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# The medial plantar artery: anatomy and implications in local flaps of the foot

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## Abstract

The medial plantar artery (MPA), as a terminal branch of the posterior tibial artery, provides perfusion to the musculature of the medial compartment of the plantar foot as well as cutaneous branches to the skin. The artery and its perforators serve as the foundation for several flaps based on various soft tissue components for the coverage of small defects of the foot. Most noteworthy is the fasciocutaneous flap, which utilizes the skin and the unique properties of the plantar foot. Understanding the anatomical relationship of the terminal branches of the MPA, the superficial and deep branches, is necessary in determining the type of tissue and the flap design to be utilized for reconstruction.

**Keywords:** Medial plantar artery, abductor hallucis, fasciocutaneous flap, flexor hallucis brevis

## INTRODUCTION

Defects of the plantar soft tissues of the foot are often difficult to resurface because of the unique anatomical and functional demands of the glabrous skin. This specialized region has higher demands and must be able to withstand repetitive shearing and significant ground reactive forces secondary to locomotion. The thick epidermal layer, with the addition of the stratum spinosum, and the specialized microarchitecture with septated fat lobules, allows for the absorption and redistribution of compressive forces [Figure 1A and B][1].

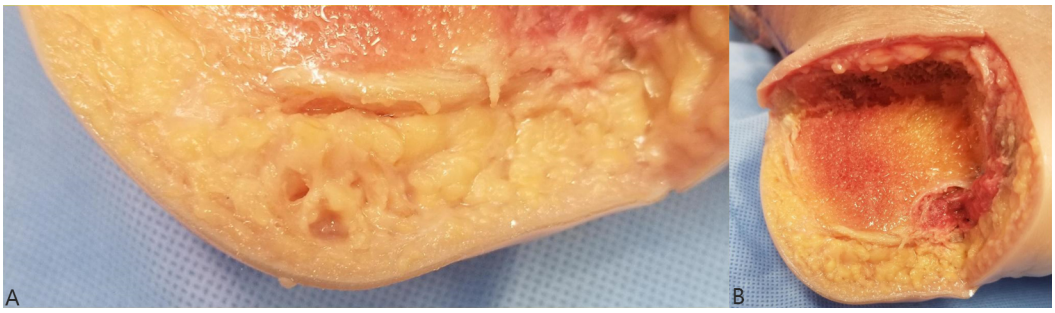


**Figure 1.** (A) The specialized fat of the weight-bearing skin is compartmentalized by thick fibrous septae that have increased collagen and elastin to dissipate the pressures of locomotion; (B) Cross section of the calcaneus demonstrating the superficial layer of the fat pad with the microchambers that have minimal deformation under loading conditions. Also present is the macrochamber, which can undergo significant deformation.

Local intrinsic muscles and fasciocutaneous flaps present an option for coverage of non-weight-bearing and weight-bearing defects, respectively, with the decision based on the functional needs of the region and the component needs of the soft tissue deficit.

The medial plantar artery and its perforators provide muscular and cutaneous branches to local tissues that can be elevated to provide a solution for the management of small-size defects of the foot. The abductor hallucis brevis muscle (ABHM) and flexor hallucis brevis muscle (FHBM) are two pedicled intrinsic muscle flaps based on the branches of the MPA, along with several fasciocutaneous options, that may provide vascularized tissue and improve local blood flow to small defects of the medial and plantar foot[2]. The goal of this paper is to describe the available regional tissues supplied by the medial plantar artery, which may serve as options for the local reconstruction of complex wounds of the foot.

## The medial plantar artery and its branches

The MPA is one of the terminal branches of the posterior tibial artery, providing perfusion for the plantar medial foot. The anatomical description of the artery and the various nomenclature of the fasciocutaneous flaps of this region remain a point of confusion with significant variations present in both nomenclature and anatomy[3,4]. The branching of the medial plantar artery starts with the division of the PTA into the medial and lateral branches approximately 3 cm from the tip anterior colliculus of the medial malleolus [Figure 2A][5]. At the cleavage point of the abductor hallucis and flexor digitorum brevis, the medial plantar artery divides into its superficial (lateral) and deep (medial) branches[6]. The MPA then courses between the abductor hallucis and the flexor digitorum brevis as it travels distally within the intermuscular septum, towards the first webspace.

The superficial branch (terminal branch of the MPA) typically serves as the pedicle for the medial plantar (instep) flap. This branch can supply up to three cutaneous perforators that are utilized in the medial plantar artery perforator flap (MPAP). The deep division often further divides into medial and lateral branches. Perforators from the medial branch of the deep MPA give supply to the medialis pedis flap. A network of accompanying venae comitantes serves as the venous drainage for these various flaps within this region [Figure 2B].

## The medial plantar artery fasciocutaneous flap (instep flap)

The course of the medial plantar artery should be outlined preoperatively, beginning at the branching near the tarsal tunnel, with the use of a handheld Doppler or color ultrasound. The flap margins are outlined to only incorporate the non-weight-bearing region. A full-thickness flap is elevated, often beginning distal, and

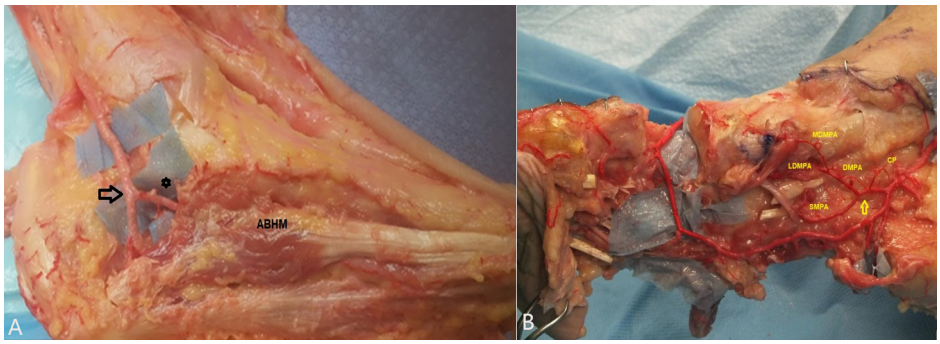


**Figure 2.** (A) The posterior tibial artery (arrow) branches into the medial plantar artery (star) and lateral plantar artery. The medial plantar artery travels beneath the abductor hallucis muscle (ABHM) and deep within the intermuscular septum; (B) The medial plantar artery (arrow) divides into a superficial (SMPA) branch and a deep (DMPA) branch. The deep division branches into a medial (MDMPA) and lateral (LDMPA) branch deep in the abductor hallucis muscle.

includes the plantar fascia. The neurovascular bundle is then isolated and carefully retained within the flap margins. A split nerve technique, as described by Bibbo, can be utilized to preserve sensation in the forefoot and restore it to the heel[7]. The flap is then elevated both medially and laterally, taking care to preserve the peritenon of the deep muscles and the synovial sheath of the flexor hallucis longus tendon. After the island flap is incised circumferentially, the proximal aspect of the abductor hallucis tendon is transected or elevated from its origin. The MPA and accompanying nerve are exposed within their respective tunnels, and the artery dissected to its origin from the posterior tibial artery, releasing the dense fascial attachments of the region, to minimize impingement during rotation. The adjacent muscles are then imbricated to cover the flexor hallucis longus tendon and improve the recipient bed of the donor site with richly vascularized tissues. The flap is then inset without tension within the deficit [Figure 3A-G, Figure 4A-C]. This flap may also be elevated and rotated distally so as to allow for coverage of soft tissue defects of the forefoot, following a similar dissection and inset technique as previously described with the flap designed based on distal perfusion.

### The medialis pedis fasciocutaneous flap

This flap was first described by Masquelet in 1989 when he defined the cutaneous branches of the medial branch of the deep division of the MPA[8]. This flap was described for small defects of the medial malleolus, posterior heel, the insertion of the Achilles tendon and a distally based variant used for the plantar aspect of the first metatarsal head. This flap also gained popularity as a free flap for finger pulp reconstruction[9]. The anatomical territory of this flap is the region from the navicular to the midshaft of the first metatarsal, where several cutaneous branches serve as the blood supply to this area. The flap design is centered over the tubercle of the navicular, with the long axis of the flap designed parallel to the medial longitudinal arch. Like the instep flap, the MPA is identified at its origin from the posterior tibial artery. The abductor hallucis origin is released along with fascial attachments and the deep branch of the MPA is identified within this region. The perforators of the deep branch will cross the posterior tibial tendon insertion to supply the skin. The flap is raised along with the deep fascia and mobilized to reach any of the various defects as described previously. The flap can be up to 5 cm in width and 10 cm in length; however, a width restricted to 2.5 cm allows for primary closure of the donor site, minimizing patient morbidity [Figure 5A-B][8].

### The medial plantar artery, superficial branch perforator (MPAP) flap

The increased popularity of the use of perforator-based flaps has expanded to the MPA. The superficial branch of the MPA provides 2-3 cutaneous perforators that exit just inferior to the abductor hallucis muscle. Unlike the traditional instep flap, the perforator flap variant preserves the plantar fascia and the

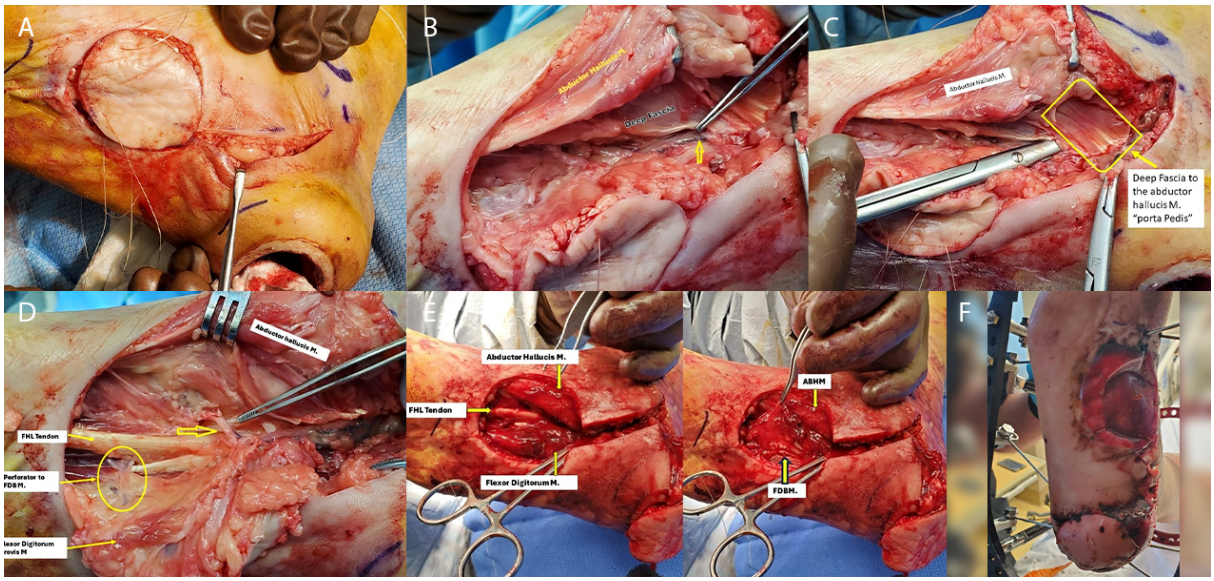


**Figure 3.** (A) The island instep flap based on the superficial branch of the medial plantar artery; (B) The superficial branch of the medial plantar artery (arrow) is identified as it emerges between the abductor hallucis and flexor digitorum muscles (not visualized in this picture) inferior to the deep fascia; (C) Transection of abductor hallucis, or elevation, from its origin and the artery is dissected to its origin to avoid constriction of the vascular pedicle and allow maximal arc of rotation and minimize tension. (D) Ligation of the deep branch (arrow) so as to allow for complete mobilization of the flap; (E and F) The abductor hallucis and the flexor digitorum brevis are imbricated over the tendon to provide an adequate wound bed for skin grafting or a dermal regenerative template; (G) Skin graft or temporization with synthetic grafting.

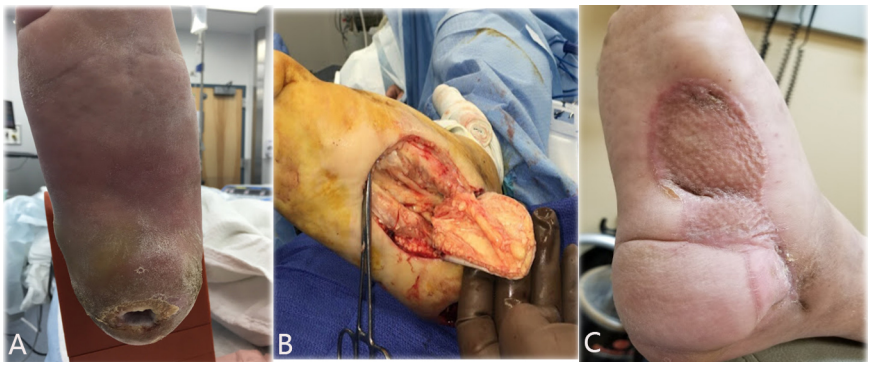


**Figure 4.** (A) A patient with diabetes and peripheral neuropathy that developed an ulceration on the plantar aspect of the heel; (B) After staged debridement, the defect was closed with a medial plantar artery fasciocutenous (instep) flap; (C)Split-thickness skin grafting over the donor site.

medial plantar artery. The distribution of the perforators is along a line drawn from the medial calcaneal tuberosity to the plantar side of the first metatarsal head. The average diameter and length of the perforators are 0.36 mm and 23 mm, respectively. This creates the ability to raise an average flap size of 2.5 × 1.5 cm per perforator. The small size of the perforators is often challenging for anastomosis and may limit its use as an isolated perforator flap without the harvest of the MPA. However, the preservation of the plantar fascia and therefore the function of the foot is an advantageous feature of this flap[10-12].

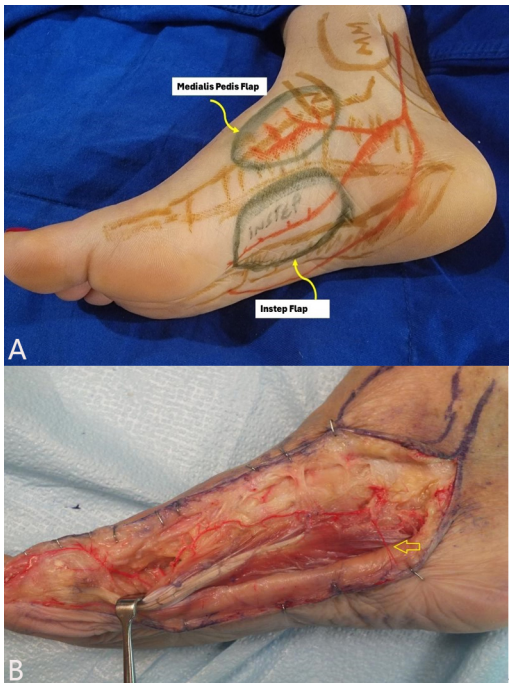


**Figure 5.** (A) The medialis pedis fasciocutaneous flap is based on the cutaneous branching of the deep division of the medial plantar artery. The territory of the flap is over the navicular tuberosity and extends to the midshaft of the first metatarsal. (B) The cutaneous branch from the deep division as it exits from underneath the abductor hallucis superiorly to supply the skin over the navicular.

### Intrinsic muscle flaps

The intrinsic muscles of the foot are classified as type II muscles, according to Mathes and Nahai, with one dominant pedicle and variable minor pedicles perfusing these muscles[13]. These muscle flaps are typically reliable for coverage of small local defects as they are capable of improving the vascularity and delivery of antibiotics as well as obliterating dead space without sacrificing the axial vessels of the foot[14]. Furthermore, the harvest technique is rapid, simpler compared to other techniques, and can be performed under a regional block. The disadvantage of these muscles is the variability in bulk and the limitation of the arc of rotation, constraining their use to nearby defects only[2]. The MPA supplies the abductor hallucis muscle (ABHM) and the flexor hallucis brevis muscles (FHBM). These two muscles are useful options for the medial forefoot, midfoot, and hindfoot.

### Abductor hallucis muscle flap

The ABHM is the most superficial muscle in the medial compartment of the foot. It is often transposed proximally based on its dominant pedicle or, less reliably, in a distally based fashion on its minor pedicles [Figure 6]. The myofasciocutaneous variant is a composite flap that includes the plantar medial skin to obviate the need for pursuant skin grafting [Figures 7A-C]. This variant has also been described as a free flap for reconstruction of the thenar defects of the hand. The incisional approach for harvest is made along the junction of the dorsal and plantar skin, which is favorable for healing from an angiosome perspective. After exposure of the muscle, the tendinous insertion is transected and reflected proximally. The minor pedicles are ligated until the muscle reaches the intended defect without tension on the flap or inset site. The dominant blood supply is preserved to ensure adequate perfusion of the flap. If further mobilization is needed, a bipolar dissection may be performed by additionally releasing the origin of the muscle on the calcaneus. The reverse process can be utilized in a distally based fashion to reach distal medial forefoot defects based on minor pedicles. This distally based approach is dependent upon the size and variability of the minor pedicles and may be less reliable because of this[14-17]. The flap is then often covered with a split-

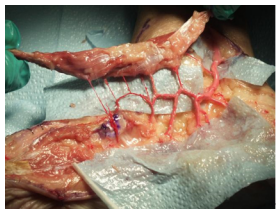

**Figure 6.** The abductor hallucis may also be mobilized in a bipolar direction to improve its arch of rotation.

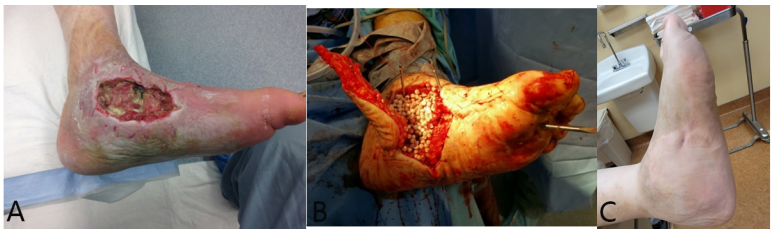


**Figure 7.** (A)A patient with diabetes and a post-operative infection with exposed hardware after open reduction and internal fixation of the navicular; (B) A composite myofasciocutaneous flap is utilized for wound coverage. The donor site was closed primarily; (C) Resolution of the infection with excellent contour of the flap for shoe gear and ambulation.

thickness skin graft or temporized with a dermal regenerative template[14-17].

### Flexor hallucis muscle flap (FHBM)

The FHB muscle is composed of two distinct heads. The medial inserts onto the plantar plate, tibial sesamoid, and the hallux proximal phalanx. The lateral head inserts on the lateral aspect of those structures. The MPA supplies the FHB proximally, while the first plantar metatarsal artery supplies the distal muscle[18]. The surgical approach is similar to the ABHM harvest, with an incision made at the glabrous skin junction, extending from the base of the hallux to the first tarsometatarsal joint. The ABHM tendon is identified distally and transected to allow for reflection proximally and exposure of the FHBM. Both heads of the muscle may be harvested; however, the medial head is more frequently utilized. This can be elevated in a proximal fashion on the major pedicle for coverage of midfoot or hindfoot deficits or in a distally based manner on the minor pedicles for coverage of forefoot defects. The flexor hallucis longus tendon can serve as a reliable indicator of the cleavage point between the two heads and care must be taken to avoid injury to the tendon and to preserve the synovial sheath. Once the FHBM is harvested and inset, the ABHM tendon can be reapproximated to maintain its function. The flap is then covered with a split-thickness graft or temporized with a dermal regenerative template. Masadeh *et al.* reported on the use of the medial hemi-FHBM in a distally based fashion for small defects of the first ray. This was shown to have a success rate of 94% when managing deficits beneath the first metatarsal [Figure 8A-B][19].

## CONCLUSION

The plantar aspect of the foot has several options for soft tissue coverage utilizing either muscle or fasciocutaneous flaps based on the use of the MPA and its divisions/branches, as highlighted in Table 1. Utilization of a regional vascular pedicle to elevate various flap options for coverage of the foot provides several benefits. The use of a myocutaneous flap *vs.* a fasciocutaneous flap is often decided based on the individual needs of the region, with myocutaneous flaps often utilized for obliteration of deadspace given their inherent bulk as compared to fasciocutaneous flap counterparts. The advantages of these flaps include resurfacing the foot with similar tissue that has unique properties, low donor site morbidity, and a short operative time in patients with multiple medical co-morbidities[10]. A thorough understanding of foot

**Table 1. Various flaps based on the use of the medial plantar artery and its branches**

| Flap name | Pedicle | Anatomic location |
|---|---|---|
| Medial plantar artery flap (MPAF) or instep flap | Superficial branch of the MPA | Skin, subcutaneous tissues, and plantar fascia of the medial longitudinal arch |
| Medialis pedis flap (MPF) | Deep branch of the MPA (The lateral branch of the deep branch) | Skin and subcutaneous tissues of the most medial portion of the arch, overlying the abductor hallucis. No plantar fascia |
| Medial plantar artery, superficial branch perforator (MPAP) flap | Superficial branch of MPA perforator | Various, based on perforator location |
| Abductor hallucis muscle flap | Medial plantar artery | Medial column of the foot |
| Flexor hallucis brevis muscle flap | Medial plantar artery | Medial column of the foot |

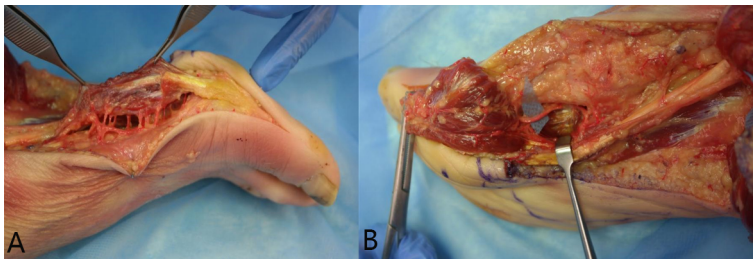


**Figure 8.** (A) The flexor hallucis brevis is a type II muscle with major and minor pedicles; (B) The muscle may also be used in a distally based fashion for forefoot ulcerations.

anatomy is mandatory for the utilization of these flaps so as to utilize local anatomic landmarks during the dissection; as previously mentioned, the anatomy of the artery may be variable[3]. The surgeon must consider the role of muscle atrophy and morphology as variations are frequently encountered in patients with diabetes mellitus, motor neuropathy and peripheral arterial occlusive disease. The medial plantar artery demonstrates a constant arterial supply for the medial and plantar skin of the foot as well as the intrinsic muscles of the medial compartment. Although there is some variation in the number of cutaneous perforators, the location of the origin of the divisions and the branching patterns of the terminal divisions, the reliability of these flaps remains high for coverage of small to medium size defects around the foot and ankle.

## DECLARATIONS

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### Authors' contributions

Conceptualization: Masadeh SB, Liette MD
Writing-review and editing: Masadeh SB, Liette MD
Supervision: Masadeh SB

### Availability of data and materials

Not applicable.

### Financial support and sponsorship:

None.

### Conflicts of interest

All authors declared that there are no conflicts of interest.

### Ethical approval and consent to participate.

The study was conducted in accordance with the principles of the Declaration of Helsinki.

### Consent for publication

Not applicable.



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