Pedal Arch Revascularization

The rationale behind this procedure and tips from preprocedure planning to intervention.

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Critical limb ischemia is a major cause of morbidity and mortality worldwide and is characterized by multilevel disease, often involving the tibiopedal vessels. There are some reports that the atherosclerotic pattern in diabetic patients affects the tibial vessels yet tends to spare the pedal vasculature.[1,2] Although this may be true in many cases, our experience has demonstrated frequent involvement of the pedal vessels, including the pedal arch. In a subset of patients with critical limb ischemia, particularly in longstanding type 1 diabetic patients and patients on dialysis, a predominance of disease involving the pedal vessels can exist with relative sparing of the tibial vessels.[3]

The pedal arch describes the connection between the anterior and posterior circulation in the foot. This typically runs from the lateral plantar artery into the dorsalis pedis and represents the final arcade of outflow for the lower extremity vasculature. Secondary or "deep" pedal-plantar loops connecting the medial and lateral tarsal arteries to the medial and lateral plantar arteries can also exist. A strong understanding of the pedal arch anatomy and its multiple connections is important for the physician performing not only pedal arch interventions, but tibial interventions as well. Familiarity with the arch anatomy increases procedural success rates in tibial intervention, as it gives the operator another collateral pathway to approach the target occlusion in a retrograde fashion.[4]

An intact pedal arch has been associated with improved wound healing, as well as a higher patency rate for bypass grafting and percutaneous interventions for inflow disease.[5-8] Although it has been suggested that revascularization of the pedal arch may benefit wound healing for these reasons,[5] this has not been validated. An angiosome-directed revascularization strategy, however, has clearly been shown to improve wound healing and limb salvage rates in both surgical and endovascular series.[9,10] Pedal arch intervention should therefore be considered in patients with advanced tissue loss, with a goal of restoring inline flow to the corresponding angiosomes. This could mean the difference between a major and minor amputation, as the options for these patients are limited and major amputation rates are high.

Figure 1. Contralateral oblique (A) and ipsilateral cranial (B) foot orientation.

TECHNIQUE DESCRIPTION

Staging of a pedal arch intervention is recommended, if clinically appropriate, to allow time for preprocedure examination of the diagnostic images and mapping the anticipated course of the pedal arch. The pedal arch and vascular connections in the foot are highly variable from person to person. Identification and anticipation of these

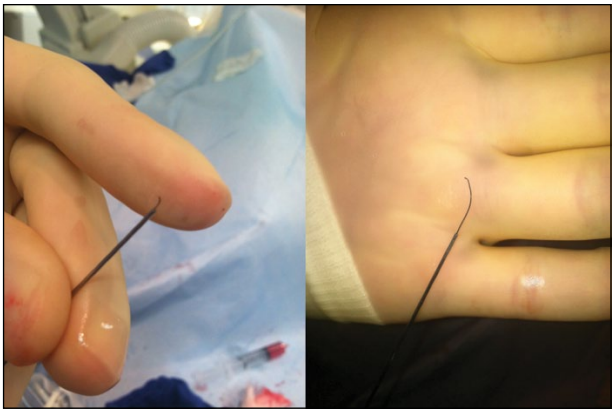

Figure 2. A double-wire bend with the acute bend close to the tip of the Fielder XT (Asahi-Intecc). This tip bend allows steerability in pedal vessels.

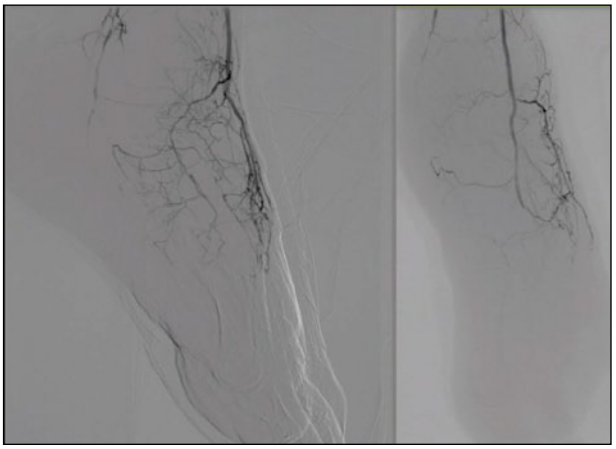

Figure 4. Total occlusion of the mid dorsalis pedis and common plantar arteries.

variants during diagnostic and interventional procedures is vital to a successful outcome.

Perhaps the most important aspect of preparing for a successful pedal arch intervention is the diagnostic imaging technique from which the procedure will be planned. Two standard views of the foot with digital subtraction angiography (DSA) should be taken with prolonged imaging to allow late collateral filling to be evident. The first view should be a contralateral oblique image (Figure 1A), which allows for the best visualization of the common plantar artery and its bifurcation, as well as the dorsalis pedis and its connection to the pedal arch via the deep perforating artery. The second view should be an ipsilateral cranial view such that the image intensifier is parallel to the dorsum of the foot and the toes are seen pointing as close to the top of the image as possible (Figure 1B).

With DSA imaging, a higher frame rate of 4 fps is preferable to study how a vessel fills via collaterals and for discriminating overlapping vessels that may have differential

Figure 3. The patient had undergone several toe amputations, and his foot showed signs of severe gangrene.

filling times. Adequate time between imaging should be allowed for complete contrast washout so as not to subtract slowly filling collaterals on the next DSA image. Nitroglycerin can be given before additional images are obtained to see if more collateral recruitment is visible.

Distal catheter placement at the time of diagnostic angiography should include a popliteal position, typically with a 0.035-inch catheter or a sheath if a same-sitting intervention is being performed. This should be followed by selective angiography in the common plantar/lateral plantar artery and proximal dorsalis pedis artery using a small (3 mL) luer-lock syringe via a 0.018-inch straight support catheter. Simultaneous injections through two support catheters or through the sheath and one support catheter should be performed during the diagnostic portion of the study, as this may be helpful in visualizing the course of the plantar arch and other connections that could be utilized. Interventions are best approached from an ipsilateral antegrade approach. A 6-F, 30- or 45-cm sheath should be placed with the distal tip in the popliteal artery if there is no significant disease seen in the superficial femoral artery. A 6-F sheath, as opposed to 5 F, will allow for more flexibility in using two wires with 0.014-inch support catheters simultaneously when approaching the chronic total occlusion (CTO) in an antegrade-retrograde fashion.

Using a support catheter, the occlusion should be approached with a steerable, atraumatic, 0.014-inch wire to navigate either the anterior tibial or posterior tibial artery to the point of occlusion. If this point is in the proximal plantar or dorsalis pedis, a 0.018-inch support catheter should be used, as it provides more flexibility with wire exchanges and better selective angiography. A 0.014-inch support catheter is more suitable if the occlusion is in the forefoot or if the arch is only partially occluded and a pedal plantar loop technique is being considered to approach a contralateral tibial occlusion in a retrograde fashion.

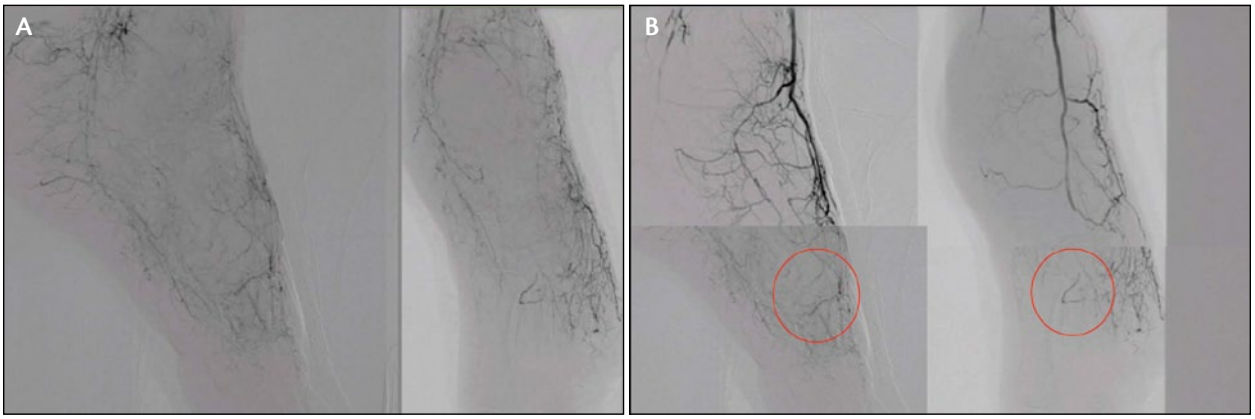

Figure 5. A long cine run revealing remnants of the pedal arch in this case (A). Stacked images help to map the course of the pedal arch (B).

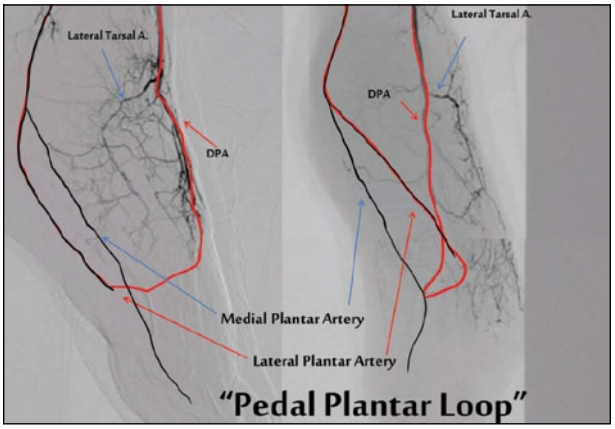

Figure 6. Preintervention mapping of the path of the plantar arch and its vessels.

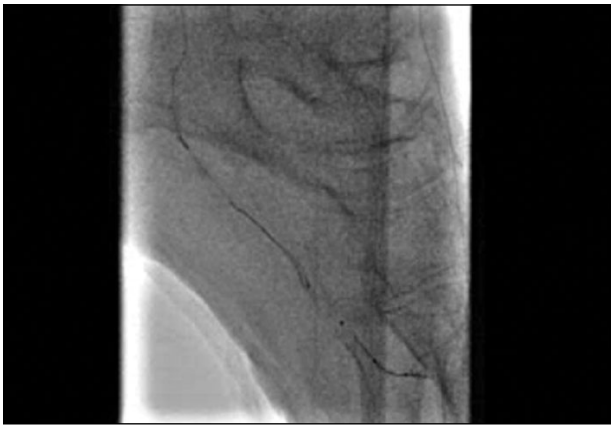

Figure 7. Wire escalation using hydrophilic wires and support catheters (0.018-inch CXI and 0.014-inch CXC) from both anterior and posterior tibial approaches with an eventual knuckled wire technique to recanalize the arch and obtain overlap of the wires in the distal lateral plantar artery.

The use of a 0.014-inch support catheter or low-profile over-the-wire balloon is essential for support during wiring of pedal vessels and the plantar arch. Wire exchanges, once the catheter has traversed the pedal arch, should be done with caution because kinking of the support catheter can occur, making passage of a new wire difficult. In this situation, a nonhydrophilic wire should not be forced forward, as it can damage the inner lumen of the catheter. Instead, a hydrophilic wire should be used and advanced with increasing pressure. Sometimes, withdrawing the catheter slightly will also help rewire the area that had kinked if the lumen is not damaged. Lastly, tenting down the distal part of the catheter with external pressure while withdrawing the catheter slightly may be enough to help straighten the bend in the artery to allow wire passage. Anticipation and avoidance of this problem would be the best strategy.

Wire choices should be based on the location and anatomy of the target vessel. In the proximal part of the foot, where it is relatively straight, a hydrophilic 0.014-inch guidewire is useful to probe for microchannels or even to try and cross an occlusion with the support catheter within a few millimeters of the tip. A low-weight 0.014-inch CTO guidewire can be useful if there is a side branch at the point of occlusion that repeatedly deflects the hydrophilic wire.

As progress is made into the forefoot, wire choices are typically hydrophilic. Wiring the pedal arch can be challenging even in situations when the vessel is partially or entirely patent but diseased. This is due to the tortuosity and the numerous side branches that are typically present. Judicious use of road mapping is useful in gauging progress and navigating the multitude of branches in this part of the foot. Procedural planning should be done with DSA images, as previously mentioned, but complete or partial unsubtracting during the procedure can be helpful to see the background bony landmarks, especially if road mapping is unavailable or not utilized.

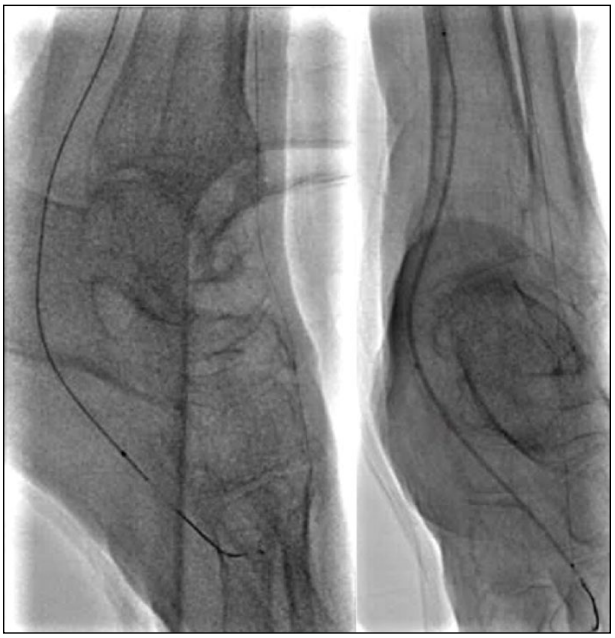

Figure 8. Orbital atherectomy and PTA of the severely calcified lateral plantar artery was performed in the section of the vessel where the wire was intraluminal.

Figure 9. With the plantar wire subintimal in the distal lateral plantar artery, a balloon was brought down over the dorsalis pedis wire and inflated. Subsequently, the plantar wire was able to pass into the arch and dorsalis pedis with relative ease. The pedal arch was dilated with a 2.5-mm balloon, and the distal posterior tibial was dilated with a 3-mm balloon.

The wire and wire bend are extremely important in maintaining directionality and steerability. A 0.014-inch guidewire, such as the Regalia (Asahi-Intecc), with superior torquability, steerability, and tip resiliency is a good first choice. However, if this wire is unsuccessful in navigating the typically tortuous pedal arch and its branches, the Fielder XT (Asahai-Intecc) is our wire of choice due to its 0.009-inch tip and its ability to hold a sharp bend very close to the tip (Figure 2). This wire is very delicate, and therefore, a support catheter should be used to exchange and deliver this wire to the point where its attributes of steerability and navigating tortuous branches is needed, so as not to damage the tip.

If no further progression of wire advancement can be made using these techniques from an antegrade approach or from the contralateral tibial artery, then a more aggressive hydrophilic wire such as a Pilot 200 (Abbott Vascular) can be exchanged to form a small radius loop to try and cross the lesion. Higher-weight CTO wires can also be used, but these are typically reserved for the contralateral pedal artery, where they will not have to be passed through the support catheter in the tortuous segment of the pedal arch. If blood return occurs at any point during wire exchanges, selective angiography or simultaneous injection angiography may be helpful. The looped wire technique can be used from both tibial vessel approaches to try and attain overlap of the wires. At that point, if the wires are in different planes, a reverse CART technique can be used to achieve through-and-through wire traversal. Wire position and progress should always be verified in two views. It is not uncommon to appear to be in the appropriate artery in one view only to find the wire inappropriately positioned in another view.

Once a through-and-through wire position is obtained, the wire can be exteriorized by driving it into a 0.018-inch support catheter in a straight portion of the tibial vessels. If successful, this can greatly assist in advancing a balloon around the arch. If a balloon is unable to be advanced despite these efforts, careful use of adjunctive orbital atherectomy may be considered. In this case, the wire would need to be exchanged for a 0.014-inch ViperWire atherectomy guidewire (Cardiovascular Systems Inc.). The use of a 1.25 Stealth Micro Crown (Cardiovascular Systems Inc.) on low speed is recommended to treat only the necessary areas with heavy calcification or where the balloon is getting caught. Keeping run times as short as possible is important given the limited amount of runoff in this distal site. Spasm can be seen in the digital vessels afterward, and liberal use of vasodilators is recommended. Orbital atherectomy should only be used in the pedal vessels by experienced operators.

Most vessels in the plantar arch can accommodate a 2.5-mm balloon (± 0.5 mm), and inflating a longer balloon to relatively low pressures (4–6 atm) is recommended. If the lesion does not dilate, adjunctive orbital atherectomy, focal force balloons, or downsizing the balloon by 0.5 mm and using higher pressures can all be considered.

Advanced bailout options to potentially salvage a partially successful pedal arch intervention include the use of digital access of the metatarsal artery or tibiopedal access. Tibiopedal access will allow the operator to continue the recanalization process in a retrograde fashion with

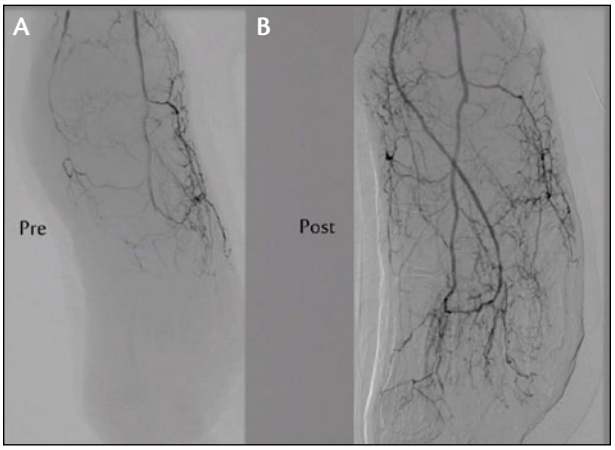

Figure 10. Preintervention (A) and postintervention angiograms showing a good result (B).

improved pushability and torquability of the equipment. The use of ultrasound for tibiopedal access is required and can be made easier by the presence of a retrograde wire in the vessel, which will improve visibility.

CLINICAL CASE

A 62-year-old man with end-stage renal disease, diabetes mellitus, coronary disease, and multiple previous toe amputations due to severe pedal artery disease presented with a gangrenous toe (Figure 3). Previous angiography showed a total occlusion of the peroneal and common plantar arteries and an occlusion of the dorsalis pedis in the midfoot (Figure 4). He had been medically managed for years while undergoing multiple toe amputations. The patient repeatedly declined below-knee amputation. At the time of consultation, we offered pedal arch reconstruction.

With a 45-cm sheath tip placed in a popliteal position, 6-F antegrade access in the left common femoral artery was achieved. Angiography confirmed the previously noted findings. Late-filling collaterals in the foot were imaged with 4 fps DSA images, and remnants of the pedal arch were visualized (Figures 5 and 6).

The dorsalis pedis was wired with a 0.014-inch Whisper wire (Abbott Vascular) and 0.014-inch CXI support catheter (Cook Medical) (Figure 7). This was brought into the lateral plantar artery where the wire could not be advanced any further. At this point, a 0.018-inch CXI catheter (Cook Medical) and Whisper wire were brought down the posterior tibial artery and the lateral plantar artery was wired, although this did require knuckling the wire at one point. Both wires were later exchanged for 0.014-inch Hydro ST wires (Cook Medical), and the lateral plantar wire was advanced into the distal branches of the foot.

At this point, we performed orbital atherectomy using the 1.25 Micro Crown device in the distal posterior tibial into the proximal lateral plantar to reduce the risk of dissection and allow better balloon expansion given the heavy calcification that could be seen by fluoroscopy within the common plantar artery and proximal lateral plantar artery (Figure 8). The area was dilated with a 3-mm balloon. We were still unable to get a wire to traverse the pedal arch far enough to deliver a balloon all the way around the arch and believed that the wires may still have been in different planes, with either one or both being subintimal. Therefore, a reverse CART technique was used, and a 2- X 80-mm balloon was inflated in the pedal arch over the dorsalis pedis wire. Subsequently, a new wire was easily able to traverse into the dorsalis pedis and up the anterior tibial arteries. Angioplasty using a 2.5- X 120-mm balloon was performed through the arch with a good result, and the procedure was concluded (Figures 9 and 10).

CONCLUSION

With the rapid advancement of operator techniques and equipment during the last decade, endovascular revascularization of the pedal arch that was seemingly impossible even several years ago is now feasible. Although there is no evidence-based argument to routinely recanalize the pedal arch, in the appropriate patient with a threatened limb, pedal arch reconstruction can be a valuable technique as part of an aggressive angiosome-based revascularization strategy. ■

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