Anatomy of the Pedal Arch and Implications for Tibiopedal Access

An overview of anatomical characteristics and access options for challenging CLI cases.

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A strong understanding of pedal arch anatomy is imperative for physicians performing lower extremity revascularization. It is especially important that this anatomy be carefully evaluated in all cases of critical limb ischemia (CLI). Morphological and functional determination of pedal arch vessel patency has an important role in planning and performing limb salvage procedures in patients with CLI.[1,2] There is usually a dominant blood supply between the two main arteries supplying the foot: the anterior tibial and posterior tibial arteries.

ANTERIOR CIRCULATION

Normally, the anterior tibial artery, which is the first branch of the popliteal artery, passes between the tibialis anterior and extensor hallucis longus muscles. At the level of the ankle, the anterior tibial artery crosses under the extensor retinaculum just lateral to the tendon of the extensor hallucis longus muscle. As it reaches the dorsum of the foot, the vessel's name changes to the dorsalis pedis artery. This artery ends at the first metatarsal space by branching to form the arcuate artery, which will supply branches to all toes and then turn sharply to join the perforator branches of the posterior plantar circulation and the pedal arch.

POSTERIOR CIRCULATION

The posterior tibial artery begins as one of the two branches of the tibioperoneal trunk. As it traverses posterior to the medial malleolus, it becomes the common plantar artery in the retromalleolar space. Then, the common plantar artery divides into medial and lateral arteries. The lateral plantar artery traverses along the lateral aspect of the plantar surface of the forefoot. After following a curvy pathway, it joins the anterior circulation by communicating with the dorsalis pedal artery at the first plantar space. The medial plantar artery crosses directly along the medial aspect of the plantar surface of the forefoot and ends at the first metatarsal space, where it becomes the hallux digital arteries.[3]

PEDAL ARCH

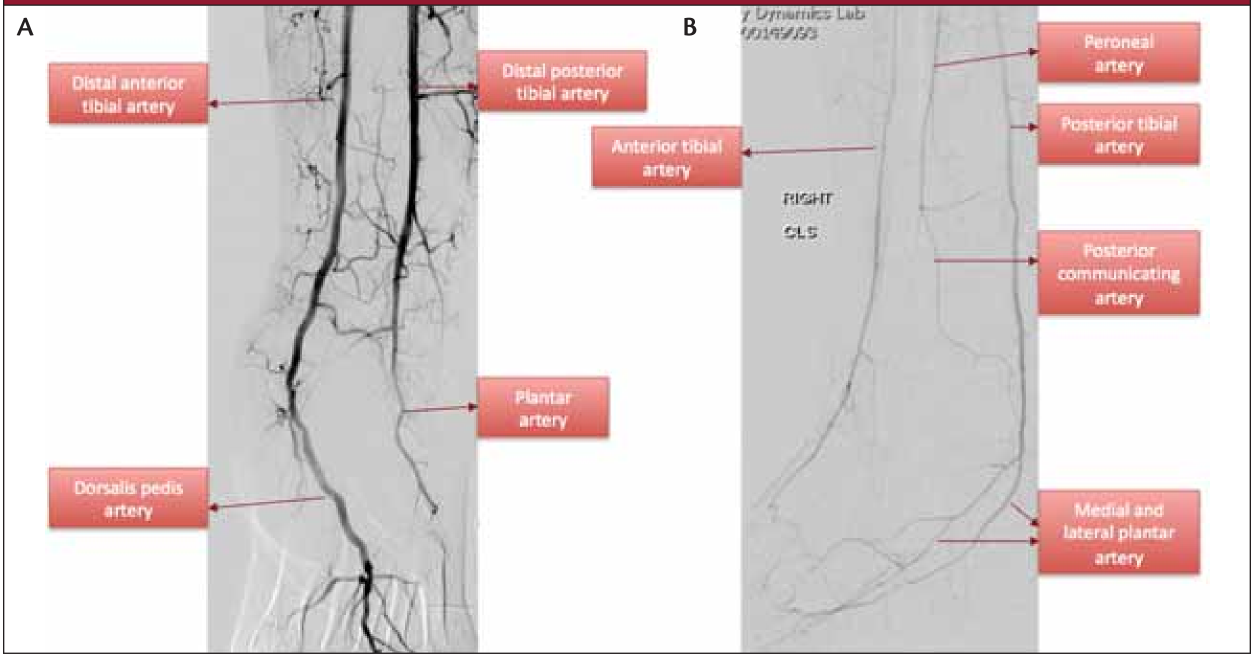
Normally, the area between the anterior and posterior circulation will form the pedal arcade. This is primarily constituted by the deep perforating branches of the dorsal artery of the foot and the lateral plantar arteries. It is crucial to understand the patency of the pedal arch for proper preoperative planning of pedal vessel revascularization. The anastomosis between the main pedal arch vessels (namely the dorsal and lateral plantar arteries) can be outlined well in oblique or lateral views seen on conventional angiography. This arcade is the stem supply for all distal forefoot circulation.

DIAGNOSIS

Optimal evaluation of the pedal arch is needed in patients with foot ulcers or ischemic changes. Although the gold standard means of evaluation may still be angiography, this option carries the risk of groin hematoma and contrast nephropathy, as well as added expense. Duplex ultrasound has been evaluated as a valid tool to examine pedal arch vessels,[4] and some have proposed the use of an 8-MHz Doppler probe to evaluate the pedal arch. Using this method, the probe should be placed in the first metatarsal space. Presence of a Doppler signal can be taken as evidence of a patent pedal arch. Digital pressure can also be applied over each tibial artery at the malleolar level to determine each vessel's communication with the pedal arch.

Computed tomographic angiography and magnetic resonance angiography are very sensitive tools that can provide significant information on the nature of the pedal vessel disease. In a recent study,[5] three-dimensional magnetic resonance angiography of distal calf and pedal vasculature in CLI was shown to be superior to conventional selective digital subtraction angiography and high-resolution duplex ultrasound. Although duplex ultrasound is a sensitive tool for tibial vessel evaluation, visualization of the peroneal artery may be difficult, and a certain level of expertise will be required. Once the tibial vessel is visualized, ultrasound imaging is

ANATOMY OF TIBIOPEDAL VESSELS AND PEDAL ARCH



not inferior to results obtained via computed tomographic angiography.[6]

APPLYING TIBIOPEDAL ACCESS IN LIMB SALVAGE

The traditional limb salvage treatment for CLI patients with rest pain or tissue loss (Rutherford 4–6) is surgical bypass.[7] However, the advent of minimally invasive endovascular therapy has offered comparable results in appropriately selected patients,[8] and the ongoing improvements in technology continue to offer more options for successful treatment of more complex disease presentations. The first steps in delivering endovascular therapy are to obtain access and traverse the lesion. When conventional approaches (antegrade or contralateral retrograde) fail, a tibial vessel approach may offer a valid alternative route to cross the lesion.

Limb salvage continues to be a challenge when treating patients in whom the traditional ipsilateral antegrade or contralateral retrograde approach (up-and-over technique) fails. In these cases, pedal access approaches utilizing the dorsalis pedis, posterior tibial, or even peroneal arteries can offer considerable advantages (Table 1). These approaches may offer a better chance of crossing long tibial occlusive segments.

INTERVENTIONAL CHALLENGES AND TECHNICAL TIPS

The size of tibial vessels poses the biggest challenge to the vascular specialist (Table 2). Access via ultrasound guidance is highly recommended because missed access or multiple attempts may contribute to significant bleeding, nerve compression, or even compartment syndrome. Due to the smaller vessel size, the use of smaller sheaths and smaller catheters based on 0.014- or 0.018-inch systems is recommended.

Patient position can be problematic, but pedal access can usually be accomplished with the patient in the supine position. When attempting to use the dorsalis pedis approach, the foot should be placed in the dorsiflexion position; supination of the foot may be required in cases using a posterior tibial artery approach.

Once access is achieved, heparin should be administered according to protocol. We have been using nitroglycerin as well as calcium channel blockers selectively in some cases, namely those in which vasospasm is occurring. Our anecdotal experience is that this combination of medications may be particularly beneficial in heavy smokers.

PUBLISHED EXPERIENCES

The feasibility of this approach has been evaluated in case reports[9] and series. Fusaro et al have indicated the feasibility of retrograde pedal artery access for below-the-knee percutaneous revascularization.[10] Kawarada et al have reported feasibility of the transpedal approach to cross occluded dorsalis pedis and paramalleolar posterior tibial arteries, which are considered a rare atherosclerotic pattern in the crural arteries.[11] The investigators achieved complete infrapopliteal recanalization and wound healing.

In a recent study by Walker,[12] pedal access was attempted after the antegrade route was deemed unsuccessful in 273 patients with CLI (Rutherford 4–6). Patient ages ranged from 42 to 90 years, 32% of patients were diabetic, and 59% were smokers. All patients had occlusive lesions. Pedal access was successful in 96% of patients—54% via anterior tibial approach, 45% via pos-

TABLE 1. ADVANTAGES OF TIBIOPEDAL ACCESS
• Small diameter of tibial vessels may help to increase the pushability of catheter or wire through occlusion
• Less likelihood of entering sidebranch or collateral
• The most difficult portion of the occlusion is the proximal segment; the distal portion is often less difficult
• In cases of occluded short segment tibial or popliteal arteries, the pedal approach may offer a shorter arterial segment to cross with balloons, catheters, and stents than traditional ipsilateral or contralateral approaches
• Useful in cases in which vessel size precludes use of embolic protection devices during antegrade or retrograde femoral approaches
• May have safety potential in obese patients in whom a groin approach may not be feasible
• May have a role in patients having a hostile or infected groin in which conventional intervention is not feasible

TABLE 2. POTENTIAL DISADVANTAGES OF TIBIOPEDAL ACCESS
• Small-diameter vessels are prone to spasm and dissection
• Vessels are often calcified
• Approach near the ankle may cause significant difficulty in sheath passage because of the sharp angulation

terior tibial approach, and < 1% via peroneal access. The investigators reported no access failures in vessels with a diameter > 1.5 mm by quantitative angiograms. In 93% of patients with successful pedal access, microcatheters, small-profile balloons, and 0.014- or 0.018-inch systems were used with definitive therapy accomplished from femoral access.

In 7% of patients, 4-F sheaths were placed initially in pedal vessels and upgraded to 6-F sheaths for definitive therapy. Technical success as defined by crossing the lesions was achieved in 93% of patients. In this study, atherectomy devices were used in 97% of patients followed by prolonged balloon inflation over a 3-minute period. Adjunctive stents were used in 58% of SFA occlusions and 13% of popliteal occlusions. Antegrade flow was restored in 99% of patients. The author noted a decrease in level of amputation after revascularization; 49 out of the 57 patients who initially presented with advanced gangrenous changes underwent minor amputation (digits). Two of the 112 patients with nonhealing ulcers required reintervention to maximize wound healing.

CONCLUSION

Pedal access is a relatively recent innovation of vascular intervention. It is a feasible approach with potential immediate benefits that may increase utilization of this approach. There is a learning curve involved with this interventional approach, and we will continue to gain further understanding of its ideal uses in the time to come. ■

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