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Reconstruction of soft tissue defects using transposition loco-regional perforator island flaps

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Abstract

Introduction Treatment of chronic non-healing wounds in the presence of deep post-traumatic soft tissue defects is a challenge for trauma reconstruction. The objective of the study was to improve healthcare quality for patients with chronic soft tissue defects of the limb. The goals included evaluation of the effectiveness of reconstruction of defects of the lower limb using local transposition perforant flaps, and rationale for a preferred choice for the keystone perforator flap. **Material and methods** The review included 48 patients with post-traumatic and osteomyelitic soft tissue defects of lower limbs. Patients were divided into 2 groups. Patients of the study group were treated with regional perforator fasciocutaneous flaps combined with osteonecrectomy that could be also performed later (n = 22). In the comparison group (n = 26), post-traumatic and osteomyelitic defects were treated with conventional methods of local wound treatment, staged osteonecrectomies followed by autodermoplasty. **Results** The use of the transposition loco-regional perforator flaps resulted in the incidence of secondary necrosis reduced by 33.7% and the two-fold reduction in the average number of staged operations. One-stage reconstruction was performed in 72.7 % patients of the study group. The length of inpatient treatment decreased by an average of 30 bed days. **Discussion** The reduced length of treatment in the study group could be caused by the absence or a significantly reduced stage of local wound treatment; there were fewer complications in the form of secondary necrosis of deep-lying tissues that would require additional treatment stages. Conclusions Reconstruction of osteomyelitic defects with the transposition of loco-regional perforant flaps allowed lower complication rate and improved functional outcomes for patients with posttraumatic and osteomyelitic defects of soft tissues of lower limbs.

Keywords: soft tissues of limb, defect, post-traumatic, osteomyelitic, perforant island flaps, chronic osteomyelitis, chronic non-healing wound

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INTRODUCTION

Advances in orthopedic surgery are evident today in many new areas. Treatment of long-term non-healing wounds in the presence of deep post-traumatic soft tissue defects is a challenge. Chronic osteomyelitis is a significant factor in the development of post-traumatic skin defects. The treatment involves medical and socio-economic aspects with 78% of patients of working age (range, 20 to 50 years), and with the highest percentage of disability (more than 70%) among them [1-4]. Chronic osteomyelitis of the limbs is often associated with soft tissue defect [5–10]. Deep soft tissue defects can develop in chronic osteomyelitis and exist for a long time due to trophic disorders. A skin defect at acute injury and with delayed healing of a postoperative wound results in dry underlying bone (or tendon), subsequently to necrosis and secondary defects [11]. Open wound management followed by secondary intention is the traditional approach in the treatment of the defects. The treatment often results in severe scars, persistent chronic wound infection and subsequent exacerbation, a significantly limited possibility of reoperations at the site of the repaired defect, leading to aggravated cicatricial process.

Replacement of post-traumatic soft tissue defects using traditional methods does not always provide the results wanted. Their localization in the anatomical, functionally loaded and other problemic areas is important. Well-vascularized tissues must be used to close the defects [12–19]. Freely transplanted tissue complexes and microanastomoses have normally better blood supply [7, 10, 20–22]. However, there is a risk of thrombosis of the anastomoses, and a specially organized microsurgical service can be required with the use.

Microsurgical technique allows for tissue complexes to form on perforating vessels and replace osteomyelitic defects by transposition without microanastomoses [13, 14, 16–18, 23]. The method facilitate soft tissue defect closure at lower cost and lower risks increasing the effectiveness of treatment. With this strategy, local wound treatment is considered as a preparatory stage before flap transposition [24]. The

tissue complexes that best correspond anatomically and functionally to those lost can be used for replacing soft tissue defects. The use of tissue located close to the defect and having similar properties to the soft tissue structures surrounding the defect can ensure maximum clinical effectiveness. This is more consistent with the method of transposition of local perforator flaps. The method is based on the principle of using well-vascularized tissue complexes with primary intention of the postoperative wound. However, with evident advantages, there are a number of theoretical and practical issues, the solution of which will help improve the anatomical and functional outcomes of the treatment of the complicated cases. We analyzed the efficiency of reconstruction of post-traumatic and osteomyelitic defects by transposition of local perforator flaps to identify the advantages of the method over traditional local wound treatment using staged necrectomy and autodermoplasty, and to justify the preferred use of a keystone flap.

The objective was to determine the optimal method for the formation of loco-regional flaps for the plastic reconstruction of chronic post-traumatic soft tissue defects of lower limbs to allow improvements of the outcomes.

Thanks to modern research and developed practice, perforant flaps of the lower limb can be conditionally divided according to the blood supply pool into those originating from the perforators of the anterior and posterior tibial arteries, the peroneal artery and those originating from the medial sural artery and the modified perforator lateral femoral flap on reversed blood flow. [26]. The distal sural flap is a fasciocutaneous flap with retrograde blood flow based on the arterial network surrounding the sural nerve and originating from the superficial sural artery and peroneal artery. The superficial sural artery originates from the popliteal or from the common sural artery. The artery anastomoses with a permanent network of musculocutaneous perforating branches of the peroneal artery [28]. The use of flaps on perforating vessels does not compromise the major vessels of the lower limb, as it does not change the blood supply to the distal zones. Surgical technique requires less operating time with use of the flaps, expensive technical support in comparison with free transplantation of tissue complexes with the formation of microanastomoses. Less surgical aggression at the donor sites is obvious [26].

There are 5 major types of perforator flap design: propeller flaps, peninsular flaps, sliding flaps, flaps with a proximal and distal base [27]. There are techniques of local perforator flaps that can be used effectively to close soft tissue defects with a minimal risk of complications. One of these methods was proposed in 1995 and termed as the "keystone island flap" by the author. The concept was developed in the course of anatomical and clinical studies by F. Behan at al. [29], who suggested that axillary perforating arteries have their own microscopic venous, neurovascular, and arterial plexuses that are closely related to each other. The practical use of the data in combination with the Taylor angiosomal theory, can significantly improve the nutrition at the site of soft tissue defect in the recipient zone and significantly increase the area of the formed regional insular flap for the transposition.

MATERIAL AND METHODS

The study included 48 patients with post-traumatic and osteomyelitic soft tissue defects who were treated in the department from 2015 to 2019, including 40 men and 8 women. The mean age of the patients was 49.9 years. The nature of the distribution of patients by age, social status, duration of illness and the number of staged operations before admission to the clinic is shown in Table 1.

Soft tissues defects of the lower limbs were both concomitant components of open fractures complicated by deep wound infection in the early post-traumatic period, and long-term non-healing ulcers against the background of chronic osteomyelitis. Open tibial fractures of 22 patients were accompanied by injury to the soft tissues at the fracture site, and tibial ulcers of 26 patients resulted from repeated exacerbation of the chronic osteomyelitis and many surgical reconstructive interventions at previous stages (Fig. 1).

Patients were conditionally divided into 2 groups. The first group (comparison group) included 26 patients who were treated with conventional methods involving staged debridements, ointment dressings and use of a vacuum system to obtain granulations followed by autodermoplasty with a split skin autograft. Osteoplastic operations at the defect site were performed after complete epithelialization at the site of autodermoplasty, preferably outside the skin graft. The second study group included 22 patients who had regional perforator fasciocutaneous flaps used to replace skin defects. The flaps were raised simultaneously with osteonecrectomy and as a separate stage. Of these, 10 patients underwent plastic surgery of a skin defect with a sural flap, 12 patients were treated with spatial redistribution of tissues and a local perforator keystone flap to repair defects.

The licensed package R (version 3.2, R Foundation for Statistical Computing, Vienna, Austria) was used for statistical data processing.

Table 1

Distribution of patients according to clinical and anamnestic parameters

Clinical and anamnestic parameters		Number of patients	
		abs.	%
Age, years	18–35	9	18.8
	36–60	27	56.3
	61–80	12	25
	> 80	–	–
Social status	worker	20	41.6
	student	1	2.1
	agricultural worker	2	4.2
	disabled person	21	43.8
	other	4	8.3
Duration of the disease, months	1–3	11	22.9
	3–6	10	20.8
	6–12	10	20.8
	> 12	17	35.4
Previous surgery	one	2	4.2
	two	19	39.6
	three	14	29.1
	> three	13	27.1
Total:		48	100

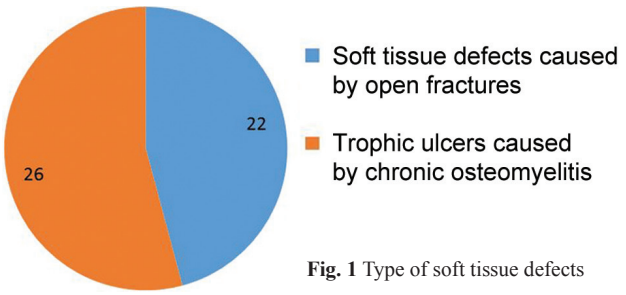

Fig. 1 Type of soft tissue defects

The data were checked for normal distribution using the Kolmogorov-Smirnov test. Means ± standard deviations were calculated as descriptive statistics for quantitative parameters; median and quartiles; minimum and maximum values in the sample. The frequencies of occurrence were calculated and the diagrams constructed for qualitative parameters. Comparison of mean levels was produced in groups using the Mann-Whitney test and frequencies identified using Fisher's exact test. Differences were considered statistically significant at $p < 0.05$.

Long-term non-healing wounds in the presence of soft tissue defects caused by chronic osteomyelitis and post-traumatic defects were indications for the operations. Nevedrov A.V. reported small wound defects in the tibia that can be repaired with loco-regional flaps, as wounds with the length being less than the width of the hand at the level of the heads of the metacarpals, and the area measuring less than half the area of the palmar surface of the patient's hand. Extensive defects with the length being greater than the width of the hand and the area measuring more than half the area of the palmar surface of the patient's hand or 0.5% of the body surface area can be closed using free revascularized flaps [31]. A severely decreased peripheral blood flow due to vascular pathology of different origin characterized by the absence of an echo signal from major arteries at the defect site was a contraindication for the use of the method in addition to decompensated somatic pathology and extensive defect size.

Preoperative preparation consisted of a standard physical examination and evaluation of the local vascular status using a portable audio Doppler with an 8 MHz Minidop-8 transducer (Bioss). The echo signal of the main arteries was identified at the level of the ankle joint (for the posterior tibial and peroneal arteries) and the dorsal foot (dorsal artery of the foot). All operations were performed under spinal anesthesia. Audio Doppler was also used to mark the exit points of the perforator vessels to plan the flap design. The shape and dimensions of the flap were matched according to the size of the defect with a margin of 0.5 cm for each measurement in order to compensate for tissue retraction after the formation of the flap.

The fasciocutaneous flap technique includes perforator arteries originating from major vessels. The sural artery is the nutrient artery for the sural flap and anastomoses with the peroneal artery through a system of perforators with the distal perforator located approximately 6–8 cm proximal to the lower edge of the lateral malleolus. The keystone flap includes several perforators located along the axis of the major vessel. Therefore, techniques for the flaps differ significantly.

The operated limb was to be elevated in the first 72 hours of sural flap surgery using the Behler splint to reduce the risk of decompensated venous outflow from the flap tissues. The limb was immobilized with plaster cast with the defects located close to the joints. Vasoactive therapy administered for patients for adequate postoperative anesthesia included sulodexide 2.0 intramuscularly once a day for 10 days, suprastin 2.0 intramuscularly once a day for 5 days, pentoxifylline 5.0 per 250.0 physiological solution for 10 days with absent contraindications and allergic reactions. Patients were exposed to physiotherapy (UHF, magnet therapy), sessions of hyperbaric oxygenation in the first 5 days, if needed. The average bed-day was 5 before surgery and 14 days after surgery. Patients continued to be followed up for 3 months, with regular checkups every 3 weeks as outpatients.

RESULTS

Patients were evaluated in the early postoperative period (before the removal of sutures) using the following parameters: the nature and quality of wound healing, the degree of engraftment (presence and magnitude of necrosis). 16 patients of the study group had complete engraftment of the flaps with primary healing of postoperative wounds. One patient developed secondary marginal necrosis during transposition of the sural flap, and 3 patients had total necrosis of the flap. Two patients experienced total necrosis of displaced tissues with a keystone flap (Table 2).

Evaluation criteria used at a long term:

– viability of transplanted grafts;

– the final functional result.

The viability of the flaps was assessed subjectively by skin color, temperature, capillary response and objectively by Doppler sonography. The viability of implanted flaps completely coincided with the corresponding characteristics of the surrounding tissues. The Doppler sonographic examination showed no differences in the blood flow of the flaps and the tissues of the healthy limb. The elasticity of the flap was slightly reduced at palpation in comparison with the surrounding skin and was excessive in some cases with use of the sural flap and showed no changes with the keystone flap. The final functional result (at 6 to 12 months of surgical treatment) was assessed by the extent of the restored limb function and was rate as good, fair and poor. Completely restored active function of the affected limb was rate as a good functional result. If the recovered function could not be considered as complete, but the patient was satisfied, the outcome was rated as fair. The result was rated as poor with absent limb function. The outcome was rated as good in 89.5% of cases and as fair, in 7.9% that indicated the highly efficient methods of osteomyelitic defect plasty. The displaced skin-fascial flaps are a source of blood supply for the underlying injured structures to significantly reduce the incidence of secondary wound infection. The restoration over the damaged area occurs as primary intention, bypassing the exudation phase. The flap protects the underlying structures from re-contamination with microorganisms. The lack of drying of deep structures, as in the local treatment of a wound, reduces the likelihood of the necrosis and development of purulent complications.

There was 27.3% incidence of secondary necrosis in the study group and 61 % in the comparison group. The average number of stage operations was 1.45 in the study group and 3.1 in the comparison group. The reconstruction was completed in one stage in 72.7 % of the study group. The duration of inpatient treatment was 59.1 bed-days in the comparison group, and 29.1 bed-days in the study group (Table 3). A statistically significant difference from the normal distribution was recorded for all quantitative parameters (Kolmogorov-Smirnov test, Table 4).

Table 2

Evaluation of early postoperative outcomes in the study group

Wound healing	Sural flap		Keystone flap		Total	
	abs.	%	abs.	%	abs.	%
Primary intention	6	27.3	10	45.5	16	72.8
Marginal necrosis	1	4.5	-		1	4.5
Totaly necrotized flap (> ½ area)	3	13.6	2	9.1	5	22.7

Table 3

Evaluation of outcomes in the groups

Evaluation criterion	Comparison group	Study group
Mean number of stage surgeries	3.1	1.45
Secondary necrosis, %	61	27.3
Inpatient treatment, bed-days	59.1	29.1

Table 4

Descriptive quatitification statistics

Parameter	Mean value ± CKO	Meadian	Quartile	min	max	p (Kolmogorov-Smirnov test)
Comparison group						
Number of stage surgeries	3.12 ± 2.1	2	[2; 3]	1	9	< **0.001**
Inpatient treatment period	59.1 ± 40.9	44	[30; 68]	12	153	< **0.001**
Study group						
Number of stage surgeries	1.45 ± 0.96	1	[1; 2]	1	5	< **0.001**
Inpatient treatment period	29.3 ± 19.7	20.5	[20; 30]	16	98	< **0.001**

Table 5

Descriptive quatitification statistics

Secondary necrosis				
		Number of observations, n	frequency, %	Total number of observations, n
Comparison group	–	10	38.5	26
	+	16	61.5	
Study group	–	16	72.7	22
	+	6	27.3	

Comparison of quantitative parameters in the groups revealed significant differences in "Number of stage operations" and "Duration of inpatient treatment" (Table 6). Greater "Number of stage operations" and "Duration of inpatient treatment" were observed in the comparison group.

Table 6

Comparison of mean quantitative parameters in groups using the Mann-Whitney test

	Comparison group, n = 26	Study group, n = 22	p
Number of stage surgeries	3.12 ± 2.1	1.45 ± 0.96	< **0.001**
Inpatient treatment period	59.1 ± 40.9	29.3 ± 19.7	< **0.001**

Note: Mean values are presented as Mean ± Standard Deviation

Comparison of the frequency of occurrence of signs allowed for identification of significant differences in: "Development of secondary necrosis" (Table 7). There were more cases of secondary necrosis identified in the comparison group as compared to the study group.

Table 7

Comparison of qualitative parameters in groups using Fisher's exact test

Secondary necrosis			
	Comparison group, n = 26	Study group, n = 22	p
–	10 (38 %)	16 (73 %)	**0.023**
+	16 (62 %)	6 (27 %)	

Note: the occurrence is presented as frequencies in the Table

Case report

A 39-year-old patient R. was diagnosed with trophic ulcer in the lower third of the right tibia and a skin defect; pronounced cicatricial post-traumatic contracture of the right ankle joint and tarsal joints of the right foot. In 2012, the patient sustained an open fracture of the bones of the midfoot on the right side and the lower third of the right tibia, extensive crushing of soft tissues in the lower third of the right tibia. A trophic ulcer and a skin defect developed on the anterior surface of tibia and failed to heal for a long time after three stage operations in the lower third of tibia. Debridement was performed and scars of the tendon of the anterior tibial muscle excised in one stage (Fig. 2). Plasty of the skin defect on the anterior surface of the lower third of the right tibia was performed with an islet skin-fascial sural flap on the distal vascular pedicle (Fig. 3, 4). Marking of the exit of the perforators of the peroneal artery was performed preliminarily using a portable audio Doppler with an 8 MHz transducer to determine the level of the rotation point of the flap and precisely highlight the feeding pedicle. The postoperative wound healed with primary intention and the patient was discharged for outpatient follow-up 13 days after the operation. The engraftment of the flap was complete in the late postoperative period, the defect replaced and a stable recovery achieved (Fig. 5.)

A 45-year-old patient S. was diagnosed with infected wound in the lower third of the right tibia and a skin defect. She was bitten by a dog 3 months before admission and suffered a long-term non-healing wound formed at the Achilles tendon (Fig. 6). The patient underwent necrectomy of the skin and soft tissues under spinal anesthesia at one stage and non-viable areas of the Achilles tendon were superficially excised. A skin-fascial keystone island perforator flap keystone flap was used to move to the defect area and sutured to the edges of the wound. The skin defect was completely repaired (Fig. 7). The postoperative wound healed by primary intention and the patient was discharged from the hospital 14 days after the operation. The color, temperature and sensitivity of the displaced flap were identical to those of the tissues surrounding the defect three months after the operation (Fig. 8). The inpatient stay was 21 days.

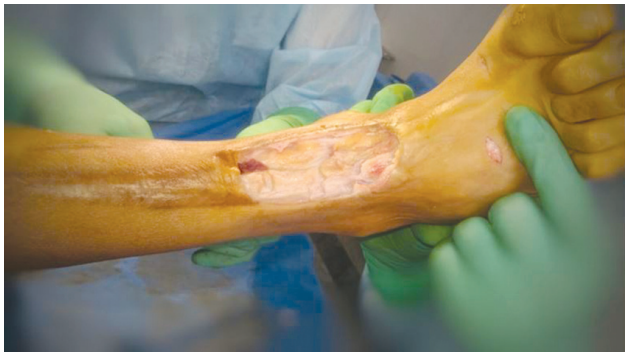

Fig. 2 Defect of the skin and soft tissues on the anterior surface of the lower third of tibia after debridement

Fig. 3 A fasciocutaneous islet sural flap formed on the distal base

Fig. 4 Defect of the skin on the anterior surface of the lower third of tibia completely repaired with sural flap

Fig. 5 Result of surgical treatment at 3 months

Fig. 6 Long-term non-healing infected wound in the projection of the Achilles tendon with its lesion

Fig. 7 The skin defect in the projection of the Achilles tendon repaired with a keystone flap

Fig. 8 Result of surgical treatment at 3 months

DISCUSSION

Complete necrosis of the sural flap in 3 patients of the study group was likely to be caused by venous insufficiency of the flap, since the venous outflow occurs counter the venous valves. The risk of developing the complications is associated with the pathology of the venous system (varicose veins, history of thrombophlebitis). Therefore, a more thorough preoperative examination should be carried out in patients aged 50 years and over, in particular, to reduce the likelihood of the complications. At least one saphenous vein in the flap stem can be suggested to prevent necrosis.

The reduction in the duration of treatment in the study group was reduced due to either exclusion or significant reduction in the stage of local wound treatment. There was also reduced frequency of complications in the form of secondary necrosis of deep-lying tissues that would require additional treatments. Repair of soft tissue structures is an integral component of persistent arrest of a purulent process. If the stage of soft tissue restoration is not completed or not completely resolved this obviously leads to aggravation of chronic wound infection, development of resistant microflora, bone death and impaired fractures healing in case of an acute injury [4].

A multi-stage local wound treatment is traditionally used for the treatment of patients with chronic osteomyelitis in presence of a skin and soft tissue defect to be followed by autodermoplasty after granulation [32]. The advantages of the approach include:

1) safety for the patient due to less trauma, simple reconstructive interventions;

2) technical simplicity for the doctor with no special skills required for the transposition of blood-supplying tissue complexes;

3) no special tools and equipment are required.

Disadvantages with traditional local treatment of wounds include:

1) duration of soft tissue restoration. Several months might be needed for granulations to form with a bone or tendon exposed to transit to the next stage;

2) the repaired skin cover can be incomplete with use of local wound treatment and cannot bear an adequate load on the supporting surface of the foot or the stump of the lower limb, regardless of the level;

3) repeated reconstructive operations are significantly limited due to incomplete healing of incisions and secondary scars;

4) additional areas of exposed bones and tendons are removed in case of inevitable repeated debridement expanding the defect.

Specific features of soft tissue defect closure with transposition of loco-regional perforator islet flaps include:

1) the technology allows for an adequate cover in the defect zone in the shortest possible time;

2) requires special skills of the surgeon and microsurgical instruments (excluding microanastomoses);

3) surgical interventions are accompanied by greater blood loss and can be lengthy. However, prevention of secondary necrosis with lower risks of maintaining foci of deep wound infection in the defect zone significantly reduces the overall treatment period and has an economic benefit for health facilities;

4) an individual approach is required in most cases choosing a reconstruction method, algorithmization of the process is difficult;

5) the transposition of skin-fascial flaps helps to restore an adequate cover at the site of a wound or ulcer defect, including fascia, subcutaneous fat and skin;

6) accurate marking of the flaps is required before transposition.

CONCLUSION

Two methods of local perforator flaps employed to close the defect in functionally important areas included keystone flap transposition and a sural flap on the distal base. The use of a keystone flap and a sural flap is practical to repair soft tissue defects using the tissues that anatomically match those lost as a result of traumatic injury or a purulent process. The review showed effective reconstruction of osteomyelitic and post-traumatic soft tissue defects with transposition of local perforator flaps with the advantages of the method over traditional local treatment of wounds using staged debridement and autodermoplasty. The keystone flap was shown to be a better option in the presence of intact, adjacent to the defect, appropriate donor resources. The method allows for adequate cover of the defect zone in the shortest possible time, reduced treatment period facilitating reliable functional and cosmetic rehabilitation. Given these advantages, the method of transposition of local perforator flaps can be considered as optimal option for plastic reconstruction of chronic post-traumatic soft tissue defects of the lower limbs to improve the outcomes for patients.

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