

# Anatomical analysis of the cause of skin necrosis of the great toe after transplantation of the great toe nail flap

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**Summary**—Necrosis of skin on the medial side of the great toe has been a significant complication of the great toe nail flap.

To investigate the reason for this, a study of the blood supply of the medial side of the great toe was carried out on 55 feet with the injection of red latex into the arteries and on 13 vascular cast specimens. It was found that, after the blood vessels from the plantar and dorsal sides of the great toe are severed during the operation, the skin of the medial side of the great toe is mainly supplied by the medial vascular network at the head of the first metatarsal bone. It is clear that the blood supply from this network may sometimes be insufficient to nourish the skin. It is suggested that the operative incision should be changed so as to increase the blood supply to the medial vascular network which may decrease the incidence of skin necrosis.

The great toe nail flap for segmental reconstruction of the thumb, reported by Hamilton and Morrison (1980), has been widely adopted recently (Chen and Wang, 1982; Yu *et al.*, 1983; Zhu *et al.*, 1984). In some cases, however, there has been necrosis, of varying extent, of the remaining skin on the medial side of the donor great toe and of the split skin graft covering the donor area (Huang *et al.*, 1985; Zhu *et al.*, 1985; Huang *et al.*, 1986). In order to find the cause of the necrosis and to suggest preventive measures, an anatomical study was carried out on 55 feet and on 13 arterial cast specimens of feet.

## The standard operative technique

The operation, as designed at present in China, is shown in Fig. 1. The vascular pedicle of the great toe nail flap is similar to that of second toe transplantation.

This composite flap is based on the dorsalis pedis artery through the first dorsal metatarsal artery, which is different from the pedicle used by Hamilton and Morrison. The venous drainage is through the dorsal vein of the great toe to the dorsal venous arch of the foot and the long saphenous vein. The innervation of the flap is provided by the medial plantar digital nerve. As Figures 1A and B show, the flap is moved with its vessels and nerve on the lateral side of the great toe and contains a sliver of terminal phalanx which provides skeletal support

(Fig. 1C); care is taken to keep the nail, nail matrix and nail bed in the flap intact. The skin and the pulp on the medial side of the great toe should not be interfered with. The donor area is repaired with split skin.

It is known that the first dorsal metatarsal artery often varies in its form and the variations have been classified into three types (Gilbert, 1976) as shown in Figures 2 and 3. The corresponding operative designs are as follows:

**Type I.** The profundus branch and the distal end of the first plantar metatarsal artery are ligated.

**Type II.** The profundus branch and both the proximal and the distal ends of the first plantar metatarsal artery have to be ligated because the first dorsal metatarsal artery has a common trunk with the first plantar metatarsal artery.

**Type III** (Fig. 3C). Because the first dorsal metatarsal artery is small or absent, it is necessary to ligate the plantar arch and take the whole first plantar metatarsal artery as pedicle.

## Anatomical study

### Materials and methods

Fifty-five adult feet with red latex injected into the arteries and 13 arterial cast specimens of feet were used to observe the blood supply of the medial skin of the great toe.

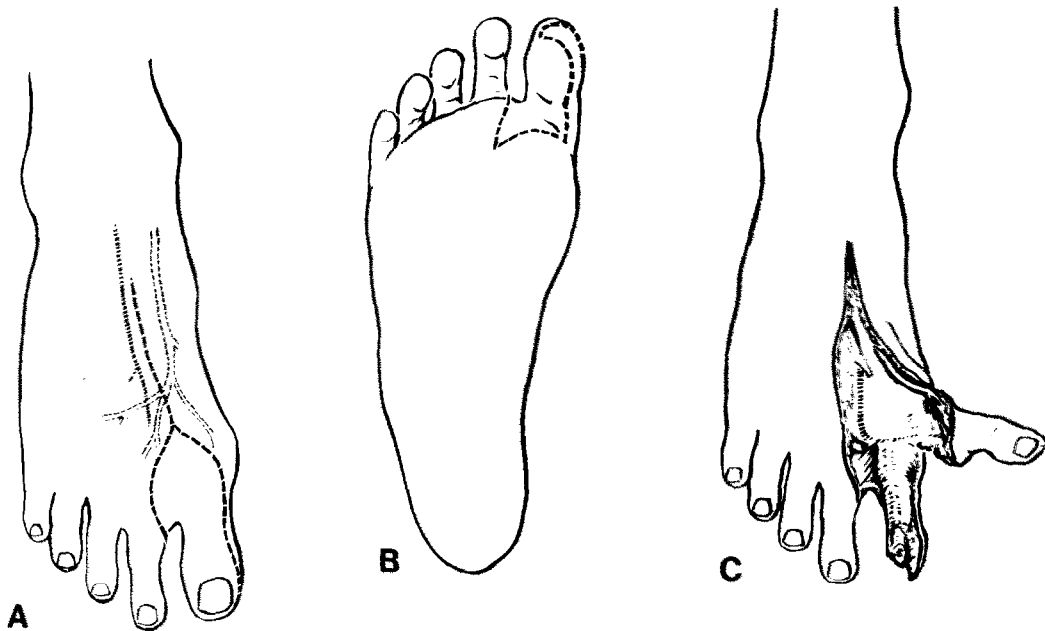


Fig. 1

Figure 1—Diagram of standard operative incision.

### Results

The blood supply to the medial skin of the great toe comes mainly from three sources (Fig. 2). In order of importance they are:

- (i) The plantar blood supply, passing from lateral to medial.
  - a. The arterial network (rete) (AR) in the pulp of the great toe.
  - b. The transverse hallucal artery (THA). This is the largest transverse communicating artery (mean diameter  $0.9 \pm 0.2$  mm) on the plantar side. It is constantly situated at the middle of the proximal phalanx.
  - c. The "cruciate anastomosis" (CA). The cruciate anastomosis is situated posterior to the sesamoid bones at the head of the first metatarsal (Xu *et al.*, 1986). The arteries on the lateral side of the cruciate anastomosis are larger than the medial vessels. Laterally are the proximal part of the first plantar metatarsal artery posteriorly (mean diameter  $1.5 \pm 0.5$  mm) and the distal part of the first plantar metatarsal artery anteriorly (mean diameter  $1.2 \pm 0.5$  mm). Medially are the anastomosing branch of the medial plantar artery posteriorly (mean diameter  $0.7 \pm 0.3$  mm) and the tibial plantar digital artery of the great toe anteriorly (mean diameter  $0.6 \pm 0.1$  mm).
  - d. The branches of the medial plantar artery (MPA). These arteries vary from 1 to 2 in number and are of a small diameter (less than 0.5 mm).
- (ii) The sources of blood supply from the medial side of the great toe (Fig. 4). From proximal to distal they are:
  - a. The arterial network (rete) at the medial side of the head of the first metatarsal bone (MAR). The network consists of many small branches originating from the medial tarsal artery (MTA), the medial plantar artery (MPA) and a branch of the dorsalis pedis artery (BDPA). The arteries in this network are sparse and small in diameter (less than 0.4 mm).
  - b. The proximal branch of the transverse hallucal artery (PB). This is small in diameter (mean  $0.5 \pm 0.1$  mm) but when the blood flow from the trunk of the transverse hallucal artery is blocked, it will play a role in the collateral circulation between the arterial network at the medial side of the

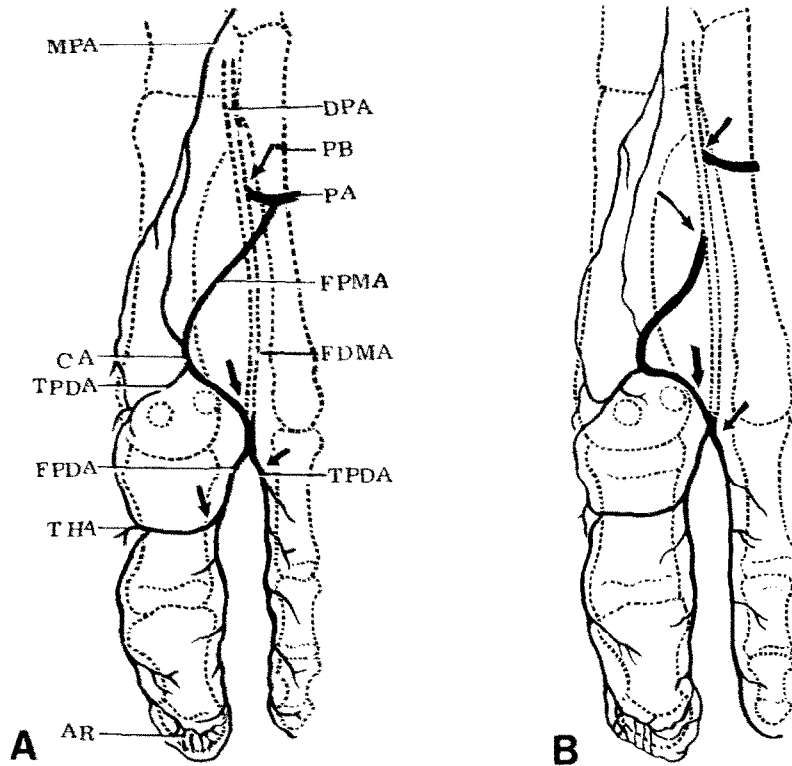


Fig. 2

Figure 2—Blood supply to the medial side of the great toe (plantar view) with variations of the first dorsal metatarsal artery. (A) Type I. (B) Type II. Arrows show ligation sites during the operation. MPA = Medial plantar artery, DPA = Dorsalis pedis artery, PB = Profundus branch, PA = Plantar arch, FPMA = First plantar metatarsal artery, FDMA = First dorsal metatarsal artery, CA = Cruciate anastomosis, TPDA = Tibial plantar digital artery of great toe, TPDA = Tibial plantar digital artery of second toe, FPDA = Fibular plantar digital artery, THA = Transverse hallucal artery, AR = Arterial rete (network).

head of the first metatarsal bone (MAR) and the distal branch of the transverse hallucal artery.

c. The distal branch of the transverse hallucal artery, (DB) which is quite a large vessel (mean diameter  $0.7 \pm 0.2$  mm).

(iii) The sources of blood supply from the dorsal side. The arteries at the dorsal side of the great toe are all small, with external diameters less than 0.4 mm.

## Discussion

### *Anatomical reasons for necrosis*

The clinical report of Zhu *et al.* (1985) on the great toe nail flap showed that necrosis of both the medial skin of the great toe and the graft covering the

donor area is most likely if the first dorsal metatarsal artery belongs to Types II or III (Figs 2 and 3). An anatomical analysis and our research data suggest reasons for this.

(i) The first plantar metatarsal artery (FPMA) is the cardinal source of the blood supply to the medial skin of the great toe. Figure 2 shows that of the four sources of blood supply from the plantar side, the cruciate anastomosis, the transverse hallucal artery and the arterial network in the pulp of the great toe all come either from the first plantar metatarsal artery or from its branches.

(ii) If the first dorsal metatarsal artery belongs to Type I, the blood supply to the medial skin of the great toe should be preserved in the standard operation. Figures 2 and 3 demonstrate that, after the plantar profundus branch and the distal segment

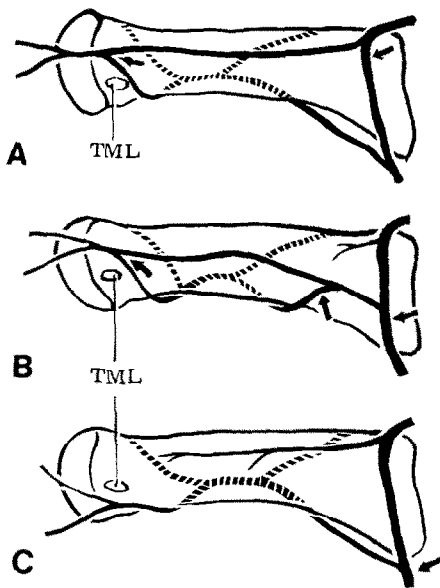


Fig. 3

Figure 3—The three types of the first dorsal metatarsal artery and the ligation sites (lateral view). (A) Type I. (B) Type II. (C) Type III. Arrows show the ligation sites. (The dashed lines indicate the branches that take part in the cruciate anastomosis.) TML = Transverse metatarsal ligament.

of the first plantar metatarsal artery are ligated during operation, the blood will flow through the plantar arch (PA) to the proximal part of the first plantar metatarsal artery (FPMA) then through the cruciate anastomosis and the tibial plantar digital artery (TPDA) to the skin.

(iii) If the first dorsal metatarsal artery is of Type II or III, the blood supply from the first plantar metatarsal artery must be lost during the operation.

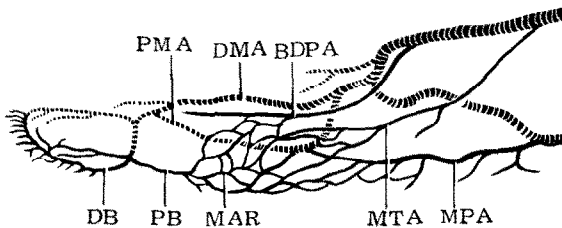


Fig. 4

Figure 4—The blood supply to the medial side of the great toe. PMA = First plantar metatarsal artery, DMA = First dorsal metatarsal artery, BDPA = Branch of dorsalis pedis artery, DB = Distal branch of transverse hallucal artery, PB = Proximal branch of transverse hallucal artery, MAR = Medial arterial rete (network), MTS = Medial tarsal artery, MPA = Medial plantar artery.

As Figures 2 and 3 show, the Type II first dorsal metatarsal artery arises from a common trunk with the first plantar metatarsal artery so that, by taking the former as a pedicle, the first plantar metatarsal artery will inevitably be ligated. As the Type III first dorsal metatarsal artery is too small to supply enough blood to the great toe nail flap, the first plantar metatarsal artery is generally used as the pedicle (Pan *et al.*, 1983; Cheng *et al.*, 1984). Both methods, therefore, block all sources of blood supply from the first plantar metatarsal artery. This is why there is a high incidence of necrosis both of the medial skin of the great toe and of the grafted skin covering the donor area.

*Prevention of skin necrosis*

When the first plantar metatarsal artery is of Type II or III, survival of the medial skin of the great toe postoperatively depends on the adequacy of its secondary blood supply. The following precautions will ensure that it is disturbed as little as possible.

(i) The arterial network at the medial side of the head of the first metatarsal bone (Fig. 4) can be protected by designing the sigmoid incision which exposes the dorsalis pedis artery so that the distal curve is placed more lateral than usual (Fig. 5). At the same time the flap should be shifted a little towards the lateral side, by ensuring that the medial incision does not lie on the medial surface of the great toe but only extends to the medial margin of the nail matrix. The lateral incision needs to be extended to the dorsal side of the second toe so as

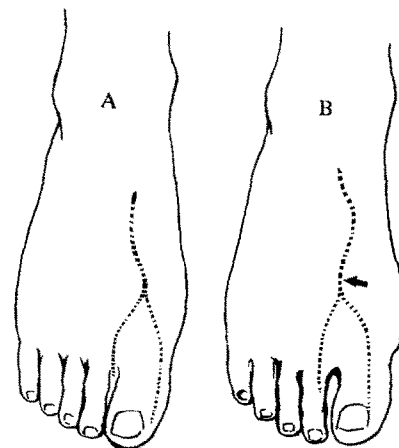


Fig. 5

Figure 5—The improved incision on the foot. (A) Conventional incision. (B) Improved incision.

to get a sufficiently wide flap. These modifications ensure a wide pedicle at the posterior end of the arterial network and more sources of the blood supply to the medial skin of the great toe are protected.

(ii) *Protection of the medial tarsal artery.* The medial tarsal artery runs along the medial side of the head of the first metatarsal bone (Fig. 4). It leaves the dorsalis pedis artery quite far proximally, but the length of the pedicle of that artery should not be too great or the medial tarsal artery may be divided.

(iii) The blood sources from the proximal end of the plantar side should be protected. If the first plantar metatarsal artery is divided, the proximal blood supply from the medial plantar artery will become important and for this reason it is unwise to extend the plantar incision posteriorly. If more tissue is needed from this area it should be taken from further laterally.

(iv) The arterial plexus on the periosteum should be protected. The matrix and nail bed should be separated from the distal phalanx by dissection superficial to the periosteum, leaving a vascular bed for a skin graft on the donor area.

(v) The operation should be done as gently and carefully as possible. As it deprives the medial skin of the great toe of its main blood supply, great attention to detail is required to protect the fine vessels which remain.

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