ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA
VOL. LIX, N 2, 190 SECTIO D 2004

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Application of local innervated skin flaps in healing of posterior and sole calcanea surfaces defects

Calcanea soft tissues defects present a difficult reconstructive problem due to specific anatomical structure of both skin and subcutaneous tissue and innervation as well as vascularity of this region. The studies showed that calcanea region is blood-supplied with a rich vascular plexus situated between the skin and the calcaneum, oriented transversely (crossly) to the long foot axis, mainly supplied by subcutaneous blood vessels originated from foot tergal artery, joining with this plexus both laterally and medially as well as to a lesser extent with lateral sole artery connected with the plexus by means of vertically oriented branches. This region is also slightly blood-supplied by medial sole artery. Both sides, lateral and medial are penetrated by branches coming from calcanea lateral artery (fibula artery) and medially by posterior tibia artery branches. This whole vascular plexus extends from the metatarsus base to posterior calcanea surface (7). This region is distally adjacent to medial sole area blood--supplied by both medial sole artery and tergal artery of foot. The region in the place of metatarsus bone heads changes into distal foot area mainly supplied by tergal foot artery and to a lesser extent by lateral sole artery. Lateral area is supplied to a greater extent by sole lateral artery and to a lesser extent by tergal foot artery. Both lateral and medial areas meet somewhere round above metatarsus space III, laterally to sole aponeurosis (7, 14).

Due to the possibility of innervated local skin flaps usage, sole innervation is also of great importance. It is crucial for healing durability. Calcanea area is mainly innervated by medial calcaneal nerve branching from tibial nerve and then radially parting in three branches at medial malleolus. In this way the whole sole calcanea surface is innervated. The nervous branches are situated at the distance of 4 mm from skin surface. Calcanea lateral side is in a slight way innervated with lateral calcanea branches derivating from calfnerve (7). Distal part of the calcanea is innervated by skin branches coming from medial (medial) sole nerve. Just a small sole part laterally to metatarsus space IV is innervated by lateral sole nerve. Proximally in 3 cm distance from metatarsus bone heads above sole aponeurosis there are branches coming from medial sole nerve lied superficially and subcutaneously in metatarsus spaces which result in sensorial innervation of the distal part of foot and fingers sole skin surface. This fact is of crucial importance for skin flaps and skin cuttings planning on the distal sole surface in order not to cause additional damage of foot innervation (7, 14).

The point of this study is to recapitulate the application of local innervated skin flaps easy for preparation and transferring to calcanea posterior and sole surfaces defects.

FLAPS FROM TIBIA POSTERIOR SURFACE.

Some flaps taken from posterior distal tibia surface have been described as used in healing of posterior calcanea surface defects. One of these is distally pediculated skin fascial innervated calf flap (Fig.1), (3). It can be transferred on posterior and sole calcanea surface as an insular flap together with a pedicle built of subcutaneous tissue, deep fascia, fibula vein, calf nerve and arterial plexus or calf artery (3, 12). The flap can be transferred basing on cellulocutaneous pedicle containing arterial vessel or arterial system situated medially to fibula vein and calf nerve (11). The axis of the prepared flap is the line coming through the apex of lateral malleolus and the centre of popliteal fossa (3, 12). The method consists in the preparation of subcutaneous-fascial pedicle at least 3 cm wide together with artery, vein and nerve. The flap fulcrum is placed 5 cm above the medial malleolus where are the reverse connections of calf and fibula arteries (3). The disadvantage of the method is the necessity to cut the calf nerve and besides, its application with elder people with arteriosclerosis is impossible because the calf artery and its distal perforator are of quite a small size (3, 12).

Fig. 1. Distal pedicled innervated skin fascial calf flap; K – medial malleolus, P – pivot point, N – sural nerve, V – short saphenous vein

In order to cover defects of posterior calcanea surface preparation by means of V–Y stairs shift of skin – fascial flap based on two lateral subcutaneous pedicles is relatively easy (Fig. 2), (5). The flap is taken in a triangle of tissues above Achilles tendon, shifted down above the defect of the posterior calcanea surface. The first segment situated next to the defect should be of the same size as the defect, the second of 1/4 and the third of 2/4 less in relation to the first one till reduction enabling to put stitches in tibia skin. The flap is medially and laterally blood-supplied by branches coming from fibula and posterior tibia arteries reaching the flap in both pedicles subfascially and subcutaneously prepared. The pedicles should not be laterally released in breadth not extending 1.5–2.5 cm. Maximal shift of the flap to distal direction equals 2.5 cm. The advantage of the flap is that skin transplantation is not necessary in the donor area and disadvantage of the method is not precise subfascial preparation of both pedicles and danger of subfascially situated structures damage (5).

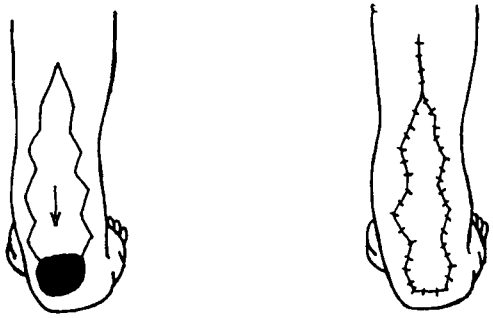

Fig. 2. Posterior calcaneal preparation by means of V-Y stairs shift of skin-fascial flap

FLAPS FROM LATERAL MALLEOLUS AREA

Usage of lateral skin-fascial calcaneal flap supplied by lateral calcaneal artery, which is the final branch of fibula artery has been known for over 20 years. Flap pedicle includes calf nerve and fibula vain (4, 8). It results in proper vein outflow and innervation of the flap. The flap is taken from the part situated between Achilles tendon and medial malleolus. The flap can be planned as a shorter pedicle form sized 8 x 4.5 cm or longer one 14 x 4.5 cm. In the latter case it is extended to the base of V metatarsus bones (4). In case of applying longer form preparation the transplantation should be preceded by Doppler's flow-meter test for lateral calcaneal artery state. Both parallel long sides of the flap should be prepared and the pedicle should be clammed in order to check its blood-supply before cutting the further part of the flap. If blood-supply is not satisfactory postponed, shift of the flap can be applied. Another well-known insular lateral calcanea flap method consists in subcutaneous preparation of pedicle together with lateral calcaneal artery, fibula vein, calf nerve (8). In order to avoid covering of donor defect with skin flap and calf nerve cutting, subcutaneous-fascial lateral calcaneous flap with sensorial fibres penetrating the flap was proposed (9). This way of preparation causes surgery complication and disturbs blood-supply of subcutaneous fascial flap and skin left in donor area. It has also been proposed to apply lateral calcaneous flap shifted by means of method V–Y above a small defect of posterior calcanea surface (6) (Fig. 3). The disadvantage of the lateral calcaneous flap is relatively small transposition range not including medial sole calcanea surface resulting in sensorial disturbances of lateral foot surface (4).

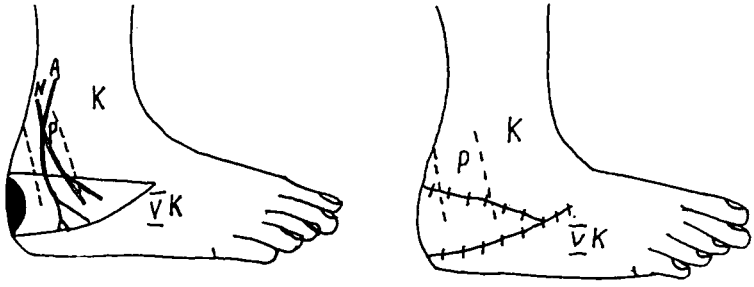

Fig. 3. Lateral calcaneal flap V-Y transposition; A – lateral calcaneal artery, K – lateral malleolus, N – sural nerve, P – pedicle flap, VK – V metatarsal bones

FLAPS FROM SOLE FOOT SURFACE

The skin of sole foot surface is the best tissue used for healing of sole calcanea surface defects. Due to simple preparation rotational cellulocutaneous sole flaps blood-supplied with a rich subcutaneous plexus which provides the skin of sole calcanea surface, reaching distally half-distance of metatarsus bones heads and the calcanea (Fig. 4), (6, 14). The flaps can be pediculated not only laterally but medially as well. They should be innervated, then the flaps ought to be medially pediculated as medial calcaneous nerve is situated on this side (14). The flap may include both the whole sole calcanea surface and a part of sole metatarsus in order not to cover IV metatarsus part. Distal skin cut must be at least at 3 cm distance proximally from I and II metatarsus bones heads not to damage sensorial branches of medial sole nerve innervating the distal part of foot skin. Flap preparation is carried out in ischemia in the layer over fascia while fascia covering the abductor muscle of both great toe and little toe as well as sole foot aponeurosis remaining unchanged. While lifting the flap sole lateral and medial nerves branches coming from between the abductor muscle of the great and little toes and the short flexor of toes must be left unchanged in the flap. Prepared flap may include skin vessels coming from medial or lateral sole artery depending on the side of pedicle. Such a procedure is, however, not necessary because blood supply by foot tergal artery system is satisfactory (6, 14). The flap shift should be planned to cover the whole lateral side of loaded foot surface, especially head and base of the V metatarsus bones, such flaps may cover only relatively small sole calcanea surfaces defects, they are simple in preparation and well innervated (Fig. 4), (14).

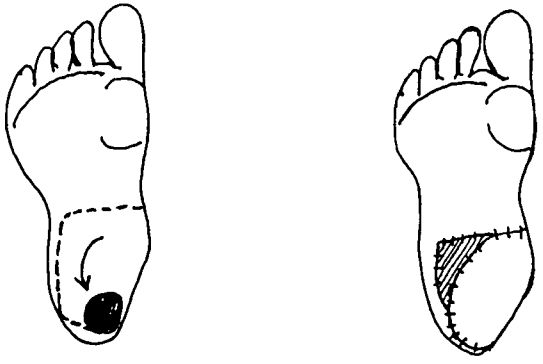

Fig. 4. Random flap from proximal sole foot surface

The useful flaps used in healing of calcanea defects are fascial-skin taken from medial part of foot instep insular, or pedicle ones (10, 13). The flap is blood-supplied by branch of sole artery and innervated by skin branches coming from medial sole nerve. The flap is planned in the range of foot instep from the area above I–III metatarsus bone (Fig. 5), (10). After the identification of sole foot aponeurosis, fascial septum between the tendon of toes short flexor and the great toe abductor muscle must be carefully prepared. Then medial sole artery must be approached and prepared together with medial sole nerve. The artery and veins are then cut in order to fix the area of proximal preparation. The nerve is left unchanged but the branches coming from it are to be included in the flap. The method described above seems to be more complicated but the flap is chosen to cover defects of sole calcanea surfaces due to its innervation and structure similar to calcanea skin. Such a preparation is used to cover medium-sized defects and it enables the covering of final part of Achilles tendon due to extended rotarial arch (2).

Fig. 5. Island fasciocutaneous flap pedicled medial plantar artery; A – medial plantar artery, N – sensor branch from medial planar nerve, PF – deep fascia, AH – abductor hallucis muscle, FDB – flexor digitorum brevis muscle

Ideal reconstruction technique should: 1) supply tissues mechanically resistant and sensorially innervated, 2) be satisfactory, 3) require only one surgery with minimum damage on donor area. The advantage of described flaps is that sensorially innervated tissues transplanted in only one surgery stage are stable, pressure and abrasion resistant. Hidalgo and Shaw pointed that blood-supply and innervation of sole foot surface was different than it was thought to be, which resulted in changing flaps planning to the medial side of the pedicle (7, 14). Presented surgeries are relatively simple preparation methods, except for the medial insular flap taken from foot instep. This method requires the preparation of medial sole nerve in order to include sensorial fibres into the flap (10). The disadvantage is mainly small sized flaps able to cover only medium defects of both sole and posterior calcanea surface. Another very important problem consists in the loss in donor area. Serious complications may be caused by difficulties with flap taking in the donor area (10).

In case of large sole calcanea surface defects the chosen healing bases on the usage of free flaps. In many of foot surgery centres this is the basic operating method. Then the operating complications do not exceed 10% regardless of the patient's age (1). The most common flaps fulfilling the requirements of specific area are fascial-skin free flaps such as: foot instep, inguinal, scapular, antebrachial (1). Free flaps taken from foot instep and antebrachial can be innervated flaps, which is meaningful in case of reconstruction of loaded foot area (1). If the defects are accompanied by calcaneum inflammation, the basic reconstruction method is the usage of free or local muscle flaps (15). The disadvantage of muscle flaps grafted on calcanea is the breadth and deformation on donor areas. As muscle flaps are disinnervated, they must be covered with skin flaps, which results in fractures and ulceration in loaded areas (1, 15).

Local innervated flaps presented in this work are not the only possible to use in defects of both sole and posterior calcanea surface. Nevertheless, they are recommended in cases of not too vast soft tissues defects without an acute infection and should be taken into consideration in healing procedure.

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SUMMARY

In the paper were shown the methods of the local innervated skin flaps, harvested from the posterior surface of the lower leg, the lateral malleolus region and the plantar surface of the foot, used in treatment of soft tissues defects of posterior and plantar surface of the heel.

Zastosowanie płatów miejscowych unerwionych w leczeniu ubytków tylnej i podeszwowej powierzchni pięty

W pracy przedstawiono w sposób poglądowy zastosowanie płatów miejscowych unerwionych, pobieranych z tylnej powierzchni goleni, okolicy kostki bocznej, powierzchni podeszwowej stopy, wykorzystywanych w leczeniu ubytków tylnej i podeszwowej powierzchni pięty.