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Original article

Enlarged Perforating Flaps of the Anterior Thoracic and Abdominal Wall: A Novel Approach to Autologous Breast Reconstruction

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SUMMARY

Aim. To develop methods for obtaining enlarged perforating flaps on the anterior surfaces of the thoracic and abdominal walls.
Material and methods: The study included 16 patients with post-burn breast deformities aged from 5 to 22 years. In the upper part of the anterior surface of the chest, the flaps were formed on the basis of 2, 3 anterior intercostal artery perforator and thoracoacromial artery perforator with the inclusion of the vascular network of the thoracic branch of the supraclavicular artery. In the lower part of the thoracic and upper abdominal wall, there were also enlarged flaps based on the superior epigastric artery perforator with the connection of vascular networks 6, 7 anterior intercostal artery perforator and perforator deep inferior epigastric artery. The obtained flaps were moved by direct advancement, rotation and transposition methods.
Results: The largest area of the wound defect was closed with flaps that were moved by rotation and it was 1.8 times larger than the area of wounds closed by direct advancement and 1.3 times larger than if using transposition flaps. The use of stretched perforating flaps from the anterior surface of the thoracic and abdominal walls allowed to obtain a positive result in 90.4% of cases with the short-term treatment, and in all cases with the long-term treatment.
Conclusion: A simple technique based on the proposed methods can be widely used for the reconstruction of the upper and lower quadrants of the breast and intermammary and submammary spaces.

Keywords: **words: perforating flaps, breast reconstruction, post-burn breast deformities, tissue expansion, perforating blood vessels**

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INTRODUCTION

Breast burn injury is very variable and varies in depth and area of damage, but the consequences after the burn have the same components that need to be removed.

Reduction of self-healing area of wounds and also reduction of grafts is always present at a thermal injury. Reduction leads to tension as one of the main causes of hypertrophic scarring and the formation of contractures (1, 2).

A special place is occupied by lesions of the upper and lower segments of the breast and submammary region. The upper segments of the breast form the lateral contours of the body and, entering the décolleté area, require increased attention to the aesthetic appearance. In turn, the lower segments of the breast and the submammary area form the lower contours of the gland and the submammary fold. In cicatricial lesions of these areas, a sufficient amount of plastic material identical to textural properties to the lost tissue is necessary.

To achieve this goal, the most suitable are tissues located near the gland. Perforator flaps of thoracodorsal artery (3), deep inferior epigastric artery (5, 6), intercostal artery (7-10), thoracoacromial artery (11, 12) are successfully used.

However, deformations of the breast are also accompanied by scarring and limited size of the surrounding areas. To increase the area of flaps, their expansion is carried out. In recent years, the expansion of perforating flaps has been used, which significantly improves their survival. In addition, tissue expansion provides a simplified lifting of the flap during the second stage and provides physiological tissue stretching, which stimulates endothelial cell proliferation and neovascularization.

It is shown that by expanding of the perforating flaps, it is possible to obtain a larger amount of plastic material compared to traditional flaps without increasing the level of complications (13 - 16).

The aim of the work was to develop methods for obtaining enlarged perforating flaps on the anterior surfaces of the thoracic and abdominal walls for the reconstruction of post-burn scar deformities of the upper and lower parts of the breast and submammary region.

MATERIALS AND METHODS

Research included 16 patients with post-burn breast deformities, aged from 5 to 22 years (mean age - 13.6 years).

All patients underwent reconstructive interventions to eliminate deformities by using enlarged flaps of the anterior surface of the chest and abdomen. Enlarged flaps were formed on the anterior surfaces of the chest and abdominal wall of different types depending on the power sources and ways of their removal. To obtain enlarged flaps, undamaged areas of tissue, the presence of its own feeding vessels, as well as intact areas of adjacent perforosoms, were taken into account for the design of the flap, the supply of which extends beyond the vascular area of the main perforator. The method of moving of the obtained flap and the area of closure of the probable wound defect were determined.

Enlarged flaps were based on 2, 3 anterior intercostal artery perforator (2, 3 AICAP) in 9 cases, on thoracoacromial artery perforator (TAAP) in 2 cases and on 2, 3 AICAP and TAAP in 2 cases. Superior epigastric artery perforator (SEAP) based flaps were used in 7 cases.

To correct the deformations of the upper segments of the breast and intermammary space, enlarged perforating flaps based on 2, 3 AICAP or TAAP were formed with the inclusion of vascular networks of adjacent perforators. Enlarged SEAP-based perforating flaps were used to eliminate deformations of the lower segments of the breast, infra and intermammary spaces. Also, in 6 cases, enlarged flaps from the lateral surface of the chest were additionally used.

Pre-stretching of the flaps was performed by using tissue endoexpanders with a volume from 350 to 650 ml.

The study included clinical data, pre- and postoperative photography, the results of ultrasound scanning (Philips Ultrasound with a diameter of 1 - 180 mm with an expected range of 2 - 3.5 mm), as well as a portable fetal vascular Doppler Heaco CD8.0 (UK) with highly sensitive 8 MHz. Doppler scans were used to determine the output of nearby perforating vessels from the deep fascia or muscles.

Flap design

The skin and soft tissues of the upper anterior part of the chest wall are mainly fed by 2, 3 AICAP branches of the internal mammary artery (IMA), TAAP, the thoracic branch of the supraclavicular artery (TBSA), and lateral thoracic artery (LTA).

The flaps of the upper part of the chest wall were formed in three ways:

- flaps based on 2, 3 AICAP with the inclusion of vascular networks TAAP and TBSA (Figure 1 A);
- flaps based on TAAP with the inclusion of vascular networks 2, 3 AICAP and TBSA (Figure 1 B);
- flaps based on two perforators - TAAP and 2, 3 AICAP with the inclusion of vascular networks TBSA (Figure 1 C).

The soft tissues of the lower chest and upper anterior abdominal wall are fed by the SEAP - the terminal branch of the IMA, by 6, 7 muscle perforator anterior intercostal artery perforator (6, 7 AICAP) and by the deep inferior epigastric artery perforator (DIEAP).

The flaps of the lower chest and abdominal walls were also formed in three ways:

- flaps based on SEAP with the inclusion of vascular networks DIEAP and 6, 7 AICAP of the same side (Figure 2 A);

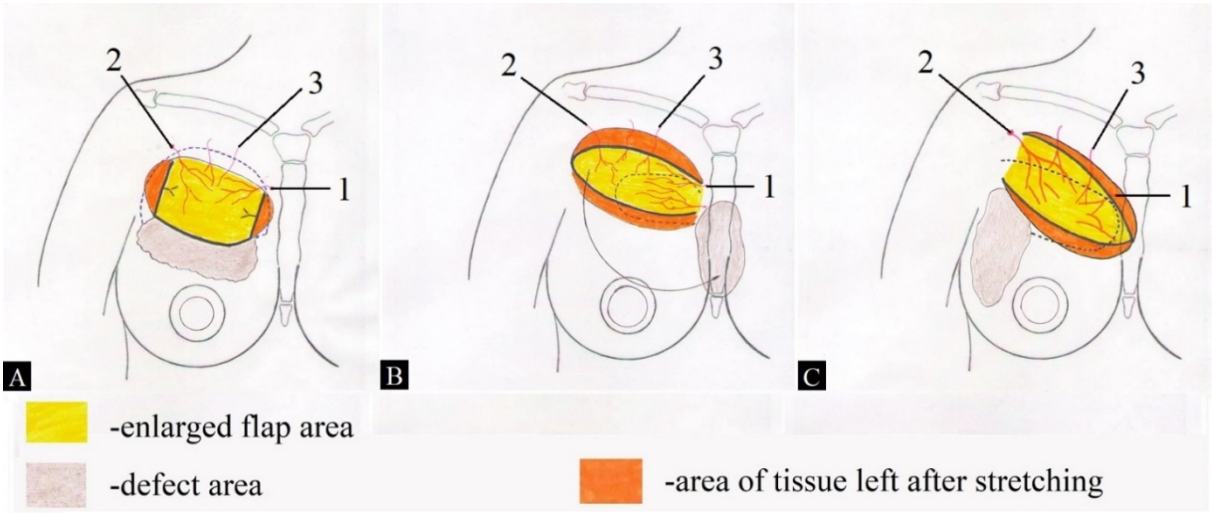

Figure 1. *The flaps of the upper part of the chest walls*
1 - 2, 3 AICAP; 2 - TAAP; 3 - TBSA

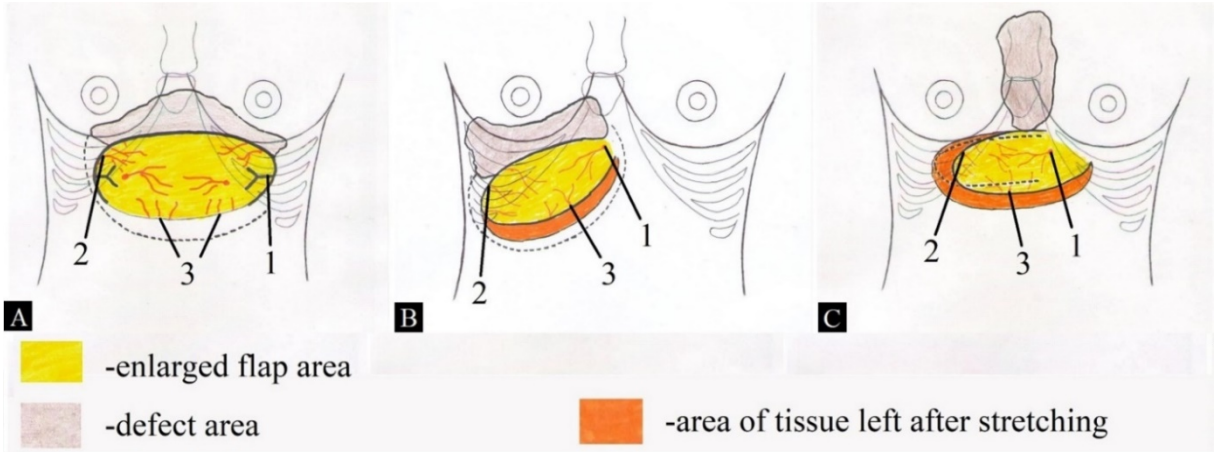

Figure 2. *The flaps of the lower chest and abdominal walls*
1 - SEAP; 2 - 6, 7 AICAP; 3 - DIEAP

- flaps based on SEAP with the inclusion of vascular networks DIEAP and 6, 7 AICAP of the opposite side (Figure 2 B);

- flaps based on two SEAP perforators on both sides (Figure 2 C).

Surgical technique

Surgical treatment included three stages. In the first stage, an expander was implanted in the formed pocket. To perform this, the soft tissues were cut together with the fascia along the edge of the scar mass. Dissection of the pocket lid was performed subfascially. The branches of the muscle perforators were ligated throughout the pocket, preserving the suprafascial vascular network. The cavity of the pocket was expanded before reaching the vascular feeding leg by 1.5 - 2 cm. After placing the expander, the wound was sutured in layers with the removal of the external port with active drainage through a separate hole on the side or bottom of the pocket.

On the second stage, the expander was expanded by injecting the saline in a volume from 5 to 10% of its total volume. After reaching the required size of the expander, in the third stage, an extended flap was formed after excision of the scars. Afterwards, it was moved to the place of the defect.

Movement of flaps was carried out by the direct advancement (direct advancement flap), rotation, and transposition.

Flap direct advancement

When moving the direct advancement flap, the main lines of the incisions outlined the contours of the expanded tissues in width and on the side adjacent to the P-shaped scars. In this manner, a flap with an axis across the width of the stretched tissues formed. The base of the flap, which included the feeding vessels, remained intact. To lengthen the flap and use the stock of expanded tissues, over the dome of the expander on the side surfaces of the incisions, additional incisions perpendicular to the main were performed. After excision of the scars, the flap was placed along its axis on the wound surface while simultaneously closing the donor area.

Flap transposition

In the formation of transposition flaps, incisions of stretched tissues were made along the long axis of the flap, which were connected on the opposite side from the base. On the opposite side of the scars, part of the stretched tissue to close the donor wound was left. After excision of the scars, the flap was moved to the wound defect at an angle of 45^0 - 90^0 to its axis. The donor area was closed by the part of the expanded tissue that remained, by suturing with the scar when moving at an angle of more than 60^0, or by suturing with the edge of the moved flap at a smaller angle of rotation.

Flap rotation

Before forming the rotation flap, the point of rotation at the base of the flap, which provides a place for the supply vessel, was determined. An incision was made along the length of the stretched tissues on the border with the scar. From the upper edge of the incision, an arcuate incision along the upper and partially opposite edge depending on the required arc of rotation of the flap was performed. After excision of the scars, the flap was moved to the wound and the donor defect around the point of rotation by direct advancement and transposition at an angle of 30^0 to 90^0.

Statistical analysis

SPSS v. 17.0. was used for statistical analysis. All identified parameters of the study were studied by using Shapiro-Wilk test. Values were expressed as mean ± standard error of the mean. A statistically significant difference between the values was considered $p < 0.05$.

RESULTS

When forming enlarged flaps, their area depended on both the volume of the expander and the method of their movement (Table 1).

In a multiple comparison of the obtained medians, the distribution differed between S rot and S direct ($p \leq 0.01$). In other cases, the statistical probability was not significant. Based on this, the average area in transposition flaps was 1.4 times larger than in direct advancement flaps.

Areas of wound defects after excision of scars, which were closed with different types of flaps without taking into account the donor area, had the following indicators (Table 2).

Table 1. *The area of the received flaps depending on a way of their movement*

Variable	Number of cases	Mean median (cm^2)
S rot	6	139.5 ± 20.3 (120; 228)
S transposition	4	106.0 ± 6.3 (96; 120)
S direct	10	96.0 ± 6.9 (88; 120)*

S rot - the area of the flaps that were moved by the rotation;
S transposition - the area of the flaps that were moved by the transposition;
S direct - the area of the flaps that were moved by the direct advancement;
* - $p \leq 0.01$.

In a multiple comparison of the obtained medians, the distribution differed between S wound transposition and S wound direct ($p = 0.02$). In other cases, the statistical probability was not significant.

According to the obtained data, the largest area of the wound defect was closed with flaps, which were moved by rotation and it was 1.8 times larger than the area of wounds closed by direct advancement and 1.3 times larger than when using transposition flaps.

The results of treatment of patients with post-burn deformities of the breast were studied in the short and long-term in the period from 6 months to 5 years. The main criteria for assessing the immediate results of treatment were engraftment of the flaps and the most complete removal of scars.

Complete engraftment of flaps with the absence of complications was obtained in 18 (90.4 ± 2.3%) cases.

Table 2. *The area of wounds that was closed by different types of flaps*

Variable	Number of cases	Mean median (cm^2)
S wound rot	6	119.2 ± 11.3 (96; 170)
S wound transposition	4	92.7 ± 5.3 (77; 99)
S wound direct	10	66.7 ± 8.9 (56; 80)*

S wound rot - the area of the wound that was closed by the rotation flaps;
S wound transposition - the area of the wound that was closed by
the transposition flaps;
S wound direct - the area of the wound that was closed by the direct advancement flaps;
* - $p = 0.02$

Clinical observation

Clinical observation 1. A 16-year-old patient received burns of the chest, right breast, right shoulder, 12% of the body surface by boiling water at the age of 6 years. The wounds healed on their own. In the area of the upper and lower parts of the anterior surface of the chest - hypertrophic scars of the chest, the stratification of the breast with a shift of the nipple-areolar complex (NAC) downward.

The upper chest flap was expanded on the basis of two perforators - TAAP and 2, 3 AICAP with the inclusion of vascular networks TBSA. The lower flap of the chest wall was formed on the basis of SEAP with the inclusion of vascular networks DIEAP and 6, 7 AICAP of the same side.

In the second stage of treatment, enlarged chest flaps were formed: the upper flap (16 x 10 cm) and the lower flap (13 x 8 cm). After preliminary marking, scars were excised and the breast was mobilized to the top. Wound surfaces of 12 x 10 cm above and 11 x 7 cm below were formed. The wound surface was closed by the formed upper flap by rotation. The lower flap was moved to the wound by direct advancement. We managed to form infra-mammary fold. However, the plastic material for the plastic of the lower quadrants of the breast was not enough and the defect was closed with a free graft. Donor sites were initially closed by flaps (Figure 3).

Clinical observation 2. A 17-year-old patient received burns of the chest and mammary glands by boiling water. The wounds healed on their own. In the area of the upper and lower parts of the anterior surface of the thorax - normo- and hypertrophic scars of the thorax, intermammary space.

The upper chest flap was expanded on the basis of perforators 2, 3 AICAP with the inclusion of vascular networks TAAP and TBSA. The lower flap of the chest wall was formed on the basis of SEAP with the inclusion of vascular networks DIEAP and 6, 7 AICAP of the opposite side.

In the second stage of treatment, enlarged chest flaps were formed: the upper flap (16 x 9 cm) and the lower flap (14 x 9 cm). After preliminary marking, scars were excised in the upper and lower parts of the chest and intermammary space. Wound surfaces 13 x 9 cm above and 12 x 8 cm below were formed. The wound surface in the above and intermammary areas was closed by rotation of the formed upper flap on the perforator 2, 3 AICAP. The lower flap on the SEAP perforator was also moved

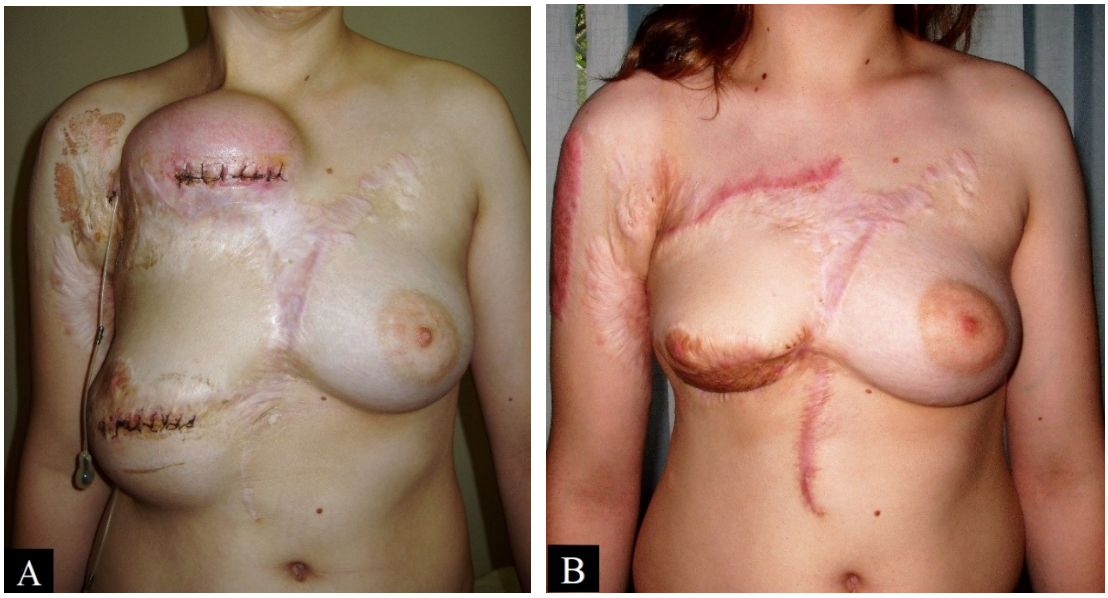

Figure 3. *Clinical case 1. (A) deformity, flattening of the right breast, scarring of the upper and lower parts of the chest, stretching of enlarged TAAP flaps and 2, 3 AICAP (upper) and SEAP (lower); (B) postoperative result after rotation flap (upper) and direct advancement flap (lower)*

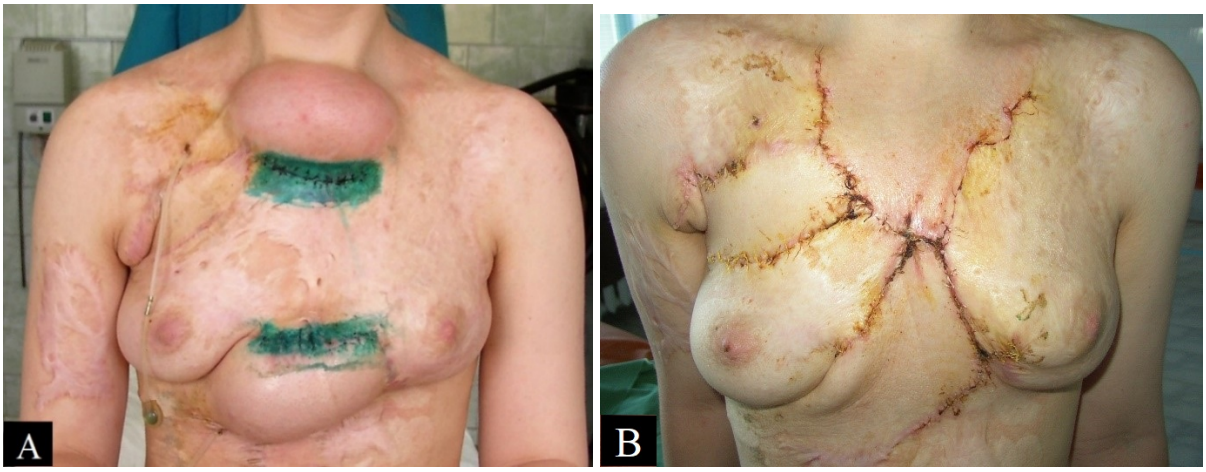

Figure 4. *Clinical case 2. (A) normo- and hypertrophic scars of the thorax, intermammary space, stretching of the enlarged upper thorax flap based on perforators 2, 3 AICAP with the inclusion of vascular networks TAAP and TBSA and lower flap on the basis of SEAP with the inclusion of vascular networks DIEAP and 6, 7 AICAP of the opposite side; (B) postoperative outcome after rotation flap (upper) and rotation flap (lower)*

to the wound by rotation. We managed to form an intermammary space. Donor sites were initially closed by flaps (Figure 4).

Clinical observation 3. An 18-year-old patient. After removal of the congenital nevus of the chest, there was a deformation of the soft tissues of the anterior surface of the chest and breast. In the area of the anterior surface of the chest wall - hypertrophic and atrophic scars with displacement of the left breast upwards. The upper thoracic flap was expanded on the basis of TAAP with the inclusion of 2, 3 AICAP vascular networks.

In the second stage of treatment, an enlarged vertical flap on the right lateral surface of the chest

sized 13 × 8 cm was formed. After preliminary marking of the location of the flap, scar excision and mobilization of the right breast were performed. A 12 × 8 cm wound was formed above the breast. The formed flap was moved to the wound by transposition at an angle of 90^0 while pulling the right breast up. The donor area was closed by the remains of stretched tissues on the lateral surface of the chest. (Figure 5).

Complications in the form of inflammation and divergence of sutures were observed in 2 cases, which was explained by suturing of healthy and scar-altered tissues and failure of sutures.

In 4 cases, the scars could not be completely removed due to the lack of plastic material, which was associated with insufficient tissue expansion. Patients underwent re-correction of deformities.

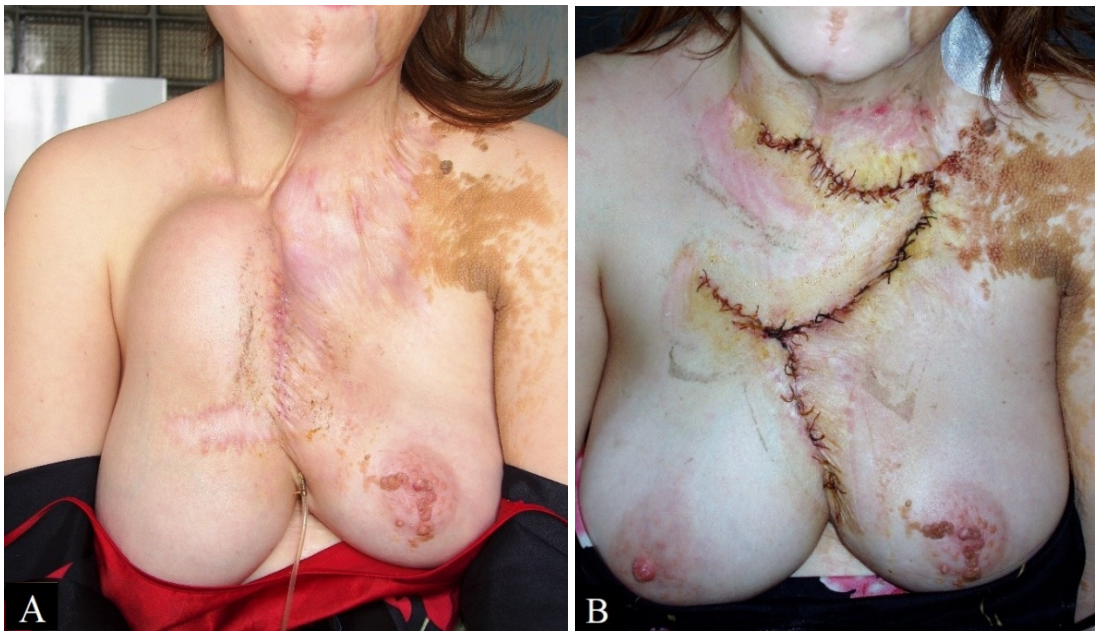

Figure 5. *Clinical case 3. (A) soft tissue deformation of the anterior surface of the chest and breast, normo- and hypertrophic scars of the chest, intermammary space, stretching of the enlarged upper chest flap on the basis of perforators 2, 3 AICAP with the inclusion of vascular networks TAAP and TBSA and lower flap based on SEAP with the inclusion of vascular networks DIEAP and 6, 7 AICAP of the opposite side; (B) postoperative outcome after rotation flap (upper) and rotation flap (lower)*

To assess the long-term results of treatment, the developed rating scale was used (17). Results were considered as good, when the contours of the affected and donor areas were restored, postoperative scars were less pronounced. Satisfactory results included preservation of uneven contours of the affected and donor areas, hypertrophic scars, incomplete removal of scar tissue. Unsatisfactory results included recurrence of deformity. Long-term results were studied in 7 (43.7%) patients, who came with deformities of other localizations.

Good results were noted in 4 (57.2%) and satisfactory in 3 (42.8%) patients. In patients with satisfactory treatment results, there was a reduction of flaps with the formation of hypertrophic postoperative scars and the preservation of previous scar tissue.

DISCUSSION

The problem of reconstruction of post-burn deformations of the mammary gland, which requires the balance between physiological and aesthetic needs, remains relevant. According to our studies, the upper segments of the breast have scarring in 6.5% - 10.8% of cases. The segments have a small amount of glandular tissue, form the lateral contours of the gland and are part of the décolleté. The skin of the upper part of the breast has high mobility and scarring of the skin leads to displacement of the

gland together with the NAC up and to the sides. In these cases, the greater the parenchymal deficit - the greater the displacement, which is probably due to burns at an early age. Scar transformations of the lateral surface of the chest and an axillary area contribute to the increase in deformation (4, 18).

The lower segments of the breast as well as the submammary zone are subjected to scarring in 14.4 - 20.3% of cases. The lower segments contain a large amount of glandular tissue and are involved in the formation of the lateral, inner and lower contours of the gland and submammary folds, which gives the gland a certain shape and aesthetic appearance. The damage of these segments leads to underdevelopment of glandular tissue, disorders of physiological growth, stratification of the gland along the front surfaces of the chest and abdominal wall, and smoothing of the submammary folds. Therefore, the restoration of these segments is of great importance in reconstructive breast surgery (19).

Currently, the priority measures are the usage of certain flaps along with the method of tissue expansion. The use of flaps from adjacent areas makes it possible to replace scar sites with similar tissue textures and colors, and the expansion of the flaps allows to increase the amount of plastic material, improve blood circulation and close the donor area. Expansion of the flaps with their own blood circulation on the basis of axial or perforating vessels significantly improves tissue nutrition and often prevents ischemic changes.

Numerous literature sources on this topic describe the use of different flaps. Thus, for the breast plastic, flaps from the chest are being used - on thoracodorsal artery, lateral thoracic artery, flaps on the perforators of these vessels, flaps on the anterior intercostal perforators, flaps on the middle intercostal perforators, flaps from the anterior abdominal wall - upper and lower deep epigastric artery, superficial epigastric artery (3, 6, 20, 21).

In our study, we paid attention to the flaps of the anterior surface of the thoracic and abdominal walls as potential tissue donors for the reconstruction of the upper and lower quadrants of the breast. However, in the traditional implementation of these flaps there are disadvantages such as their limited size and the lack of blood circulation. Perforating blood vessels that carry blood flow in the flaps cannot nourish the skin outside the flaps. With the enlargement of the flaps based on individual perforators by expanding, the area of blood supply increases due to the inclusion of vascular networks of adjacent perforasomes in the disclosure of choke anastomosis and neoangiogenesis (22, 23).

Depending on the location of the scars, perspective donor sites and the subsequent movement of tissues, we formed several modified flap versions. In the upper part of the anterior surface of the thorax, flaps are based on 2, 3 AICAP and TAAP with the inclusion of the vascular network of TBSA. Flaps were formed by including two perforators 2, 3 AICAP and TAAP, or were formed separately on one of them - 2, 3 AICAP and TAAP.

The expanders were placed in the subfascial layer along the length in the direction of the axis of the future flap.

In the lower part of the thoracic wall and upper part of the abdominal wall, enlarged flaps based on SEAP with the connection of vascular networks DIEAP and 6, 7 AICAP were also formed. Modification of the flaps was carried out in three versions depending on the location of the SEAP feeding leg on the same side or on the opposite side of the defect.

The location of the expander on a rigid base, which is the chest, allowed to effectively expand the soft tissues and to increase the area of guaranteed vascularization of the flaps. Simultaneously with the expansion, the effect of surgical delay was achieved with increased neoangiogenesis, which reduced the risk of flap necrosis (23).

For more efficient use of stretched tissues and the primary closure of the donor site, the movement of the obtained flaps was used in three ways: direct advancement, rotation and transposition. As the experience of certain movement of enlarged flaps has shown, the largest area of wounds after excision of scars could be closed by using flaps moved by rotation and transposition.

The closure of the donor site depended on the method of moving the flaps. Thus, when shifting by direct advancement method, the flaps had a wide base and, in some cases, two supply vessels. Closure of the defect and the donor site was carried out simultaneously by the formed enlarged flap. When moving such flaps, the expanded tissues are used irrationally due to the exclusion of stretched lateral areas formed above the expander.

When moving the enlarged flaps by transposition, it was possible to close the wounds of the larger area and rationally use the expanded tissues of the lateral surfaces of the expander by including

them in the closure of the donor site. One of the disadvantages of this movement was the formation of an additional line of sutures, located perpendicular to the flap.

A more rational plasticity of the defect was the movement of the flaps by the rotation method, which combined the effect of transposition and direct advancement. In this case, by rational cutting of the flaps, it was possible to simultaneously close both the defect and the donor area with the least number of incisions. The flap had a wide nourishing leg and covered large wound surfaces with a good cosmetic effect.

When forming flaps for movement, the feeding leg was not allocated separately to preserve innervation and lymphatic drainage, which allowed to preserve the natural properties of the flaps and prevent their reduction.

Despite the small number of clinical observations, a positive treatment result was obtained, which provides a basis for the wider use of enlarged stretched flaps on perforating vessels in reconstructive surgery of the breast.

CONCLUSION

The simple technique of forming and moving enlarged dilated flaps from the anterior surface of the thoracic and abdominal walls on the basis of perforators of the internal mammary, thoracoacromial and superior epigastric arteries with vascular sources of adjacent perforosoms can be widely used for the reconstruction of the upper and lower quadrants of the breast and intermammary and submammary spaces.

Study complies with ethical standards.

Financial support and sponsorship: nil.

Conflicts of interest

There are no conflicts of interest

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Uvećani perforator režnjevi prednjeg torakalnog i abdomonalnog zida: novi pristup autolognoj rekonstrukciji dojke

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SAŽETAK

Cilj. Razvijanje metoda za dobijanje uvećanih perforator režnjeva na prednjoj površini torakalnog i abdominalnog zida.
Materijal i metode. Studija je uključila 16 bolesnika sa deformitetima dojke nakon opekotina, starosti od 5 godina do 22 godine. U gornjem delu prednje površine grudnog koša formirani su režnjevi na osnovu 2, 3 perforator prednje interkostalne arterije i perforator torakoakromijalne arterije sa obuhvatanjem vaskularne mreže torakalne grane supraklavikularne arterije. U donjem delu torakalnog i gornjem delu abdominalnog zida nalazili su se uvećani režnjevi bazirani na perforator supernoj epigastričnoj arteriji sa uključivanjem vaskularne mreže 6, 7 perforator prednje interkostalne arterije i perforator duboke inferiorne epigastrične arterije. Dobijeni režnjevi prebačeni su metodama direktnog povlačenja, rotacije i transpozicije.
Rezultati: Najveća površina defekta rane zatvorena je režnjevima koji su prebačeni rotacijom. Bila je 1,8 puta veća od površine rana koje su zatvarane direktnim povlačenjem i 1,3 puta veća od rane zatvorene transpozicionim režnjevima. Primena rastegnutih perforativnih režnjeva sa prednje površine torakalnog i abdominalnog zida omogućila je dobijanje pozitivnog rezultata u 90,4% slučajeva, primenom kratkoročnog lečenja, kao i dobijanje pozitivnog rezulta kod svih bolesnica na dugotrajnom lečenju.
Zaključak. Jednostavna tehnika bazirana na predloženim metodama može biti široko primenljiva u rekonstrukciji gornjih i donjih kvadranata dojke, kao i intermamarnog i submamarnog prostora.

Ključne reči: **perforirajući režnjevi, rekonstrukcija dojke, deformiteti dojke nakon opekotina, širenje tkiva, perforirajući krvni sudovi**