Tibiopedal and Hybrid Percutaneous Arterial Access

Improving success rates in limb salvage and amputation prevention procedures.

BY JIHAD A. MUSTAPHA, MD, FACC, FSCAI; LARRY J. DIAZ-SANDOVAL, MD, FACC; CARMEN M. HEANEY, RN, BSN, CCRC, CIP; AND MATTHEW W. SEVENSMA, DO

In patients with severe peripheral arterial disease (PAD), obtaining adequate arterial access may represent the difference between amputation and limb salvage or the difference between major and minor amputation.

The incidence of severe PAD is steadily rising as we see our population with somewhat controlled cardiovascular risk factors aging into their late 80s to early 90s. Despite the relative control of these risk factors, the severity of tibiopedal disease continues to evolve with aging, and therefore, it is not surprising to see a directly proportional increase in the number of lower limb amputations.[1] Because of the gravity of the prognosis, all patients presenting with Rutherford class 5 or 6 must undergo an exhaustive evaluation. This should start with a thorough physical examination with delineation of the cutaneous angiosome, detailed noninvasive imaging of the tibiopedal vessels proximally and distally (looking for reconstitution of occluded "hibernating" vessels), and selective angiography of the target limb with delayed imaging (looking for collaterals) to determine which is the best arterial access and interventional strategy to follow for the planned limb salvage procedure[2,3] (Figure 1).

PHYSICAL EXAMINATION

The examination will focus on the detailed vascular history, as well as on evaluation of the femoral, popliteal, and tibiopedal pulses. The Rutherford classification is then completed with assessment of the presence or absence of ulcers and/or gangrene. Subsequently, the wound assessment is finalized with pictures taken in four standard views (dorsal, plantar, medial, and lateral) to obtain the cutaneous angiosome.

Figure 1. Cutaneous angiosome.

NONINVASIVE IMAGING

Ankle-Brachial Index

In patients with advanced PAD (Rutherford 5 and 6), ankle-brachial index (ABI) findings become less specific. ABIs are frequently found to be falsely elevated in patients with tibiopedal disease due to the presence of severe calcification of the vessel walls. Therefore, a complete evaluation should include a baseline Doppler flow interrogation, as it will be of extreme importance during follow-up to detect persistent patency or recurrence of occlusive pathology in the tibiopedal outflow vessels in these patients.

Duplex Ultrasound

Duplex ultrasound imaging is used at our institution to map the tibiopedal circulation. Imaging is repeated at the ankle and pedal levels to assess for distal reconstitution and the presence of hibernating vessels. This information can be used to determine potential areas for retrograde tibiopedal

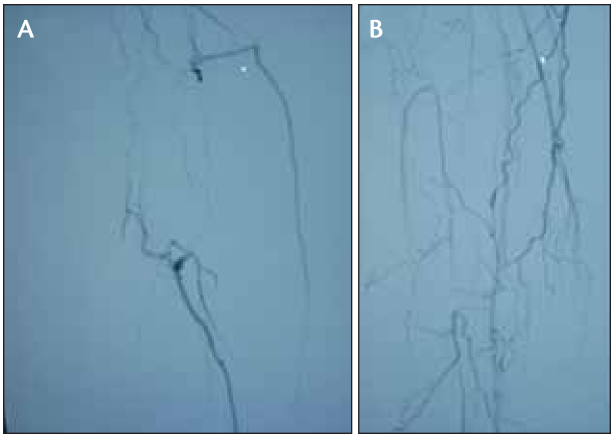

Figure 2. Superficial femoral artery (SFA)/popliteal chronic total occlusion (CTO) reconstituting at the anterior tibial artery (ATA) with poor tibiopedal runoff. Distal SFA and popliteal are absent (A). Absence of distal tibial runoff (ATA) (B). Angiograms obtained via an antegrade sheath in the common femoral artery (CFA).

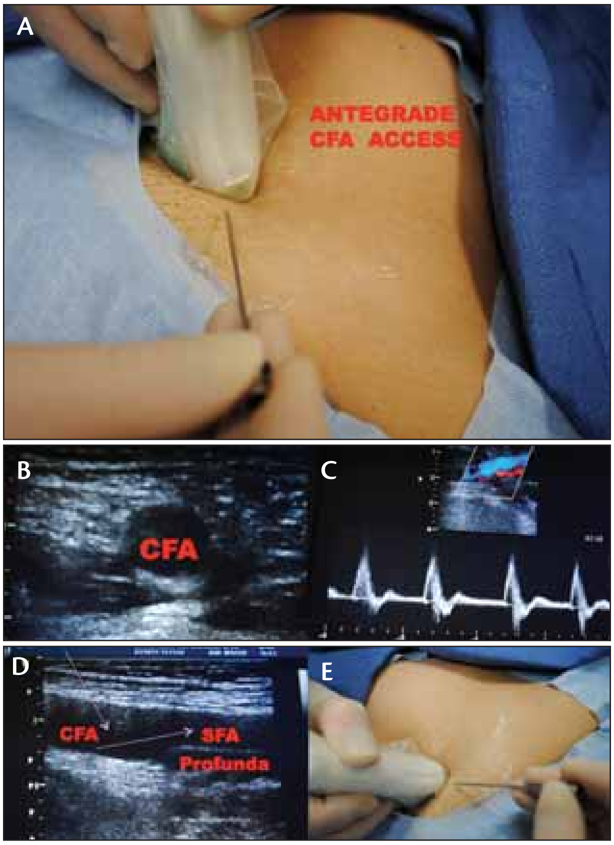

Figure 3. The preparation was ultrasound guided, and in this patient, the CFA bifurcation was low. Antegrade access guided with ultrasound (A). Normal CFA by direct ultrasonic visualization along with color flow and pulse wave: appearance of a normal cross-sectional image of the CFA (B). Normal color-flow Doppler along with triphasic pulse wave of the CFA (C). Longitudinal axis plane during CFA ultrasound-guided antegrade access (D and E). This can be used to guide access into a CTO of the SFA with angiographic "flush" occlusion (no SFA nub).

arterial access in complex tibiopedal cases. This mapping provides the noninvasive angiosome, which is then correlated with the cutaneous angiosome.

Selective Angiography

Historically, selective angiography has been the gold standard in defining the presence or absence of tibiopedal arterial inflow and outflow. Selective angiography will show the inflow and outflow vascular anatomy as well as the collateral circulation and the time to vessel reconstitution, which we use to determine the Jenali collateral scoring system[1] and to create the arterial angiosome map. The map is then correlated with the cutaneous and noninvasive angiosomes. This strategy will allow us to identify the vessel that requires endovascular intervention, as well as which will be the best arterial access approach.

Unfortunately, many decisions to perform major amputations have been made based on the inability to identify outflow vessels during selective angiography. At our institution, patients who undergo selective angiography and do not show evidence of tibiopedal outflow during delayed imaging with digital subtraction angiography must undergo tibiopedal duplex ultrasonic imaging, because this method will allow mapping of hibernating tibiopedal outflow vessels (Figure 2).

DETERMINING ACCESS APPROACH

Using the knowledge gained during the workup of the patient, the operator should have sufficient information to make the best decision regarding which arterial access strategy to use and, if needed, will be able to correlate the results of the cutaneous, noninvasive, and angiographic arterial angiosome mapping in order to select the appropriate tibiopedal vessel for access and intervention.

ARTERIAL ACCESS AND INTERVENTIONAL STRATEGIES IN LIMB SALVAGE/AMPUTATION PREVENTION PROCEDURES

Contralateral Retrograde CFA Access

The main advantage of the contralateral retrograde CFA approach is the familiarity of most operators with this technique. The main disadvantages are (1) loss of the coaxial force vector used to advance devices when attempting to cross a below-the-knee chronic total occlusion (CTO) and that (2) most of the available peripheral interventional

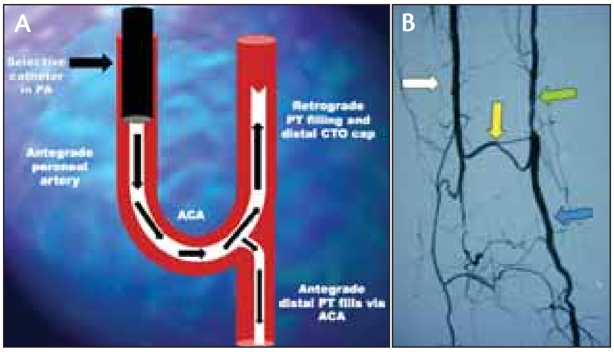

Figure 4. Selective peroneal artery (PA) angiography with retrograde filling of the distal cap of the CTO in the posterior tibial artery (PTA) via the anterior communicating artery (ACA). There is also antegrade filling of the distal patent PTA (A). Angiogram showing retrograde filling of the distal cap of the CTO in the PTA via the ACA (B). There is also antegrade filling of the distal patent PTA. Antegrade peroneal artery (white arrow), ACA (yellow arrow), retrograde PTA filling and distal CTO cap (green arrow), antegrade distal PTA fills via ACA (blue arrow).

devices are not long enough to reach lesions located at or beyond the distal third of the calf (Jenali zone 3)[2] from the contralateral approach.

IPSILATERAL ANTEGRADE CFA ACCESS

The ipsilateral antegrade CFA approach has evolved into the most commonly used arterial access site during below-the-knee complex limb salvage/amputation prevention procedures. The main disadvantage of this approach is the increased rate of complications from the access site. It is common to see more complications in obese patients who also have other comorbidities.

We have developed a rigorous protocol for ipsilateral antegrade CFA access, which has reduced the associated complication rates. At our institution, we start with preplanned placement of the patient in the antegrade position. The patient is then prepped and draped based on the preprocedure ultrasound used to identify the level of the CFA bifurcation into the superficial femoral artery (SFA) and profunda femoris artery, which is marked on the patient's skin to allow for adequate placement of the drape's window. In obese patients, the pannus is systematically retracted to expose the groin. Subsequently, we use fluoroscopy and palpation to identify the anatomic bony landmarks followed by intraprocedural ultrasound-guided arterial access with the use of a micropuncture echogenic-tip needle and a microsheath. Once access is confirmed angiographically, the microsheath is exchanged for a regular-sized sheath using standard techniques (Figure 3).

In patients with more complex anatomy, there are several

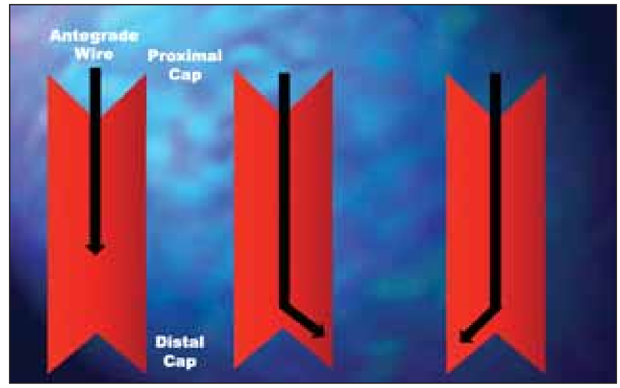

Figure 5. Wire crossing of the proximal cap of a CTO from the antegrade common femoral arterial access approach.

strategies with diverse degrees of complexity.

Generally, the next step is to look for the distal reconstitution of the occluded below-the-knee vessel. In cases of total occlusion of the PTA) and/or the ATA with a patent PA, we look for the presence of a large collateral vessel (termed *anterior communicating artery* [ACA]), communicating the PA with either the PT (most commonly variant observed) or the ATA. Then, we advance the 0.014-inch wire in an antegrade fashion through the PA, gain access into the ACA, and come back upward to gain retrograde access to the distal cap of the CTO in either the PTA or the ATA (Figure 4).

The main disadvantage of this approach is the lack of pushability once the wire is redirected upward. To compensate for the loss of the coaxial force vector, which can pose an obstacle to crossing the CTO, we always add an 0.018-inch support catheter and cross the CTO with 0.018-inch CTO wires.

Another option is to advance in an antegrade fashion via the nonoccluded vessel to the arches of the foot and turn back up via the arch connections into the occluded vessel in a retrograde fashion. The preferred devices for the pedal circulation are 0.014-inch systems. We compensate for the loss of coaxial force vectors by using 0.014-inch catheters and stiff 0.014-inch wires.

HYBRID PERCUTANEOUS ARTERIAL ACCESS

Combined Ipsilateral Antegrade CFA Access and Tibiopedal Retrograde Arterial Access

In complex interventions at our institution, the approach that is becoming routine is hybrid percutaneous arterial access. We gain access to the proximal cap of the CTO via antegrade arterial access in the CFA. Approaching the proximal cap of the CTO in the antegrade fashion increases the likelihood of successful crossing given that in most cases, the proximal cap has a concave-up morphology that allows for easier penetration (Figure 5).

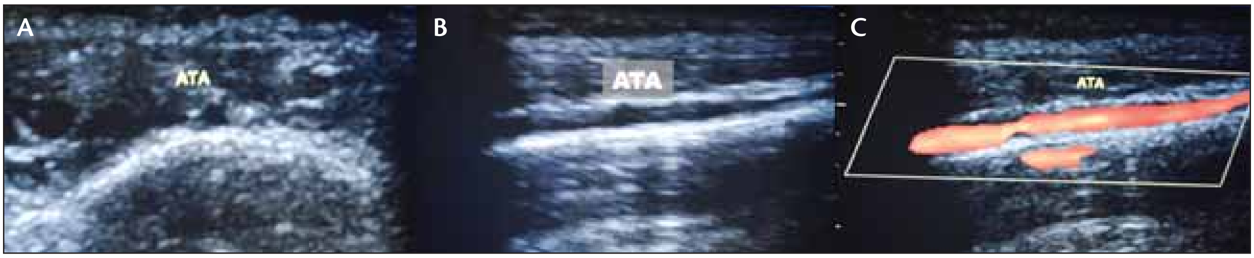

Figure 6. Ultrasound-guided ATA access. The ATA in the cross-sectional view (A). The ATA in the longitudinal view (B). The ATA in the longitudinal view with color-flow Doppler (C).

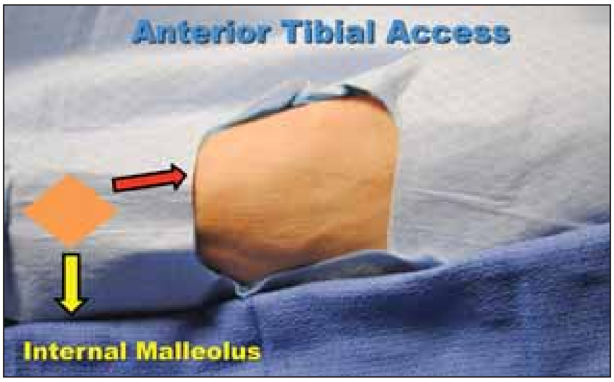

Figure 7. Tibial access preparation: The drape is placed at the area found by ultrasound to have no tibial veins surrounding the tibial artery.

The disadvantage of this approach is that once the distal cap of the CTO is reached, given its typical convex morphology, the wire (or other crossing devices) tends to bounce to either side of the center of the lumen, which is why we opt to cross the distal cap of the CTO with a retrograde approach via tibiopedal arterial access.

Tibiopedal arterial access is a technique that is becoming more common in recent years secondary to improvement in access technologies, interventional techniques, and increased indications for tibiopedal outflow endovascular treatments. Assessing the ideal spot for tibiopedal arterial access site is done by a combined approach using physical palpation of the target artery, knowledge of anatomical landmarks, and the use of ultrasound guidance. The preparation to access the tibiopedal arteries generally starts with an arterial ultrasound performed before the patient enters the catheterization laboratory and/or the operating room (to map the potential ideal access sites and to properly place the drapes) (Figures 6 and 7). The patient is positioned on the table in antegrade position, and an extra draped table is placed distal to the patient's feet serving as an extension to the table.

We use intraprocedural ultrasound, which allows us to accurately visualize and identify the tibial arteries and the accompanying veins and evaluate them with color Doppler and pulse-wave in both cross-sectional and longitudinal planes. This is of paramount importance because it decreases the likelihood of venous puncture, venous sheath placement, AV fistulas, and tibial artery spasm, which decreases the likelihood of success, because the lumen of the vessel is likely already compromised. By allowing direct visualization of the lumen (in the longitudinal plane), operators will be able to maneuver the guidewire around the plaque (Figures 8 through 10).

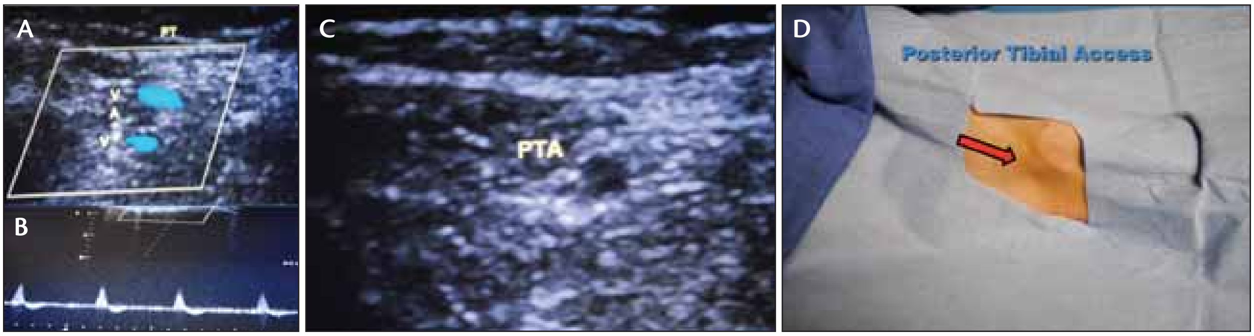

Figure 8. Ultrasound-guided PTA access. Notice how the PTA is surrounded by the posterior tibial veins, making access difficult and prone to complications. By scanning up and down along the vessel, we can find the "ideal" spot for access, and allow for the correct draping. Note the posterior veins surrounding the tibial arteries by their blue color (A). Pulsed-wave interrogation of the posterior tibial artery accurately identifies the artery from the veins (B). Isolating a tibial vessel from the surrounding veins is possible by scanning up and down along the plane of the target tibial artery (C). PTA access (D).

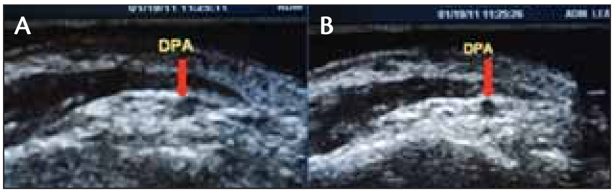

Figure 9. Ultrasound-guided access to the dorsalis pedis artery (DPA). Notice how minimal changes in the positioning of the probe can prove crucial in obtaining retrograde arterial access. Slight rotation/tilt of the ultrasound probe can define the target vessel with improved resolution. Cross-sectional image of the DPA "off plane" (A). Cross-sectional image of the DPA "in plane" (B).

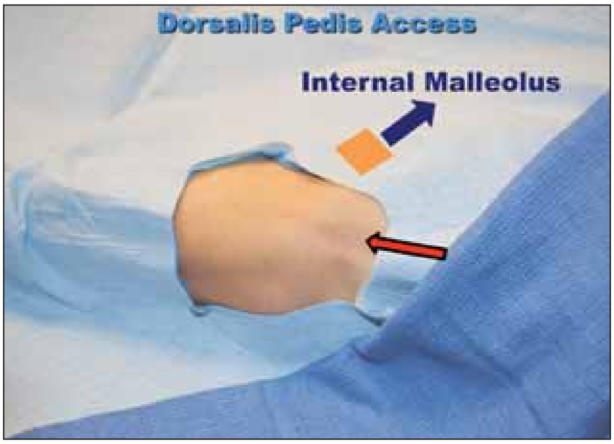

Figure 10. Preprocedural ultrasound aids in proper access-site selection and correct preparation and draping of the site.

Figure 11. Ultrasound probe, guiding access to the PTA with use of an echogenic-tip micropuncture needle.

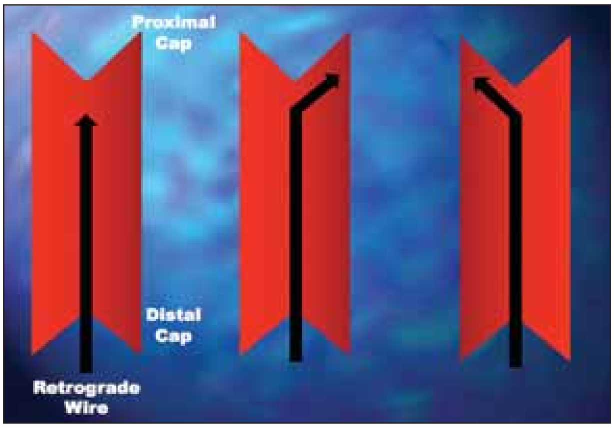

Figure 12. Wire crossing of the distal cap of a CTO from the retrograde tibiopedal arterial access approach.

Undoubtedly, being able to visualize the target vessel as the echogenic-tip micropuncture needle enters the anterior wall of the artery allows the operator to stop in the center of the artery and avoid any additional trauma to the posterior vessel wall, automatically reducing the complication rate (including AV fistulas) and increasing the procedural success rate, all of which underscore the importance of direct visualization instead of "blind" percutaneous tibial access. This approach, although highly successful (once the learning curve is overcome), does require extra time and preparation. However, in this set of patients with advanced disease and comorbidities who are being referred for high-risk complex interventions, taking the extra time and planning the intervention and access approach ahead of time will result in better outcomes and fewer complications (Figure 11).

Once we achieve retrograde tibiopedal arterial access, we proceed to cross the distal cap of the CTO. Given its typical convex morphology, we have a high rate of success when we attempt to cross it. Once we advance the wire/device through the hibernating lumen to the level of the proximal cap of the CTO, the wire/device tends to be deviated to either side of the center of the lumen given the "concave-up" shape of the proximal cap (Figure 12).

Once the proximal and distal caps of the CTO are crossed and both wires are in the hibernating lumen, the access is transformed to an antegrade approach with the larger sheath placed in the CFA. The reversal process is performed by exchanging the antegrade wire for a snare; we then proceed with antegrade snaring of the retrograde 0.018-inch wire (Figures 13 and 14). Once the snared wire is through the antegrade sheath in the CFA, a new 0.018-inch catheter is advanced in the antegrade fashion while removing the retrograde 0.018-inch catheter from the tibial access site. Once the antegrade 0.018-inch catheter is advanced past the distal CTO cap, the retrograde wire and the microsheath are removed, and hemostasis of the tibial access site is achieved (Figure 15).

As many interventionists may argue, this technique is time- and resource-consuming. To illustrate our argument,

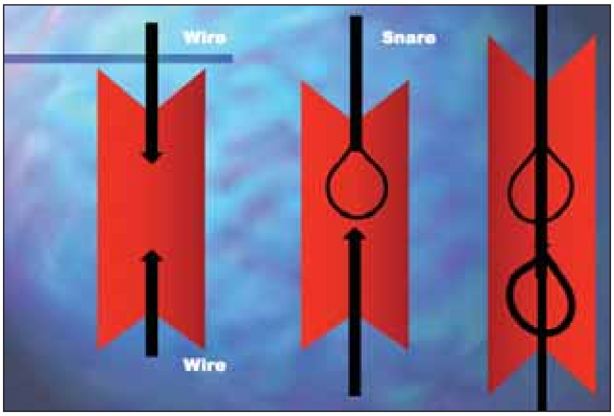

Figure 13. Wire crossing of both the proximal and distal cap of a CTO using the hybrid percutaneous arterial access approach.

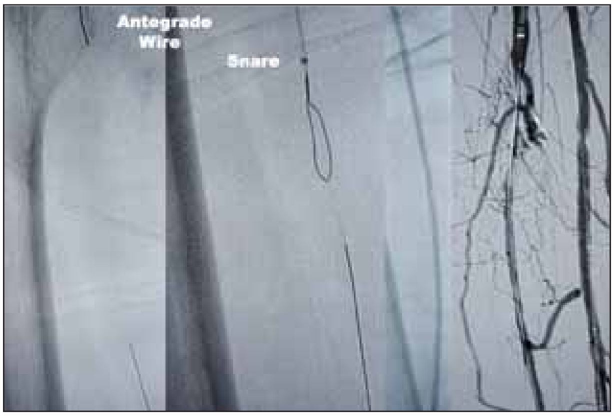

Figure 14. Angiograms showing the antegrade snaring technique after hybrid percutaneous arterial access.

Figure 15. Tibial access site hemostasis.

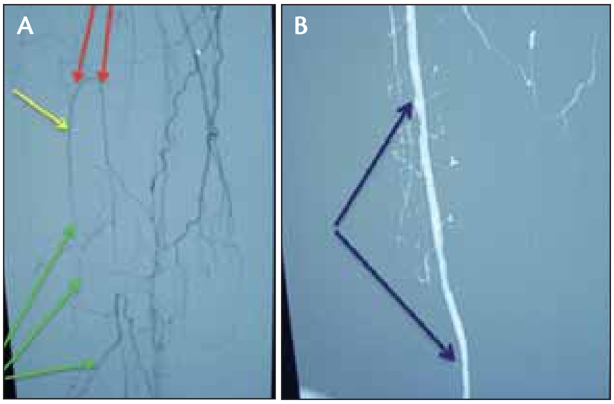

Figure 16. Arteriogram shows complex ATA CTO (A). This requires antegrade CFA access to secure flow into the ATA and tibial access to cross the distal cap retrogradely. Very complex ATA CTO with flow into the peroneal artery (red arrows), proximal ATA (yellow arrow), no distal ATA runoff (green arrows). After retrograde tibial access, we cross the ATA CTO distal cap and find the "hibernating" lumen on retrograde angiogram (B). Hibernating ATA found on ultrasound and confirmed after ultrasound-guided tibial access and retrograde arteriography (blue arrows).

we will use the case of a patient with critical limb ischemia (CLI) and no evidence of distal tibial runoff. Some interventionists would advocate using "blind stick" tibial access. However, in this particular case, this would be difficult because the tibial runoff does not reach beyond Jenali zone 2.[2]

Ultrasound-guided access is essential to ensure access into the target artery and to increase the likelihood of obtaining direct flow to the distribution of the ATA and the DPA where the tissue loss is located based on arterial and cutaneous angiosome mapping (performed before the procedure in the office setting). After obtaining tibial access and crossing the distal cap of the CTO in the ATA, we can see the "hibernating lumen" via a retrograde angiogram obtained via the 4-F microsheath in the ATA (Figure 16).

The ATA has a much longer patent segment than what originally was seen on the antegrade angiogram. The arterial mapping is now complete, and this allows us to plan the interventional strategy to use, which in this case will require connecting the ATA to the CFA.

The complexity of the ATA requires crossing its distal CTO CAP from the retrograde approach to ensure preservation of the proximal/ostial ATA's patency. The Treasure 12 wire (tip load 12 grams) (Asahi Intecc USA, Inc., Santa Ana, CA) is used to cross the distal CTO CAP and advanced into the popliteal artery in a retrograde fashion. Via the antegrade approach, the Crosser 14S (Bard Peripheral Vascular, Inc., Tempe, AZ) was used to cross the proximal SFA CTO and then advanced all the way through the SFA-popliteal hibernating lumen down to the spot in the popliteal artery where the retrograde Treasure wire is parked (Figure 17).

Once there, the antegrade wire is exchanged through a QuickCross catheter (Spectranetics Corporation, Colorado Springs, CO) for a snare wire, and the distal Treasure wire is snared proximally through the antegrade sheath in the CFA, allowing antegrade use of equipment to finish the intervention (Figures 18 and 19).

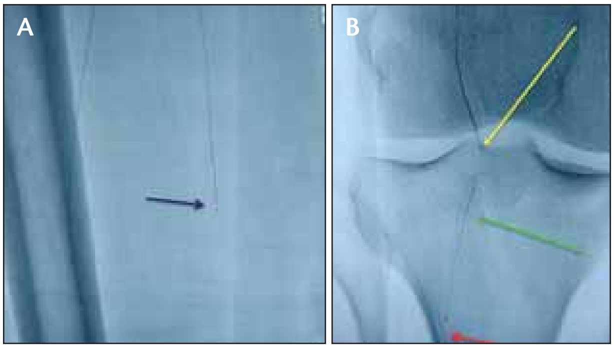

Figure 17. Crosser from the antegrade CFA 7-F sheath traversing the SFA CTO (A). Crosser in SFA (blue arrow). Treasure 12 from the retrograde ATA tibial microsheath (B). Crosser tip (yellow arrow), Treasure 12 (green arrow), QuickCross 0.018-inch (red arrow).

Figure 19. Postpercutaneous transluminal angioplasty angiograms. Hibernating SFA lumen (A). Direct flow into the ATA from the popliteal artery (B). Hibernating distal ATA with good runoff (C).

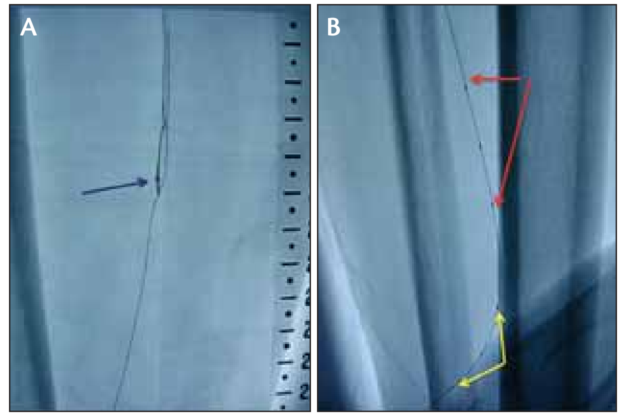

Figure 18. Gooseneck snare of Treasure 12 wire (A). Snare tip (blue arrow). Antegrade 0.018-inch catheter (red arrows) advanced over the squared 0.018-inch wire and removal of the retrograde 0.018-inch catheter (yellow arrows) (B). The equipment is now advanced antegrade from the 7-F sheath in the CFA.

CONCLUSION

Complex endovascular tibiopedal interventions are gradually becoming the first line of therapy for CLI patients with the endpoint being either limb salvage (with performance of a lesser degree of amputation) or complete amputation prevention. To achieve this goal, operators must understand and master the rapidly evolving interventional techniques as well as the preprocedural planning, which requires establishing rigorous protocols that encompass the basic bedside examination (to establish the cutaneous angiosome), the noninvasive evaluation (to establish the noninvasive angiosome and mapping of the hibernating vessels that could be used for tibiopedal access), and the performance of selective and subselective angiography to identify collateral circulation, recreate the arterial angiosome, and finalize the identification of the target vessels for access and intervention.

Although time-consuming, after this protocol, using the hybrid percutaneous arterial access strategy will prove beneficial by increasing the likelihood of staying intraluminal after finding the hibernating lumen[4] without invading the subintimal space, which, as opposed to the above-the-knee circulation in the tibiopedal territory, is likely to signify procedural failure with the ensuing consequences for our patients. This will improve procedural success rates, decrease the significant morbidity and mortality related to CLI and amputations, decrease health care costs, and enhance the quality of life of our patients. ■

Jihad A. Mustapha, MD, FACC, FSCAI, is with the Department of Cardiology, Metro Health Hospital in Wyoming, Michigan. He has disclosed that he is a paid consultant to and receives grant/research funding from Bard Peripheral Vascular. Dr. Mustapha may be reached at jihad.mustapha@metrogr.org.

Larry J. Diaz-Sandoval, MD, FACC, is with the Department of Cardiology, Metro Health Hospital in Wyoming, Michigan. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein.

Carmen M. Heaney, RN, BSN, CCRC, CIP, is with the Department of Clinical Research, Metro Health Hospital in Wyoming, Michigan. She has disclosed that she holds no financial interest in any product or manufacturer mentioned herein.

Matthew W. Sevensma, DO, is with the Department of Cardiology, Metro Health Hospital in Wyoming, Michigan. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein.

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