

APPLICATION OF THE BALLOON SKIN EXPANSION METHOD IN PEDIATRIC RECONSTRUCTIVE SURGERY

Khagurov RA^{1,2}✉, Alexandrov AV¹, Ribchenok VV¹, Samorukova NN¹, Velskaya Yul¹, Lvov NV¹, Koval SYu¹

¹ Department of Reconstructive and Plastic Microsurgery, N. F. Filatov Children's Municipal Clinical Hospital No.13, Moscow, Russia

² Department of Pediatric Surgery, Pediatric Faculty, Pirogov Russian National Research Medical University, Moscow, Russia

The article describes the treatment of children with vast scar deformities and extensive benign soft tissue neoplasms. The method is presented in a clinical case of successful skin restoration using balloon skin expansion. The opinion and recommendations of the authors on optimal treatment of these defects and decrease of possible complications using laser Doppler flowmetry for evaluation of the state of microcirculation in the skin flap are based on the results of the long-term use of this method in the Department of Reconstructive and Plastic Microsurgery of Filatov Children's Municipal Clinical Hospital No.13.

Keywords: balloon skin expansion, soft tissue expander, expansion, scarring alopecia, skin grafting

✉ **Correspondence should be addressed:** Ruslan Khagurov
ul. Sadovaya-Kudrinskaya, d. 15, korp. 2, kab. 214, Moscow, Russia 103001; hagurov@gmail.com

Received: 26.09.2016 **Accepted:** 11.10.2016

ПРИМЕНЕНИЕ МЕТОДА БАЛЛОННОЙ ДЕРМАТЕНЗИИ В ДЕТСКОЙ РЕКОНСТРУКТИВНО-ПЛАСТИЧЕСКОЙ ХИРУРГИИ

Р. А. Хагуров^{1,2}✉, А. В. Александров¹, В. В. Рыбченко¹, Н. Н. Саморукова¹, Ю. И. Вельская¹, Н. В. Львов¹, С. Ю. Коваль¹

¹ Отделение реконструктивной и пластической микрохирургии, Городская детская клиническая больница № 13 имени Н. Ф. Филатова, Москва

² Кафедра детской хирургии, педиатрический факультет, Российский национальный исследовательский медицинский университет имени Н. И. Пирогова, Москва

В статье описана методика лечения детей с обширными рубцовыми деформациями и объемными доброкачественными новообразованиями мягких тканей на примере клинического случая успешного восстановления кожного покрова с помощью метода баллонной дерматензии. Мнение и рекомендации авторов об оптимальном лечении подобного типа дефектов, а также о снижении числа возможных осложнений при использовании лазерной доплеровской флоуметрии для оценки состояния микроциркуляции в кожном лоскуте основаны на результатах многолетнего применения данного метода в условиях отделения реконструктивной и пластической микрохирургии ДГКБ № 13 им. Н. Ф. Филатова.

Ключевые слова: метод баллонной дерматензии, тканевый эндоэкспандер, экспансия, рубцовая алопеция, кожная пластика

✉ **Для корреспонденции:** Хагуров Руслан Асланчериевич
ул. Садовая-Кудринская, д. 15, корп. 2, каб. 214, г. Москва, 103001; hagurov@gmail.com

Статья поступила: 26.09.2016 **Статья принята к печати:** 11.10.2016

The method of balloon skin expansion, first proposed by an American scientist C. Newman in 1957, has been successfully used in plastic and reconstructive surgery. The method is based on such properties of normal soft tissues and skin as elasticity and growth potential. It was described by a number of Russian and international authors. The scientists showed the advantages of this method [1–6].

An expander is a device for temporary implantation under the skin, which increases and stretches when filled with fluid. After attaining enough tissues, the expander is removed and the obtained stock of tissues is used for grafting. Expanders differ by size, profile, shape (round, oval, rectangular, in the form of a half-moon) and volume to which they can stretch. All expanders, both domestic and foreign, have a certain mandatory set of constructional elements and consist of biocompatible materials — silicone or latex. A balloon formed by

a thin elastic membrane (smooth or textured) and a filling valve are compulsory constructional elements of expanders. The volume of the expander varies from 3 to 2000 ml. There are expanders with a high and low profile and with a strengthened base which allows stretching tissues in strictly given direction. Expanders with textured surface have a number of advantages: the fibrous capsule formed around them is more elastic; they do not shift and have a built-in valve. Comparing intratissue expanders in use, it may be noted that latex ones have a higher expansibility degree, while silicone expanders have higher strength properties with virtually the same biological response of surrounding tissues to both materials [1, 3–10].

Recently, the balloon skin expansion method has been widely used in pediatric plastic surgery for treatment of cicatricial deformities in the area of face, neck, trunk and limbs. Patients with benign neoplasms of complicated anatomical

location constitute a sizable group of patients in which a single-stage radical surgical removal of the neoplasm cannot always be performed. Therefore, such patients need long-term staged treatment frequently resulting in forming vicious cicatrix of soft tissues replacing tumor tissue. A separate group of patients is composed of children with cicatricial alopecia arising from injuries, burns or purulent inflammations. Cicatricial defect and cicatricial alopecia are serious cosmetic issues causing a patient constant distress, and in adolescence they provoke disturbance of social adaptation of a child among peers [3–5, 10].

For now, many morphological, histological and functional aspects of tissue endoexpanders have been studied. The studies of stretched skin flaps carried out in animals and humans showed that minor changes occurred in epidermis during tissue stretching. Using laser Doppler flowmetry, it was found that during expansion in the process of stretching, skin perfusion did not decrease but on the contrary did increase. This indicates that skin vessels participate in expansion. It is very likely that the vascular system is the main factor determining the degree of soft tissue stretching. Blood supply in a flap formed using the expander is effected on account of increase of vascularization of border zones and neoformation of vessels in the flap, their adaptation to stretching and formation of a vascular-fibrous capsule. In as little as several days after start of expansion, increase in the number of arterioles and venules occurs [1–5, 11–13].

The method of balloon skin expansion has been used in the Department of Microsurgery of of Filatov Children's Municipal Clinical Hospital No.13 since 1993. A solid experience has been accumulated in treatment of patients with alopecia, deformities, and skin and soft tissue congenital abnormalities. Additional instrumental methods of control of the state of the skin flap above the expander has been developed and embedded in practice, a mathematical method of calculation of the area of each flap has been developed which led to decrease in the number of complications and expansion time. 53 patients at the age from 1 month to 17 years were treated in the Department. Among them were 23 children (15 girls, 8 boys) with posttraumatic alopecias of the hairy part of the head, 19 children (12 girls, 7 boys) with extensive benign neoplasms of soft tissues, and 11 adolescents with scrotum hyperplasia.

Clinical case

A female patient Sh., 5 years old, was admitted to the Department of Microsurgery of Filatov Children's Municipal Clinical Hospital No.13 with soft tissue necrosis of the parieto-occipital area.

The child was bitten by a dog 1 month before admission. The initial surgical debridement of the wound of the parieto-occipital area was performed in a primary care facility. Later the necrosis of the skin flap of the parieto-occipital area developed (Fig. 1). In the Department of Reconstructive and Plastic Microsurgery, the necrectomy and free dermatoplasty were performed (Fig. 2).

As a result of the treatment, the wound defect was fully closed, the free skin flap showed signs of full recovery; however, later alopecia of the parieto-occipital area was formed with the size of 15.0 × 15.0 cm (Fig. 3, 4).

Six months later the tissue latex endoexpander was implanted. The endoexpander was manufactured in the Scientific Research Institute of Rubber and Polymer Goods (Russia) (Fig. 5). Filling of the expander began on postoperative day 14 after removal of sutures. The expansion was carried

out using 10–20 ml sterile saline solution 2 times a week under control of laser Doppler flowmetry. Two months after installation of the expander, when maximum volume was achieved and the required stock of plastic material was formed, surgical treatment was performed — the removal of the tissue endoexpander and skin grafting with local tissues. As a result of the treatment, we managed to eliminate the alopecia patch in the right parietal region (Fig. 6).

Subsequently, the balloon skin expansion was repeated twice in this patient, and 1.5 years after the start of the treatment, the alopecia in the parieto-occipital region was fully eliminated (Fig. 7, 8).

DISCUSSION

The cosmetic result of treatment was evaluated as good. The alopecia patch was fully eliminated. Postoperative scars were normotrophic. Turgor and sensitivity of the skin flap above the expander were retained.

Application of tissue expanders in each patient requires accurate preoperative planning in selection of shape, size, profile, expander volume and the number of expanders. It is necessary to assess localization, size and configuration of a skin lesion subject to excision, to choose nearby zone or zones of normal soft tissues which expansion will allow achieving an excess sufficient for transplantation in the form of a local flap and closing of a tissue defect without tension. It is necessary to make sure that scar tissue incapable of stretching and growing adequately does not get into a zone of planned expansion; otherwise it will lead to non-uniform skin expansion, suture line disruption, exposure of the expander and development of local infection. It is also important that a surgeon should take into account individual skin traits of a patient in advance [1, 2, 6, 11, 12, 14, 15].

Tissue necrosis over the expander is one of the most frequent complications of the described method. The skin expansion under control of laser Doppler flowmetry may decrease the number of such complications. Using laser Doppler flowmetry, it was found that the indices of perfusion oxygen saturation in blood and specific consumption of oxygen in tissues increase



Fig. 1. Female patient Sh., 5 years old. Necrosis of the skin flap of the parieto-occipital area

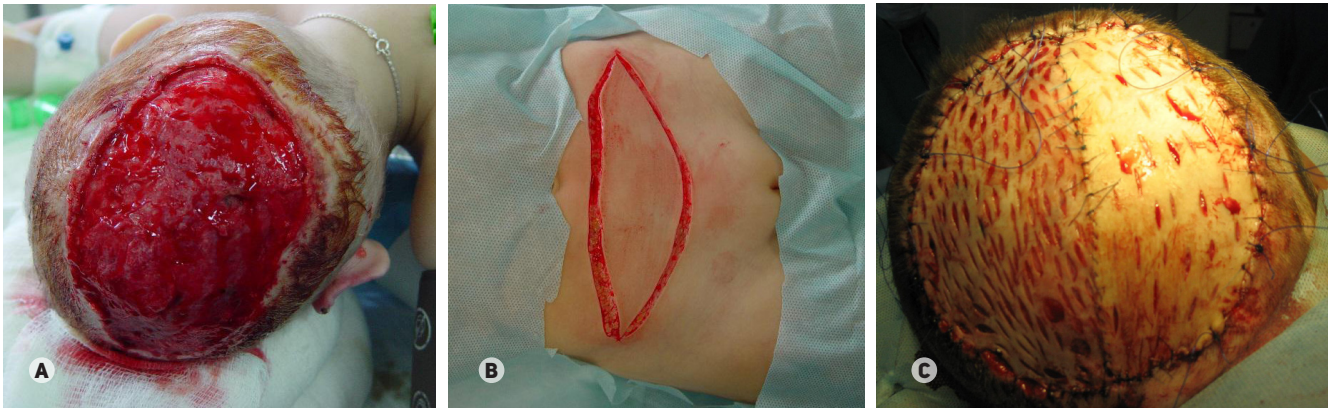


Fig. 2. Female patient Sh., 5 years old. Surgery stages: (A) Removal of the necrotic skin flap of the parieto-occipital area.; (B) Free skin grafting from the anterior abdominal wall; (C) the wound defect is fully covered with the skin flap



Fig. 3. Female patient Sh., 5 years old. Clinical photograph taken 14 days after surgery. The wound defect is fully closed, the full engraftment is observed



Fig. 4. Female patient Sh., 5 years old. Alopecia of the parieto-occipital region



Fig. 5. Female patient Sh., 5 years old. The tissue endoexpander implanted in the right parietal region



Fig. 6. Female patient Sh., 5 years old. Clinical photograph after elimination of alopecia in the right parietal region



Fig. 7. Female patient Sh., 5 years old. Clinical photograph after implantation of two tissue endoexpanders



Fig. 8. Female patient Sh., 7 years old. Clinical photograph taken 1.5 years after treatment

during expansion regardless of shape and size of the expander as well as of its localization and the number of endoexpanders implanted in the same anatomical region [1, 2, 4, 5, 15, 16].

CONCLUSIONS

There are different options of surgical repair of skin and surrounding tissues: local flap grafting, local grafting with

triangular flaps, free skin grafting, combined skin grafting. However, such procedures may be very complicated and challenging, and are often poorly tolerated by patients and require the involvement of another skin region. Balloon skin expansion method is more efficient and should be considered an optimal technique of skin recovery. The laser Doppler flowmetry can be used for the monitoring of the microcirculation in the skin flap above the expander to prevent possible complications.

References

1. Avdeev AE. Plastika rubtsovykh porazhenii kozhnykh pokrovov metodom endoekspandernoi dermatenzii u detei [dissertation]. Moscow: Tsentral'nyi nauchno-issledovatel'skii institut travmatologii i ortopedii imeni NN Priorova; 1997. Russian.
2. Bzhasso DM. Vybora metoda plasticheskogo zakrytiya obshirnykh defektov myagkikh tkanei golovy i shei [dissertation]. Moscow: Rossiiskii nauchnyi tsentr khirurgii imeni akademika BV Petrovskogo; 2008. Russian.
3. Vaganov NV. Khirurgicheskoe lechenie obshirnykh defektov i deformatsii pokrovnykh tkanei etapnoi ballonnoi dermatenziei [dissertation]. Moscow: AV Vishnevsky Institute of Surgery; 2015. Russian.
4. Trusov AG. Effektivnost' khirurgicheskogo lecheniya detei s alopetsiyami metodom ballonnoi dermatenzii s primeneniem komp'yuternogo modelirovaniya [dissertation]. Moscow: Moskovskii nauchno-issledovatel'skii institut pediatrii i detskoj khirurgii; 2000. Russian.
5. Khagurov RA. Primenenie metoda ballonnoi dermatenzii v detskoj rekonstruktivno-plasticheskoi khirurgii [dissertation]. Moscow: Pirogov Russian National Research Medical University; 2011. Russian.
6. Argenta LC, Marks MW, Pasyk KA. Advances in tissue expansion. Clin Plast Surg. 1985 Apr; 12 (2): 159–70.
7. Vaganova NA. Novye khirurgicheskie sposoby lecheniya deformatsii volosistoi chasti golovy, litsa i shei s primeneniem ballonnogo rastyazheniya tkanei [dissertation]. Moscow: AV Vishnevsky Institute of Surgery; 2006. Russian.
8. Cherry GW, Austad E, Pasyk K, McClatchey K, Rohrich RJ. Increased survival and vascularity of random-pattern flaps elevated in controlled expanded skin. Plast Reconstr Surg. 1983 Nov; 72 (5): 680–7.
9. Chassagne JF, Brice M, Maxant P, Flot F, Dinh Doan G, Brice M, et al. Evaluation des idees dans les techniques de reparation du scalp. Ann Chir Plast Esthet. 1986; 31 (4): 325–35. French.
10. Duck GO, Brown SA. Breast reconstruction using modified tissue expansion. Plast Reconstr Surg. 1986 Apr; 77 (4): 613–20.
11. Argenta LC, VanderKolk CA. Tissue expansion in craniofacial surgery. Clin Plast Surg. 1987 Jan; 14 (1): 143–53.
12. Coleman DJ, Sharpe DT, Naylor IL, Chander CL, Cross SE. The role of the contractile fibroblast in the capsules around tissue expanders and implants. Br J Plast Surg. 1993 Oct; 46 (7): 547–56.
13. Pasyk KA, Argenta LC, Austad ED. Histopathology of human expanded tissue. Clin Plast Surg. 1987 Jul; 14 (3): 435–45.
14. Khodorkovsky MA, Petrov BV, Skorynin OS, Glushchenko AV, Khodorkovsky MM. [The variants of plastic substitution of scalp defects]. Annaly plasticheskoi, rekonstruktivnoi i esteticheskoi khirurgii. 2012; (3): 45–51. Russian.
15. Esposito C, Dado DV. The use of tissue expansion for the treatment of burn scar alopecia. Plast Surg Nurs. 1997 Spring; 17 (1): 11–5.
16. Moroz Vlu, Sarygin PV, Sharbaro VI, Vaganova NA. [Complications of balloon tissue distention]. Khirurgiia (Mosk). 2000; (3): 65–8. Russian.

Литература

1. Авдеев А. Е. Пластика рубцовых поражений кожных покровов методом эндоэкспандерной дермотензии у детей [диссертация]. М.: ЦИТО им. Н. Н. Приорова; 1997.
2. Бжассо Д. М. Выбор метода пластического закрытия обширных дефектов мягких тканей головы и шеи [диссертация]. М.: РНЦХ им. акад. Б. В. Петровского; 2008.

3. Ваганов Н. В. Хирургическое лечение обширных дефектов и деформаций покровных тканей этапной баллонной дермотензией [диссертация]. М.: Институт хирургии им. А. В. Вишневского; 2015.
4. Трусов А. Г. Эффективность хирургического лечения детей с алопециями методом баллонной дермотензии с применением компьютерного моделирования [диссертация]. М.: Московский НИИ педиатрии и детской хирургии; 2000.
5. Хагуров Р. А. Применение метода баллонной дермотензии в детской реконструктивно-пластической хирургии [диссертация]. М.: РГМУ; 2011.
6. Argenta LC, Marks MW, Pasyk KA. Advances in tissue expansion. *Clin Plast Surg*. 1985 Apr; 12 (2): 159–70.
7. Ваганова Н. А. Новые хирургические способы лечения деформаций волосистой части головы, лица и шеи с применением баллонного растяжения тканей [диссертация]. М.: Институт хирургии им. А. В. Вишневского; 2006.
8. Cherry GW, Austad E, Pasyk K, McClatchey K, Rohrich RJ. Increased survival and vascularity of random-pattern flaps elevated in controlled expanded skin. *Plast Reconstr Surg*. 1983 Nov; 72 (5): 680–7.
9. Chassagne JF, Brice M, Maxant P, Flot F, Dinh Doan G, Brice M, et al. Evaluation des idees dans les techniques de reparation du scalp. *Ann Chir Plast Esthet*. 1986; 31 (4): 325–35. French.
10. Duck GO, Brown SA. Breast reconstruction using modified tissue expansion. *Plast Reconstr Surg*. 1986 Apr; 77 (4): 613–20.
11. Argenta LC, VanderKolk CA. Tissue expansion in craniofacial surgery. *Clin Plast Surg*. 1987 Jan; 14 (1): 143–53.
12. Coleman DJ, Sharpe DT, Naylor IL, Chander CL, Cross SE. The role of the contractile fibroblast in the capsules around tissue expanders and implants. *Br J Plast Surg*. 1993 Oct; 46 (7): 547–56.
13. Pasyk KA, Argenta LC, Austad ED. Histopathology of human expanded tissue. *Clin Plast Surg*. 1987 Jul; 14 (3): 435–45.
14. Ходорковский М. А., Петров Б. В., Скорынин О. С., Глуценко А. В., Ходорковский М. М. Варианты пластического замещения дефектов волосистой части головы. *Анн. пласт. реконструк. и эстет. хир.* 2012; (3): 45–51.
15. Esposito C, Dado DV. The use of tissue expansion for the treatment of burn scar alopecia. *Plast Surg Nurs*. 1997 Spring; 17 (1): 11–5.
16. Мороз В. Ю., Сарыгин П. В., Шаробаро В. И., Ваганова Н. А. Осложнения метода баллонного растяжения тканей. *Хирургия. Журнал имени Н. И. Пирогова*. 2000; (3): 65–8.