Complications of Post-Burn Tissue Expansion Reconstruction: 9 Years Experience with 42 Pediatric and 26 Adult Patients

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ABSTRACT: **Background:** Burn scar reconstruction is extremely challenging, even for the most proficient reconstructive surgeon. Within the arsenal of tools at the plastic surgeon's disposal, tissue expansion provides an efficient modality for reconstruction despite the reported complication rates.

Objectives: To critically review our experience with tissue expansion for burn scar reconstruction, comparing particularly the adult and pediatric populations.

Methods: We conducted a retrospective study of the outcomes of patients who underwent burn scar reconstruction with tissue expansion at Hadassah Medical Center between January 2003 and July 2012. The data included patient age, anatomical site of expansion, number of procedures, and associated complications. The outcomes of the above-mentioned populations were also compared with those in a control group of patients undergoing reconstruction with tissue expansion for indications other than burn scars.

Results: Sixty-seven tissue expansion procedures were carried out in 50 patients, 42 in the pediatric population (< 16 years of age) and 25 in the adult population. Complications were observed in 10 of the 42 pediatric procedures (23.8%) and in 3 of the 25 adult procedures (12%). This difference was statistically significant. When the complication rate for each population was compared to its control group (tissue expansion for indications other than burn scar reconstruction, such as reconstruction for motor vehicle accident scarring, congenital nevi, or vascular malformations), no statistically significant difference was found between them (complication rates 19.8% and 12.5%, respectively). Furthermore, there was no statistically significant difference in complication rates between the different anatomical areas of expansion within both populations undergoing burn scar reconstruction. Most of the complicated cases completed successful reconstruction.

Conclusions: Tissue expansion is a useful surgical tool in post-burn scar reconstruction, both in the adult and pediatric populations and in all anatomic sites, despite consistently high complication rates, especially in the pediatric population. This complication rate is not higher than that in patients undergoing tissue expansion for indications other than burn scar reconstruction.

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Tissue expansion is a recognized surgical technique used for reconstruction of a wide variety of skin and soft tissue conditions and defects. Since first reported in 1957 [1], its application has allowed plastic surgeons worldwide to achieve functional and esthetic results previously unattainable. However, tissue expansion is not without a myriad of associated risks, and complication rates as high as 40% in infants and children have been reported [2]. The risks for such complications have been described in numerous studies and have been categorized by patient age, wound type, surgeon experience, and socioeconomic class. Recent series report overall complication rates ranging from 15% to 43.1% [3–6]. Despite the available literature on complications of tissue expansion, it is difficult to interpret the data in an impartial manner, mainly because the studies are retrospective and because different authors have different definitions of the term 'complication'.

Tissue expansion in burn patients justifies a separate and perhaps more specific evaluation. Burn scar tissue may extend far deeper than the subcutis, requiring contracture release, and may be more prone to breakdown and ischemia if the expansion process is carried out too close to the burn scar.

In a search of the medical literature for information on tissue expansion complications, we found that most studies focus either on pediatric tissue expansion alone, or describe a combined population of pediatric and adult patients (including breast tissue expansion). Despite the convenience of incorporating all ages in one group, pediatric and adult patients have different characteristics that may affect the outcome of tissue expansion and thus should be studied separately. For example, scar formation in a child's arm may affect the rate of limb growth. Furthermore, because young children are actively developing their sense of self-awareness, severe burns can alter a child's sense of identity and place him or her at high risk for future emotional and psychologic disturbances [7].

In this study we present a critical review of our experience with tissue expansion for treatment of pediatric and adult burn-scars, and we compare the frequency and severity of complica-

tions from different anatomic sites along with their effect on the final reconstruction.

PATIENTS AND METHODS

We reviewed the medical charts and surgical reports of patients who underwent non-breast tissue expansion at Hadassah Medical Center between January 2003 and July 2012. Forty-four adult and 119 pediatric patients (under 16 years of age) underwent 56 and 202 procedures, respectively. Of the 56 adult and 202 pediatric tissue expander procedures, 25 and 42 respectively were for burn-scar reconstruction [Table 1]. The data collected included patient age, anatomical site of expansion, surgical indication, number of procedures performed, and presence of any complication (hematoma, exposure, infection, flap necrosis), and treatment regimen with either conservative management or premature expander removal. Complications were studied and analyzed using the Pearson chi-square test.

Review of the literature regarding post-burn scar reconstruction with tissue expansion, along with associated complications, revealed an inconsistent cutoff age between children and adults [8]. Our decision to use 16 as the cutoff age between children and adults was made based on the classic tables of total body surface area estimation of burns by Lund and Browner showing that only at around age 15 does the surface area of the body reach that of the adult. After age 15, there are minimal differences between body surface areas with regard to the head, extremities, and torso [9].

TECHNIQUE

Rectangular expanders with a soft bottom and remote injection port (SoftspanTM Tissue Expander, Bauer Design, Special Surgical Products, Victor, MT, USA) were used in all body regions. All expanders with their accompanying remote ports were placed subcutaneously. The surgical incision through which the pocket was created was made parallel to the lesion or affected area. The incision was made approximately 1–2 cm away from the scar and within healthy skin to minimize the risk of skin breakdown and eventual exposure of the expander. At the end of surgery we inflated the expander (approximately 20–30 ml of saline) through the port to check for any leaks or mechanical obstruction. A surgical drain was always left in place and subsequently removed when drainage volume was less than 20–30 ml per day.

Starting 1–2 weeks post-surgery, expansions were performed in the clinic on a weekly basis for a total of 10–12 weeks. There was no difference between children and adults in terms of the inflation rate of the tissue. The surgeon performed all subsequent expansions, adhering to strict sterile protocol. Inspection of skin color, capillary refill, and simple palpation of the expander was carried out during the inflations, and patient comfort was taken into consideration when deciding on the volume of each expansion. The time lapse between the final expansion and the second surgery varied, ranging from 1 week to 1 month depending on scheduling and operating room availability. The total volume of expansion ranged from 70 ml to 1000 ml.

Table 1. Indications for operation among patients with complications

Indication	Adult procedures	Complications: adult procedures (% of total adult procedures)	Pediatric procedures	Complications: pediatric procedures (% of total pediatric procedures)
Burn scar	25	3 (5.3%)	42	10 (4.9%)
MVA scar	5	0	9	2 (1%)
Vascular malformation	3	1 (1.8%)	9	2 (1%)
Tumor	3	1 (1.8%)	3	0
Scar	7	1 (1.8%)	1	0
Nevus	12	1 (1.8%)	135	26 (12.9%)
Alopecia	1	0	2	0
Combined	0	0	1	0
Total	56	7 (12.5%)	202	40 (19.8%)

MVA = motor vehicle accident

After expansion was completed and the patient was ready for the second surgery, reconstruction via local expanded flaps was planned, with transposition flaps usually achieving more coverage than pure advancement flaps. In serial cases when more than one expansion cycle in the same anatomical area was necessary, scars from the previous surgery limited our flap design, and advancement flaps rather than transposition flaps were used.

RESULTS

A total of 67 tissue expansion procedures in 50 burn scar patients were identified, 42 in the pediatric population (younger than 16 years of age) and 25 in the adult population. Complications [Table 1] were observed in 10 of the pediatric procedures (23.8%) and 3 of the adult procedures (12%). When the complication rate for each population was compared with its control group (tissue expansion for indications other than burn scar reconstruction, such as reconstruction for motor vehicle accident scarring, congenital nevi, or vascular malformations), no statistically significant difference was observed (23.8% vs. 19.8% in pediatric and 12% vs. 12.5% in adult procedures). The complication rate within the pediatric burn group was significantly higher than in the adult burn group (23.8% vs. 12%, $P = 0.047$). Interestingly, this significant difference was not evident when comparing pediatric and adult complication rates when tissue expansion was performed for indications other than burn scar reconstruction. There was no statistically significant difference in the complications rate between the different anatomical areas of expansion [Table 2]. Although there seems to be a tendency for more complications in the extremities (3 of 8 patients, 37.5%),

Table 2. Post-burn patients: complication rate according to anatomic site

Anatomic site of expansion	Adult procedures (%)	Complications: adult procedures (% of total adult procedures)	Pediatric procedures (%)	Complications: pediatric procedures (% of total pediatric procedures)
Head & neck	7 (28%)	1 (4%)	24 (57%)	6 (14.3%)
Torso	11 (44%)	0	17 (40%)	3 (7.1%)
Legs	5 (20%)	1 (4%)	1 (3%)	1 (2.4%)
Arms	2 (8%)	1 (4%)	0	0
Combined	0	0	0	0
Total	25 (100%)	3 (12%)	42 (100%)	10 (23.8%)

Table 3. Post-burn patients: treatment of complications

Treatment	Pediatric procedures (n=42)	Adult procedures (n=25)	Total (67)
Conservative	2	3	5
Expander removal and flap reconstruction	4	1	4
Expander removal without flap reconstruction	1	1	3
Lavage and exchange of expander		1	1

when comparing this rate in the extremities to the complication rate in any other area of expansion (10 of 59 patients, 17%), no statistically significant difference was observed ($P = 0.244$). Most of the cases with complications (10 of 13 patients, 77%) completed successful reconstruction [Table 3].

DISCUSSION

Reconstruction using tissue expansion presents many advantages over other reconstructive techniques, such as replacing a defect with local tissue that is similar in quality, color, texture and thickness. Expansion allows for vascular delay, provides an elegant solution to lack of available tissue for reconstruction (which is the case with large burn scars), and is associated with minimal scarring and low risk of infection.

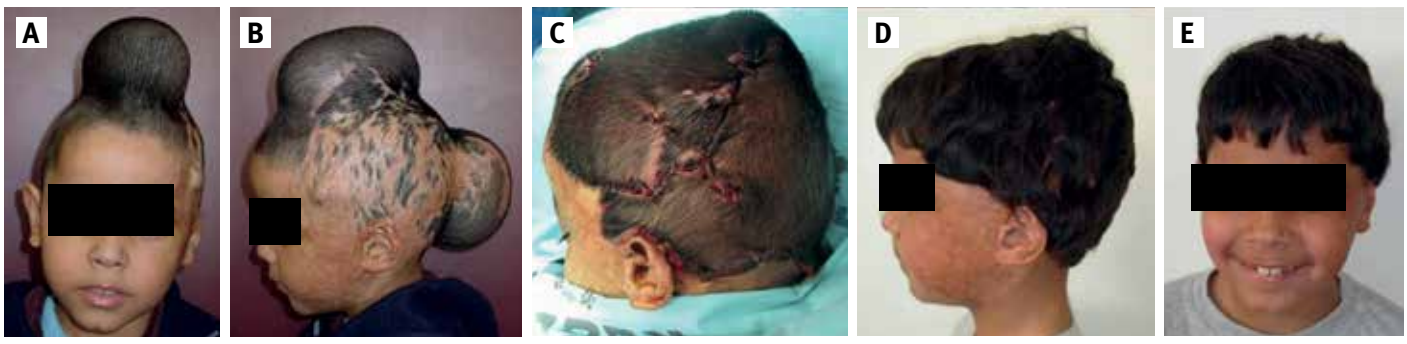
The expanded tissue can be planned as a random flap as seen in scalp or torso reconstruction [Figure 1], or as a pedicled flap as seen in pre-expanded supraclavicular pedicled flap for facial reconstruction. Expanded flaps provide large areas of skin to be used for reconstruction, with donor sites that in most cases can be closed primarily. A less frequently employed modality of tissue expansion is the pre-expanded free flap [10]. In our practice, random pre-expanded flaps are usually planned as transposition rather than advancement flaps, mainly because larger areas can be reconstructed with the former over the latter [Figure 1].

Although described in the literature as a highly accepted reconstructive modality, tissue expansion has a complication rate that has remained consistently high over the years. An important finding was that the majority of complications can be managed conservatively without removing the expander until the expansion process is complete or almost complete, with the reconstructive goals having been achieved [11–13].

Our study did not find a statistically significant difference between the complication rates of tissue expansion for burn scar reconstruction and conditions other than burn scars. This finding is corroborated by the results found in the study by Bozkurt et al. [8].

Some debate exists regarding the relationship between patient age and tissue expansion complications. When isolated for burn scar reconstruction, we found a statistically significant higher rate of complications in the pediatric population vs. the adult population, but when checked for all indications for tissue expansion this difference showed no statistical significance. In a study performed by Friedman and colleagues [14], evaluation of tissue expansion in pediatric patients ranging from 8 months to 15 years revealed significantly more complications in patients under age 7 years. They postulated that there was less tissue available for expansion in the younger age group and that children under the age of 7 are perhaps more likely to accidently traumatize the expander site. Another study by Gibstein et al. [15] observed a higher complication rate in children aged 1–12 years, but the authors did not address possible causes for this finding in their discussion. Interestingly, one study on burn scar reconstruction via tissue expansion noted that older age was in fact a risk factor for complications [16]. In our experience,

Figure 1. [A and B] Front and side view of an 8 year old boy with temporal and parietal scalp alopecia due to burn scars, with two 350 ml inflated tissue expanders. **[C]** Immediate result after reconstruction with transposition using advancement flaps. **[D and E]** Long-term result



significant trauma such as a direct high impact blow is needed to adversely affect the expansion. Soft tissue in children is more pliable and expands more easily, thus we would not expect a higher complication rate in children despite their decreased compliance. These erratic findings can probably be attributed to different patient selection patterns by different groups and perhaps to different surgical techniques, namely anatomic placement of the expander and the expansion process itself. Our finding that lower age is a risk factor for tissue expansion complications in burn scar reconstruction may reflect the fact that our pediatric burn scar patients have larger and more complex surface areas to reconstruct, along with proportionally smaller areas of "healthy" skin to serve as potential expansion sites. Another possible explanation for the difference in complications between adult and pediatric patients is that most of the expansions in children were in the head and neck (57%) area while in adults the most common area was the torso (44%). Our findings are therefore not surprising given the overwhelmingly safer profile of expansion in the torso region as documented in the literature [15–18].

A higher rate of tissue expansion complications in the lower limbs has been reported in the literature [16,17], and our study corroborates this finding. Despite the lack of a statistically significant difference in complication rates between the different anatomic sites, we did observe a trend towards more complications in the extremities (all our extremity complications were in the lower limb, distal to the thigh).

The complication rate in our burn scar patients does seem to be related to the surgeon's experience [19], and it is noteworthy that a weakness of our study is that different surgeons with different level of experience and expertise were involved in the reconstruction of our cases.

Variation exists in the medical literature regarding types of expanders, external versus internal ports, and location of the incision. As mentioned in the Technique section above, we consistently plan our incision line parallel to the lesion, thus minimizing wasting of "healthy" tissue. Nonetheless, we recommend planning the incision 1–2 cm away from the border of the scarred skin in an attempt to minimize the chances of skin breakdown. The issue of incision location and orientation is subject to debate and has yet to be studied. Opponents of the parallel incision claim that parallel orientation of the incision relative to the lesion renders the surgical wound particularly susceptible to dehiscence due to tension forces during expansion, but we rarely encounter expander exposure or any complication resulting from our parallel incisions.

In our practice, we are meticulous about the subcutaneous pocket preparation. The expander pocket dimensions should closely reflect the dimensions of the expander itself, ideally 1–2 cm larger on each perimeter so that the tissue expander may lie comfortably and without any sharp folds. The expander is placed a few centimeters away from the incision to minimize risk of exposure. The most important consideration for our team is the anticipated design of the final flap to be transposed. We spare no effort in attempting to predict how the expanded tissue will be manipulated over the defect in the most efficient and esthetically pleasing manner possible. The major drawback of making a perpendicular incision is losing "healthy" tissue available for reconstruction, since this kind of incision, or part of it, is placed within "healthy" tissue but cannot be included in the final flap design.

Although a recent prospective study reported good experience using external ports, with low associated complication rates [20–22], we use subcutaneously placed remote ports only. There are several advantages to an external port, especially in children. It may completely eliminate the pain involved in the expansion process since there is no skin puncture, and it may have the advantage of involving the child in the process by letting him or her perform the actual expansion under supervision. Nevertheless, we feel that the chances of infection via an external port are simply too high, and it may in fact be just as easy for a child to cope with an internal port as it is with an external one. Despite the pain associated with puncturing the skin overlying the internal port, the expansion process need not necessarily be an unpleasant experience for the child, especially when using preemptive measures such as the application of anesthetizing cutaneous cream before injection and having a medical clown present in the clinic. Other types of tissue expanders, such a self-filling osmotic expander, are described in the literature, but drawbacks such as limited control over expansion volumes and associated complication rates [23] make such options less attractive.

CONCLUSIONS

Tissue expansion serves as an excellent surgical modality for burn scar reconstruction in all age groups, despite consistently high complication rates, especially in the pediatric patient population. Nonetheless, the rate of complications is not higher than that seen with tissue expansion for indications other than burn scar reconstruction and, as such, we advocate this surgical method as the best available treatment for these devastating wounds.

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Capsule

How to grow hair or sweat glands

Unlike other mammals that must pant or seek shade or water when overheated, humans are able to self-cool to tolerate extreme heat. Sweat glands, which enable humans to run in marathons, are instrumental for this remarkable feat. Lu et al. investigated skin appendage diversity during development of the furry backs and sweaty paws of mice. They also examined human skin, which is capable of making both hairs and sweat glands in the same area of the body. Epithelial mesenchymal interactions, with varied signaling pathways that act at specific times in development, are key to producing different skin appendages for adaptation to the environment.

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Eitan Israeli

"The most certain test by which we can judge whether a country is really free is the amount of security enjoyed by minorities"

Lord Acton (1834-1902), English Catholic historian, politician and writer. He is perhaps best known for the remark, "Power tends to corrupt, and absolute power corrupts absolutely. Great men are almost always bad men"