Case Reports and Series

Aplastic Posterior Tibial Artery in the Presence of Trimalleolar Ankle Fracture Dislocation Resulting in Below-the-Knee Amputation

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Knowledge of anatomic variations in the branching pattern of the popliteal artery is important because damage to its branches can be limb threatening. Kim et al (1) proposed a new classification of the branching pattern of the popliteal artery by modifying the original classification system by Lippert and Pabst (2). They classified the branching patterns into 3 categories and 3 subtypes (Table). The main distinction of the new classification system is their third category. This describes a normal branching pattern and sequence; however, the proximal segments of the anterior tibial (AT) and/or posterior tibial (PT) branches are congenitally absent or hypoplastic. Category III variants have the most clinical significance to vascular, orthopedic, and podiatric foot and ankle surgeons. The 3 major variants in the popliteal branching pattern reported by Kim et al (1) are its trifurcation (IB), high division with a normal branching sequence (IIA), and the hypoplastic-aplastic PT with the distal PT replaced by the peroneal (PR) artery (IIIA). These major variants were also predominantly seen in a review by Kropman et al (3).

Normally, the popliteal artery divides into the AT and PT arteries. In some cases, it can bifurcate into the AT and PR arteries, with the PT artery absent or rudimentary (4–6). Angiographic studies have shown the incidence of a hypoplastic-aplastic PT artery ranges from 0.8% to 3.8%. In anatomical studies, the incidence has ranged from 1.5% to 11% (1,2,5,7–11). Compensatory hypertrophy of the PR artery with a hypoplastic or aplastic PT or AT artery might indicate a variant arterial supply to the foot (1). This enlarged PR artery, the “peronea magna” or “great” peroneal artery as described by Senior (6,12) either joins and reinforces the PT artery or replaces it in the distal leg and foot (4,6,12,13). When the PR artery has replaced the PT artery at the ankle, the distal aspect typically continues into the sole as the lateral plantar artery. The medial plantar artery is then usually absent (6,12,13). Cases have been reported in published studies that have documented the PR artery replacing the PT artery but with the distal segment in the same anatomic location as the expected, but absent, PT artery (1,14). Cases of a hypoplastic-aplastic PT artery have also been documented in individuals with inborn foot deformations (15–17). In other cases, the arterial defect might not be diagnosed for years and might only be recognized incidentally (11,18).

Detection of this anatomic variant on physical examination can be deceiving and not easily determined. Chow et al (19) retrospectively evaluated multidetector computed tomographic angiography (CTA) to determine donor and recipient site arterial suitability for vascularized free flap transplantation. They found 4 of 32 lower extremities (12.5%) had anatomic variants. These variants involved the popliteal, AT, PT,
and pedal arteries. All results were compared with their original physical examination findings. Their physical examinations findings, in all cases, were not predictive of the presence of any arterial anomaly.

Significant negative outcomes can occur when anatomic variations of the popliteal artery have not been appreciated. Orthopedic, vascular, and podiatric foot and ankle surgeons should be aware that anatomic variants exist. However, the question remains whether we necessarily need to perform preoperative vascular screening with angiography and/or CTA. No guidelines have been set for its use in foot and ankle surgery and trauma. According to the published data, the routine use of angiography and/or CTA is controversial, even for cases in which such imaging modalities are most commonly used, such as free flap reconstructive surgery (19).

We present an interesting, but unfortunate, case of an 86-year-old female who sustained a trimalleolar ankle fracture dislocation that resulted in below-the-knee amputation after open reduction and internal fixation of the fracture. This patient ultimately had a type IIIA popliteal variant (Table) that was not appreciated on physical examination. The incidence of this variant is approximately 3.8% according to the published data. To the best of our knowledge, this is the first documented case report discussing type III popliteal variants in foot and ankle surgery.

Case Report

The patient was an 86-year-old female who presented to the emergency department with a right ankle fracture dislocation. She had no secondary injuries. The right ankle was globally tender. The patient had full, painless range of motion at the right hip and knee. The compartments were soft. Her skin was intact, with diffuse ecchymosis and edema localized to the ankle. Sensation was intact to all lower extremity nerve distributions. The PT and dorsalis pedis (DP) pulses were nonpalpable and intact. Radiographs revealed a displaced trimalleolar fracture with the talus posteriorly dislocated. The fibula was comminuted and displaced. Fractures were present in the medial and posterior malleolus (Fig. 1). The right ankle fracture was reduced and splinted without complications. Postreduction plain radiographs confirmed the reduction. A noncontrast-enhanced computed tomography scan of the right lower extremity was obtained for preoperative planning. The patient was admitted for pain control and social placement.

The patient returned 8 days later for definitive fixation. On admission, the examination findings were unchanged. The vascular examination revealed palpable PT and DP pulses with a brisk capillary fill time (CFT). The next day, she underwent open reduction and internal fixation of the right trimalleolar ankle fracture with posterior lip fixation. The patient was positioned prone. The posterior malleolus was stabilized with a posterior malleoli plate and 3.5-mm locking and nonlocking screws. The fibula was stabilized with an anatomical fibular plate, and the medial malleolus was fixated with 2 partially thread cannulated screws (Fig. 2). No intraoperative complications were noted. Shortly after the procedure, the nursing staff noted delayed CFT to the digits; however, the CFT returned when the foot was placed in a dependent position. The next day the patient was evaluated and found to have palpable PT and DP pulses and a brisk CFT. The patient’s pain was well controlled, and she was discharged to a local skilled nursing facility.

The patient returned for a follow-up examination 1 week after being discharged from the hospital. The physical examination revealed nonpalpable pedal pulses, but the PT and DP pulses were identifiable on ultrasound examination with a handheld Doppler probe. Ischemic changes were noted along the dorsal and lateral aspects of the foot. The hallux and third toe remained viable but demonstrated prolonged CFTs. The incision was well approximated. No erythema, discharge, drainage, or dehiscence was present; however, full-thickness tissue necrosis had developed, consistent with dry gangrene, along the lateral aspect of the right heel and measuring 5 × 5 cm. The patient was readmitted to the hospital, and vascular surgery was consulted. A lower extremity arterial duplex Doppler examination was ordered by the vascular surgery team, with the official impression of the study noting no hemodynamically significant arterial disease at the right lower extremity. Because of the degree of necrosis, the vascular surgery team consulted with the interventional radiology staff to evaluate the limb with angiography with right lower extremity runoff. The official interventional radiology report (Fig. 3A,B) concluded:

- Traumatic occlusion of the distal aspect of the right AT artery at the level of the superior aspect of the talus with no reconstitution of the DP artery
- Likely congenital absence of the PT artery
- Traumatic segmental occlusion of the PR artery approximately 10 cm above the ankle that was reconstituted approximately 5 cm distally into the normal expected course of the PT artery and was the only significant arterial supply to the foot

The angiogram revealed no trifurcation of the popliteal artery. The branch of the PT artery was congenitally absent. The branches of the AT and PR arteries were present (Fig. 3C). When reviewing Fig. 3A,B, the interventional radiology report noted traumatic occlusion of the AT artery. The prevailing explanation was that the AT artery had been traumatically occluded. This could have resulted from either an iatrogenic cause or intimal injury (20) not detected during the index examination. It is also plausible that the AT artery was congenitally hypoplastic; however, this would be difficult to prove definitively without a previous arteriogram or CTA. The finding of a congenitally aplastic PT artery is consistent with the IIIA popliteal variant using the Kim classification (1). This has an occurrence rate of 3.8%. This, combined with the traumatically occluded AT and PR artery, single-handedly eliminated all the blood supply to the foot, causing critical pedal ischemia. Peculiarly, the patient still exhibited pedal pulses identifiable on ultrasound examination with a handheld Doppler probe, although obvious clinical and angiographic signs of pedal ischemia were present. The results of the angiogram demonstrated a result consistent with that described by Chow et al (19). The physical

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Abbreviations: AT, anterior tibial; PR, peroneal; PT, posterior tibial.
examination findings in the present case were not predictive of any arterial anomaly present until noted on the angiogram.

The vascular surgery team offered the patient a bypass based on the angiographic findings. However, because of the significant amount of soft tissue necrosis that had occurred, a high likelihood of failure was explained to the patient. Initially, the patient wanted to pursue limb salvage measures but then decided to proceed with below-the-knee amputation. The patient was doing well since the amputation. She was fitted for a prosthesis and participated in physical therapy once she was cleared by her vascular surgeon. At approximately 18 months after her below-the-knee amputation, she was living at home with her family and able to complete her activities of daily living in an independent manner.

Discussion

Angiosomes

Throughout the preoperative and perioperative workup, no physical examination findings were present indicating the possibility
of vascular insult leading to critical limb ischemia. The patient had pulses at the location of the PT and DP arteries that were identifiable on ultrasound examination with a handheld Doppler probe. The pedal pulses were faintly identifiable on the day of her below-the-knee amputation. It is difficult to understand how this could occur when both the AT and PR arteries were traumatically occluded. Angiosomes of the foot and ankle have been well described by previous investigators (21–23). In the presence of popliteal variants, the angiosomal vascular distribution to the foot and ankle can be significantly altered.

Arterial connections around the ankle are complex and difficult to evaluate. Normally, the PT, AT, and PR arteries of the leg communicate with each other at the level of the ankle joint. In the presence of a popliteal variant, this predictable distribution becomes more convoluted. In the normal anatomy, the AT and PR arteries are directly connected through the anterior perforating branch of the PR artery and the lateral malleolar branch of the AT artery. The flow of the PR artery can be retrograde from the AT artery by way of the lateral malleolar artery. The flow can also be antegrade, to provide a collateral support to the AT artery. Within the foot, the AT and PT arteries communicate directly by way of the anastomosis of the DP with the lateral plantar arteries (21).

Theorized Mechanism of Perfusion

In the present case, it was difficult to determine the exact mechanism of blood flow, especially in the presence of an anatomic popliteal variant. Because the patient had a type IIIA popliteal variant, the PR was dominant to replace the aplastic PT artery. This became the primary vascular supply to the plantar aspect of the foot. If pulses were identifiable on ultrasound examination with the handheld Doppler probe, even on the day of the patient’s below-the-knee amputation, it is quite possible that antegrade arterial inflow was occurring from the perforating branch of the PR, which was not traumatically occluded. The anastomosis with the lateral malleolar artery failed to supply antegrade or retrograde support owing to the traumatic disruption to the AT artery.

Antegrade flow from the remaining aspect of AT artery then most likely traveled through the anastomosis of the first dorsal metatarsal artery between the DP and the lateral plantar artery. Retrograde flow at this anastomosis most likely explains the pulses identifiable on ultrasound examination with a handheld Doppler probe at the other end of the traumatically severed PR.

Angiographic Imaging

No guidelines are available to justify the routine use of invasive angiographic imaging after foot and ankle trauma. Intuitively, patients with known peripheral arterial disease, claudication, or other metabolic conditions contributing to vascular disease require invasive angiographic imaging before any surgical intervention. Patients with an ischemic foot or a Gustillo IIIb/IIIc fracture should be considered

Fig. 2. The posterior malleolus was stabilized with a posterior malleoli plate and 3.5-mm locking and nonlocking screws. The fibula was stabilized with an anatomic fibular plate, and the medial malleolus was fixated with 2 partially threaded cannulated screws.

Fig. 3. (A and B) Traumatic occlusion of the distal aspect of the right anterior tibial (AT) artery. Traumatic segmental occlusion of the peroneal artery approximately 10 cm above the ankle that was reconstituted approximately 5 cm distally. (C) No trifurcation of the popliteal artery was present. The branch of the posterior tibial artery was congenitally absent. The branches of the anterior tibial and peroneal (PR) arteries were present.
high-risk patients necessitating angiographic imaging to assess the blood flow to the lower extremity.

On the surface, our case was a straightforward trimalleolar fracture dislocation in an otherwise healthy elderly patient. Obviously, an angiogram or CTA would have been helpful in identifying the variation in the vascular anatomy. However, no physical examination findings or patient risk factors were present to warrant the use of invasive angiographic imaging.

Lower Extremity Allen Test

Several methods are available to evaluate the vascular status of the lower extremity. These range from physical examination to invasive tests, such as angiography. Other common tests include ankle/brachial indexes, directional Doppler flow studies, toe pressure determination, and magnetic resonance angiography (24–29). Each of these tests helps define the anatomy and aid in the evaluation of healing potential. However, these tests could fall short in addressing specific functional changes in the lower extremity circulation (30).

In the presence of foot and ankle trauma, performing a manual vascular examination at the bedside can be difficult owing to the localized soft tissue edema. An ultrasound examination using a handheld Doppler probe is a quick method to assess the blood flow to the foot at the AT, PT, and PR arteries. Haddock et al (30) described the lower extremity Allen test (LEAT) as an adjunct examination to the angiographic data available when determining the appropriate recipient vessel during the planning for free tissue transfer. This test is performed by placing a handheld Doppler probe at the first dorsal metatarsal artery in the first web space. Initially, both the DP and PT arteries are compressed (Fig. 4). A persistent signal indicates collateral flow through the PR. Haddock et al (30) did not describe the exact mechanism by which a signal remains but did note this would be highly unusual, because the PR artery usually reconstitutes at the DP pulse, which has already been initially compressed.

If the signal is not heard at the first interspace, pressure on the DP artery should be released (Fig. 5). A return of the signal would indicate adequate inflow at the DP artery. If releasing pressure on the DP artery does not result in a return of the signal, the PT artery should be released (Fig. 6). If the signal returns under these conditions, the distal foot is dependent on the PT artery for perfusion.

The discussion of the LEAT demonstrates that simple digital pulse examination can be potentially misleading, because retrograde flow can yield palpable vessels in an otherwise healthy patient. This is the
basis of our theorized blood flow mechanism discussed above and could explain why our patient’s pulses were identifiable on ultrasound examination with a handheld Doppler probe even on the day of our patient’s below-the-knee amputation. Haddock et al. (30) described the LEAT as an easy test to perform that can detect cases in which a single vessel might be responsible for distal perfusion of the foot. The LEAT can be of service to the foot and ankle surgeon. The ability to identify abnormal distal perfusion to the foot could provide enough insight to warrant evaluating the patient with angiography or CTA.

In conclusion, to the best of our knowledge, this is the first case report describing popliteal variants that ultimately resulted in critical limb ischemia and below-the-knee amputation after foot and ankle trauma. This was an unfortunate case in which the anatomic variation altered the expected outcome from a relatively straightforward surgical case. Although the incidence of popliteal variants is rare (1), it is possible the LEAT could have been helpful in initially identifying the obvious anatomic variation in the vascular supply to our patient’s foot. The LEAT is extremely easy to perform at the bedside, and we propose it should be a part of any initial physical examination to ensure accurate identification of possible abnormalities in the vascular supply to the foot in the presence of foot and ankle trauma.

References