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Застосування техніки «пропелер» для пластики обширних ран дистального відділу нижньої кінцівки

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The «Propeller»–technique in plastic surgery of the extensive wounds of distal leg and the foot

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Реферат

Мета. Підвищити ефективність пластики обширних дефектів м'яких тканин, які виникли внаслідок механічної та/або теплової травми чи в результаті інфекційно–некротичного процесу, застосовуючи щадну резекцію нижньої третини гомілки і стопи.

Матеріали і методи. Проведена ретроспективна оцінка застосування техніки «пропелер» для переміщення шкірних клаптів на литковому судинно–нервовому пучку у 11 пацієнтів, оперованих у 2014 – 2017 рр. До 1–ї групи увійшли 2 пацієнти з мінно–вибуховою травмою та 2 пацієнти з травматизмом, отриманим на вугільній шахті, які мали обширні ушкодження м'яких тканин гомілки і стопи. До 2–ї групи увійшли 3 пацієнти з остеомієлітом і 4 пацієнти з відмороженням.

Результати. У всіх пацієнтів було достатнє кровопостачання уражених кінцівок, навіть у 3 пацієнтів 2–ї групи, у яких збереглася лише одна артерія. Під час усіх оперативних втручань вторинну хірургічну обробку ран, некректомію та відновлення дефектів м'яких тканин виконували в один етап.

Висновки. Використання техніки «пропелер» для мобілізації клаптя покривних тканин є ефективним способом закриття глибоких комплексних дефектів дистального відділу нижньої кінцівки різної етіології.

Ключові слова: дефекти м'яких тканин; мобілізаційний клапоть; механічна травма; теплова травма.

Abstract

Objective. To increase the efficacy of plastic surgery in treatment of the extensive soft tissue defects, applying "sparing" resection of the lower third of the shin and foot for consequences of mechanical and/or thermal trauma or infectious–necrotic processes.

Materials and methods. We conducted a retrospective evaluation of the "Propeller"–technique application for the elevation of the skin islet flaps on sural neurovascular pedicle in 11 patients, who underwent surgery between 2014 and 2017. The task for investigation was to eliminate the shin and foot defects, developed due to large–scale tissue damage. The Group 1 was organized for patients with the mine–blast trauma and the coal mine occupational injuries (2 patients followed in each category). Management of purulent–necrotic wounds (Group 2) was required in cases of amputation and resection of the foot due to either osteomyelitis (3 patients followed) or frostbites (4 patients followed).

Results. All the patients had an adequate vascular supply of the affected limbs, even in 3 patients from the Group II, who had only one artery preserved. In all cases a secondary surgical debridement, necrectomy and the soft tissue defect repair were performed during the same operation.

Conclusions. Using of the tegument tissues mobilization complex "Propeller"– technique is an effective instrument for sealing of deep complex defects of different etiology, localized in distal part of the lower extremity.

Keywords: defects of soft tissues, mobilization flap, mechanical trauma, thermal injury.

Sealing of large soft tissue defects at the level of the lower third of the shin and foot is important and often complicated task in reconstructive surgery. Complex anatomy and high functional significance of this lower limb anatomical segment require adequate approach towards restoration of the integumentary soft tissue that is particularly important in the setting of widespread defects. Large wound defect is a full thickness loss of integument tissue which can't be eliminated through self–regeneration process or wound margins approximation and requires application of the superficial redistribution, or tissue stretching technologies [1].

One of the main approaches in plastic surgery is "reconstructive steps" principle which is characterized by achieving obtainable wound healing and reconstruction in certain time period by the means of optimal choice of intervention into the disease course with minimal losses for patient's health and quality of life. For decades early removal of necrotic tissue and auto–dermal plastic surgery remained a standard for widespread wounds management and tissue flap technique was the method of choice in case of deep structure lesion for functional restoration and prevention of permanent cosmetic defects [2].

An extended number of methods with varying efficacy were proposed: cross–graft on the temporary supplying stem, transposition of muscle flaps, free flaps on the microvascular anastomoses and flaps from stretched tissues (desmotensia). However these methods have a number of associated issues: prolonged forced position and immobilization if the contralateral

limb is used; loss of functional elements in donor sites in case of muscle flap grafting; free flaps on the microvascular anastomoses require special equipment , skilled microsurgeons and are overall expensive; dermotensia requires the surgery to be performed in several steps [3].

During few years tissue flap grafting technique has been perfected under the influence of the angiosome theory. H. Hyakusoku et al. in 1991 were first to propose surgical "Propeller"–technique for islet flaps which were grafted on perforant vessels. This technique has a great significance but it represents only a fraction of a new direction because for present day there are a plenty of unsolved issues associated with it such as undetermined optimal size of perforant flaps, their tissue composition and viability especially in case of large scale injury and infectious contamination of the tissues [4].

Assuming that plastic surgery method selection requires taking into account both functional qualities of regenerating tegument and anatomic features of the damaged area, the problem arises frequently that area of skin "islet" is limited and can't cover greater size wound defect completely. Application of traditional method of flap sampling often results in flap partial or even complete loss that requires further improvement in operative technique [5, 6].

Goal of the research: is to increase the efficacy of plastic surgery for the widespread soft tissue defects applying "sparing" resection of the lower third of the shin and foot that sustained injury due to mechanical and/or thermal trauma or as a result of infectious–necrotic process.

Materials and methods

We conducted retrospective evaluation of the "Propeller"–technique application for the elevation of skin islet flaps on sural neurovascular stem in 11 patients who underwent surgery between 2014 and 2017 at combustiologic departments in Kramatorsk and Mariupol, Ukraine, as well as at surgical department in Druzhkovka, Ukraine. The task to eliminate shin and foot defects with large–scale tissue damage (group 1) was established for patients with mine–blast trauma and coal mine occupational injuries (2 patients followed in each category). Management of purulent–necrotic wounds (group 2) was required in cases of amputation and resection of the foot due to either osteomyelitis (3 patients followed) or frostbites (4 patients followed).

4 patients from the first group had 4 extremities operated, 7 patients from the second group had 8 extremities reconstructed (one of the patient who had amputation due to 4th degree frostbite underwent stump formation on both of his lower limbs) (*see table*). All patients were males of 40.3±7.4 years of age. Majority of the wounds were spreading onto weight–baring surface of the extremity. In 9 cases defect was localized on the distal segment of the foot, in another 3 cases it was combined with defects of the heel and Achilles tendon areas. 2 out of 3 patients with osteomyelitic ulcers and necrosis had additional vascular risk factors including atherosclerosis and macroangiopathy.

Visualization of the neurovascular stem and perforants was performed by portable Doppler ultrasound device ("IABP–Doppler, Datascope®", USA).

Results

All patients had adequate vascular supply to the affected limbs even in 3 patients from the second group who had only one artery preserved (anterior tibial artery in 1 case, posterior tibial artery in 2 other cases). During hospitalization bac-

List of the clinical observations

No	Age (years)	Etiology	Tissue defect	Flap size (cm)	Complications
1	40	Mine professional injury	Defects of the heel, medial malleolus	12/15	
2	29	Mine professional injury	Ankle, heel, Achilles tendon area, medial and lower third of the tibia	19/13	
3	57	Mine-blast trauma	Ankle, heel, Achilles tendon area, medial and lower third of the tibia	12/22	Marginal ischemia of the flap distal area
4	63	Osteomyelitic flegmon	Ankle, heel, Achilles tendon area, proximal and lower third of the tibia	6/18	Marginal necrosis of the flap
5	45	Osteomyelitic flegmon	Achilles tendon area, medial malleolus, heel	8/14	Flap necrosis due to venous thrombosis, diabetic gangrene progression
6	47	Osteomyelitic flegmon	Achilles tendon area, medial malleolus, heel, dorsum of the foot	10/19	
7	53	Frostbite	Heel, stump of the foot	14/29	Ischemic flictenas
8	32	Frostbite	Heel, stump of the foot	14/22	
9	32	Frostbite	Heel, stump of the foot	12/29	
10	46	Frostbite	Heel, stump of the foot	14/29	
11	38	Mine-blast trauma	Defects around the ankle joint, traumatic amputation of the first toe, heel and plantar surface of the foot wounds	8/29	Marginal ischemia of the flap distal area

terial cultures from soft tissue wounds were obtained, wide–spectrum antibiotics were given, VAC–therapy was used locally for 3–7 days until inflammatory signs resolved. In all cases secondary surgical debridement, necrectomy and soft tissue defect repair were performed during the same operation.

Flap elevation technique. On the operation table patient lies in supine position. After antiseptic cleaning of the operation site necrotized tissue removal is performed. A point in the middle of the groove between the heads of gastrocnemius muscle is mapped. Other two points are chosen at the tip of the lateral malleolus and at the calcaneus tuberosity. Distance between them is divided in half – that is the position of the fourth point. Connect the first and the fourth point with the straight line. This line coincides with the projection of the sural neurovascular stem.

Next step is to choose one of the perforants which were previously defined within 5 to 8 cm proximal to the lateral malleolus tip at its posterior surface. Distance from the perforant vessel to distal margin of the defect is measured. Defect form is copied onto sterile transparent cellophane. Distance measured above is transferred onto projection of the sural flap's vascular stem from the perforant vessel towards gastrocnemius muscle heads. 2 cm is added to the final distance measurement to take into account an extra tissue needed for flap rotation. Then the form of the skin flap is "drawn" with consideration of its further rotation (*Fig. 1*).

Flap sampling is started from its proximal edge. Sural neurovascular stem is separated by first incision. Then it is cut off proximally to the flap, ligated and attached to the flap together with the deep fascia. Incision continues on the both margins of the flap distally from the sural neurovascular stem projection. To avoid vascular compromise between skin islet and its stem fascia is attached to them by two sutures temporarily. Then flap and its vascular stem separation from the underlying tissues continues distally until it reaches the perforant vessel we selected earlier.

During application of the "Propeller"–technique it is considerable that sural artery in 100% of the cases has anastomoses with fibular artery due to the septocutaneous perforators which pass through shin deep fascia septum.

It is worth to emphasize that angiosome isolation is relative in many ways. Blood pressure in the center of the angiosome is higher than it is in its peripheral areas where it equalizes with counter pressure from the synergic sources of blood supply. At the border areas of the vascular ramification pressure equalization in two independent vascular networks is observed so pressure decrease in one area facilitates blood flow beyond another network standard area. By dissecting tissues at certain distance which exceeds peripheral border of the angiosome surgeon promotes cessation of the counter–pressure. Real size of any angiosome is larger than projection area of any single vessel. That is why there is always a possibility to form an additional tissue area on 1:1 scale on the angiosome periphery so the flap that needs to be enlarged within the borders of its vascular distribution preserves all the chances to survive.

The fact discussed above requires including mentioned earlier fascial septum as a compound to sural flap and its stem complex. Vascular branches are passing through posterior intermuscular septum of the shin heading towards its posterior surface where multiple anastomoses are formed along sural nerve and are located within 4 cm area surrounding nerve stem. Most distant constant septal skin branches are situated 6–10 cm above the tip of the lateral malleolus. Venous drainage from the flap is performed by veins which are forming a fine mesh located along sural nerve with eventual drainage into small saphenous vein.

Yielding 1–3 cm distally to the perforant skin bridge is dissected sparing the place of perforant vessel exit so skin flap becomes "islet"–shaped. This makes vascular stem separation easier as well as helps to avoid its compression after flap translocation onto defect.

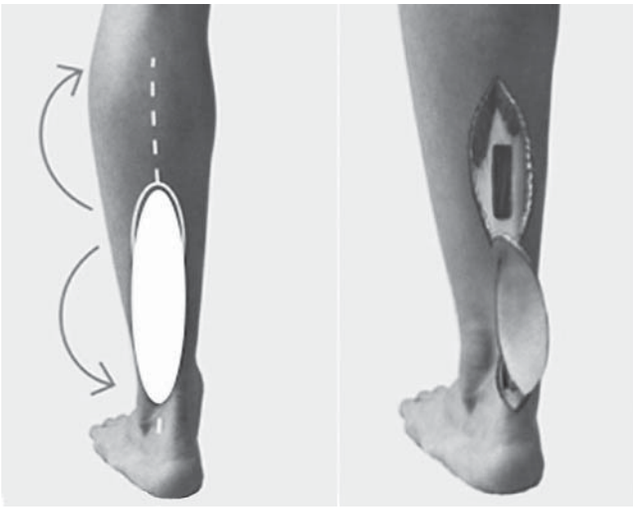

Fig. 1.
Schematic illustration of the neurovascular stem with skin islet located on it and flap rotation onto distal shin defect.

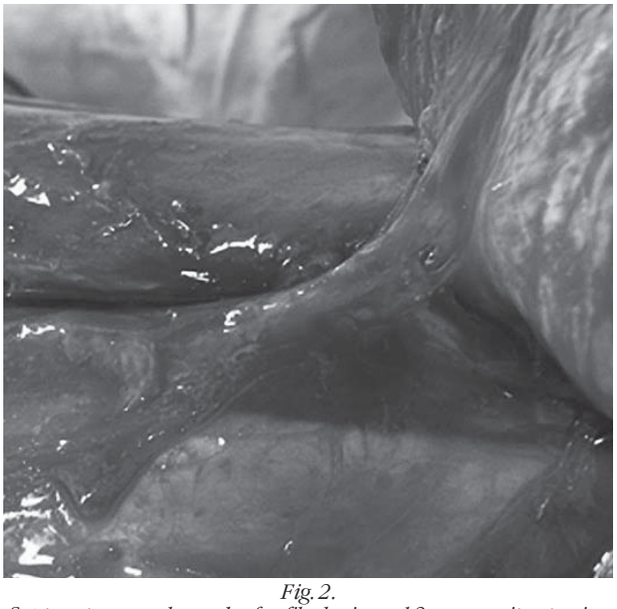

Fig. 2.
Septocutaneous branch of a. fibularis and 2 concomitant veins exiting from the posterior intermuscular septum of the shin.

Fig. 3.
Both feet stump plastic surgery after 4th degree frostbite with tissue megacomplexes at sural artery using "Propeller"–technique.

During this procedure septocutaneous branch of fibular artery and two concomitant veins that exit from posterior intermuscular septum of the shin within 6 cm area and proximally to the lateral malleolus tip (*Fig. 2*) were thoroughly separated.

Elevated on the distal stem fasciocutaneous flap is then rotated 180° with further fitting of it onto defect margins by sparse fixating noose intradermal sutures PDS 4.0 without skin tension and after primary fitting it is sutured to wound defect margins (*Fig. 3*).

Space under the flap was drained passively. Donor wound was covered using combined 0.3 cm thick autodermoplastic grafts. Total operation duration was between 1 hour 20 minutes and 2 hours 10 minutes.

Research results were evaluated retrospectively using a rate of cases in which primary intention uncomplicated wound healing was achieved. Complication rate was defined as graft complete or partial necrosis and/or presence of local purulent complications. Duration of follow up was from 6 to 11 months with mean of 9.6 months. Mean treatment duration was 46.2±19.3 days. 11 out of 12 flaps (91.7%) engrafted and provided functional skin tegument of the shin after reconstruction. In cases of frostbites maximal size of islet sural flap was 349.2±19.3 cm^2. Mean area of islet flaps formed in cases of mine–blast injuries and acute trauma was 230.8±15.7 cm^2. Patients with osteomyelitic necrosis of the shin and foot had smaller mean area of the skin flap that was 136.7±20.35 cm^2 (*Table*).

Venous thrombosis and diabetic gangrene progression that required reamputation in 12.5% of cases were observed in the second group. Signs of flap venous insufficiency accompanied by flictena formation complicated 1 case (12.5%); in 2 other cases (25%) flap marginal necrosis developed that required additional auto–dermal plastic surgery.

In 2 cases from the first group marginal ischemia of the flap distal area was observed but none of these patients required additional auto–dermal plastic surgery due to this issue. Based on our experience, fatal microcirculation impairment most likely was associated with functional state and location of the flap vascular stem. During application of the "Propeller"–technique the stem was isolated adequately from environment by the own tissues of the flap while during traditional elevation method the stem was either located in the tunnel of the surrounding tissues which were very likely to carry pathological changes themselves or required additional covering by using free split skin autograft.

Discussion

Even after most thorough surgical debridement of the large injury or infectious defect their tissues remain contaminated. Only covering with vascularized tissues may prevent secondary necrosis progression and infectious complications.

The condition of wound recipient surface had paramount significance for prevention of the purulent complications development because any reparative process needs adequate blood supply. Equal rate of wound suppuration supports this statement.

Thus, after performing the traditional technique of the flap grafting signs of the local infection were present in 50% of the patients (in 2 out of 4 patients from the first group and in 4 out 8 patients from the second group).

Due to the limited amount of the soft tissue resources available for flap reconstruction of the foot one should always make an effort to save limb weight–baring surface using the means of the shin tissues because it is the only way to perform amputation at the lowest possible level and provide viability of the exposed deep structures of the distal lower extremity.

None of the patients achieved complete resumption of the limb ability to bare weight or pre–injury level of ambulation until 3 to 6 months after surgery though patients were satisfied with acquired range of motion.

Conclusions

1. Interpretation of the study data is limited due to the small sample size and undetermined maximal flap islet size that depends on individual peculiarities of the wound structure and concomitant general condition of each patient.

2. Using of the tegument tissues mobilization complex "Propeller"–technique is an effective instrument for sealing of the distal lower limb deep complex defects of the different etiology. Successful wound plastic surgery can be performed without microsurgery and meets ordinary surgical department budget requirements due to the stable revascularization of the damaged tissues, restoration of the tegument, decrease in the foot deformation severity and shortening of the terms needed for prosthesis preparation and functional rehabilitation.

Підтвердження

Фінансування. Робота виконувалася відповідно до плану наукових досліджень Донецького національного медичного університету. Фінансової підтримки з боку компаній–виробників лікарських препаратів автори не отримували.

Інформація про внесок кожного учасника:

Самойленко Г.Є. – концепція та дизайн дослідження, корегування тексту, Жаріков С.О. – збір та обробка матеріалів, написання тексту, Кліманський Р.П. – аналіз отриманих даних, написання тексту. Всі автори прочитали і схвалили остаточний варіант рукопису.

Конфлікт інтересів

Автори, які взяли участь в цьому дослідженні, декларують відсутність конфлікту інтересів щодо цього рукопису.

Згода на публікацію

Всі автори дали згоду на публікацію цього рукопису.

References

1. Macedo JLS, Rosa SC, Neto AVRF, Silva AAD, Amorim ACS. Reconstruction of soft–tissue lesions of the foot with the use of the medial plantar flap. Rev Bras Ortop. 2017 Oct 19;52(6):699–704. doi: 10.1016/j.rboe.2017.10.009. eCollection 2017 Nov–Dec.
2. Wu H, Sheng JG, Zhang CQ. Free Medial Plantar Flap Connection with a Posterior Tibial Artery Flap in Reconstruction of Fore–Mid Foot Skin Defect. Plast Reconstr Surg Glob Open. 2016 Nov 28;4(11):e1091. PMID: 27975013.
3. Myung Y, Yim S, Kim BK. A comparison of axial circumference between superficial circumflex iliac artery perforator flap and other workhorse flaps in dorsal foot reconstruction. J Plast Surg Hand Surg. 2017 Dec;51(6):381–386. doi: 10.1080/2000656X.2017.1279621.
4. Norbeck O, Avventi E, Engström M, Rydén H, Skare S. Simultaneous multi–slice combined with PROPELLER. Magn Reson Med. 2018 Aug; 80 (2):496–506. doi: 10.1002/mrm.27041.
5. Turan K, Tahta M, Bulut T, Akgün U, Sener M. Soft tissue reconstruction of foot and ankle defects with reverse sural fasciocutaneous flaps. Rev Bras Ortop. 2017 May 13;53(3):319–322. doi: 10.1016/j.rboe.2017.05.002.
6. Cuomo R, Nisi G, Grimaldi L, Brandi C, D'Aniello C. Use of ultraportable vacuum therapy systems in the treatment of venous leg ulcer. Acta Biomed. 2017 Oct 23;88(3):297–301. doi: 10.23750/abm.v88i3.5737.