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One-staged coverage and revascularisation of traumatised limbs by a flow-through radial mid-forearm free flap

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SUMMARY. **The concept of flow-through circulation in free flaps is an interesting and useful one. Its importance is paramount in the clinical field, if one applies it as a one-staged technique for cover and revascularisation in major trauma of the extremities.**

This paper describes the practical use of this concept in two clinical cases (hand and foot), in which an uninterrupted arterial and venous flow was established through the radial mid-forearm fasciocutaneous flap, allowing revascularisation of the ischaemic extremity.

After introduction of the concept of axial-pattern flaps (McGregor and Morgan, 1973), many axial flaps have been described and all have in common a vascular pedicle which provides the blood supply for the flap tissue. Muscles have been classified on their patterns of vascular anatomy (Mathes and Nahai, 1982) and this morphological study made an enormous contribution, particularly for the selection of muscles which could be used for flaps. Fasciocutaneous flaps have also been classified according to their patterns of vascularisation (Cormack and Lamberty, 1984).

On analysing all the described axial flaps, one finds few have the capacity to allow a flow-through circulation. This idea was suggested by Soutar *et al.* (1983) for head and neck reconstruction, establishing an uninterrupted arterial flow through a flap between the external carotid and distal facial artery and also by Cormack and Lamberty (1984) with the Siamese or sister flaps in which a flap could be attached onto the end of another flap. The flaps which were considered suitable for this were the antecubital forearm flap (Lamberty and Cormack, 1983) and the radial forearm flap (Lamberty and Cormack, 1983; Soutar *et al.*, 1983).

Lamberty and Cormack (1983) reported one clinical case of head and neck reconstruction in which they used an antecubital fasciocutaneous free flap, to reconstruct an excisional defect after removal of a squamous cell carcinoma, involving the left pinna and external auditory meatus. The proximal end to the divided facial artery was anastomosed to the proximal end of the radial artery and the distal end of the radial artery was looped back to be anastomosed to the distal end of the facial artery.

The clinical importance of this concept is paramount. Exposure of deep structures, like tendons, nerves and/or bone, with vascular damage which often accompanies major trauma of the extremities, may warrant flap cover with its own blood supply. If the clinical situation is complicated by the ischaemia of the distal segment (hand or foot), we are also dealing with a double problem of coverage and revascularisation. In this type of situation, the choice of soft tissue reconstruction is not confined to the immediate problem of wound closure, to the quality of the soft tissue cover or the possibilities of subsequent reconstruction, but also, we must consider the vascular pattern of the flap to be used, allowing a flow-through circulation, to achieve a one-staged technique of soft tissue coverage and distal revascularisation, without having to resort to an interpositional reversed vein graft to bridge the vascular gap (Fig. 1).

Anatomical and surgical considerations

The radial forearm flap is based on the radial artery which is included in a condensation of the deep fascia, called the lateral intermuscular septum of the forearm. The basic anatomy of this flap has been described previously (Guofan *et al.*, 1981; Song *et al.*, 1982; Mühlbauer *et al.*, 1982; Soutar *et al.*, 1983) as well as the surgical technique of raising it.

For preoperative investigations, we normally use the Allen test and/or Doppler to establish the presence of patent palmar arches and a good ulnar artery.

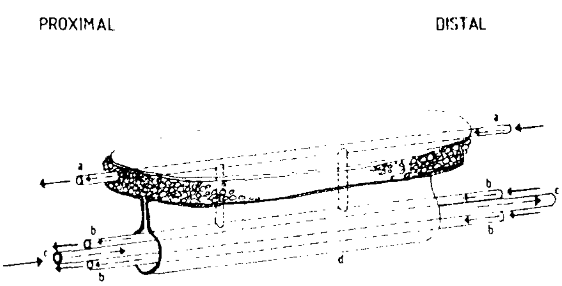

Fig. 1

Figure 1—Diagram showing the anatomical and dynamic concept of a flow-through fasciocutaneous free radial mid-forearm flap; a—superficial vein; b—venae comitantes, c—radial artery and d—lateral fascial intermuscular septum of the forearm.

Venous drainage of the flap is provided by two venae comitantes which accompany the radial artery and by subcutaneous forearm veins which drain into the cephalic, basilic and medial cubital veins. Either the deep or the superficial venous systems are sufficient to drain the flap with the anastomosis of one of those veins.

A large amount of tissue is available, including all the volar aspect of the forearm from the elbow down to the wrist, with radial and ulnar dorsal extensions. The territory of the flap may be divided in three regional areas and consequently, we can speak about three radial forearm flaps: the proximal, the mid and the distal flaps (Soutar *et al.*, 1983). Each one has its own advantages and disadvantages, as well as clinical indications, as pointed out by these authors and also discussed later in this text.

A radial mid-forearm flap may be harvested allowing considerable length of proximal and distal vascular pedicles. This feature gives the capacity to bridge long vascular defects and, most important, the functional vascular advantage of a flow-through circulation. We report the use of this flap in two clinical cases in which both coverage and ischaemia of the traumatised extremity were solved by this technique.

Case reports

Case 1

A 32-year-old man sustained a severe crush-degloving injury to his left forearm when it was caught in a roller machine. The injury comprised loss of skin, flexor muscles, radial and ulnar arteries, median and ulnar nerves, with avascularity of his left hand (Fig. 2A). An interpositional saphenous graft to the ulnar artery, performed by the vascular surgery team was unsuccessful (Fig. 2D arrow). A flow-through type of flap was needed and the radial forearm flap was selected (Fig. 2B). The flap was raised, including Palmaris Longus tendon (PL) to reconstruct Flexor Policis Longus (FPL) (Fig. 2C). The flap was transposed and the two ends of the radial artery, one venae comitantes and the cephalic vein of the forearm flap were anastomosed end-to-end to the proximal and distal ends of the sectioned vessels of the injured forearm. After flow-through was established, the hand became perfused well (Fig. 2D). Most of the defect was covered and healing was uneventful (Fig. 2E).

After a rehabilitation programme of 4 months, a free functional neurovascular gracilis transfer was performed, also with complete survival (Fig. 2F, G). The neurovascular gracilis pedicle was anastomosed end to end to anterior interosseous vessels and the nerve to the anterior interosseous nerve. The median nerve was reconstructed with two sural nerve grafts (16 cm). After 7 months, the patient had some grip strength and a limited range of excursion which allowed him to grasp small and large objects. He is still under a rehabilitation programme, including resisted exercises; further recovery is expected (Fig. 2H).

Case 2

A 20-year-old man sustained a crush-degloving injury to the lower third of his left leg and ankle when he was run over by a bus. The injury comprised loss of skin, soft tissue, extensor tendons, anterior tibial and peroneal vessels with exposed compound fractures of tibia and fibula, with avascularity of the foot (Fig. 3A). An emergency arteriogram revealed a triple vascular occlusion, in the lower third of his left leg, at the fracture level (Fig. 3B). Reduction and fixation of the fractures were achieved, but the foot remained ischaemic (Fig. 3C). Exploration of the posterior tibial artery was performed by the vascular surgical team which revealed multilevel lesions of the vessel; an interposition reversed saphenous vein graft was performed which was unsuccessful (Fig. 3D). A decision to use a flow-through type of flap was made and the selection was again the radial mid-forearm flap (Fig. 3E, F). The anterior tibial and dorsalis pedis vessels were identified and their stumps prepared for anastomosis. After proximal and distal anastomosis between these vessels and the radial artery and its two venae comitantes, an immediate flow-through circulation was established; the foot was perfused and the defect closed primarily. Postoperatively there were no complications and primary healing of the soft tissues and bones was obtained (Fig. 3G, H).

Discussion

The use of a free flap for soft tissue cover offers extra vascularity of the traumatised extremity and may even assist in revascularising damaged structures.

The territory of the radial forearm flap has three distinct areas which, by their anatomical characteristics, deserve to be considered separately (Soutar *et al.*, 1983). The proximal forearm flap is thicker, hairy and is easier to elevate; it leaves a suitable bed for grafting over muscle and a long retrograde arterial pedicle may be raised distally. The distal forearm flap is thinner and hairless, especially in women, but leaves a poor suitable bed for grafting over exposed flexor tendons; it may include vascularised bone and a long proximal vascular pedicle may be raised. The mid-forearm flap combines these advantages of easy dissection, is hairless, has thin skin and provides a suitable bed for grafting, also inclusion of bone and, most important, the possibility to dissect proximal and distal vascular pedicles allowing a flow-through circulation to be established. Another advantage is that either the venae comitantes or a superficial vein, or both, may be used to drain the flap and the distal revascularised segment of the extremity; this double venous drainage system of the flap links the superficial and deep venous systems of the reconstructed extremity. We believe that this technique achieves possibly the most physiological reconstruction in these clinical situations.

Other axial flaps may be used to put into practice this dynamic concept of flow-through circulation. The lateral arm flap is based on the posterior radial collateral artery which is a branch of the profunda brachial artery and has been described by Song *et al.* (1982) and by Katsaros *et al.* (1984). This flap has a shorter and thinner pedicle, particularly distally where its artery anastomoses with the recurrent interosseous artery, and its elevation is more difficult compared with the radial forearm flap. While it would probably be possible to use this flap as a flow-through flap, this has not been reported to our knowledge. The ulnar forearm flap is based on the segment of the ulnar artery distal to the common interosseous branch and has been described by Lovie *et al.* (1984); many of its properties are shared with the radial flap although

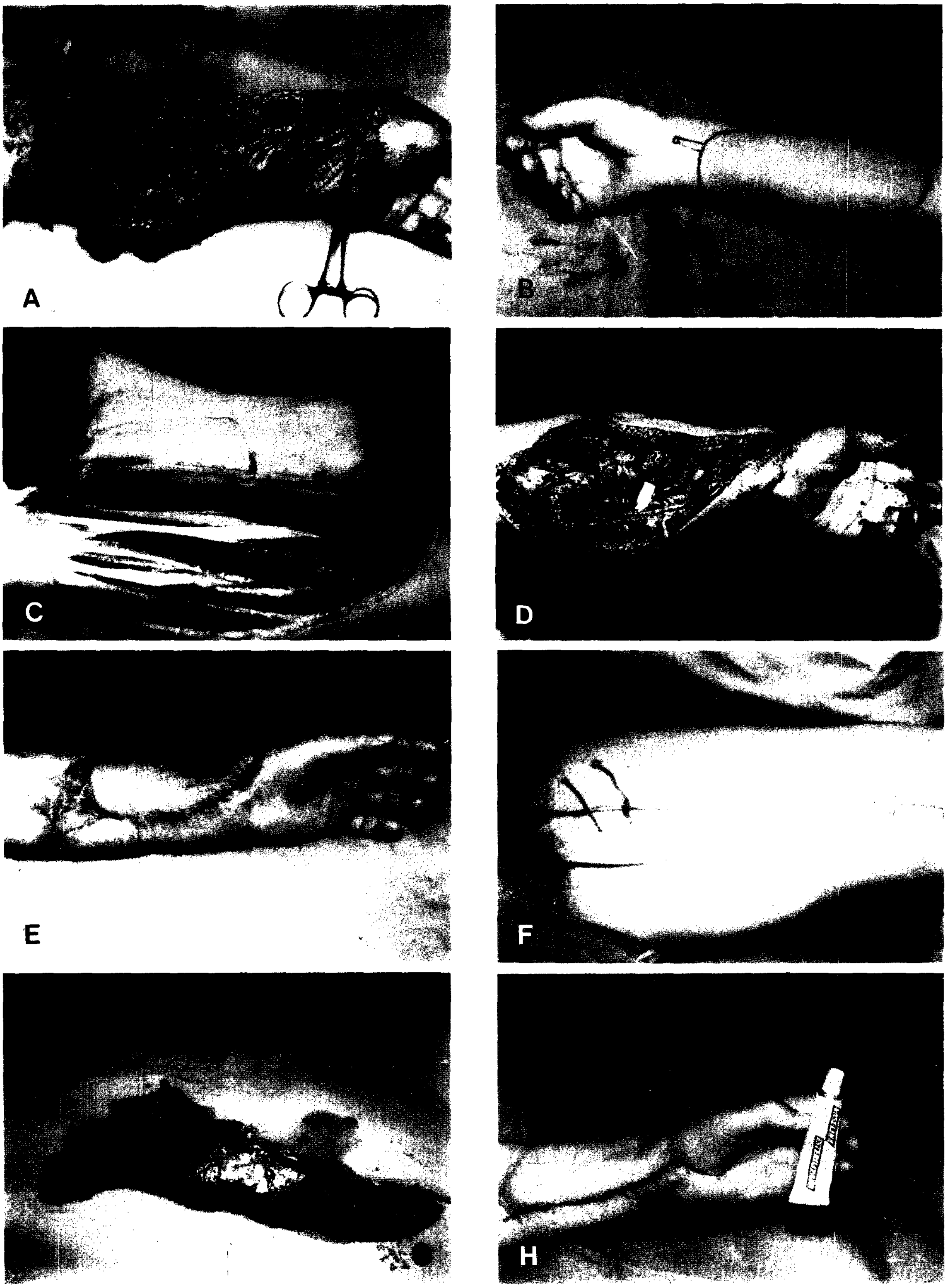

Fig. 2

Figure 2 (A) Crush-degloving injury, involving the anterior aspect of the left forearm, with loss of skin, flexor muscles, radial and ulnar arteries, median and ulnar nerves and an ischaemic hand. (B) Marking of the flow-through radial flap. (C) Raised flap, including PL tendon. (D) Transposed flap after proximal and distal arterial and venous anastomosis have been performed. The arrow points to the thrombosed interpositional reversed saphenous graft to the ulnar artery. (E) Appearance at 4 months after surgery with viability of the flap and the hand. (F, G) Drawing and harvesting of the free functional gracilis muscle transfer. (H) Appearance at 7 months after surgery. The patient already has a useful grip capacity.

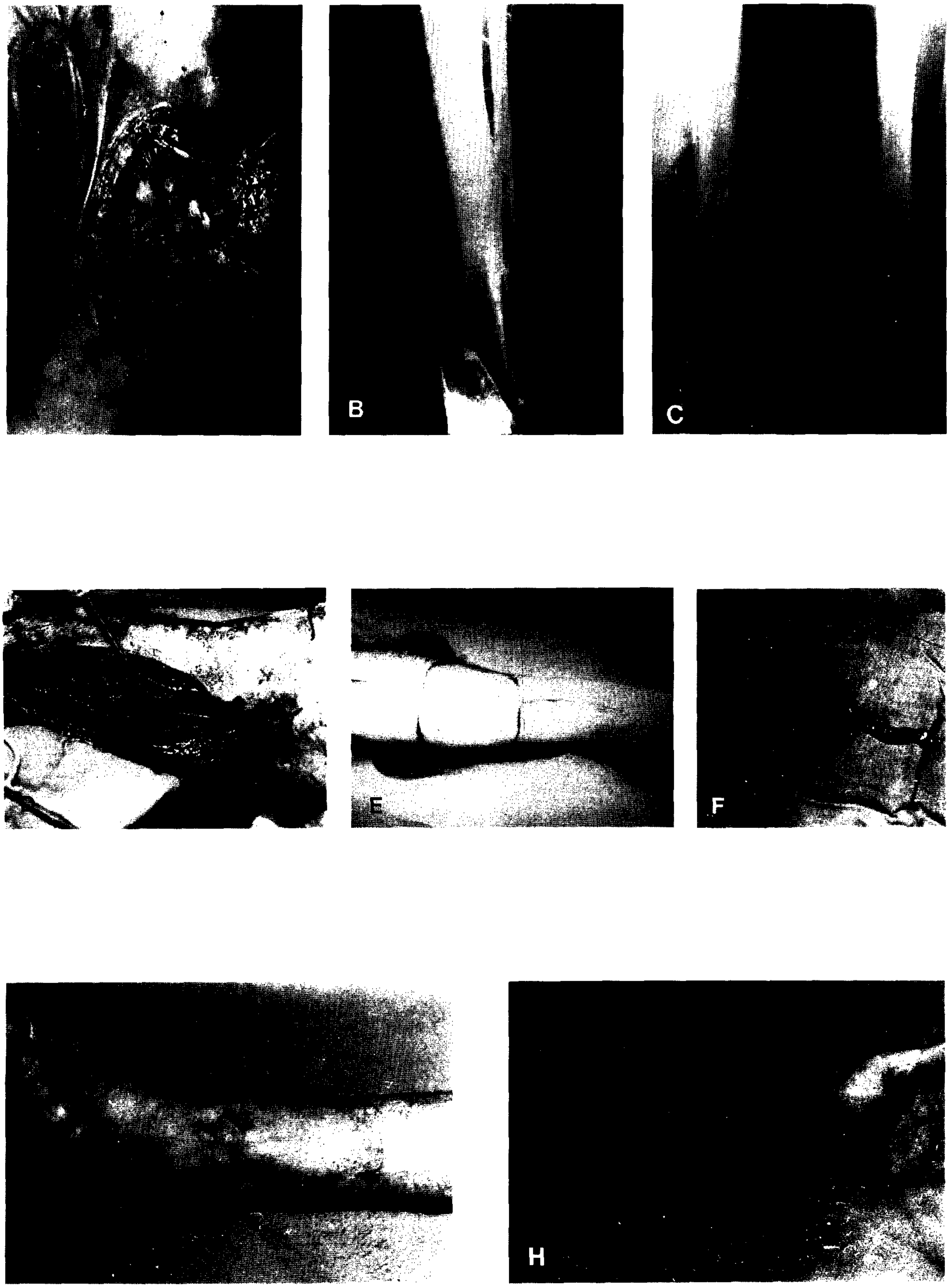

Fig. 3

Figure 3—(A) Crush-degloving injury, involving the lower third of the left leg, with loss of skin, extensor tendons, anterior tibial and peroneal vessels with exposed compound fractures of tibia and fibula and also an ischaemic foot. (B) Arteriography showing triple vascular occlusion, at the fracture level. (C) X-ray after reduction and fixation of the fractures. (D) Medial aspect of the left leg, showing the unsuccessful interpositional reversed saphenous vein graft to the posterior tibial artery. (E, F) Drawing and harvesting of the flow-through free flap. (G) Postoperative appearance after 3 months with a viable flap and foot. (H) The donor area was meshed-split skin grafted.

with some advantages: less hairy territory, less obvious donor site and, more important, when flexor carpi ulnaris muscle is included in the flap, it may be used to fill cavities; on the other hand, disadvantages are also present, such as a slightly more difficult dissection and the danger of devascularisation of the ulnar nerve.

The antecubital fasciocutaneous flap based on the inferior cubital artery, a branch of the radial artery, has been described by Lamberty and Cormack (1983); it was classified as a type B modified fasciocutaneous flap (Cormack and Lamberty, 1984). Its essential characteristic is the T-junction between the pedicle and the radial artery which enables a much longer distal arterial pedicle to be dissected; another advantage is that the length of the pedicle is independent of the flap length whereas in the radial forearm flap the length of the pedicle is inversely related to the size of skin flap; however, two major drawbacks exist with this flap: they are the absence of a significantly sized inferior cubital artery and the type C variety of this flap in which the vessel arises from the radial recurrent which has its point of origin from the brachial artery.

In conclusion, the flow-through concept is one of considerable use in the clinical field of major trauma of the extremities where compound tissue losses are combined with devascularisation of the distal segment. The free flaps which offer adequate characteristics for this vascular achievement are the radial forearm, the ulnar forearm, the antecubital forearm and the lateral arm fasciocutaneous flap, although we believe the advantages of the mid forearm radial flap outweigh the others.

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