CHAPTER **35**

INCISION PLANNING AND PLACEMENT IN THE LOWER EXTREMITY: Considerations for Dermal, Soft Tissue Angiosomes

Jaclyn M. Schwartz, DPM

INTRODUCTION

An angiosome is an artery's supply to a defined area of tissues. The word angiosome is derived from Greek terms angeon, meaning blood vessel and somatikos, describing the pertinence to the body. In 1987, Taylor coined this term, and in 1998, he identified five angiosomes of the lower extremity (1, 2). This has proven to be a valuable concept. An improved understanding of arterial supply and angiosome principles have allowed for decreased rates of wound dehiscence and amputation. The purpose of this update is to define the angiosomes of the foot and ankle and discuss their relevance in placing incisions.

ANGIOSOMES OF THE FOOT AND ANKLE

Taylor described five angiosomes of the lower extremity, the angiosomes of the popliteal, sural, anterior tibial, posterior tibial, and peroneal arteries (2). Most tissues receive branches from two or more angiosomes. This update focuses specifically on the anterior tibial, posterior tibial, and peroneal artery angiosomes since these pertain to the foot and ankle.

Anterior Tibial Artery Angiosome

The anterior tibial artery (ATA) angiosome includes the anterior compartment of the leg. The medial border of the tibia and the fibula define its territory proximally (3) (Figure 1.) When the ATA reaches the ankle, it gives off the medial and lateral malleolar arteries, which anastomose with the posteromedial artery of the posterior tibial artery (PTA) and anterior perforating artery of the peroneal artery (PA). At the ankle joint, the ATA becomes the dorsalis pedis artery (DPA), which passes inferior to the extensor retinaculum to supply the dorsum of the foot. Distally, the DPA gives off the proximal and distal tarsal arteries and the arcuate artery. After giving off the arcuate artery, the DPA enters the first interspace at a 90° angle, and then terminates as the first dorsal metatarsal artery and its digital branches, which supply the lateral hallux and medial second toe (3).

Posterior Tibial Artery Angiosome

According to Attinger, the PTA angiosome in the lower leg extends from the medial aspect of the lower leg to the posterior calf (3) (Figure 2). The anterior tibial surface delineates its anterior border, and the central raphe of the Achilles tendon delineates its posterior border. The PTA angiosome supplies the tibia, deep flexor musculature, and overlying skin (4). At the level of the medial malleolus, the PTA gives off two branches: the posterior medial malleolar artery and the medial calcaneal artery. The posterior medial malleolar branch supplies the medial malleolar area to then anastamoses with the anterior medial malleolar branch from the DPA. The medial calcaneal artery supplies the posterior-medial heel and plantar heel; its distribution extends to the lateral glabrous junction where the posterior and plantar heel skin meets (3). Distally, the PTA bifurcates into the medial and lateral plantar arteries. This division usually occurs at the transverse septum between the abductor hallucis longus and

Figure 1. The anterior tibial artery angiosome includes the anterior compartment of the leg and supplies the dorsum foot.

Figure 2. The posterior tibial artery angiosome in the lower leg extends from the medial aspect of the lower leg to the posterior calf and supplies the sole of the foot.

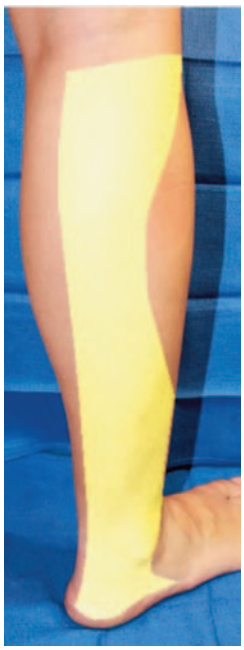

Figure 3. The peroneal artery angiosome territory extends from the central raphe of the Achilles tendon to the anterior border of the lateral compartment and supplies the lateral supra-malleolar area and heel.

flexor digitorum brevis muscles, within the calcaneal canal (3,4). The proximal distribution of the medial plantar artery extends to the anterior-medial edge of plantar heel. Laterally, its distribution spans midline to the plantar midfoot; its distribution varies distally to include the hallux or the posterior edge of the plantar forefoot. Medially, its distribution extends to the anterior border of the naviculo-cuneiform joint (3). The medial plantar artery gives off a superficial and deep branch at the talonavicular joint level (3). The lateral plantar artery's distribution includes the remainder of the plantar skin and structures.

Peroneal Artery Angiosome

The peroneal artery (PA) angiosome extends from the central raphe of the Achilles tendon to the anterior border of the lateral compartment (3) (Figure 3). The PA angiosome supplies the lateral aspect of the Achilles tendon, the lower half of the soleus muscle, a portion of the deep posterior, and the lateral compartment. Before reaching the lateral malleolus, the PA gives off the lateral calcaneal and anterior perforating arteries. The lateral calcaneal artery distributes to the lateral heel and plantar heel, extending distally to the fifth metatarsal base (3). The perforating peroneal artery supplies the lateral malleolus and anterior intermuscular septum (3) (Figures 4, 5).

ANGIOSOME PHYSIOLOGY

Angiosomes provide a description of blood flow patterns and distribution to tissues. The understanding of angiosomes and the relationship among them can be emphasized by the choke vessel phenomenon. Choke vessels link neighboring angiosomes together via tributaries. These vessels are only dilated in times of occlusion or vascular compromise. When an increased pressure gradient develops due to local ischemia, these vessels become patent over a 3-10 day period (4). Placing incisions at the junction of angiosomes allows collateral flow from choke vessels, thus incisions along these areas have been advocated. In the presence of acute emboli or trauma, this mechanism can be impaired. Age and smoking are factors that also decrease the ability of choke vessels to dilate and permit collateral flow (3).

CONSIDERATIONS IN INCISION PLACEMENT

Angiosomes should be considered when planning surgical incisions. Attinger provided four considerations to placing any incision: an incision should provide adequate exposure of target tissues, an incision should allow blood supply from both sides of incision, an incision should spare motor and sensory nerves, and an incision should be parallel to resting

Figure 4. Lateral (above) and medial (below) view of the foot angiosomes. Anterior tibial artery (pink), posterior tibial artery (green) and peroneal artery (yellow).

skin tension lines (3). The safest incisions, according to Attinger, are shorter and located at the junction of adjacent angiosomes (3). Obeying these principles, however, may compromise exposure. In these situations, many of these criteria should be carried out on a case-specific basis.

Achilles Tendon

Attinger describes midline skin incisions over the Achilles tendon to be the safest incision at this area because this location theoretically allows perforators from the PTA and PA angiosomes to provide blood from the medial and lateral aspects of the incision (3). Conversely, Yepes promotes a posterior-medial and posterior-lateral incision as it avoids the centrally located watershed area (6).

A medial to lateral S-shaped incision may facilitate exposure while avoiding neurovascular structures (Figure 6.) For retrocalcaneal heel spur dissection where the incision must continue distally, it should be biased lateral to midline because the blood flow from the calcaneal branch of the PA is more significant than the calcaneal branch of the PTA (3). Hammit et al reported a relatively low posterior midline incision wound complication rate of 15% (5).

Pilon Fracture/Ankle Arthrodesis

For exposure of the distal tibia and fibula, a possible approach involves a posterior-lateral fibular incision. Subperiosteal reflection of the ankle joint from lateral to medial then allows preservation of the ATA in its soft tissue envelope. This incision respects the angiosomes of the skin overlying the ankle, thus, its use has been advocated (3, 7). Meanwhile, anterior ankle incisions placed over the course of the ATA can compromise this angiosome (8). This approach is noted to have higher rates of wound complication. Violation of the angiosome principles has been proposed to

Figure 5. Plantar view of the foot angiosomes. The posterior tibial artery (green) and peroneal artery (yellow) supply the plantar heel. The medial and lateral sole converge midline and are both supplied by the posterior tibial artery.

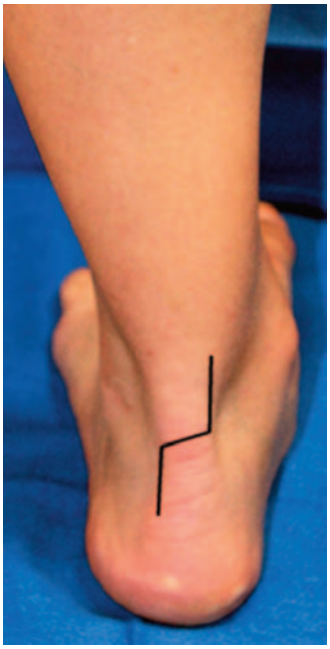

Figure 6. Achilles tendon. A medial to lateral S-shaped incision may facilitate exposure while avoiding neurovascular structures.

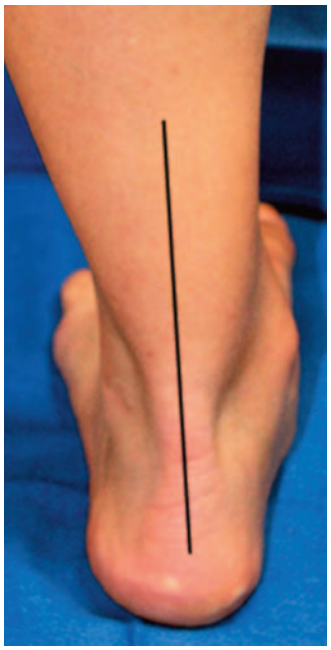

Figure 7. Ankle arthrodesis. A posterior midline approach for arthrodesis of the ankle and subtalar joint has been described for salvage procedures.

be a main reason why total ankle arthroplasty via an anterior incision has wound complication rates up to 25% (9,10).

A posterior approach for ankle or subtalar joint arthrodesis has been described for salvage procedures. Hanson retrospectively reported ten patients (100%) which successfully fused a pantalar fusion without complication (Figure 7).

Lateral Calcaneus

The safest surgical incision to provide complete exposure to the lateral calcaneus is placed along the glabrous junction between the skin at the dorsal and plantar aspect of the rearfoot. This lies between the DPA and lateral plantar artery's distribution (8). Modifications to the lateral extensile incision have been suggested to prevent flap necrosis and wound complications. Care should be taken to delicately preserve a full-thickness flap that includes periosteum, the sural nerve, transected calcaneal fibular ligament, and peroneal tendons (3). The vertical arm of the incision should be made anterior-lateral to the Achilles tendon; this is posterior to the sural nerve and lateral calcaneal artery (3). This incision avoids injury to major angiosomes of the lateral foot and ankle. Additional collateral flow to the full-thickness flap is supplied by the lateral malleolar and lateral tarsal arteries. In less severe calcaneal fractures, a shorter incision overlying the posterior facet of the subtalar joint may allow for adequate exposure without extensively violating vascularity (Figure 8).

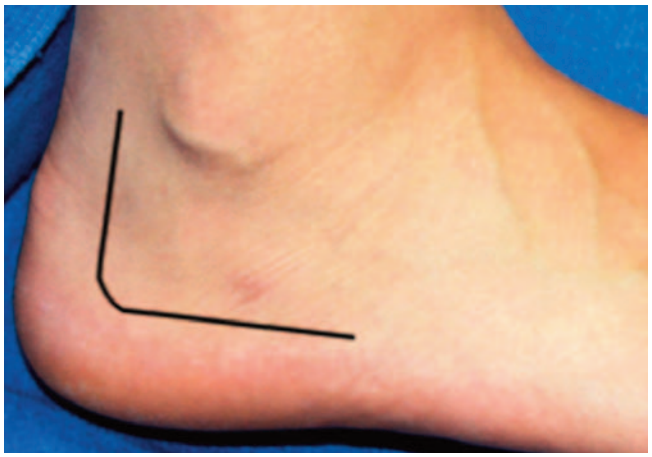

Figure 8. Lateral calcaneus. The safest surgical incision to provide complete exposure to the lateral calcaneus is placed along the glabrous junction between the skin at the dorsal and plantar aspect of the rearfoot.

Figure 9. Sinus tarsi. A short incision placed parallel to the lateral dorsal vessels, running medial to lateral, minimizes vascular compromise.

Sinus Tarsi

A horizontal incision over the lateral sinus tarsi overlies the "rete" of arteries coming from the ATA (3) (Figure 9). It is therefore a safe incision for subtalar joint fusion (3). This incision is placed parallel to the lateral dorsal vessels, running medial to lateral, and minimizes disruption of blood flow. This incision can be carried to the calcaneal cubiod joint or more distal. Similar incisional approaches have been used at our institution for calcaneonavicular bar resection, calcaneocubiod arthrodesis, and lateral exposure for triple arthrodesis.

Medial Calcaneus

The PTA passes the medial aspect of the calcaneus. Incisions over the course of the tarsal tunnel should be placed parallel to the curvature of the tarsal tunnel to avoid injury to its contents (3) (Figure 10). Inferior incisions at this level should be avoided due to the risk of damage to the medial calcaneal neurovascular bundle. Careful dissection must be performed in this region to avoid trauma to the posterior tibial nerve and vessels.

Figure 10. Medial calcaneus. Incisions over the course of the tarsal tunnel should be placed parallel to the curvature of the tarsal tunnel.

Figure 11. Medial arch. The safest surgical incision for the medial aspect of the midfoot and hindfoot is placed 2-3 cm dorsal to the glabrous junction between the skin at the dorsal and plantar aspect of the foot.

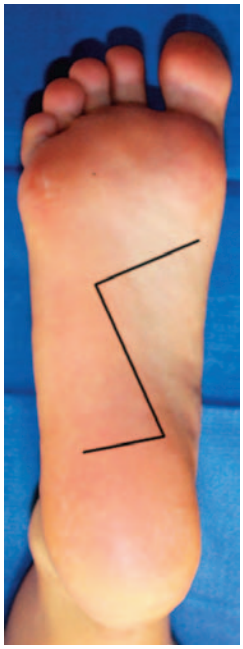

Figure 12. Plantar heel and midfoot. Incision placement for plantar fibromas may require a curved or Z-shaped incision.

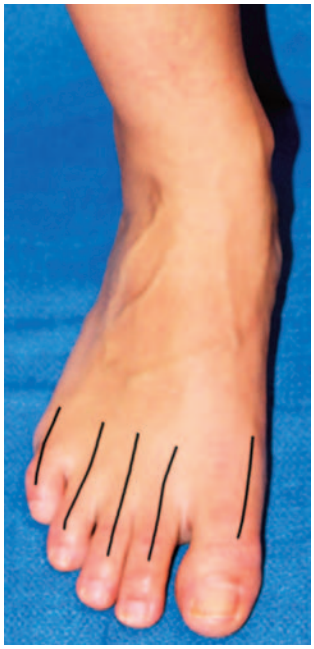

Figure 13. Dorsal and plantar forefoot. Multiple parallel longitudinal incisions over the distal dorsal forefoot can be performed safely as long as preservation of the dorsal metatarsal arteries is observed.

Medial Arch

Roukis suggests the safest surgical incision for the medial aspect of the midfoot and hindfoot is placed 2-3 cm dorsal to the glabrous junction between the skin at the dorsal and plantar aspects of the foot (8). This incision lies between the superficial branch of the medial plantar and the DPA distribution (3) (Figure 11.)

Plantar Heel and Midfoot

The plantar aspect of the heel is supplied by the calcaneal branches of the PTA and PA. Coronal incisions, similar to those used for an in-step plantar fasciotomy, minimize the risk of damage to sensory nerves.

For plantar midfoot incision placement, a single midline incision is safest along the juncture of the medial plantar and lateral plantar midfoot (3). Incision placement for plantar

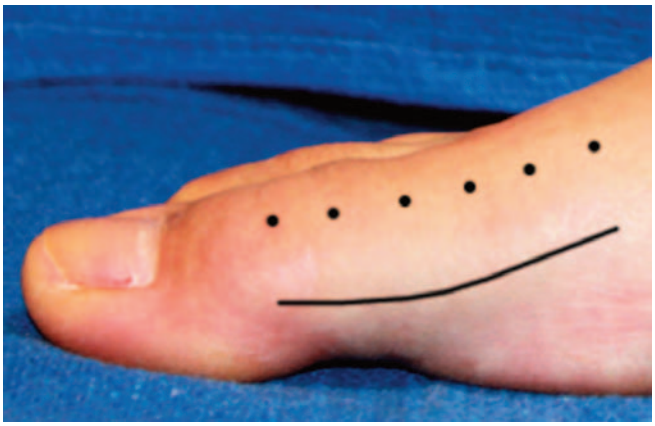

Figure 14. First metatarsophalangeal joint. Dorsomedial (dotted) and straight medial (solid) incisions have been advocated for exposure of the first metatarsophalangeal joint.

fibromas may require a curved or Z-shaped incision (11) (Figure 12). When using a plantar Z incision, placing the apex of the Z laterally is preferential since it better respects the angiosomes.

Dorsal and Plantar Forefoot

Controversy exists for optimal incision placement for pan metatarsal head resections. Different approaches have been described including either a dorsal or plantar approach. Dorsal incision placement may incorporate three to five longitudinal incisions. According to Attinger, multiple parallel longitudinal incisions over the distal dorsal forefoot can be performed safely as long as the dorsal metatarsal arteries are preserved (3). In patients with severe dorsal dislocations of the lesser toes, a plantar transverse approach, as described by Hoffman, may be preferable (12) (Figure 13).

First Metatarsophalangeal Joint

Dorsomedial and straight medial incisions have been advocated for exposure of the first metatarsophalangeal joint. The dorsomedial incision is favored at our institution for access into the first interspace. Attinger believes the medial incision along the medial glabrous junction best maintains dorsal and plantar circulation. A dorsomedial incision, just medial to the EHL, is also acceptable and better avoids the first digital proper nerve. Anecdotally, the dorsomedial incision is not plagued by wound healing complications (Figure 14).

CONCLUSION

Understanding of vascular anatomy is vital when planning incisions. Surgical hemostasis can be achieved by not placing incisions over vascular structures and tissue healing can be maximized by respecting angiosomes. Incisions placed at the junction of angiosomes may still have wound healing complications if there is an inadequate vascular supply; therefore, a thorough vascular work-up should be performed prior to elective surgery. Wound complications and amputations can be minimized by performing atraumatic surgical technique and placing incisions that respect the angiosomes.

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