RADIAL FLAP IN RECONSTRUCTIONS OF THE HAND - CASE SERIES STUDY

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ABSTRACT

Radial forearm flap is an axial flap that has become an important technique in reconstructive surgery as a free flap or as a pedicled flap. Defects of the skin and other tissues on the hand are very common and most often they are work-related injuries. In deep defects, flap must be used, as well as in reconstruction of the amputated thumb. There are many flaps that provide adequate soft tissue coverage for the hand. Therefore, the aim of this paper is to present the results of the use of radial forearm flap in various reconstructions on the hand. The retrospective study included 35 patients who underwent reconstruction with radial forearm flaps due to defects of the skin and other tissues on the hand, in the period 1997-2019. Results and complications of the surgery were analyzed. The functional and aesthetic outcome was assessed using Michigan Hand Outcome Questionnaire. All patients were followed for a minimum of 1 year. Fasciocutaneous flap was the most commonly used (65.71%), followed by adiposofascial (20%) and osteocutaneous (14.29%). The size of the fasciocutaneous flap ranged from 2.2x3.1cm to 9x13.5cm. The majority of donor sites were closed with split-thickness skin grafts (56.52%), and less frequently with direct suture, local skin flap, and full-thickness skin graft. There were no complete flap losses in the study. Marginal necrosis was noted in 8.57%, and graft failure at the donor site in 14.29%. Secondary surgical procedures were performed in 13 patients. The functional-aesthetic result of the operation, based on the MHQ score, ranged from 31 (1/35) to 130 points (3/35). The ultimate aim of hand reconstruction is to restore sufficient function and form, also, closing the wound within three days following the injury is desirable. Meticulous intraoperative dissection of radial flap and early physical therapy after surgery are mandatory. The radial flap is a suitable method, especially for large and more distal skin defects on the hand, and a very good method for thumb reconstruction.

Keywords: Flap, surgery, reconstruction.

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INTRODUCTION

A flap is a segment of skin or other tissues that has its own vascularization, used for soft tissue coverage. It is most commonly performed when direct suture and skin grafting are not possible, due to lack of circulation in the area of the defect, or it is undesirable for functional or aesthetic reasons. The flap can be random or axial, which has the clear defined vascular basis.

The radial flap is one of the well known flaps in plastic and reconstructive surgery. It is also called Chinese flap because it was used for the first time in China in 1978. (1-2). It is an axial flap containing a radial artery with accompanying veins. Radial forearm flap (RFF) may be fasciocutaneous, adiposofascial, but may also contain other tissues, such as bone, muscle, tendon and nerve. According to the transfer, the RFF can be pedicled or free-microvascular. According to the direction of blood flow, there are a proximally and a distally based or reverse radial flaps. A proximally based RFF is used as a pedicled flap for defects in the proximal part of the forearm, elbow area and distal part of the upper arm, or as a free microvascular flap. A distally based flap is used for hand defects. Retrograde blood flow through it originates from the ulnar artery and the deep palmar arterial arch. The perforant branches of the radial artery are numerous, constant, and extend through the lateral intermuscular septum of the forearm, ending on the superficial side of the deep fascia of the forearm. The vascular cutaneous territory of the RFF is therefore large. Constant anatomy, reliable vascularization, large arch of rotation, thin and pliable skin, make this flap widely used, not only on the hand and upper extremity, but also on almost all parts of the body, as a free flap (defects in the face, lip, oral cavity, pharynx, esophagus, penis reconstruction, vagina, lower extremity defects) (3). For defects in the hand, the forearm flap was first used by Stock, Mühlhauer and Biemer (4, 5). Due to its long vascular pedicle and large vascular cutaneous territory, the radial flap can be applied to various skin defects in the hand.

Skin defects of the hand are common and sometimes affect other tissues. Traumatic etiology is most common. Sometimes it is necessary to use a flap for coverage of the defect. For smaller defects, local skin flap is appropriate. Various methods (6-9) have been used for larger defects in the hand, with two-stage distant direct flaps from the anterior chest and abdomen, the most commonly inguinal flap. Also, microvascular transfer of distant free flaps is used (10). Most of these methods are associated with prolonged surgeries, multi-stage procedures, undesirable patient positions, prolonged and difficult rehabilitation. In addition to the radial forearm flap, other flaps from the forearm can be used: ulnar artery flap or interosseus posterior flap (11, 12). For medium-sized defects, flaps with radial or ulnar artery perforators may also be used (13, 14).

Since defects of the skin and other tissues on the hand are quite common, primarily due to injuries, but also other pathological conditions (tumors, infection, iatrogenic), in many

situations it is necessary to use the flap as a method of reconstruction. So, the aim of this study is to present experiences with the use of radial forearm flap (RFF) in various skin defects of the hand.

METHODS

A case series study in the period 1997-2019. included patients who had a skin defect in the hand that had to be closed with a flap, or skin defect could not be covered by a free skin graft for other reasons (need for secondary surgical procedures on deeper structures, functional or aesthetic reasons). Excluding criteria were: age under 18, injury or more extensive scar on the anterior forearm, positive Allen test (weak anastomosis between radial and ulnar artery), incomplete medical records (insufficiently long observation period) and severe forms of systemic diseases.

Allen test and Doppler ultrasonography were performed preoperatively (Fig.1). The operations were performed under general or regional anesthesia, under the tourniquet control (Fig.1). Block anesthesia was used in a smaller flap when donor site was suitable for closure by direct approximation. Longitudinal lazy "S" incision at the forearm was used in all patients, and flap dissection was performed subfascially (Fig.2, Fig.3), with the preservation of the superficial branches of the radial nerve (Fig.2). According to anatomical conditions, a cephalic vein or other superficial vein of the forearm was incorporated into the flap to improve venous drainage within the flap. Anticoagulant prophylaxis was not used. All patients underwent intensive physical therapy as early as possible. The test parameters were race, age and gender, side (right/left), hand dominance, etiology, localization and size of defect, type and size of flap, type of anesthesia, length of surgery and length of hospitalization, success of flap transfer, donor site, presence and type of complication of surgery, and functional-aesthetic result.

Figure 1. Allen test with pulse oximeter before surgery (picture first left and second left).

Doppler ultrasonography -10MHz probe placed in the course of radial artery (image on the right). Image at the right end: Marking the flap at the beginning of the surgery under the tourniquet control

Figure 2. Radial forearm flap dissection under tourniquet control.

Figure 3. Completed elevation of distally based radial forearm fasciocutaneous flap

Figure 4. On the left: massive hand defect after injury. On the right: giant hand squamocellular carcinoma

In the picture on the right (analog photography), radial blood vessels and superficial branch of the radial nerve are marked with arrows.

Figure 5. Fasciocutaneous flap with donor defect closed by split-thickness skin graft (picture left).

Flap coverage of the dorsum of the hand and middle finger (picture in the middle). Right: adipofascial flap radial flap, with direct closure of the donor site.

Figure 5. Small Chinese flap in thumb reconstruction

Figure 7. Small Chinese flap in thumb reconstruction

Total thumb reconstruction with osteocutaneous radial flap.

Figure 8. Hand reconstruction with osteocutaneous forearm radial flap. Picture at the end: thumb grip after surgery: note the hair growth at the tip of the flap (analogous photos).

Scheme 1. Schematic cross section through the forearm.

Radial blood vessels in the intermuscular septum between the brachioradialis muscle (BRM) and the flexor carpi radialis muscle (FCRM). Marked: segment of skin, adipose tissue and fascia in the flap. Vv.: cephalic and basilic veins; PLM: Palmaris longus muscle.

The functional and aesthetic result of a surgery was assessed using a modification of the MHQ Score (Michigan Hand Outcome Questionnaire)¹⁵ which included six groups of questions: general hand function, quality of normal and frequent daily life activities, work ability in major aspects, presence and intensity of pain, subjective assessment of aesthetic results of surgery and general patient satisfaction with surgery. The overall function of the hand was estimated by answering 5 questions: How does your hand work/How well do your fingers move/How well does your wrist move/What is your fist strength/How do you feel your hand? Responses were rated from 1 to 5 (very bad, bad, medium, good and very good). Daily life activities were evaluated by answering questions related to the use of certain items and frequent activities (doorknobs, keys, glasses, buttons, pads, forks and knives, washing dishes and hair, picking up small items, carrying a bag). Work ability was examined by answering questions related to the working status of the patient, the amount of work load, interruptions at work due to difficulties, etc. The fourth category of the questionnaire referred to pain, in terms of whether it exists (always, often, sometimes, rarely) or not, as well as the intensity of the present pain (very strong, severe). The aesthetic aspect was assessed by the question: What impression did you get when you looked at your fist in the last 7 days?; with answers: it interferes with my social activities; I am depressed; sometimes I am uncomfortable when I am in the company; I am satisfied). The last question was about the satisfaction with the operation, with the answers: very dissatisfied, somehow dissatisfied, neutral, somehow satisfied, very satisfied. The MHQ score totaled 41 questions, with a minimum of 24 points and a maximum of 137, with a higher score for better functional and aesthetic results. Period of observation was one year, or more. In the statistical data processing, a descriptive approach was applied whereby categorical variables were presented as absolute and relative frequencies of individual categories, and continuous variables were summarized as the mean and the associated range of variation.

RESULTS

All patients were caucasians, mostly male (82.86%), and aged from 23 to 67 (mean: 44.2). Men ranged from 23 to 67 years and women from 28 to 44 years. The right hand (60%) and the dominant hand (71.43%) were injured more often. The etiology of the defect (Fig.4) was different: injury in 30 patients (85.71%) excision of skin tumors in five patients (14.28%) and infection in two patients (5.71%). Most injuries were mechanical in nature (25/35). In three patients, there was explosion wound (3/35) and in two patients, a deep electrical burn (2/35). Most patients with traumatic skin defects were from rural areas (22/30). Localization of skin defect was most common on the dorsum of the hand (18/35). Other sites of the defect were: palm of the hand (3/35), finger (6/35), and combined (8/35). Surgery was performed in all cases as primary delayed or secondary closure of the defect. Five patients underwent excision of a previously placed skin graft because of the need for secondary surgical procedures on deeper tissues. In 27 patients, the surgery was performed under general anesthesia and in eight patients under regional anesthesia.

According to compose, fasciocutaneous flap (Fig.5) was most commonly used (23/35). Adiposofascial flap (Fig.5) was used in seven patients (20%) and osteocutaneous in five patients (14.29%). The size of the skin segment in the flap ranged from 2.2x3.1cm to 9x13.5cm (average: 8x4.5cm). The donor site of fasciocutaneous flap (Fig.5, Fig.6) was closed by a split thickness skin graft in 13 cases (56.52%), direct suture in five patients (21.73%), local skin flap in three patients (13.04%) and a full thickness skin graft (FTSG) in one patient (4.35%). The Z-plasty was used in two patients (8.69%), a rotational flap in one (4.35%) and a bilobar flap in one patient. The length of the operation ranged 75 to 175 minutes (mean 145 minutes). There were no cases of complete flap necrosis. In three patients, partial necrosis occurred (8.57%) with no significant consequences. Wound dehiscence in the flap was noted in five patients (14.29%), infection in three (8.57%), hematoma and seroma in five patients (14.28) and graft failure in the donor site in five patients (14.29%). Three patients underwent total lysis of the graft, and two patients had partial lysis. In one patient, the skin graft was partially lysed on the fascioadipose flap. The length of hospitalization was 8-31 days (mean 17). Secondary surgical procedures were performed in 13 cases (37.14%). Tenoplasty (17.14%) was performed in 6 patients and osteoplasty (11.43%) in four patients. In six patients, flap debulking was necessary (17.14%).

The functional-aesthetic result of the operation based on the MHQ score ranged from 31 (1/35) to 130 points (3/35) and averaged 95.5 points. There were no minimum (24) or maximum points (137), with the average value of MHQ scores being more than half of the maximum.

DISCUSSION

The idea of transferring forearm skin as a cross-forearm flap (16) was not widely accepted because it is a two-stage procedure, with a forced upper extremities position and possible functional impairments. An insular, axial skin flap with a radial artery and veins was first used in 1978 in China as a microvascular free flap for neck reconstruction in extensive scar contraction after deep burn. Three years later Chinese authors published the results of large series of this method in various complex defects of the face (3). Inspired by this technique, European surgeons, after their visit to China, began to use this flap, not only as microvascular, but also as pedicled flap, first for reconstructions on the hand (4,5). Extensive anatomical studies were performed (19, 20). The radial flap has become widely used for defects in other localizations, making it one of the most used flaps. The main reason was its reliable vascularization.

The radial artery is lateral terminal branch of the brachial artery and extends from the neck of the radial bone to the styloid process. It is located in the intermuscular septum, between flexor carpi radialis muscle and brachioradialis muscle. Numerous branches of radial artery (about 13) enter the forearm fascia, the largest of which is the inferior cubital artery. There are many fasciocutaneous perforant vessels (is 9-16), and the most proximal of them is the largest one (about 0.8mm). Vascular cutaneous territory of the RFF envelops almost the entire anterior aspect of the forearm, proximal to the antecubital fossa and distally to the flexion crease of the wrist, except small ulnar skin segment of forearm, about 3 cm wide. Agenesis or congenital absence of the radial artery is very rare (27), as are anatomical variations: high origin or high terminal branching of the brachial artery and presence of the superficial radial artery (28, 29). These cases are usually seen during the angiography. Two committing, radial veins usually join in the proximal third of the forearm. In the distally based flap, retrograde blood flow through the radial veins, contrary to the valves, is explained by the presence of anastomoses in the form of a ladder or loop, or by vein denervation.

The radial flap, originally fasciocutaneous, was used as adiposofascial and also with other tissues as a composite flap: neurocutaneous, osteocutaneous, myocutaneous (brachioradial muscle, palmaris longus), and tendocutaneous. Also, to provide a thinner flap and a direct suture in the donor region of the flap, an adiposofascial flap covered with a skin graft is used (17). This method shows good results in the early surgical treatment of deep burns on the dorsum of the hand, especially electrical burns. The superficial branch of the radial nerve may be included in the flap for the reinnervation in the recipient site, especially in the thumb. Segment of radius in the RFF for thumb reconstruction was first used by Biemer and Stock (4). Radius fracture after osteocutaneous RFF has an incidence of up to 25%. However, this percentage may be lower due to the keel shape technique of taking the bone segment of the radius with beveling the proximal and distal cuts or prophylactic placement of the plate. Considering the fact

that the thumb accounts for about 40% of the hand function, there is importance of osteocutaneous RFF in subtotal or total thumb reconstruction (22-25) (Fig.7, Fig.8). The radial forearm flap can be used in flap prefabrication (30,31), such as cartilage transfer for reconstruction in the face.

During dissection of the RFF, it is important to preserve paratenon in order to avoid complications when skin graft is placed to the donor site. Also, attention should be paid to ulnar vessels and ulnar nerve that sometimes may be quite superficial. In fact, toward the dissection of the soft tissues of the flap (except for blood vessels), we agree with Lister's recommendation: "The skin hook and the knife are more precise and less damaging than the forceps and the scissors and should be used in preference." (6) For more extensive hand defects, the pivot point of the flap should be at least 5 cm proximal to the wrist crease, for safer hand vascularisation. If possible, one subcutaneous vein should be included in the flap, and if there are suitable conditions, an anastomosis should be performed with one of the veins in the area of the defect (32,33). This is important in reducing postoperative edema of the RFF. Identification of superficial radial nerve branches in RFL dissection is very important.

The donor site of the RFF may be closed by direct suture, or, in larger flaps, by some of the additional surgical procedures, usually split thickness skin graft (STSG). The complications of this method are relatively common, and the aesthetic result is sometimes pure. Therefore, a number of alternative methods have been used: full thickness skin graft, local skin flap, tissue expansion, vacuum assisted closure (VAC), cell cultures, synthetic skin substitutes (35-44). No one of these is ideal and many researches are still focused on the donor site of RFF (32, 34). If STSG was used, secondary transplantation of adipose tissue into the donor site of the flap is advised (45).

When considering a defect in the hand and the method of reconstruction, several points should be considered: localization, diameter and depth of the defect, types of tissue missing (skin, muscle, tendon, bone), age, sex, profession, hobby, as well as psychological profile of the patient in terms of accepting the course of the whole treatment (including intensive physical therapy) and possible complications. Reconstructive surgeons are always looking for the best surgical technique in terms of the better functional and aesthetic result, easier surgical technique, shorter operative time and the whole course of treatment, more economical treatment, minimization of complications, reliable vascularization of the transferred tissues, better quality of these tissues in relation to the characteristics of the recipient region, etc. If the skin defect on the hand is small, a local skin flap may be used. Medium-sized defects can be covered by the interososes posterior flap, such as the first commissure, and medium-sized defects in the proximal or medial part of the palmar region may be closed by the dorsal ulnar flap. When choosing a reconstructive method, one should consider from simple to complex, with the best possible functional and aesthetic result. Due to the great importance of the hand, single-stage surgery has the

advantage of early physical therapy. One of the most important factor for successful flap transfer is a good blood supply of the flap. If we look at these two important things, radial forearm flap is a reasonable solution. As any flap, the radial forearm flap has advantages and disadvantages. In general, there are more advantages (46). However, current studies are based on using a flap with radial artery perforators, wherever possible. Unfortunately, the size of the flap and the arc of rotation are limited (47). Also, there are opinions that it is better to use the fascial radial flap which is thinner and the flap donor site complications are less frequent. However, postoperative monitoring of this flap is more difficult and there is a potential failure of the skin graft placed on the fascia.

According to the size of the island fasciocutaneous RFF, there are a few literature data about the minimal skin segment that can survive. Here we emphasize the dimensions of the RFF we used for reconstruction of the tip of the thumb: 2.2x3.1cm (Fig.6).

The complications of radial forearm flap transfer are various. Acute ischemia of the hand is the most dramatic, but only one case has been described (48). Other complications are of local, non-specific: edema, hematoma, seroma, dehiscence and infection. There are also specific complications: partial or total necrosis of the flap, lysis of the skin graft, tendon exposure in the donor site, bulky flap, donor site sensory disruptions, lymphedema of the hand (49). Our results regarding the complications of RFF are generally similar to those of other studies.

Alternative methods for RFF are ulnar flap, interosseous posterior flap (IPF), forearm perforator flaps and free flap. The advantages of the ulnar flap are primarily the absence of hairs and thinner skin, but the disadvantages may be more significant: a more dominant artery, more difficult dissection, and the possibility of an ulnar nerve lesion. Any additional injury of the forearm may be fatal to the hand. The interosseous posterior flap and the perforator forearm flap have a great advantage in preservation of the main blood vessels, but also the disadvantage that they can be applied only to smaller and more proximal defects. Free flap needs special equipment, personal training, longer surgery time and possible functional and aesthetic consequences in the donor region. Various free flaps (temporal fascial, parascapular, radial flap from the opposite forearm, etc.) allows fast rehabilitation of the hand, but sometimes they are undesirable, as with more extensive injuries of the hand and forearm due to difficulties with the choice of recipient blood vessels in the recipient region. Sometimes, the only solution is distant pedicled flap, preferable inguinal flap.

There are a few reports of late vascular complications in the hand and fingers after the use of RFF. This may be important in patients suffering from some peripheral vascular disease, as well as chronic renal disease with the need for hemodialysis. In general, RFF is not recommended for children, and because of the possible presence of hair on the flap, it is not recommended for many women. That should be

evaluated preoperatively by considering the degree of hairiness on the forearm.

The results obtained with functional outcome and aesthetics are similar to those of other authors (50, 51). MHQ does not say that all patients were satisfied or dissatisfied, but on a scale ranging from few points (indicating a worse subjective impression) to more points (indicating a better one), there is the statistical significance that more patients scored more than half (80.5).

The advantages of the radial flap are numerous: constant vascular anatomy, long vascular pedicle (up to 20 cm), large diameter of blood vessels (radial artery: 2-3 mm, radial veins: 1-3 mm and cephalic vein: 3-4mm), vascularization of skin and other tissues, large vascular cutaneous territory, relatively easy dissection, transfer of different tissues (skin, bone, tendon, nerve), thin and elastic skin with the potential to provide sensibility, one operative field, one-stage surgery, early physical therapy, more cost-effective treatment. Due to the fact that the operative method is in one operative field, as well as that it is a one-stage operation, it can be concluded that there are lower risks for postoperative infections. The main disadvantages of RFF are loss of the magistral artery and the scar on the donor site. The incidence of graft failure at the donor site ranges up to 30%, with tendon exposure in about 14% of patients. Another disadvantage of RFF is hair growth on the flap (Fig.8). It is recommended to cover the tendon of the flexor carpi radialis muscle with surrounding muscles (suturing flexor pollicis longus and abductor pollicis longus muscles to flexor digitorum superficialis muscle), as well as to immobilize the wrist in dorsiflexion to improve skin graft survival.

We conclude that the radial flap is a suitable for covering various tissue defects in the hand, as a result of constant vascular anatomy, thin and pliable tissue and its ease of harvest. We emphasize the importance of this flap in thumb reconstruction (Fig.7, Fig.8). However, it is imperative to choose the optimal reconstructive method which provides appropriate functional and aesthetic result in the recipient and donor site. Pedicled or free radial forearm flap should be in the "repertoire" of plastic surgeon as a method of choice, or as an alternative method.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and the Helsinki Declaration of 1975, as revised in 2013.

CONFLICT OF INTEREST

There are no conflicts of interest.

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