Why Do Transmetatarsal Amputations Have a High Rate of Failure?

Use of the angiosome theory and proper incision placement can improve results.

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In 1855, transmetatarsal amputations (TMA) were originally used to treat trench foot. However, their use has since become widespread by podiatric, vascular, and orthopedic physicians to treat patients with several diagnoses. Diabetic patients (DM) are often a subgroup who receive this level of amputation as an alternative to more proximal amputations. A TMA is an effective procedure to manage severe forefoot infection and ulceration in DM patients because it aims to maximize foot function and energy expenditure by preserving a significant portion of the foot.[6] TMAs allow patient ambulation, can maintain a patient's independence, and can be disguised with normal footwear.[6]

However, research has shown that despite TMAs being a good surgical option for DM patients, many of the recipients tend to experience difficulty with wound closure. Wound breakdown is a common complication that has been shown to occur in 40-70% of TMAs, and 82% of patients who receive TMAs go on to need additional procedures due to complications.[5,6] Several theories have been proposed to explain this phenomenon, but none have been accepted as a definitive explanation.

Figure 1: Illustration of the angiosome distribution of the foot.[8]

Angiosomes

A proposed hypothesis to the high rate of TMA failure is ischemic and angiosome injury. The angiosome theory was first described by Ian Taylor in the upper extremity and was later expanded to all areas of the body (Figure 1).[9] It divides the foot into six different angiosomes, or three-dimensional blocks of tissue fed by a single source artery,[10] Three angiosomes originate from the posterior tibial artery: the medial calcaneal branch, medial plantar, and lateral plantar arteries. One comes from the anterior tibial artery: the dorsalis pedis artery. Two angiosomes come from the peroneal artery: the lateral calcaneal branch and anterior perforating branches.

Furthermore, vascular redundancy links neighboring angiosomes to one another via artery to artery connections and choke vessels.[9] The application of the angiosome theory to wound healing has shown to significantly increase the rate of limb salvage in DM patients.[3] Also, direct revascularization of the foot angiosome affected by ischemic tissue may improve wound healing and limb salvage rates compared to indirect revascularization approaches.[3]

A second aspect of the angiosome theory examines antegrade and retrograde flow through vessels. Ante-

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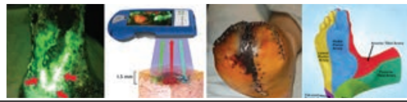

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grade flow is defined as blood coming to the area from the direct source artery. Retrograde flow is blood coming to the area indirectly from a different source artery. Vascular redundancy allows for retrograde flow to develop if the direct route is disrupted or compromised. The dorsalis pedis, medial plantar, and lateral plantar angiosomes are the dominant blood supply involved when performing a TMA.

Antegrade flow of the dorsalis pedis angiosome typically comes from the anterior tibial artery. Retrograde flow to the dorsalis pedis can source from the medial plantar artery via the deep plantar perforating branch in the 1st interspace or the perforating branch from the peroneal artery. The antegrade flow for the medial and lateral plantar angiosomes is from the posterior tibial artery. The retrograde flow for the medial plantar can be supplied by the dorsalis pedis via the deep plantar perforating branch in the 1st interspace and the lateral plantar artery via the crucial anastomosis. The retrograde flow for the lateral plantar artery is the dorsalis pedis directly and the medial plantar artery via the crucial anastomosis.

Figures 2 and 3: Clinical presentation of patient post-operatively. Black ischemic tissue can be seen along the plantar flap and incision.

A major consideration when planning a TMA surgery is incision placement. A balance between four factors is needed for optimal surgical incision placement: adequate exposure of the surgical site, adequate blood supply to the incision area, the sparing of nerves, and incision being parallel to the skin tension lines. According to Attinger, et al., blood flow to the incision is maximized when the incision is between two angiosomes.[2]

Furthermore, Creech, et al. conducted a cadaveric study and concluded that resection of the first metatarsal within 2 cm of the first metatarsocuneiform joint jeopardized severing the deep perforating artery.[4] This artery was 15.62 mm from the joint on average, and 89.41% were within 2 cm of the joint.[4] The deep perforating artery provides a route for retrograde flow between the medial plantar and dorsalis pedis arteries. If disrupted, the patient is at risk for ischemic flap complications.[4]

The posterior tibial artery and its end arteries are of particular importance when planning a TMA due to the plantar flap's dependency on these vessels. If the posterior tibial, medial plantar, lateral plantar arteries or their anastomoses are disrupted, the plantar flap is at risk for ischemic failure. TMAs are usually closed with the plantar skin moving dorsally to meet the superior portion of the incision. Because of this surgical technique to plan for greater walking surface of the foot, the posterior tibial, medial plantar, and lateral plantar angiosomes are more vital to the ultimate success of the TMA.

Blood Flow Evaluation

Evaluation of the direction of blood flow through the posterior tibial artery can dictate the surgical planning. For example, if biphasic Doppler sounds can be heard through the posterior tibial artery, this does not necessarily indicate antegrade blood flow. If a physician can occlude the lateral plantar artery and the Doppler sounds cease, then it can be insinuated that the posterior tibial artery has strong retrograde flow via the lateral plantar artery. This example illustrates that biphasic Doppler sounds do not always indicate direction of blood flow and can be due to vascular redundancy. Therefore, it is paramount to evaluate all angiosomes separately and plan surgical incisions based on this information.

If retrograde flow is established to the plantar flap, presumably due to occlusion of the posterior tibial artery, then the connection between the dorsalis pedis and lateral plantar artery also needs to be taken into consideration at the time of the incision in order to preserve this retrograde flow.[7] If an anastomosis is disrupted by surgical trauma in a retrograde flow angiosome, the risk for wound ischemia and dehiscence is increased.[1] The lateral plantar artery's connection to the dorsalis pedis needs to be protected so it can continue to supply oxygen and nutrients to its angiosome. One approach to preserve this connection is by extracting the lateral four metatarsals laterally and the 1st metatarsal medially,[7] thus preventing the disruption of the perforating vessel. If the retrograde flow through the posterior tibial artery is compromised, then the same effect on the plantar flap is expected. Ultimately, if retrograde flow is disrupted to the arteries supplying the plantar aspect of the flap, the risk for ischemic in-

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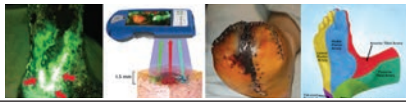

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jury and failure is expected to increase substantially. The same logic can also be applied to the dorsal aspect of the TMA flap.

In the case below, the angiosomes are examined for a patient that has undergone a TMA. The patient is a 71-year-old male with a history of diabetes mellitus, peripheral neuropathy, HTN, TIA, first degree heart block, and glaucoma. Podiatry services were consulted during an in-patient hospital stay for suspected cellulitis, and a plantar forefoot wound was discovered (5.0 cm x 3.0 cm with 100% dry eschar base)(Figures 2 and 3). Periwound erythema was noted. The patient was a poor historian, but states pain in the foot had gotten worse in the three days prior to podiatric consultation. The physical exam revealed dorsalis pedis, and posterior tibial pulses were palpable, but diminished bilaterally. Pitting edema was noted to the right foot. Capillary refill time was greater than five seconds bilaterally. Light touch was diminished bilaterally distal to the ankle. Motor function and range of motion were intact bilaterally.

A TMA was deemed an appropriate treatment for his forefoot ulceration. Post-operatively, the plantar flap of the TMA site was noted to appear darker in color from the dorsal flap with black eschar noted along the incision site. Per the protocol of the hospital, vascular services were consulted to assess the blood flow of the failing TMA site, and an angiogram was performed. Vascular surgeons performed a digital subtraction angiogram and noted severe posterior tibial arterial occlusion and partial peroneal arterial occlusion. This finding led to a right posterior tibial artery angioplasty, but unfortunately, the limb could not heal and a below-the-knee amputation was completed a week after the vascular intervention.

A possible explanation of this TMA failure is the decreased blood flow in the posterior tibial, medial plantar, and lateral plantar angiosomes, leading to plantar flap failure and ultimately dehiscence (Figure 4). Even though vascular angiogram assessment was performed post-operatively, plantar medial and lateral arteries were not addressed by vascular surgeons.

Additionally, traumatic de-bulking technique or incision planning may have disrupted the blood flow to the plantar flap. This lack of blood flow to the TMA flap may have resulted in ischemic injury and death of this tissue. This case exemplifies the authors' hypothesis that poor angiosome assessment and disruption may be an explanation for the high

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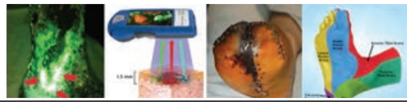

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rate of TMA dehiscence. This case also makes a strong argument for the importance of the plantar flap and the posterior tibial artery for TMA survival and success.

While in-office Doppler studies may be useful, it should also be cautioned that pulsatile blood flow through an artery may in fact be strong retrograde blood flow from another artery. For example, the posterior tibial artery may have a clearly audible pulse, but the flow may be retrograded through the lateral plantar artery (which is often not evaluated by physicians). If the lateral plantar artery is then damaged during surgical proceedings, the posterior tibial angiosome and subsequently the plantar flap of the TMA closure has a higher chance of dehiscence. This example illustrates an important point that all angiosomes should be evaluated.

Figure 4: Angiosome of clinic case patient post-operatively. The angiosome assessment was completed after the TMA site showed signs of ischemic injury and possible plantar flap failure.

Another caution authors would like to note is that this hypothesis solely considers blood flow and ischemic risks for failures. Practicing medicine requires an examination of a multitude of patient factors when developing a treatment plan. TMA failure may also be due to infection, non-compliance, patient co-morbidities, and micro-vascular pathophysiology, to give a few examples. The procedure of TMAs themselves may also lend to the dehiscence and failure rates. The de-bulking of soft tissue to obtain closure is traumatic and may disrupt vascular pathways to the flaps (micro- and macro-vascular). This obstruction of blood flow may limit nutritional and infection defense resources to the area.

While there are other possible explanations for TMA failure, the authors feel that ischemic risk to flaps can be minimized with angiosome principle utilization and examination of incision placement in surgical planning. The authors would like to establish a call to arms and draw physicians' attention to these important points:

- Utilize Doppler studies during surgical planning.
- Evaluate ALL angiosomes during surgical planning and/or in the operating room.
- Establish antegrade or retrograde flow patterns.
- Take special care to protect angiosome connecting vessels while in surgery.

The literature has demonstrated the importance of incisional planning and optimized blood flow to the incision site. Doppler studies can be done in an office setting and/or in the operating rooms to definitively establish the integrity of each angiosome, the quality of the blood flow through each vessel, and the incision site that is most likely to prevent wound complications due to ischemic injury. The authors propose that wound complications may be minimized if physicians planning on performing a TMA utilize the angiosome theory and properly place incisions based on blood flow to the area. However, more research is needed to evaluate the validity of this hypothesis and TMA failure in general. **PM**

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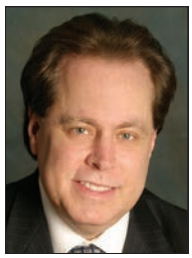

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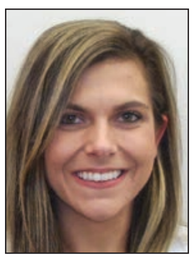

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