THE USE OF TISSUE EXPANSION IN BURN DEFORMITY RECONSTRUCTION: PART TWO

Tissue expansion has been used extensively in the treatment of chronic burn sequelae for three decades. Since the works of Radovan and Austad in 1975, several techniques and indications have been reported. In the second part of this two-part review, the authors examine tissue expansion techniques and their post-operative complications.

'Often, more than one expander is used simultaneously to obtain a sufficient amount of tissue for coverage'

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In the second and final part of this review, the authors will shed light on the techniques involved in tissue insertion and inflation as they relate to burn deformity reconstruction. Previously, the first part of the review focused on the history, pathophysiology and applications to different areas of the body.

Tissue expansion usually combines at least two operating phases (Drissi Qeytoni et al, 2007). The first phase consists of the expander insertion and its gradual filling, while the second phase, which takes place about two to three months later, consists of the expander removal and the covering of the alopecic area (if on the scalp) by the expanded flaps (Drissi Qeytoni et al, 2007).

The authors will begin by summarising the process of tissue expansion in the scalp, then move to the rest of the body, but always keeping in mind that the process is similar throughout the body with special considerations given to each area.

Preoperative planning is of paramount importance and consists of taking accurate measurements of the defect, selecting the donor site of non-involved areas, considering the direction of the hair, and respecting the hairline of implantation (if on the scalp). This will reflect the choice of the type, size, number, and shape of the expander to be used (Zaki, 1989; Voulliaume et al, 2007).

The expander's shape (rectangular, round, crescent, elliptical, etc) depends primarily on the site of expansion and reconstruction needs, and it can affect the amount of tissue expansion that can be achieved (Gil et al, 2008). The size and quantity of the expanders used depends on the amount of tissue required to cover the anticipated defect before surgery and on the available tissue that is amenable to expansion (Zaki, 1989; Motamed et al, 2008). It is always preferable to overestimate the surface area needed due to the major tension on the resultant scar tissue (Filho et al, 2007).

Often, more than one expander is used simultaneously to obtain a sufficient amount of tissue for coverage (Filho et al, 2007). Divergent opinions have been expressed about the indications of using tissue expansion techniques in the scalp, focusing on the size of the scarred area. Some authors recommend using scalp expansion whenever the estimated defect post scar excision is more than 25cm^2 or greater than 5% of the whole scalp surface area, whereas others believe that if the estimated scar alopecia is less than 50cm^2, then scalp expansion is useless (Buhrer et al, 1988; Leedy et al, 2005; Voulliaume et al, 2007).

Therefore, the choice of the expander size is difficult. The convex aspect of the cranial vault adds to the difficulty in calculating the volume needed to be expanded (Voulliaume et al, 2007).

Several methods were introduced to calculate the size, but none of these

KEY WORDS

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are particularly practical (Voulliaume et al, 2007). It is usually the surface of the expander's base that determines the amount of skin gained. One major limitation to scalp expansion is the size of the remaining, adjacent, normal scalp (Voulliaume et al, 2007). Indeed, in some cases where the estimated scar alopecia is moderate to severe, for example, more than 300cm^2, only partial treatment can be obtained, necessitating further expansion (Silfen et al, 2000; Voulliaume et al, 2007). Nevertheless, even these results are often preferable for patients compared with their current scars. The solution is not perfect, but sometimes, for example, a patient can wear a cap and look relatively normal (Silfen et al, 2000).

Therefore, in such cases, it is important to focus on camouflaging the residual defect by decreasing the percentage of alopecia and reconstructing the 'social' zones of the scalp, such as the anterior, frontal, and temporal hairlines (Silfen et al, 2000). Unfortunately, for very severe cases with a minimal amount of hair-bearing area, therapeutic abstention is the most reasonable choice (Buhrer et al, 1988; Voulliaume et al, 2007).

In the preoperative phase, it is essential to evaluate the donor site for any scars and matching skin (Fan and Yang, 1997). In scalp reconstruction, the donor site earmarked to receive a tissue expander is selected depending on:

- The position of the defect to be corrected
- The hair direction required in the recipient site, especially in the reconstruction of the frontal hairline or sideburn
- The hairstyle preference of the patient
- The area of permanent hair (Fan and Yang, 1997).

Most of the expanders are inserted in the subgaleal space, between the galea aponeurotica (the tough layer of dense fibrous tissue that covers the upper part of the cranium) and pericranium (the external periosteum that covers the outer surface of the skull), through incisions that are made, whenever possible, within the borders of the lesion, in a direction perpendicular to the expander's major axis to prevent dehiscence of the wound and extrusion of the expander (Nazerani and Motamedi, 2008).

A slightly bigger expander's pocket — designed to allow easy placement without folding and to avoid tension on the surgical wound — is then created in the subgaleal space through blunt dissection, in which the expander is accommodated (Nazerani and Motamedi, 2008). The dissection of the pocket in the avascular space of Merkel is usually easy and atraumatic (Nazerani and Motamedi, 2008). Before placement of the expander, testing with saline injection is performed for any possible defect-causing leakage (Voulliaume et al, 2007).

After placement, about 10% of the expander's theoretical volume is inflated by saline intraoperatively to prevent any hematoma or seroma formation (Voulliaume et al, 2007). It is also important to obtain a tension-free closure to prevent alopecia from hair follicle loss (Leedy et al, 2005). A suction drain is sometimes applied and a dose of perioperative antibiotics for a period of 48 hours is usually recommended (Voulliaume et al, 2007).

The valve is usually placed at a distance from the expander in a separate pocket, but through the same single incision, to avoid any future displacement and to decrease the risk of infection and necrosis (Gurlek et al, 2004; Voulliaume et al, 2007). Most of the expanders that are used have their valves placed at a distance to avoid incidental punctures during injections and the entry is narrowed to prevent the valve from migrating back (Zaki, 1989; Motamed et al, 2008). External valves are recommended by some because they make the expansion easier to perform by non-specialised staff, however, they increase the likelihood of infection and require bandages that limit physical activity for patients during the expansion period, especially in paediatric patients (Filho et al, 2007).

Expansion usually begins about two weeks post-operatively and is carried out twice-weekly (Zaki, 1989). The hard surface of the bony prominence of the scalp permits efficient expansion and better identification of the port during insufflations (Voulliaume et al, 2007). Expansion is usually guided by both patient tolerance (pain) and tissue response (skin blanching), keeping in mind that overexpansion is the rule

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(Voulliaume et al, 2007). Expansion is stopped when the necessary amount of expanded skin needed to reconstruct the scalp defect is achieved (Zaki, 1989; Motamed et al, 2008).

The usual, total mean duration of expansion is about one and a half to three months. On occasion, more than one expander is placed in the same area or in different sites, while at other times, the re-expansion technique is used (Zaki, 1989; Motamed et al, 2008).

Expander removal and flap repositioning

A properly designed flap is raised and draped (transposition, advancement, rotation, etc) over the scalp soft-tissue defect to reconstruct it around two to four weeks after the last injection and after sufficient skin tissue has been obtained (Oh et al, 2007; Nazerani and Motamedi, 2008). The proper design of these flaps requires preservation of the native hairline, redirection of hair follicles in acceptable patterns, the incorporation of major vascular pedicles, and closure without excessive tension (Leedy et al, 2005). Burn scars strongly retract and, when removed, the area to be covered tends to expand (Filho et al, 2007).

Therefore, the optimum timing for expander removal is when the expanded area becomes at least twice as large as the area to be resected or there are no more expansion gains. Then the expander may be removed and the flap advanced or transposed (Voulliaume et al, 2007). The absence of subcutaneous fat in the scalp allows the maintenance of a homogeneous thickness of the teguments during expansion (Voulliaume et al, 2007).

The expander is removed through the original incision to avoid further scarring (Voulliaume et al, 2007). The easiest approach for flap rising is to dissect around the capsule contour, without damaging the vascular pedicle (Edmond and Padilla, 1994). Usually, capsulectomy is only used to cut the surrounding capsule of the expander base, in order to encourage mobility of the expanded tissue without affecting the flap survival (Fan and Yang, 1997).

Consequently, the burn scar is completely or partially removed. In the case of partial excision due to insufficient expanded skin, re-expansion or multiple expansions may be necessary (Voulliaume et al, 2007). This is performed by keeping the empty expander in place and subjecting it to a further series of insufflations, or alternatively, in order to shorten the time required to achieve the aesthetic goal after maximal expansion, the expander can be exchanged for a larger one before definitive adjacent tissue transfer (Leedy et al, 2005; Voulliaume et al, 2007).
It has been shown that several serial expansions of hair-bearing scalp for the reconstruction of scalp alopecia are feasible and can provide an adequate and long-lasting aesthetic result, without compromising hair growth (Gil et al, 2008).

Di Mascio et al (2006) described the use of the overexpansion technique in the trunk rather than the conventional serial expansion techniques. They suggested that filling the expanders by around 3.6 times their original volume creates wider and more malleable flaps, decreases cost and increases patient compliance.

In addition, the ability of the tissue to expand without significantly increasing the tension over the area is important in the aforementioned technique. Despite all of the advantages of the 'overexpansion technique', its use in the buttocks and the back may interfere with normal everyday function, thus multiple expanders have been used instead of overinflating a single device in those areas (Di Mascio et al, 2006; Tsoutsos et al, 2007).

The overexpansion technique was modified further by Tsoutsos et al (2007) in a study in which contractured anterior chest wall scars and unilateral breast hypoplasia were reconstructed for the first time using a three-stage process with the expansion of bilayered artificial skin.

This technique was found to be 'associated with naturally looking reconstructed breast with no re-contracture, and thus is a safe and effective alternative to thick split thickness grafting or flap coverage for breast reconstruction' (Di Mascio et al, 2006).

Extremities

Traditional methods are still being used in the extremities, but new techniques have contributed to the decrease of

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the complication rates (Caleffi et al, 1990). Multiple expanders are now recommended and their best position is axial to the defect. Their placement on a long axis of the extremity is not optimal and would require a greater amount of expansion (Caleffi et al, 1990).

Nevertheless, Filho et al used a single expander in conjunction with the re-expansion technique, arguing that it would solve the problem of a shortage of donor sites, extensive scar tissue areas, multiple injuries, and the financial limitations of the simultaneous use of several expanders (Caleffi et al, 1990). According to some authors, re-expansion should be performed at 6-12-month intervals following the same guidelines and standards of primary expansion (Kimura et al, 2001). Other authors, such as Hudson et al (2000) and Friedman et al (1996), argue that, theoretically, re-expansion can increase the probability of complications.

Recently, tissue expansion has been facilitated by the use of balloon dissectors, predominantly in the extremities. These dissectors can be placed in fascial clefts and then inflated with either air or saline. Due to the natural tissue planes, large pockets could be created rapidly with balloons that obviate the need for open dissection (Friedman et al, 1996).

The advantages of this new technique include:

- Immediate fill of expanders
- More rapid completion of expansion
- Less risk of extrusion
- Less hospital time
- Lower cost
- Earlier healing
- Fewer complications
- Greater patient satisfaction and improved results (Friedman et al, 1996).

After the placement of the expander, with the help of the dissectors or any other method, slow expansion at a rate of 5% maximum inflatable size rather than 10% was found to preserve the blood supply and reduce the complication rates in the extremities, regardless of the method of placement or the number of devices, although this will prolong the time required for expansion more than in other regions of the body (Ghalambor, 2007; Gousheh et al, 2008). As for the inflation port, its placement in the external position offers several advantages, despite the postulated higher risk of infection (Van Beek and Adson, 1987).

All of the aforementioned techniques were used for expansion in certain selected burn cases, but not those burns involving more than 50% of the distal lower leg or foot due to the high risk of failure in those cases (Levin et al, 1997).

In terms of burns of the hand and foot, tissue from distant donor sites (such as the abdomen, and thigh) have been utilised to cover the defected area. In 2008, Gousheh et al devised a new technique by utilising super thin abdominal pedicle flaps. The 'super thin flap' technique carries all of the functional advantages of other flaps and lacks the drawbacks of skin grafts. The flap can be used to cover exposed joints and exposed tendons with normal blood circulation through the subdermal vascular plexus. This obviates the risk of partial necrosis and failure (Gousheh et al, 2008).

Like any other flap, with this technique contracture relapse is not a concern. Furthermore, from the aesthetic viewpoint, the reconstructed skin is not bulky and appears similar to the skin of the rest of the extremity, with adequate colour match, laxity and suppleness (Gousheh et al, 2008). Similar to other pedicle flaps — compared to skin grafting — the only disadvantage of the procedure is the two stages required, and, in the case of tissue expander re-usage, it becomes a three-staged operation (Meland et al, 1992).

PAEDIATRICS

As for the paediatric population, more factors are involved in the process of tissue expansion, and the psychological aspect is one of the most important. In 1993, Neale et al studied the limitations of tissue expansion in the lower face and anterior neck of paediatric patients. In their introduction, and after a literature review from 1984 to 1990 combined with their experiences, they put in place groundwork for some operative guidelines.

They concluded that caution should be used in advancing the expanded neck skin beyond the border of the mandible to prevent scar widening and possible lip and

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eyelid ectropion (as it would in adults), and advised that overexpansion would decrease this problem (Neale et al, 1993). This factor, like many others, was more significant in the growing body because it was expected that tensile strength on the expanded flap would be higher. They also concluded that children add an extra challenge to treatment with their tendency toward hypertrophic scarring along the suture lines. Neale et al also favoured the caudad advancement of the expanded tissue, as opposed to cephalad, in an attempt to decrease the complications.

On the other hand, Grevious et al (2008) complemented the conclusions made by Neale et al, but suggested several modifications that might help in decreasing the complication rates and increasing compliance. They stated that the location of the scar on the anterior neck would increase the risk of a contracture. They also concluded that excision and grafting combined with splinting would be a reasonable option for the prevention of post-burn contractures and should be considered the first step (Grevious et al, 2008).

However, they added that this method still had a high rate of recurrence, and thus, in their opinion, the best method would be tissue expansion with the use of an external port and frequent injections of small volumes to an overinflation of 25–40% of the original volume required (Grevious et al, 2008). This modification will help to prevent the expander itself from being pricked by mistake, decrease inconvenience, increase compliance and satisfaction, and decrease the risk of skin necrosis and adverse complications (Jackson, 1987; Grevious et al, 2008).

COMPLICATIONS

Although based on a simple concept and despite its evident benefits, tissue expansion is still associated with certain post-operative complications. Some of these complications are related to the surgical procedure itself, while others are related to the presence of a prosthesis (Hudson and Grob, 2005; Bozkurt et al, 2008).

The success of tissue expansion very much depends on the indication for its use, individual risk factors, detailed surgical planning (Bozkurt et al, 2008) and, most importantly, following procedural factors as outlined by Hudson and Grob (2005). Direct comparison with other studies is limited due to the fact that each study has its own definition of complications. Reported rates of complications in the literature have been neither precise nor consistent, ranging between 5% and 60%, depending highly on the surgeon's experience. Indeed, these rates have decreased significantly during the last decade (Bozkurt et al, 2008; Hudson and Grob, 2005).

Risk factors and the sources of complications remain multifactorial, such as:

- Age group
- Sex
- Indication for expansion
- Port configuration and placement
- Prior expansion
- Timing of expander removal
- Number of expanders
- Expander volume
- Anatomic site
- Health of the tissues undergoing expansion
- Poor or rushed technique during expansion
- Staff experience in inflating the expander
- Complications per staff surgeon (Neale et al, 1993 Friedman et al, 1996; Bozkurt et al, 2008).

However, in different independent studies, these factors influenced the risk of complications in tissue expansion (Bozkurt et al, 2008). Depending on the aforementioned factors, one can estimate the rate of success for the procedure. The factors that were regarded as high risk for complications in some studies turned out not to be influential in other studies (Bozkurt et al, 2008).

Paediatric age group is a commonly cited risk factor for complications in tissue expansion, with a complication rate that varies widely between centres. Paediatric burn patients have been the most studied (Cunha et al, 2002; Hurvitz, 2005). Most authors reported complication rates between 9% to 37%, however, the rates range between 0% and 48% with a mean value of 30.8% (Cunha et al, 2002; Hurvitz et al, 2005).

The common factor between these studies

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is that the rate is variable depending also on the anatomic site of expansion, which is another risk factor in all age groups and not only in paediatric patients (Gibstein et al, 1997; Cunha et al, 2002). An increased rate of complications was mainly observed between 0 and 10 years of age and it increased with the use of internal expander ports, and a history of two or more prior expansions (Cunha et al, 2002).

It has been postulated that the relatively small amount of tissue available for expansion in paediatric patients may predispose them to expansion difficulties (Friedman et al, 1996). Cooperation with expansion and the likelihood of damaging expanders during their daily activities are other factors that make children a specific risk factor for complications during tissue expansion, especially toddlers and preschool children (Friedman et al, 1996).

Anatomic site

The anatomic site is also an important factor in terms of complication risk in tissue expansion (Gibstein et al, 1997; Stan et al, 2007). There has always been a debate about which areas carry the most risk (Neale et al, 1993; Friedman et al, 1996; Bozkurt et al, 2008). This is due to the fact that studies were done in different centers and for different indications (Youm et al, 1999; Cunha et al, 2002; Hurvitz et al, 2005). Despite this, most authors agree that the highest rate of complication occurs in the extremities (mainly lower extremities) regardless of the pathology for which expansion was performed (Friedman et al, 1996; Neale et al, 1988; Bozkurt et al, 2008).

The second highest area of risk was found to be the scalp, followed by the trunk (Youm et al, 1999; Cunha et al, 2002; Hurvitz et al, 2005). The cause of higher complication rates in the extremities and the scalp is probably due to the rigid structures, such as the calvarium or long bones, against which the expansion is performed, resulting in increased pressure, ischaemia, necrosis, and possible extrusion (Manders et al, 1988; Vogelin et al, 1995). One hypothetical reason for the increased complication rate in tissue expansion in the extremities is the increased hydrostatic pressure and the decreased venous drainage. This results in oedema and decreased oxygen partial pressure affecting gas exchange at the tissue level (Manders et al, 1988; Vogelin et al, 1995; Hurvitz et al, 2005). Another hypothetical risk is the limited area for the tissue to expand and the geometry of flap design and movement (Hawary, 1998). The average complication rate in the extremities across seven reported series is 38%.

Despite many suggestions for minimising complications and potential implant exposures, the rate of complications remains high. This is due to certain anatomical and physiological differences between the extremities and other areas (Pandaya et al, 2002). However, most of the complications in expanded extremities can be remedied and will not affect the end result. This is probably due to the increased awareness of the risks of this anatomic area (closed wound monitoring) and to the higher patient compliance (Bozkurt et al, 2008).

Expanders

A third risk factor for complications during tissue expansion is the number of expanders used at the same time, with the complication rate increasing significantly with the number of expanders used (Neale et al, 1993; Youm et al, 1999).

Other factors associated with an increased risk of complications during the use of tissue expanders include the volume of the expander, the number of previous expansions and the port type. The larger the volume of the expander, the larger the tissue pocket to be dissected. This results in a higher risk of infection, haematoma, and contracture, due to the larger periprosthetic capsular formation and the severe impairment of the intra- and subdermal vascular system (Bozkurt et al, 2008; Pallua et al, 2006).

A history of two or more prior expansions is also associated with a higher risk of complications compared with zero or one prior expansion (Pallua et al, 2006; Bozkurt et al, 2008).

The infection rate in tissue expansion is probably related to the large foreign body and to the number of injections and injectors (Gibstein et al, 1997). It is also conceivable that external trauma can play a significant role in complications that subsequently develop with the use of tissue expanders. It is also considered that rapid expansion will increase the

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ischaemia to the tissues and might pose an independent risk factor in making the tissues more prone to infection (Ortega et al, 1990).

Finally, expander ports imbedded within the implant are associated with a significantly higher rate of device failure than remote subcutaneous ports due to needle puncture of the expander with attempted injection (Friedman et al, 1996).

Self-care

In 2001, Mohmand et al performed the first study on the safety and reliability of expander inflation at home by the patient or carried out by a relative. They noticed that there was a higher incidence of minor complications in the home-inflation group than with the control in-hospital group, however, both groups had similar incidences of major complications.

Most of the studies have focused on identifying risk factors for complications associated with the technical aspects of tissue expansion. However, burn injuries have been identified as a risk factor associated with a higher complication rate with tissue expansion, compared with other pathologies (Friedman et al, 1996; Gibstein et al, 1997; Hudson and Grob, 2005). This is probably due to the fact that the skin surrounding the lesion is already stretched through scar contracture and due to the compromised vascularity of burned or scarred areas (Friedman et al, 1996; Cunha et al, 2002; Hudson and Grob, 2005).

Healed burned tissue has an altered lymphatic drainage capacity and a greater deficiency of soft tissue as a result of scar contracture (Pallua and Demir, 2008). This highlights the importance of the relative health of the tissue being expanded. Indeed, if the tissues being expanded have been previously compromised, such as irradiated, burned or scarred tissue, a higher complication rate has been noticed (Youm et al, 1999).

Factors not related to the complication rate include gender, wound drainage upon expander insertion or removal, and intraoperative use of antibiotic irrigation. Minimal filling of the expander during operative insertion may prevent fluid from collecting in the dissected pocket (Wieslander, 1991). In addition, meticulous hemostasis and tension-free wound closure are vital (Friedman et al, 1996). Finally, in 1995, Hallock concluded in a retrospective study that no adverse sequelae attributable to the expanders' overinflation occurred.

Classification

Several classifications of complications have been introduced in the literature based upon different criteria (Neale et al, 1988; Friedman et al, 1996; Youm et al, 1999). Complications have been classified either as 'major' and 'minor', or 'absolute' and 'relative' (Mohmand et al, 2001; White et al, 2003). Regardless of the nomenclature, major or absolute complications are defined as those that resulted in:

- Altering the original surgical plan
- Premature loss of the expander
- Requiring additional surgery
- None of the preoperative plan was completed (Friedman et al, 1996; Neale et al, 1988; Youm et al, 1999).

These types of complications mainly consist of:

- Infection (primary and secondary)
- Dislocation of the expander, leakage, exposure of the expander
- Wound dehiscence
- Extrusion
- Overlying soft tissue necrosis
- Trauma sustained by the patient
- Implant failure
- Poor patient compliance (to injections or to follow-up visits) with early termination (Neale et al, 1993; Cunha et al, 2002; Bozkurt et al, 2008).

Minor or relative complications are defined as those cases where the planned reconstruction was still successful, those that resulted in only partial satisfaction of the preoperative plan, or any complication that did not require surgical intervention in order to achieve the final pre-set goal (Friedman et al, 1996; Neale et al, 1993; Youm et al, 1999).

These complications consist of:

- Haematoma
- Seroma
- Skin breakdown
- Port failure or extrusion
- Bone resorption
- Delayed wound healing longer than 14 days
- Expander deflation

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- Significant pain
- Striae distensae (stretch marks)
- Hair loss in scalp expansion
- Dog ears (a skin defect created when an elliptical surgical incision is either too short or one side is longer than the other)
- Scar hypertrophy
- Scar widening (Zuker, 1987; Cunha et al, 2002; Bozkurt et al, 2008).

If the treatment of the complication led to the completion of expansion, this is termed 'salvage', whereas if the expansion process had to be abandoned, it is termed 'failure' (Mohmand et al, 2001; Bozkurt et al, 2008).

Infection

Infection is the most common complication encountered with soft tissue expansion. It is due mainly to direct inoculation of skin flora at the insertion of the expander or due to its extrusion caused by skin erosion where a bacterial infection of the periprosthetic pocket has developed (Ortega et al, 1990).

In paediatric patients, infection may also be caused by hematogenous spread from another distant site of infection (Corde Mason et al, 1999). When exposure or infection occurs early in the course of expansion, revision or removal of the expander is indicated. If this complication occurs late in the expansion process, removal of the expander and advancement of the expanded flap can be successfully accomplished (Ortega et al, 1990).

Distortion and movement of tissue expanders during expansion is another type of complication that has its own specific consequences for the surgical plan. Kuwahara et al (2003) found that it can cause expansion of the wrong area, such as the scar being resected, which will necessitate alteration of the flap design and the need for additional reconstruction.

Although tissue expansion may be a rewarding technique, one must discuss with the patient the risk of related complications and the active measures that must be taken to prevent them, both during expansion and once the expander has been removed (Piccolo-Daher et al, 2007).

PREVENTION

Prevention can be achieved through knowledge of the frequency of complications, precise instruction of the medical staff, as well as detailed and continuous education of the patients. Indeed, this not only helps prevent complications, but may also help to further increase the efficacy of the tissue expansion process (Bozkurt et al, 2008).

It is of paramount importance to ensure the surgical procedure is meticulously performed, through careful preoperative planning. Even though tissue expansion is a simple and easy technique, if any surgical rules are neglected, it will be difficult to achieve a satisfactory result (Wieslander, 1991; Guzel et al, 2000). Some simple modifications in the surgical technique may help to prevent possible complications. For example, minimal filling of the expander intraoperatively during insertion and the insertion of a suction drain may prevent fluid (haematoma or seroma) from collecting in the dissected pocket (Wieslander, 1991).

Prevention of scar widening in the expanded scalp through employing some simple modifications to surgical technique is another example of preventing complications (Guzel et al, 2000).

The surgical steps that a surgeon should be aware of are:

- Minimal tension at the incision line
- Protection of hair follicles at the flap edge and the normal scalp
- Z-plasties adaptation of expanded flaps
- Scoring of the capsule with multiple crossing incisions.

If these last two steps are not performed then sufficient flap mobilisation and adequate adaptation cannot be achieved and rigid capsular contracture occurs in the early and late postoperative period (Guzel et al, 2000).

Another important aspect of prevention of complications is the preoperative assessment for any morbidity that could affect the postoperative course and wound healing (Ortega et al, 1990; Corde Mason et al, 1999). A typical scenario is to check for any distal infection from the surgical site, especially in paediatric patients, as this can significantly increase the risk of wound or expander infection, postoperatively.

'Prevention can be achieved through knowledge of the frequency of complications, precise instruction of medical staff, as well as detailed and continuous patient education'

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‘Major or absolute complications are those that require the surgeon to stop the expansion process’

Therefore, any history of exposure to viruses and other childhood illness (chickenpox, measles, etc) must be ascertained to prevent superinfections of fresh surgical wounds (Ortega et al, 1990; Corde Mason et al, 1999). In paediatric patients undergoing post-burn tissue expansion, it is important to educate the parents and the family prior to expander insertion and to prepare them for the postoperative care and follow-up compliance in order to avoid postoperative complications. It is also important to educate the child if he or she is cooperative, or to supervise them when playing with siblings and others to avoid undue trauma (Zeitlin, 1997; LeDoux et al, 1998; Robert et al, 1998).

Strict attention to both realistic operative planning and technique, as well as patient and family education, will lead to a more satisfactory surgical result (Neale et al, 1988). Like any surgical intervention, scalp expansion is not free of complications. Different studies have been conducted to study the various types and rates of complications. It has been found that complication rates may vary from 3% to 40%, although the higher rate belongs to older studies (Voulliaume et al, 2007). It has been observed that the complication rate is highly dependent on the surgeon’s experience. In addition, a higher rate of complication was observed in expansion related to post-burn alopecia compared with any other aetiology. This might be due to the increased tension at the suture lines, which is caused by the high contraction of burn scars.

A higher complication rate was also observed in the paediatric age group, probably due to decreased wound care and the major risk of trauma in the wound. On the other hand, no difference in complication rate was observed in serial expansion of the same expander, use of multiple expanders, prophylactic antibiotic use, or the usage of drains (Voulliaume et al, 2007).

Different classifications of complications have been proposed in different series, such as minor versus major complications, or relative versus absolute complications, where these classifications have approximately the same characteristics (Voulliaume et al, 2007; Filho et al, 2007). Minor or relative complications are those that do not affect the final result of treatment, do not interfere in tissue expansion, or those that interfere at the end of the procedure, but do not compromise the final result (Voulliaume et al, 2007; Filho et al, 2007).

Major or absolute complications are those that require the surgeon to stop the expansion process (Voulliaume et al, 2007; Filho et al, 2007). Most of the major complications are caused by inappropriate surgical technique or careless planning (Gurlek et al, 2004).

In paediatric patients, the bones are constantly growing and remodelling, thus any external force applied can alter their growth. Mckinney and colleagues in 1987, followed by several authors, studied the alterations in the anatomy of the bone underlying the tissue expanders (Colonna et al, 1996; Calobrace and Downey, 1997). These alterations were numerous, such as thinning of the calvarium, outer table skull erosion, and full thickness erosion of the skull. Many of these observations were made by computerised tomography (CT)-scan imaging and histological studies (Colonna et al, 1996; Calobrace and Downey, 1997). These features appeared to be more evident in the paediatric group and in patients previously affected by local trauma or deep burns (Colonna et al, 1996).

These bony changes were more pronounced when the expanders were left in place for an extended period, when larger expanders were used, and when serial expansion was applied (Colonna et al, 1996). However, it is imperative that pre-existing cranial deformities be recognised before expansion takes place (Bauer, 1996). It has been observed that the reactions associated with the expansion process usually subside within nine months of the removal of the expander (Schmelzeisen et al, 1999).

In addition, it is estimated that one-quarter of children sustaining head and neck burns have a concomitant burn of the scalp resulting in alopecia (Silfen et al, 2000). In these younger patients, expansion of the scalp is not recommended until closure of the fontanelles (soft spots on a child’s head) is complete (Maves and Lusk, 1987). It is very important to locate the port out of the patient’s field of vision so as to

prevent him or her from observing the needle puncture during the expansion (Schmelzeisen et al, 1999).

The use of expanders with semi-rigid backings has been advocated if there is a concern about skeletal deformity, and the expansion should be delayed until the patient is aged six to nine months if there is an evident cranial deformity (Bauer et al, 1990). In 2003, LoGiudice and Gosain also concluded that patient compliance is a more significant factor in the extremities when compared with expansion of the trunk or the head and neck, and that breast reconstruction in the context of a burn injury to the chest in a child or adolescent can be more complicated than in an adult.

LoGiudice and Gosain (2003) also concluded that complication rates were between 13% and 20% and that the majority were in the extremities, particularly the lower extremities followed by the head and neck (Gibstein et al, 1997; Friedman et al, 1996; Pisarki et al, 1998). These rates were then challenged by Elias et al, who reported that the scalp (followed by the trunk) was the region associated with the greatest rate of tissue expander-related complications in the paediatric population (Elias et al, 1991).

In contrast, a large series from Boston Children's Hospital found no difference in complication rates based on the anatomical region treated, but later in 2005, a study conducted by Hurvitz et al showed a 30.8% overall complication in the expansion of the head distributed as follows: neck (44.4%), scalp (31.7%), forehead (31.3%), and cheek (16.7%) with the most common complications being exposure, infection and rupture of the expander or the tubing. As for the reasons why the complication rates differed, different authors presented various opinions (Youm et al, 1999; Hurvitz et al, 2005; Pallua and Demir, 2008).

Antonyshyn et al (1988) felt that the high complication rate of neck expanders was due to the relatively thin subcutaneous layer of this area and the constant shearing forces caused by neck movement (Antonyshyn et al, 1988; Friedman et al, 1996). Neale et al (1988), on the other hand, postulated that scalp expanders have a higher failure rate due to the unyielding nature of the skull, which, in turn, leads to increased pressure, ischaemia, and a higher possibility of extrusion.

OTHER USE OF EXPANDERS

The authors of this article have previously listed the complications of tissue expanders in post-burn sequelae and found that the complication rates vary between 5% to 60%. It would not suffice to end this section without comparing the complication rates with those of expanders used for other purposes. There is a wide pool of literature concerning the complications of allogenic materials and tissue expanders used for different purposes in the body, including: expanders used in the face for aesthetic purposes (malar augmentation), breast augmentation, buttock augmentation and several others.

In addition, there is extensive use of alloplastic, non-expandable material in specialities other than in plastic and reconstructive surgery, such as the use of prostheses in orthopaedic surgery, bone-like cement in neurosurgery and several others. Nevertheless, the complication rates in all of the aforementioned scenarios has been shown to be less than in those found in tissue expanders. In 2005, Pozowski et al published an article focusing on the complications following total knee replacements with a cemented condylar endoprosthesis. In this article, the authors concluded that complications ranged from 0.9% (late infectious complications and sterile destabilisation of the implant), to 2.7% (early infectious complications).

In addition, Bae et al (2010) evaluated sinus bone grafts using new alloplasting bone graft material and found that perforation of the maxillary sinus occurred in some 37.5% of the cases, maxillary sinusitis occurred in around 10% of the cases, and 6% failed to osteointegrate.

Numerous other studies are found in the literature showing complications in the use of allogenic material in the body, but none expressed the complication rates shown in tissue expansion. Although the complications of tissue expansion in burns differ between different areas of the body, they still stay higher than in non-burn patients. The authors tend to believe that this is because burn patients have an

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'Although the complications of tissue expansion in burns differ between different areas of the body, they still stay higher than in non-burn patients'

altered immune response to foreign bodies introduced either directly post burn or in a delayed manner.

In terms of the immunologic changes that occur after the introduction of alloplastic material into the body, a study conducted by Kessler et al (2010) showed that 'the early implantation of alloplastic material modulates the immune system and leads to an increased survival of a plymicrobial sepsis.' In their paper, Kessler et al deduced that minor surgical treatment and the placement of allogenic material causes an increase in the immune response by raising the levels of IL-6 and IFN gamma, however, they did not find any serum elevation of the major inflammatory mediators, concluding that the regulation of the immune response results from an interaction between peripheral insults and the autonomous nervous system.

This study was conducted on mice and will need to be extrapolated to humans, with further studies needed in future. This field is still evolving and more molecules studies will be needed in order for us to know the pathophysiologic changes that occur during the placement of alloplastic material in the body (Wolfram et al, 2010).

IMPLICATIONS FOR PRACTICE

A summary of steps that can be followed in order to minimise complications either in the preoperative planning or in the surgical technique includes:

- Preoperative teaching: the patient must understand that two operations are required and all of the steps must be explained before any surgical intervention commences
- Expander size: it is preferable that this be the largest possible
- Incision: it should be preoperatively planned and performed at the edge of the defect in normal healthy skin. The same incision is to be used to remove the expander
- Perioperative antibiotics: to decrease the bacterial load in burnt skin
- Pocket: it should be of an adequate size, larger than the dimensions of the expander placed into it. This will help to avoid erosion of the expander through the walls of the cavity by pressure necrosis, and allows tension-free closure
- Complete meticulous haemostasis, copious irrigation of the pocket with 10% povidone iodine or even with normal saline, and finally, drainage of the expander cavity are all prerequisites for success in any surgical procedure
- Closure: this must be performed in multiple layers to minimise any possible risk of extrusion
- Immediate filling of the expander should be performed at the time of insertion, but only up to 10% capacity
- Expansion process: with rigorous sterile technique, it should begin at least two weeks after placement with a rate of two injections weekly
- If external reservoirs are used, the external filler dome should be placed a reasonable distance from the expander through a small separate incision in healthy tissue, preferably on a solid structure to make it easily accessible and facilitate the inflation process. However, it is preferable to avoid the use of internal expander ports in children less than seven years of age. In addition, the use of external ports prevents the possibility of puncturing the expander during serial fillings.

By adhering to these simple principles, the incidence of complications can be minimised (Friedman et al, 1996; Hudson and Grob, 2005; Kotb and Soliman, 2007).

CONCLUSION

Through proper and careful patient and case selection, extensive preoperative planning, avoidance of indiscriminate use of tissue expanders, meticulous surgical technique, attention to detail, effective postoperative care, and development of expertise, tissue expansion can be considered an extremely useful tool in reconstructive surgery with minimal complications (Youm et al, 1999; Pandaya et al, 2002; Kotb and Soliman, 2007). Indeed, these principles are important in minimising complication rates and ensuring success in each case.

Finally, tissue expansion complements existing reconstructive methods by providing a surgical alternative for managing various defects, despite the high incidence of complications. However, the benefits of tissue expansion far outweigh the risks and, therefore, should be used when the anticipated results from other techniques are not acceptable (Hawary, 1998). WUK