Surgical treatment of frostbite of the fingers using a radial forearm flap

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Abstract

Objective. To improve the results of treatment of patients with frostbite of III – IV degree of fingers by using skin and fascial flaps with retrograde blood circulation.

Materials and methods. Five patients (all males) aged 26 to 48 years with frostbite of 14 fingers of 7 hands were under observation. Radial skin and fascial flaps with retrograde blood circulation were used to close the finger defects.

Results. All patients had complete engraftment of radial skin and fascial flaps with retrograde circulation. The use of skin and fat or skin and fascial flaps of the trunk with random circulation is characterised by such disadvantages as flap necrosis, prolonged immobilisation of the limb, which leads to neurodystrophic syndrome. To preserve the length of the bone, it is necessary to perform revascularisation operations with tissue complexes with axial circulation.

Conclusions. The use of radiation skin–fascial flaps with retrograde blood circulation in patients with frostbite of the fingers helps to preserve the proximal and middle phalanges of the fingers, which are covered with full skin, and the length of the fingers by 1–1.5 cm in contrast to standard methods of treatment.

Key words: frostbite of the fingers; radial flap of the forearm.

Frostbite is a severe ischaemic injury that occurs as a result of exposure to low temperatures and leads to various injuries to civilians and the military, accompanied by disability [1, 2]. Most often, the hands and feet are affected. Frostbite among the civilian population occurs most often in patients with mental illness, after alcohol and drug abuse. These patients are usually men between the ages of 30 and 50. In addition, frostbite is observed in mountain climbers, people who work with cold objects and liquids without adequate limb protection. The degree of frostbite depends on many factors, such as ambient temperature, presence or absence of wind, humidity, individual sensitivity, and the presence of concomitant diseases of the vascular or nervous system [3]. In the treatment of frostbite, there are pre–hospital and hospital stages. At the pre–hospital stage, the limbs are warmed using thermal insulation bandages or warm water baths. Rapid warming in warm water (40 – 42 °C) remains the standard of care. At the hospital stage, anticoagulant, rheological and anti–inflammatory therapy is performed. Numerous studies have shown that thrombolytic therapy improves tissue salvage [4, 5]. Emergency surgical treatment involves fasciotomy in the presence of compartment syndrome of the affected limb [6]. Subsequent surgical treatment consists of amputation of limb segments after demarcation is formed. As a rule, this occurs in 1 to 3 months after the injury. During this time, patients undergo dressings of the affected areas with antiseptic solutions. To restore the skin, primary wound suturing or skin grafting is most often used [7]. It is possible to use free skin grafting, but this material is unsuitable in places where there are exposed bones, joints, tendons or neurovascular bundles. To close them, plasty is used with tissues from distant parts of the body, vascularised tissue complexes [8]. However, this treatment is accompanied by a significant shortening of the finger stumps, which is associated with significant negative functional and psychological consequences [9].

The aim of the study is to improve the results of treatment of patients with frostbite of the third to fourth degree of fingers by using skin and fascial flaps with retrograde blood circulation.

Materials and methods

Five patients (all men) aged 26 to 48 years with frostbite of the fingers were under observation. In total, 14 fingers of 7 hands were frozen: four I fingers and ten II to V fingers. In all patients, a radial skin–fascial flap with retrograde blood circulation was used to close the defects.

The four–stage Cauchy classification of frostbite was used to assess the depth of lesions and predict the level of amputation [10]. According to this classification, all patients had frostbite of III–IV and II–III degrees. All patients were operated on within 16–21 days after the injury. After hospitalisation, the patients were examined clinically, laboratory and instrumentally. Before the operation, patients underwent Allen's test to assess the patency of the hand arteries in the affected limb [11].

Anatomical vascular basis of the flap

The surgical treatment consisted of two stages. At the first stage, a necrectomy of the affected fingers was performed. All non–viable soft tissues, thrombosed finger vascular bundles were removed, and the nail phalanges of the fingers were amputated. The bottom of the wounds consisted of finger phalanges, flexor and extensor tendons, joint capsules, i.e. all tissues with low metabolic activity. In all patients, the
remaining tissues were viable with signs of capillary bleeding.

The second stage consisted of closing the exposed deep structures of the fingers. After necrectomy, a tourniquet was applied to the shoulder of the affected limb and a skin–fascial flap on the radial vascular pedicle with retrograde blood circulation through the superficial palmar arch was isolated according to the generally accepted method [12]. After forming the flap, the tourniquet was removed, and hemostasis was performed. The flap on the vascular pedicle was deployed 180°. The skin on the back surface of the hand between the base of the flap pedicle in the area of the radiocarpal joint and the defect on the fingers was dissected. The vascular pedicle was inserted into the wound, and the flap was used to cover the wound surfaces on the fingers after necrectomy with the formation of artificial syndactyly. Donor sites on the forearms formed after flap harvesting were partially sutured and covered with a free split skin flap.

In 1.5–2 months after closure of the defects, surgical interventions were performed to mobilise the finger stumps, which were connected in an artificial syndactyly with a radial skin–fascial flap with retrograde blood circulation, as well as to model lipophilic finger flaps.

**Results**

All patients had complete engraftment of the radial skin–fascial flaps with retrograde blood circulation on the fingers. In 1 patient, suppuration of the subfascial space on the stump was observed, which was treated with conservative methods. We present two clinical observations.

1. Patient X., 45 years old, suffered frostbite of III – IV degree (II – III degree according to the Cauchy classification) of I–V fingers of both hands (Fig. 1, A) and feet, anterior surface of both knee joints in a state of alcohol intoxication. He was initially treated in another medical institution. Upon admission, his condition was moderate. He received infusion, antibacterial, disaggregant and anticoagulant therapy. Surgical treatment consisted of excision of necrotic tissue with subsequent plastic surgery with a radial skin–fascial flap with retrograde circulation (Fig. 1, B). Long–term results of treatment were also observed (Fig. 1, C).

2. Patient K., 26 years old, suffered frostbite of III – IV degree (II – III degree according to Cauchy classification) of the first finger of the left and II–V fingers of the right hand. Upon admission, his condition was moderate. The patient received infusion, antibacterial, disaggregant and anticoagulant therapy. He underwent necrectomy with plastic surgery with a radial skin–fascial flap with retrograde circulation 3 weeks after hospitalisation (Fig. 2).

**Discussion**

Various methods are used to close defects in the soft tissues of the hand and fingers with exposure of deep structures, most often plastic surgery with skin and fat or skin and fascia flaps from the trunk with random circulation, and transfer of flaps from distant parts of the body using microvascular anastomoses. These methods for closing defects after frostbite are not without such disadvantages as frequent suppuration of the subfascial space, partial or complete necrosis of the skin and fat flaps, thrombosis of microvascular anastomoses, prolonged immobilisation of the limb, which in turn leads to neurodystrophic syndrome with subsequent limb dysfunction, especially in elderly patients.

A radial dermal–fascial flap with retrograde blood circulation is often used to close post–traumatic defects in reconstructive hand surgery. In this variant of flap placement, blood circulation along the radial vascular bundle is carried out by the superficial palmar arch through the ulnar artery. The flap is supplied with blood through perforating vessels that extend from the radial artery along its entire length and are included in the flap during its formation. The venous outflow occurs through the adjacent veins. The disadvantages of us-

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*[Fig. 1. Photos of the left hand of patient X.: A – at hospitalisation; B – 3 months after necrectomy and plastic surgery with a radial dermal–fascial flap with retrograde blood circulation; C – 3 months after mobilisation of the fingers and modelling of the flaps on their stumps.]*
ing this flap are necrosis of skin grafts in the donor area with exposure of flexor tendons, cosmetic defect in the donor area, and decreased hand strength.

As is well known, the phalanges of the first finger are supplied by the palmar and posterior carpal arteries, and the phalanges of the third and fourth fingers by the palmar arteries. Small branches extend from them to the diaphysis of the phalanges, and the periosteal vascular network is formed. The diaphyseal vessels provide blood supply to the contents of the bone marrow cavity and the cortical plate of the diaphysis. The periosteal network is closely connected with the vessels of the surrounding soft tissues. Small, thin vessels extend from the periosteal vessels in large numbers to the surface layer of the compact substance of the diaphysis, where they anastomose with vessels coming from the bone marrow cavity. In other words, frostbite disrupts both sources of blood supply to the phalanges due to vascular thrombosis. This requires revascularisation surgery to preserve the length of the bone. Studies [13] have shown that the presence of blood vessels in the tissues surrounding the bone accelerates angiogenesis, which in turn accelerates osteogenesis.

Thus, in view of the above, the exposed phalanges of the fingers after necrectomy should be closed with vascularised tissue complexes with axial circulation. In our opinion, the optimal flap for the reconstruction of the hands after frostbite is the radial skin–fascial flap with retrograde blood circulation.

Conclusions

The use of a radial skin–fascial flap with retrograde blood circulation allows improving the results of surgical treatment of patients with frostbite by preserving the proximal and middle phalanges due to their closure with a full skin covering, as well as the length of the fingers by 1–1.5 cm as opposed to standard methods of treatment.

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