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Distally based dorsalis pedis island flap for coverage of the distal portion of the foot

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Summary—A distally based dorsalis pedis island flap is described which has been successfully used for reconstructing the distal portion of the foot in two patients with amputation of all 5 toes.

The indication for this flap is a wide skin defect of the distal half of the dorsal foot without history of local vascular disorder.

The arterial inflow of the flap comes from the posterior tibial artery via the deep plantar branch of the dorsalis pedis artery, while the venous drainage is most likely to be through the venae comitantes of the dorsalis pedis artery to those of the deep branch.

Various types of distally based island flaps, *i.e.* reverse flow island flaps, have been reported with varying success since 1976 when Bostwick et al. first reported on a reverse flow temporal artery island flap for reconstructing lateral forehead defects. A search of the pertinent literature, however, fails to reveal any report of a distally based dorsalis pedis island flap. This paper describes the flap which was successfully employed in two cases to reconstruct the distal portion of the foot. Anatomical considerations in connection with design and viability of the flap are also discussed.

Anatomy

The major arteries supplying the foot are the posterior and anterior tibial arteries. The former further divides into the medial and lateral plantar arteries (Fig. 1).

The anterior tibial artery terminates in the dorsalis pedis artery, which then gives off the deep plantar branch over the proximal third of the first intermetatarsal space to communicate with the lateral plantar artery, forming the plantar arch.

This direct arterial anastomotic system seems to ensure the viability of a distally based dorsalis pedis island flap by retrograde arterial flow via the plantar arch, without endangering the blood supply to other portions of the foot. The venous system will be discussed later.

Case reports

Case 1

A 33-year-old man sustained a crush injury which caused skin avulsion and multiple fractures in the distal half of the right foot. Skin necrosis, starting from the distal end of the toes, gradually progressed until it was demarcated by the line running from the interphalangeal joint of the 1st toe to the metatarsophalangeal joint of the fifth toe (Fig. 2A).

He had no previous history of vascular diseases of any kind. A Doppler flowmeter showed a normal arterial flow of both the dorsalis pedis artery and the lateral plantar artery. Three weeks after injury an operation was performed which included debridement of the wound and amputation of the toes at the level of the necrotic line (Fig. 2B).

A large distally based dorsalis pedis island flap, 14 × 12 cm in size, was elevated and immediately transplanted (Fig. 2C, D) and the donor site was resurfaced with a free skin graft. The technique is described separately in detail. The postoperative course was uneventful, with a good take of both the flap and the skin graft. There was no disturbance in his gait, using an arch support, at follow-up after 14 months (Fig. 2E, F).

Case 2

Thirty-one years before presentation, a 56-year-old man had sustained frostbite of the feet, which resulted in amputation of all the toes at the level of the distal portion of the metatarsus. The consequent raw surface had been covered with a free skin graft.

About 1 year previously an ulcer developed at the distal

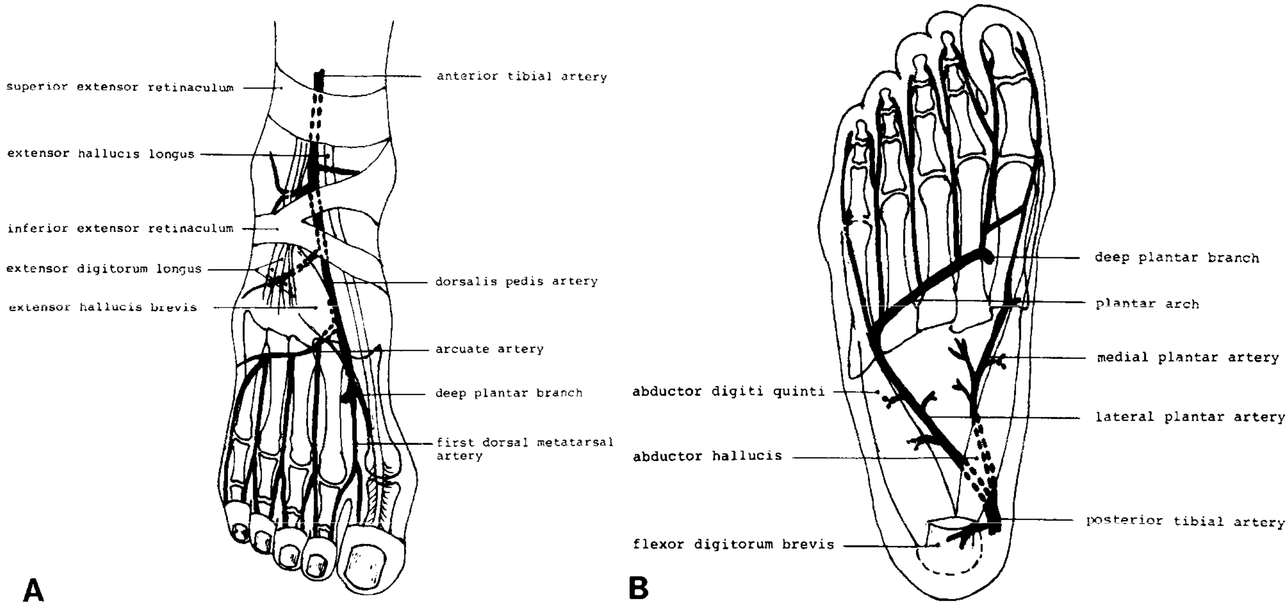

Fig. 1

Figure 1—Arterial anatomy of the foot. (A) Dorsal. (B) Plantar.

portion of the left foot (Fig. 3A). Biopsy showed pseudocarcinomatous hyperplasia.

After excision of the ulcer and surrounding skin, the defect was closed with a distally based dorsalis pedis island flap, 5 × 7.3 cm in size (Fig. 3B, C, D). Two months later the patient could walk with an arch support without difficulty (Fig. 3E, F).

Surgical technique for a distally based dorsalis pedis island flap

Using a pneumatic tourniquet, a skin incision was first made on the proximal side of the flap so that the anterior tibial or dorsalis pedis artery and veins were exposed. Special care was taken not to separate the vessels from the flap. Dissection was continued distally down to the level of the deep plantar branch to make a bipedicled arterial flap, based on the anterior tibial or dorsalis pedis artery and the deep plantar branch.

The superficial venous system, *i.e.* the greater and lesser saphenous veins, was divided, but the deep venous system, *i.e.* venae comitantes accompanying the dorsalis pedis artery, was preserved for venous drainage. The deep peroneal nerve was divided, while the superficial peroneal nerve was preserved in the bottom layer.

The tourniquet was then released to assess the change in colour of the flap. When the anterior tibial artery or dorsalis pedis artery and veins in the proximal pedicle were clamped initially for 20 minutes to observe the consequent circulatory changes in the flap, the flap turned slightly dark, indicating mild venous congestion, but gradually regained almost normal colour as the congestion was washed out.

To confirm that the flap had developed adequate venous return, a flap venogram was performed with injection of about 5 ml Urografin (76%) into one of the anterior tibial veins or dorsalis pedis veins just distal to the clamped site. A reverse drainage from the anterior tibial vein or dorsalis pedis vein towards the plantar arch area through both the venae comitantes was clearly demonstrated. The existence of the several communicating branches between the two venae comitantes, as described by Lin *et al.* in 1984, was also confirmed radiographically.

The anterior tibial or dorsalis pedis artery and veins at the proximal pedicle of the flap were ligated and divided. The flap was then turned around on the distal pedicle, that is the deep plantar branches of the dorsalis pedis artery and veins, to cover the skin defect. The donor site was resurfaced by a free full thickness skin graft which was taken from the groin. The foot was immobilised by a plaster cast for the postoperative 10 days.

Discussion

Indication

Reconstruction of the distal portion of the foot has always presented a difficult problem which has most commonly been handled by the use of either cross-leg (foot) flaps or free flaps. The cross-leg flap requires a two-stage operation, forcing the patient

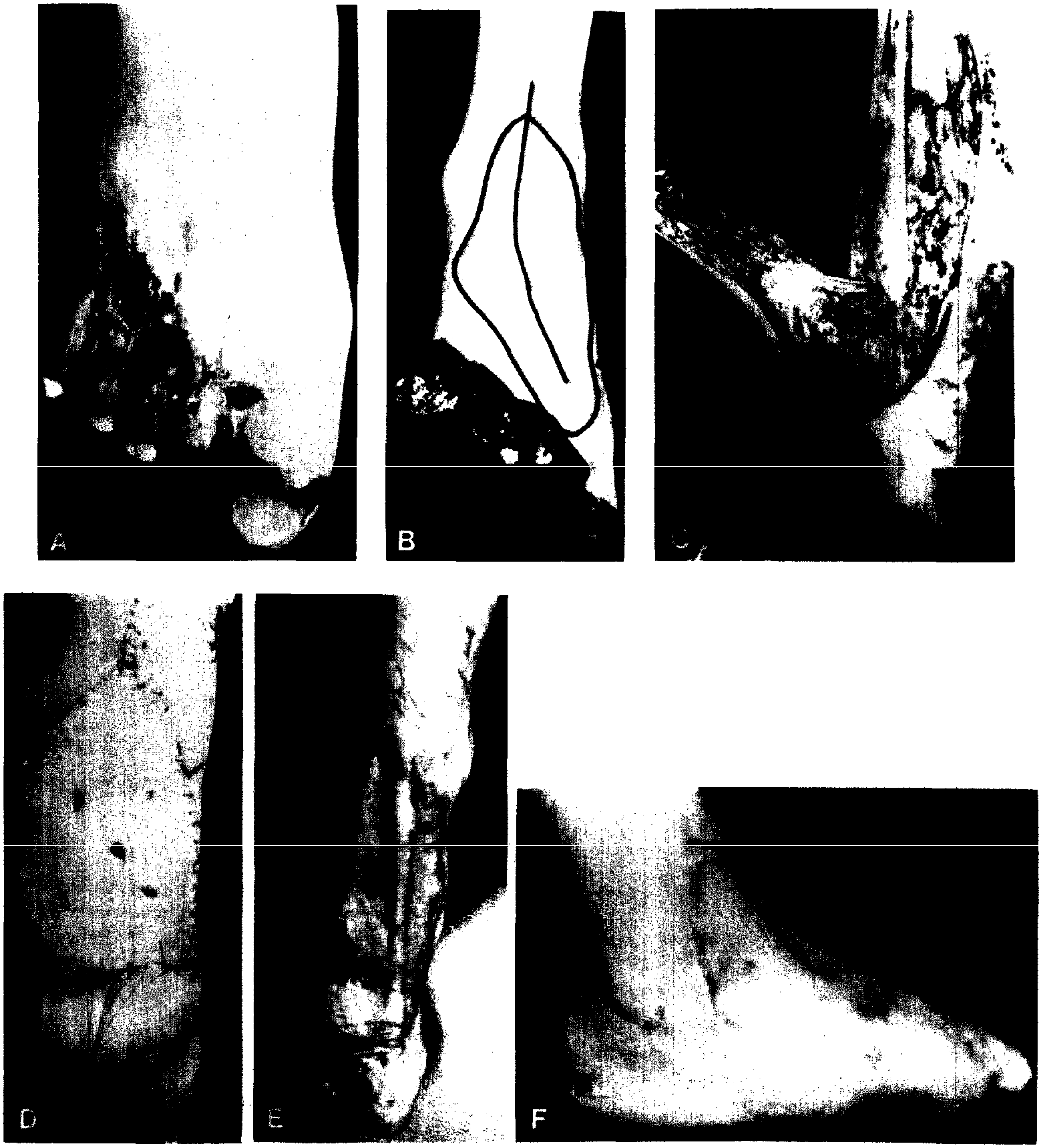

Fig. 2

Figure 2—*Case 1.* (A) Preoperative appearance 3 weeks after injury. (B) After debridement, all the toes have been amputated except for the 1st proximal phalanx. The flap, 14 × 12 cm, is outlined. (C) Elevation of the flap has been completed. Distally based pedicle (deep plantar branch) indicated by arrow. (D) The distal portion of the foot has been covered with the flap and the donor site with a free skin graft. (E) 14 months postoperative appearance: dorsal view. (F) Lateral view.

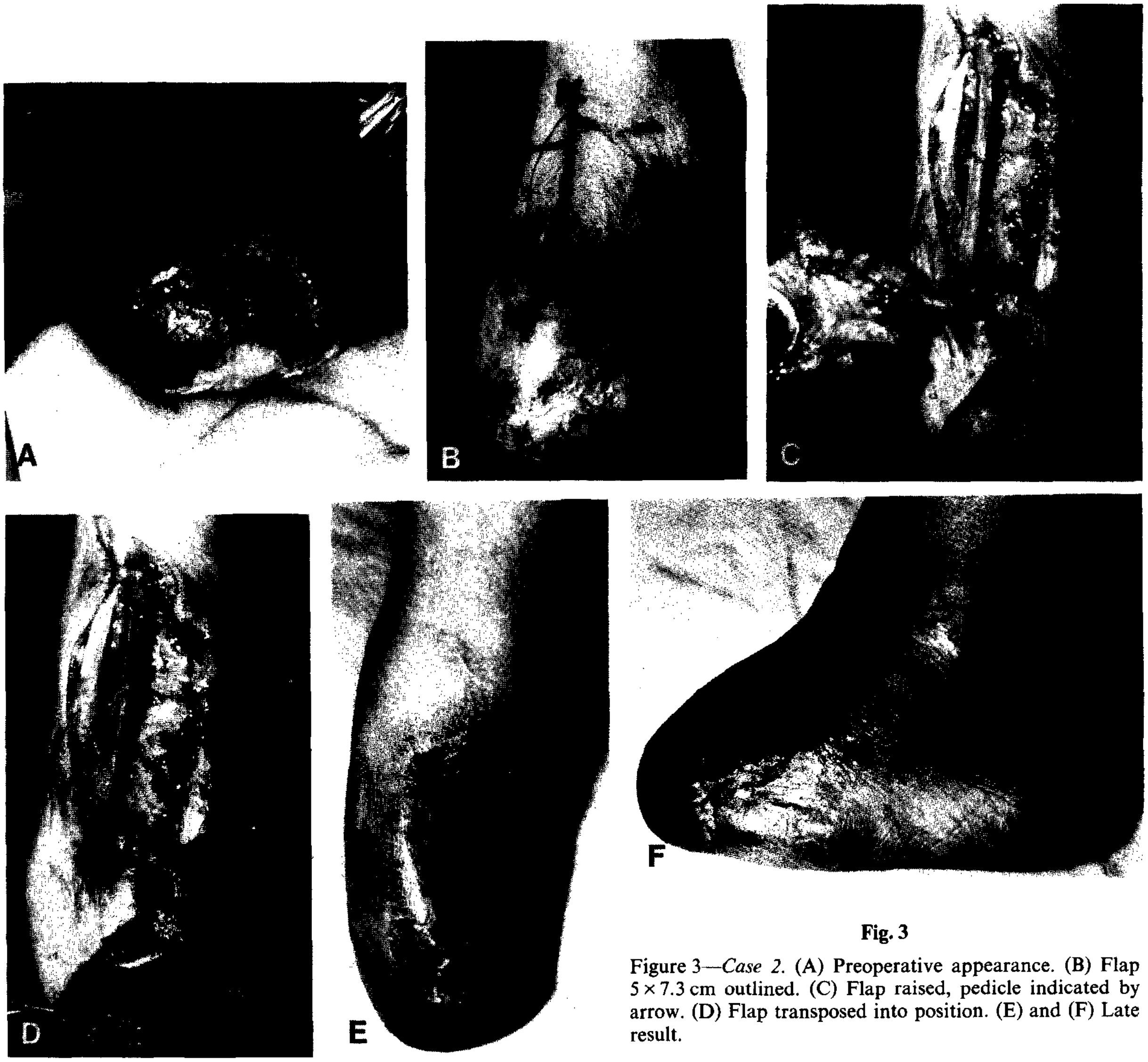

Fig. 3

Figure 3—*Case 2*. (A) Preoperative appearance. (B) Flap 5 × 7.3 cm outlined. (C) Flap raised, pedicle indicated by arrow. (D) Flap transposed into position. (E) and (F) Late result.

to be immobilised in an unnatural position. The free flap, though free from these restrictions, is always attended by a risk of thrombosis at the site of anastomosis, which has, however, been much reduced by recent advances in microsurgical technique. Recently the distally based abductor digiti minimi muscle flap (Yoshimura *et al*., 1985) and the distally based flexor digitorum brevis musculocutaneous flap (Suzuki *et al*., 1985) have been found to be useful, but a large skin defect, as in our cases, seems to be beyond the indications for these flaps. The distally based dorsalis pedis island flap described here avoids most of the disadvantages of the flaps mentioned above.

The best indication for the flap would be found in the repair of a wide skin defect after amputation of the toes.

This flap cannot be used in the presence of any local vascular problems such as those induced by trauma, particularly to the area between the anterior and posterior tibial arteries and the plantar arch. Another limitation of this flap is the size of the wound that can be covered by it.

Mobility and extensibility of the flap are limited by the anatomy of the pedicle, that is, the deep plantar branch, and only rotation of the flap is possible. The usefulness of the flap largely depends on the maximum size of the flap that is available.

The flap size and design

The maximum size of the flap obtainable depends on two factors: (i) circulatory extension of the cutaneous branches of the dorsalis pedis artery and (ii) the site of anastomosis between the superficial venous system (the dorsal venous arch and the dorsal superficial plexus) and the deep venous system (the dorsalis pedis veins).

McCraw and Furlow (1975) stated that the site of cutaneous branching from the dorsalis pedis artery is located distal to the extensor retinaculum with the main branches halfway between the extensor retinaculum and the deep plantar branch, while Ohmori and Harii (1976) found the arterial cutaneous branches most abundant in the area between the distal end of the extensor retinaculum and the bases of the 1st and 2nd metatarsals. Takayama *et al.* (1982) noticed apparent branches at the site where the dorsalis pedis artery emerges from the lower border of the extensor retinaculum, just distal to the extensor hallucis brevis muscle. On the basis of 23 cadaver studies, Man and Acland (1980) reported in detail that there were on average 5.4 branches between the proximal and distal ends of the extensor retinaculum and 3.8 branches from the distal end down to the deep plantar branch. Briefly, cutaneous branches cannot be expected cranially beyond the proximal margin of the extensor retinaculum, but several branches exist distal to it.

Although communication between the superficial and deep venous systems apparently exists, its site has not been clearly reported. Ohmori and Harii (1976) stated that it may be located at the base of the 1st intermetatarsal space. Since the venous drainage of this flap depends on the deep venous system, sufficient communication between the superficial and deep is essential to its success. From this viewpoint, it is advisable to incorporate at least a part, or preferably half, of the dorsal venous arch, as pointed out by McCraw and Furlow (1975) and Ohmori and Harii (1976).

Judging from the above circulatory map, the flap would be safely obtained below the level of the extensor retinaculum. Our Case 1, however, indicated that a larger flap 3 cm above the extensor retinaculum is possible without delay. From our experience a flap can be raised safely from the whole width of the foot and extending proximally over the extensor retinaculum for 3 cm.

For a smaller flap, the cutaneous branches from the dorsalis pedis artery and the venous network should be at least partially incorporated in the flap. The flap should be designed so that the dorsalis pedis artery is at the middle of the flap.

Possible complications

A potential risk in using this flap is that venous drainage is through the venae comitantes and if this is inadequate the flap will die.

In our two cases, however, adequate retrograde venous flow was substantiated both by clamping the proximal pedicle and by a retrograde venogram.

A disadvantage of the flap may be related to donor site morbidity such as ulcer formation, functional disability or circulatory disturbance, as previously reported for the dorsalis pedis flap. Our cases, however, demonstrated none of these problems and only slight deformity.

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