accidents, firearm injuries, stab wounds, and falls. The most commonly injured vessels include those of the upper extremity, followed in decreasing frequency by abdominal trauma (eg, inferior vena cava, iliac and renal vessels), lower extremity, chest, and neck vessels.

What are the most common hard and soft signs?

Compared to adult vascular trauma, pediatric vascular injuries are more likely to be asymptomatic and associated with vasospasm. Therefore, consideration of "soft signs" is essential. Soft signs warrant further diagnostic considerations (often duplex ultrasound and/or CTA); these include persistent shock despite adequate resuscitation, hematoma, diminished peripheral pulses, proximity of wound trajectory to major vessels, and/or evidence of nerve injury (adjacent to a named vascular bundle). Additionally, given pediatric physiologic reserve, blood pressure is often maintained despite significant hypovolemia. Importantly, tachycardia, tachypnea, cool extremities, and lethargy may forewarn cardiovascular collapse prior to hypotension. "Hard signs" are well described and warrant prompt intervention; these include pulsatile and visible bleeding, rapidly expanding hematoma, and clinical exam findings that support arteriovenous fistula or distal ischemia (eg, pallor, pulselessness, poikilothermia, paresthesia, and pain).

Pediatric vascular trauma has not been extensively studied, and there is no consensus for optimal management (eg, nonoperative management, primary repair, interposition graft, patch, endovascular). What are the challenges of determining proper care in a field with limited ability to collect prospective, uniform data?

Given the rarity of pediatric vascular trauma, limited data (despite large trauma data sets), and limited experience by most surgeons, guidelines for treatment are lacking. Moreover, the "field" of pediatric vascular surgery is compromised by a discrete change in training paradigms. The rise of integrated vascular surgery residency training concurrent with a decrease in open vascular surgical procedures has seen general surgery residents and pediatric surgery fellows less exposed to open vascular surgery, and vascular surgery residents rarely exposed to pediatric surgery. Moreover, the management of pediatric vascular trauma varies widely by institution and whether there is a freestanding children's hospital supported by a "vascular team." This dilution of collective comfort with a critical and often urgent pathology challenges the care of these special patients. Proactive and innovative training paradigms will need to be prioritized alongside larger prospective registries and pragmatic clinical trials to further define best practices in care.

What special considerations are there when deciding between open and interventional repairs for children, and what are the greatest distinctions between your considerations in trauma involving adults?

Endovascular technology remains limited for pediatric vascular surgery injuries. Most commonly, catheter-based techniques are employed for aortic stent grafting and vascular embolization. The former has been extrapolated from the successful use of aortic stent grafts in adult trauma patients and further supported by the experience of stent grafts to treat congenital thoracic aortic coarctation. However, access and size-

specific graft limitations restrict wide applicability of this technology to all children.

How does the dilemma regarding the longevity of implant need and anticipated physical growth of the patient differ between open and endovascular repair?

Future somatic growth is a critical limiting factor for the wide adoption of endovascular techniques for "comprehensive" pediatric vascular surgery in contrast to adult vascular surgery. Similarly, future growth combined with small vessel size limits the utility of prosthetic conduits and homografts in these cases. To that end, preservation of in-line flow by way of repair/revascularization with autogenous conduit (saphenous vein, hypogastric artery), when possible, is especially relevant for extremity trauma to avoid future limb length discrepancy and the functional sequelae of such (eg, limb hypotrophy, gait disturbance, scoliosis). Interrupted suture lines and generous spatulation will enhance the durability of anastomoses and limit future stenosis from a purse-string effect.

Other considerations include intraoperative magnification to manage small vessel size and vasospasm. Importantly, temporary vascular shunting is feasible even in the smallest patients and indicated for prolonged ischemia with the aid of smaller diameter neonatal and/or pediatric cardiopulmonary bypass cannulas, neonatal chest tubes, and/or pediatric feeding tubes. Liberal use of vasodilators (eg, papaverine) will reverse predicted vasospasm.

What is follow-up like for young patients who undergo repair compared to adults? What are the unique needs and concerns?

Judicious follow-up is required for all pediatric vascular trauma patients. When ligation or embolization is employed, follow-up should assess for progressive limb length discrepancy and/or symptoms of chronic ischemia that manifest as the child grows and becomes more active. For those patients undergoing vascular repair (open or endovascular), annual surveillance to assess for vein patch/graft dilation, anastomotic stenosis, and/or conduit "outgrowth" will offer an important opportunity to preserve primary patency.

Recent years have seen a trend toward endovascular therapy in pediatric vascular trauma, with embolization of internal iliac injury and thoracic aortic endografts as some of the most common, as presented in Branco et al.[2] Yet, there's still much to be learned about the appropriateness and long-term outcomes of these techniques. What do you see as the key limitations of current endovascular therapies for pediatric vascular injuries?

I agree with the authors of this study that the main limitations of endovascular therapies in the treatment of pediatric vascular injuries are primarily related to the fact that stents won't grow with a child, device platforms are often too large to permit safe "access," and stent sizes are limited for use in pediatric patients with small vessels.[2]

Sadly, I see the misuse of endovascular technology in children with some frequency in the care of pediatric renovascular hypertension; more specifically, stents for renal artery stenosis in children not only fail to offer durability (over an anticipated otherwise normal life expectancy) but also compromise remedial surgery, tempering the hypertension benefits of surgical renal revascularization and increasing the risk of partial or complete nephrectomy.

Have any recently introduced types of devices been particularly useful in pediatric trauma intervention?

I will refrain from referencing specific devices, but I do believe that advances in the treatment of congenital cardiac disease (inclusive of patent foramen ovale embolization, thoracic aortic coarctation stenting, cardiopulmonary bypass, and left ventricular assist device support) will influence additional technologic advances that may trickle into the care of pediatric vascular surgery patients.

Are there any pediatric-specific technologies and techniques on the horizon? What would an ideal technology as applied to a specific type of injury look like for you? What developments are most needed?

A competent, readily available conduit that has the ability to grow with a child and remodel/repair in vivo to resist aneurysmal degeneration and chronic inflammation could eliminate the need for multiple reoperations and long-term morbidity. Developing technologies like bioresorbable stents and grafts may be promising to overcome the current growth-related challenges of endovascular techniques and prosthetic conduit. Additionally, balloon-expandable polytetrafluoroethylene and serial balloon angioplasty with drug-coated balloons—extrapolated from reports for developmental pathology like midaortic syndrome—may prove useful to facilitate conduit expansion with growth. I am most excited about the growing body of work supporting

decellularized, tissue-engineered, growable vascular grafts. Several attempts are being made to translate this technology from bench to bedside (including scaffold-based and self-assembled), which may address the current limitations we face in optimizing the revascularization of small, growing arteries!

What is your advice to vascular specialists who want to learn more or train further in this field?

Find a strong clinical mentor, gain relevant exposure, read, be innovative, and persist. Although a robust clinical exposure to pediatric vascular surgery is unlikely for most trainees, forging a strong foundation of skills that encompasses pediatric anatomy and physiology as well as open vascular surgical exposures and techniques will prove extremely valuable. Maintain humility and leverage institutional collaborative expertise. Always do what is best for the patient and learn from those who care for children with regularity (including, but not limited to, congenital cardiac surgeons, pediatric surgeons, vascular surgeons, pediatric interventional radiologists, and microvascular specialists). Children are surprisingly resilient and can bounce back from seemingly devastating injuries, maintaining optimism and persistence in the most challenging of cases. Pediatric vascular disease (inclusive of trauma) is ripe for innovation, and I believe it fully captures the spirit of team science and multidisciplinary care. ■

1. Heinzerling NP, Sato TT. Pediatric Vascular Injuries. In: Dua A, Desai SS, Holcomb JB, Burgess AR, Freischlag JA, eds. Clinical Review of Vascular Trauma. Springer-Verlag Berlin Heidelberg; 2014.
2. Branco BC, Naik-Mathuria B, Montero-Baker M, et al. Increasing use of endovascular therapy in pediatric arterial trauma. 2017;66:1175–1183. doi: 10.1016/j.jvs.2017.04.072

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