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Pediatric Tissue Expansion: Our Experience with 103 Expanded Flap Reconstructive Procedures in 41 Children

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ABSTRACT: **Background:** Tissue expansion is a well-recognized technique for reconstructing a wide variety of skin and soft tissue defects. Its application in the pediatric population has enabled the plastic surgeon to achieve functional and aesthetic goals that were previously unobtainable.

Objectives: To review the use of tissue expansion in the pediatric population, with particular emphasis on indication, operative technique, regional considerations and how to avoid complications.

Methods: We retrospectively reviewed data on 103 expanded flap reconstructions performed in 41 pediatric patients during the period 2003–2006. Tissue expanders were placed on a subcutaneous plane above the fascia and inflated weekly. The expanded skin was used as a transposition flap or a full thickness skin graft for the reconstruction of the involved area. Forty-three tissue expanders were inserted to the head and neck in 21 patients, 45 were inserted to the trunk in 13 patients and 15 were inserted to the groin and lower extremity in 8 patients. Twenty-eight patients had one round of tissue expansion, while 13 patients had two to six rounds. A plastic surgeon, medical student and a lawyer reviewed the patients' photographs and evaluated their aesthetic outcome:

Results: Eighty-six percent of the head and neck reconstructions and 40% of the trunk and extremity reconstructions were graded as having excellent aesthetic outcome, and 11% of the head and neck reconstructions and 37% of the trunk and extremity reconstructions were graded with good aesthetic outcome. The remaining patients were graded with moderate outcome. None of our patients was graded as poor aesthetic outcome. Complications included infection in 6 patients (6%), extrusion in 3 (3%), hematoma in 2 (2%), flap ischemia in one patient (1%), and expander perforation after percutaneous stabbing in one patient (1%).

Conclusions: Tissue expansion is an efficient and valuable technique for reconstruction of large skin lesions and scars.

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KEY WORDS: tissue expansion, congenital pigmented nevus, scar, reconstruction, surgical technique

The expansion of skin was first reported in 1957 by Neumann [1], who used a rubber balloon with an external port to reconstruct a traumatic ear defect. Almost 20 years later, Radovan [2] presented his experience with breast reconstruction. In 1982 Austad and Rose [3] described a self-inflating expander. Tissue expansion in children was first described in 1983 by Argenta et al. [4] who used it to treat neck contractures in burn patients.

Both animal and human studies have documented histological changes in soft tissue undergoing expansion. A mechanical force applied to skin influences numerous aspects of cellular architecture and function [5-7]. Tissue expanders are available in a variety of shapes, sizes, contours and backing configurations. Our experience, as well as others, has shown that careful planning, use of high profile rectangular tissue expanders, and transposition or rotation flap design (in contrast to direct advancement) are essential for a successful reconstruction.

PATIENTS AND METHODS

We performed 103 expanded flap reconstructions in 41 pediatric patients between the years 2003 and 2006 [Table 1]. All of these patients were operated on by the senior author (A.M.). The indications for tissue expansion were large and giant congenital pigmented nevi (46%), extensive scars and scar contractures (32%); the remainder comprised a variety of congenital and acquired deformities such as vascular malformations, hemangiomas and aplasia cutis. Tissue expansion was used to increase the size of full-thickness skin grafts in 2 patients, local flaps in 37 patients, and distant flaps in 2 patients. The youngest age at the start of the expansion was 7 months, and the mean patient age was 3 years and 10 months. One to four tissue expanders were placed per patient during the first procedure (average of two tissue expanders). The expansion period lasted from 8 to 12 weeks (average 10 weeks).

Forty-three tissue expanders were inserted into the head and neck in 21 patients (51%), 45 were inserted into the trunk in 13 patients (32%) and 15 were inserted to the groin and lower extremity in 8 patients (20%). The mean tissue expander volume for head and neck lesions was 297 ml, for

Table 1. Characteristics of patients who underwent flap reconstructions

Patient no.	Age (mos)	Location of skin problem	Dimension of defect (% TBSA)	Mean volume of TE	No. of cycles	Complications
1	8	Back	15	450	2	
2	7	Scalp	5	350	1	Hematoma
3	12	Scalp	3	350	1	
4	9	Scalp and cheek	4	225	2	
5	9	Scalp, forehead	6	350	2	
6	216	Thigh	9	750	2	Percutaneous stabbing of the TE
7	96	Neck	4	500	2	
8	216	Thigh	4	500	1	
9	10	Trunk, neck	22	500	3	Hematoma
10	156	Thigh	3	425	2	Infection, extrusion
11	60	Back	12	300	2	
12	108	Abdomen, left thigh	20	500	1	
13	120	Scalp	4	250	3	Infection, extrusion
14	108	Scalp	2	350	2	
15	8	Trunk, right thigh	34	400	5	Seroma, infection
16	48	Back, left thigh	30	740	5	Seroma, infection, extrusion
17	24	Groin	3	250	1	
18	84	Neck	2	250	1	
19	24	Back	2	500	1	
20	216	Back	8	550	1	
21	204	Cheek	6	70	1	
22	72	Cheek	1	70	2	
23	84	Scalp	3	350	1	
24	180	Anterior trunk	2	350	1	
25	36	Cheek	2	350	1	Infection
26	132	Scalp	3	250	1	
27	132	Abdomen, thigh	42	750	1	
28	12	Anterior and poterior trunk	20	750	3	Wound dehiscence following trauma, flap ischemia
29	18	Back	2	350	1	
30	36	Right temporal region	1	70	1	
31	144	Left lip	1	70	1	
32	36	Scalp	5	350	2	
35	96	Scalp	2	350	1	
36	108	Scalp	3	350	1	
37	12	Scalp	2	250	1	
38	12	Abdomen	5	350	2	Infection
39	120	Trunk	4	350	2	
40	9	Scalp	1	250	1	
41	42	Abdomen	1	500	1	Extrusion

TBSA = total body surface area, TE = tissue expansion

trunk and torso lesions 480 ml, and for lower extremities lesions 446 ml.

Twenty-eight patients (68%) had one round of tissue expansion, while 13 patients (32%) had between two and six rounds: 7 patients (17%) required two sessions, 3 patients (7%) required three sessions, 1 patient (2%) required four sessions and 2 more (5%) required more than five sessions to fully reconstruct the defect.

A plastic surgeon, medical student and a lawyer reviewed the patients' photographs and evaluated their aesthetic outcome. Results were graded as excellent, good, moderate, and poor. Eighty-six percent of the head and neck reconstructions and 40% of the trunk and extremities reconstructions were graded as having excellent results; 11% of the head and neck reconstruction and 37% of the trunk and extremity reconstructions were graded with good outcome. The remaining cases were graded with moderate outcome. None of the patients was considered to have a poor aesthetic outcome.

TISSUE EXPANDERS

Rectangular expanders with a soft bottom and a remote injection port (Softspan™ Tissue Expander, Bauer Design, Special Surgical Products, Victor, MT, USA) were used in all body regions, with the expanders in place for an average of 10 weeks. The volume of the tissue expanders ranged from 70 to 1000 ml. The expanders were injected weekly (or as often as every 4 to 5 days in some cases). Expanders were typically overinflated beyond the manufacturer's recommended full capacity [8,9].

OPERATIVE TECHNIQUE

All of the expanders are placed while the patients are under general anesthesia. All patients received one dose of intravenous cephazolin an hour before the procedure. Incisions for placement of the expanders were carefully planned, with the most important consideration being the visional design of the final flap. The expander pocket should reflect the dimensions of the expander to be placed, being 1–2 cm larger in each dimension, so that the tissue expander will lie comfortably without sharp folds. Extreme care should be taken when dissecting the pocket to minimize trauma to the skin flap being elevated.

We use internal remote injection ports in all of our patients. The port should be low profile and placed in areas where there is no potential pressure on the overlying skin. It is important that the port be distanced from the expander to ensure that the expander is not punctured when accessing the port [7].

After insertion of the expander, the pocket is closed with two layers of nylon sutures. The skin nylon suture is not removed throughout the entire process of expansion. We routinely use drains, with one drain placed in each expander pocket. The drains are removed 4–5 days after the surgery.

EXPANDER INFLATION

The inflation process is initiated one week after expander insertion and the injections are repeated on a weekly basis. The volume of expansion varies according to the size of the expander and the anatomic site in which it was implanted. Inspection of skin color, capillary refill and simple palpation are performed when administering injections, and patient comfort is taken into consideration. Typically, 8 to 10 weeks are sufficient to fill the expanders. Jackson et al. [10] reported their experience with tissue expanders of the extremities and the successful use of external ports with an infection rate of only 6%. Others, like us, are reluctant to use external ports due to fear of infection [11].

FLAP RECONSTRUCTION

After the expansion has been completed, the patient is ready for the reconstructive surgery. Local and regional expanded flaps are the cornerstones of the reconstruction in most cases; expanded full-thickness skin grafts, expanded free flaps, and expanded prefabricated flaps are used far less frequently.

RESULTS

A plastic surgeon, a medical student and a lawyer reviewed the photographs of the patients and evaluated their aesthetic outcome. Results were graded as excellent, good, moderate, and poor. There was no significant difference between the three evaluators. Head and neck reconstructions were graded as having excellent outcome in 86% of the cases, 11% as having good results and the remainder as moderate outcome.

The outcome of trunk and extremities reconstructions was graded as excellent in 40% of the cases and good in 37%. The remaining patients were those who had undergone multiple expansions with the resultant widening of the scars, and were graded with moderate aesthetic outcome. None of our patients was considered to have a poor aesthetic outcome.

COMPLICATIONS

The overall rate of major complications (complications that delay the process of expansion and reconstruction) in our series was 13%. Hematoma occurred in 2 patients (2%), infection in 6 (6%), expander exposure in 3 (3%), flap ischemia in 1 patient (1%), and perforation due to percutaneous stabbing in 1 patient (1%).

DISCUSSION

Controlled skin expansion is a clinical technique for providing localized donor tissue for reconstructive surgery [12,13]. In this article, we present our experience with 103 expanded flap reconstructions performed in 41 pediatric patients. The indications for tissue expansion were large and giant

congenital pigmented nevi (46%), extensive scars and scar contractures (32%), and the remainder comprised a variety of congenital and acquired deformities. Surgical strategies were reviewed retrospectively to determine the location in the body where the tissue expansion was performed, the number of procedures required to accomplish the goal of reconstruction, and the design of the expanded flap that was used to reconstruct the area in question. Favorable outcomes were achieved in all our patients and were largely dependent on thorough preoperative planning, parent and patient teaching, and meticulous surgical technique.

REGIONAL CONSIDERATIONS

• Scalp

Tissue expansion is the preferred treatment for reconstructing scalp lesions [14,15]. As surgical experience increases and planning improves, larger defects can be reconstructed with fewer procedures and better restoration of normal hair patterns [16-18]. Treatment can be administered to patients as young as 8 months old, with some cranial molding expected by the time the expanders are removed. As in the study of Colonna et al. [19], no long-term cranial deformity was noted in our series of operations in children. According to their data, the underlying bone reacts to the presence of an expander, but this reaction subsides within 9 months with moderate sequelae in the general bony architecture.

• Face

Large and giant nevi of the face and extensive facial scars present the plastic surgeon with a major challenge. These are usually treated with expanded local flaps whenever possible, with the addition of expanded full-thickness skin grafts for the periorbital and eyelid areas and occasionally for the nasal dorsum [20,21].

Planning the expansion and reconstruction of the forehead must be directed at minimizing any possibility of distorting the eyebrow and the normal distance from brow to hairline. Nevi and extensive scars of the cheek are best reconstructed with expanded or non-expanded post-auricular flaps. Expanded full-thickness skin grafts have been used effectively for excision and reconstruction of nevi of the periorbital, eyelid and occasionally the nasal areas [18]. A single, large, expanded full-thickness graft from the supraclavicular area can cover eyelids, the canthus and the region between eyelid and brow, without the multiple "seams" that follow the use of multiple smaller grafts.

• Neck

Posterior and posterolateral neck defects can be successfully reconstructed with expanded flaps from the upper back and the shoulders [17]. The flap is designed in such a way that it can be wrapped around the neck, eliminating the "webbing" created by pure upward advanced flaps. With this design the reconstructed neck has a better contour and more favorable scar location.

Tissue expansion is also very effective in treating anterior burn scar contractures of the neck. The expanders are placed in the unburned skin in the posterolateral neck or the supraclavicular region. The flaps are designed as large transposition flaps, wrapped around the anterior neck to release these challenging mentosternal contractures. When no adjacent tissue is available for expansion, island or prefabricated expanded flaps from the supraclavicular areas can be transplanted into the anterior neck defect.

• Trunk

Use of expanded transposition flaps has enabled excision of nevi of the upper back and buttock/perineal region, where previously it was thought that only skin grafting was possible [22]. Tissue expanders in the 500–750 ml range are used most commonly in infants and young children. Serial expansion with careful planning and increased use of the expanded transposition flap design has made possible the excision of progressively larger nevi of the back and buttocks, with excellent results. Importantly, the expanded transposition flap overcomes the problem of "diminishing gain" seen with serial advancement flaps, facilitates coverage of the shoulder and the posterior neck with improved contour and less risk of contracture, and allows reconstruction of the buttocks and perineum while maintaining natural contour.

Expansion must be avoided in or around the area of breast buds in females, and lesions of the breast should be left until after breast development, regardless of the psychological implications of delaying the treatment until that age.

• Extremities

Tissue expansion in the extremities has limitations and is associated with a higher complication rate, particularly in the lower extremities. Tissue expansion has been of some help in treating smaller lesions, where tissue is available both proximal and distal to the lesion and the lesion is confined to a fairly small segment of the limb. The geometry of the extremity, as well as the limited flexibility of the skin (particularly in the lower extremity) limits the use of regional expansion [23,24].

When dealing with larger lesions, however, more creative techniques must be applied to overcome these limitations. Lesions in the upper arm and the shoulder can be reconstructed with a large expanded transposition flap from the scapular region. Circumferential nevi from the elbow to the wrist can be reconstructed with expanded pedicled flaps from the flank and abdomen. For the dorsum of the hand and the fingers, expanded full-thickness skin grafts have been used with excellent aesthetic outcomes.

For the resurfacing of even larger nevi, expanded full-thick-

Figure 1. [A] Large congenital pigmented nevus of the upper back extending into the axilla, the upper arm and the lateral chest. **[B]** Expander in place in the upper back. **[C]** Postoperative views. Excision of the nevus was followed by reconstruction with expanded flap transposed from the upper back. This design of the flap allowed for an excellent final contour of the axilla with less anatomic distortion in this challenging area.

ness skin grafts and expanded free flaps from distant regions can be used. However, these procedures are used only in very carefully selected patients, and the optimal timing for these complex reconstructive procedures is still under investigation.

COMPLICATIONS

Tissue expansion has been associated with significant complications since its inception. The risks have been described in numerous studies and overall complication rates ranging from 13% to as high as 40% have been reported. However, some of the minor complications will not delay the process of expansion and reconstruction, in contradistinction to major complications such as infection or extrusion. In this series, the overall complication rate was 13%. In eight patients the complication delayed the expansion and reconstruction. In these cases we removed the tissue expander and had to start the process again after a short recovery period.

Careful patient selection and meticulous surgical technique are the two most important factors for avoiding complications [7]. Although not evident from this series, we believe that extremity expansion results in more complications than expansion in other regions, and we perform it only in very selected cases. Moreover, we do not perform direct expansion distal to elbows or knees under any circumstances. The age of the child does not appear to be a major risk factor for complications, with the only apparent exception being molding of the skull in the first 2 years of life.

One has to envision the expanded flap for the final reconstruction during placement of the expander and plan the incisions and the pocket accordingly. In planning the design of the expanded flap, we found that there are significant advantages in using expanded transposition flaps over pure advancement [Figure 1]. Restricting the expanded flap design to advancement alone in order to minimize potential scarring severely limits the reconstructive capabilities of the added tissue and distracts from the surgeon's ability to achieve the initial goal of reconstructive surgery. The cost of additional incisions is worthwhile in order to achieve a better final contour of the reconstructed part, lower risk of anatomic distortion, better position of the scars and lower risk of scar contracture.

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