A Minimally Invasive Approach to the Placement of Tissue Expanders

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ABSTRACT

Plastic surgeons are frequently faced with difficult and challenging soft tissue defects in all areas of the body. To reconstruct these defects, there are many operative approaches available to the reconstructive surgeon including skin grafts, local flaps, regional flaps, and free-tissue transfer. Despite these many options, occasionally the best alternative for reconstruction of a wound is tissue expansion, where skin of similar quality, texture, and color can be used to close a soft tissue defect. Unfortunately, there are significant problems related to tissue expander reconstruction including a complication rate as high as 50%. As a result, tissue expander reconstruction has not achieved the widespread popularity commensurate with its potential clinical utility. To reduce the complication rate related to open tissue expander placement, and consequently to improve its clinical utility, we have employed endoscopic techniques for the placement of tissue expanders. Endoscopic approaches are currently being used in many areas of surgery and have resulted in substantial benefits. Endoscopic placement of tissue expanders has the benefit of reducing operative time, major complication rate, time to full expansion, and length of hospital stay. The purpose of this article is to critically examine the current open technique for tissue expander placement and to compare this technique with minimally invasive endoscopic tissue expander placement. We will discuss in detail the current problems associated with open tissue expander placement, the benefits of endoscopic tissue expansion, the technique of endoscopic tissue expander placement, and the outcomes for these techniques.

KEYWORDS: Endoscopy, endoscopic plastic surgery, tissue expansion

Plastic surgeons are frequently called upon to reconstruct large or complex soft tissue defects in all regions of the body. There are many operative approaches available for reconstruction of these defects including skin grafts, local flaps, regional flaps, and free-tissue transfer. Skin grafts can be effectively used for reconstruction of many defects, but the aesthetic outcome is frequently suboptimal. In addition, secondary contraction of the skin grafts can lead to aesthetic deformities and functional limitations. Local flaps pro-

vide reasonable aesthetic results by preserving the skin color and specific dermal features of the adjacent defect but often lack the size or volume to reconstruct the larger defects. Free-tissue transfer can provide a well-vascularized source of tissue for reconstruction of many defects, particularly when large volumes are needed, but these flaps are associated with donor-site morbidity and additional scarring.

Despite the many options available for operative treatment of a wound, occasionally the best option for

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reconstruction is tissue expansion. Tissue expansion was first described in 1957 by Neumann, who used a subcutaneous rubber balloon that was gradually filled with air to expand the overlying skin immediately adjacent to a wound.¹ He observed that by using this technique, he could create new, undamaged skin that could be used to cover large cutaneous wounds. In addition, this expanded tissue was similar in color and texture and had the same sensory and hair-bearing characteristics of the missing tissue, with minimal scarring and donor site morbidity.¹⁻⁴

Since 1957, the biologic adaptation of skin to tissue expansion has been carefully examined in animal models and human studies. It has been well demonstrated that the quantitative increase in skin overlying a tissue expander is the result of both stretching of the existing overlying skin and an increase in the amount of skin. Through tissue expansion, there is thinning of the epidermis, thickening of the dermis, and thinning of the subcutaneous tissue resulting in expansion of the existing skin. There is also an increase in dermal mitotic activity leading to an overall increase in cellularity. In addition, there is also an increase in the vascularity of the skin leading to enhanced microcirculation of the expanded skin, particularly in the capsule formed around the expander itself.⁵⁻⁸ This enhanced vascularity and compensatory increased circulation has been shown to improve random-pattern flap survival compared with control skin.⁶

The overall strategy for reconstruction of a wound with tissue expanders has generally remained unchanged over the past 50 years; however, the materials and techniques used to achieve the expansion have undergone many improvements.^{3,9-15} Currently, most tissue expanders have a silicone shell with self-sealing fill ports either incorporated in the tissue expander itself or connected to the expander by a fill tube. The tissue expanders are then typically filled with percutaneous injections of saline in the outpatient setting, either in the home of a trained individual or in the plastic surgeon's office. In the pediatric population, tissue expander fill ports have been successfully used extracorporeally to obviate the need for percutaneous access of the fill ports. There have been several more technically advanced tissue expanders that have been developed, such as osmotic-gradient-driven self-expanding devices,¹⁶ but these have not achieved universal acceptance and are less commonly used. In addition to the advances in materials and the filling mechanisms, there is a wide array of shape and size configurations that have been developed to maximize the tissue expansion in any given anatomic location. These innovations have allowed for the use of tissue expanders in an increasing number of difficult clinical situations, thus becoming a very important tool at the disposal of the reconstructive surgeon.

THE PROBLEM

Despite the many benefits of tissue expander reconstruction of large and complex soft tissue defects, there are several significant problems that limit their clinical applicability. First, if an open approach is used for placement of the tissue expander, an incision must be placed in proximity to the tissue expander pocket to allow visualization of the pocket during dissection. Unfortunately, this approach creates a wound near the tissue expander pocket that increases the risk of wound dehiscence when the tissue is stretched during expansion. To reduce the risk of wound dehiscence, surgeons typically wait several weeks after surgical placement of the tissue expander to allow wound healing before initiating the tissue expansion; however, the wound only achieves 70% of its original strength after 6 weeks of healing, so initiating tissue expansion 6 weeks postoperatively does not eliminate the risk of wound dehiscence. Techniques have also been devised to try to make smaller incisions and thus reduce the risk of wound dehiscence, but this has come at the cost of poor visibility and increasing difficulty obtaining hemostasis. Although numerous surgical approaches have been designed to reduce this risk as much as possible, surgical wound dehiscence remains a significant problem when open techniques are employed.

Overall, the complication rate for tissue expander reconstruction is disappointingly high with a range of 11 to 39% in various reports.^{2,6,13,17} The complication rate has been reported as high as 50% when tissue expanders are used in extremity reconstruction. The most commonly cited complications are infection, hematoma, seroma, extrusion, wound dehiscence, and tissue expander exposure, any of which may warrant removal of the expander, hospitalization of the patient, and/or delay in completing the reconstruction.^{13,17} It is also possible that the tissue expander itself may fail at any stage of the reconstruction including at the time of tissue expander placement or throughout the expansion process. Indeed, this very high complication rate coupled with declining reimbursement has diminished the utility and appeal for tissue expander reconstruction in the current medical environment of high-volume, performance-based practices.¹⁸

A technique that would reduce this complication rate while maintaining the effectiveness of the reconstructive technique would greatly improve the clinical usefulness of tissue expansion.^{6,19,20} These goals have been achieved in many surgical fields by applying endoscopic approaches for performance of common procedures. Based on this premise, we have begun using endoscopic approaches for performance of tissue expander placement with the hope that the complication rate can be reduced without minimizing the effectiveness of the reconstructive technique.

ENDOSCOPIC TISSUE EXPANSION

History

Endoscopy was originally developed in the early 19th century by Phillippe Bozzini of Frankfurt, Germany, who used a silver tube illuminated by candlelight, which was reflected by a mirror, to view internal structures.²¹ During the next 150 years, the technique was modified and the instrumentation was improved to allow use of endoscopy for performance of many diagnostic and therapeutic procedures in many regions of the body. Despite these advances, endoscopic surgery never achieved widespread acceptance. In 1951, the Hopkins Rod was introduced, which paved the way for a series of innovative technologic advances that propelled endoscopy into the mainstream of clinical practice.²² In 1987, the first laparoscopic cholecystectomy was performed, which revolutionized the field of general surgery, soon becoming the standard of care for laparoscopic cholecystectomy and many additional operative procedures. New technological innovations such as robotic surgery and miniaturization of instrumentation continue to this day, paving the way for further groundbreaking procedures. Most recently, these innovations have led to the development of natural orifice transluminal endoscopic surgery (NOTES), which is under development as a transoral-transgastric alternative to diagnose and treat abdominal pathology, completely avoiding skin incisions.²³

In plastic surgery, endoscopic procedures were first introduced in 1984 by Teimourian and Kroll, who used the endoscope for vessel identification after liposuction.²⁴ Nearly simultaneously, Vasconez, Ramirez, and Isse described use of the endoscope in cosmetic facial surgery. Since that time, minimally invasive endoscopic procedures have become increasingly popular in plastic surgery and have expanded to include many operative procedures including flap harvest, chest wall reconstruction, breast reconstruction, breast augmentation, abdominoplasty, and vessel and nerve harvest.^{25–30} The benefits of minimally invasive operations have been well defined in the literature and include shorter hospital stays, reduced complication rates, and decreased postoperative morbidity.^{30–33} Based on this, minimally invasive approaches have been developed for the placement of tissue expanders.

Overview

Endoscopically assisted tissue expander placement was first described by Serra et al in 1997.³⁴ In this case series, they demonstrated a reduced risk of extrusion and full tissue expander inflation intraoperatively while minimizing patient discomfort. Since that time, endoscopic tissue expander placement has been shown to have several advantages over traditional open techniques

including remote incisions, fewer incisions, reduced operative time, reduced complication rates, less time to full expansion, and shorter length of hospital stay. The endoscopic approach allows placement of tissue expanders through smaller, remote incisions. Specialized endoscopic instruments allow improved visualization of the tissue expander pocket through smaller incisions. The benefits of this approach are that the incision can be placed at a distance from the tissue to be expanded, thus reducing the stress on the incision during performance of the tissue expansion and potentially reducing the risk of tissue expander extrusion through the incision. In addition, more tissue expanders can be placed through a single incision because of the improved visualization and ability to operate remotely using endoscopic instruments. This is critically important in clinical situations where there is skin of altered integrity, such as a large burn, with minimal normal surrounding skin. In addition, the risk of hematoma is reduced due to the improved visualization of the tissue expander pocket, facilitating more precise hemostasis. The advantage of the endoscopic approach has translated into a reduction in time to full expansion, shorter hospital stay, a decreased rate of wound dehiscence, a decreased rate of tissue expander extrusion, and a reduction in major complication rate compared with conventional open tissue expander placement.³⁵

The Procedure

To begin performing endoscopic tissue expander placements, the surgeon may need to purchase some endoscopic equipment, unless endoscopic instruments already exist at his or her hospital. A majority of the instruments required for endoscopic tissue expander placement including video carts, endoscopes, light sources, graspers, scissors, cautery hooks, and dissectors are included in a standard laparoscopic cholecystectomy set; the remainder of the instruments including retractors and curved cautery devices may need to be purchased separately, however, there are very few requirements. The improved outcomes noted with endoscopic tissue expander placement will easily offset these relatively minimal costs. Cost analysis comparing the financial impact of endoscopic versus open procedures actually demonstrates nearly equal financial costs from a billing standpoint,³⁶ although the “cost” of these techniques is not easily defined due to locoregional variations, surgeon, and hospital volume.³⁷ Despite these controversies, most patients would agree that minimally invasive approaches are superior to open approaches.

Indications and Contraindications

The indications and contraindications for endoscopic tissue expander placement are identical to those for

traditional, open tissue expander placement. There are no restrictions to placement of tissue expanders endoscopically based on the location, size, or shape of tissue expander needed or size of the wound or defect to be reconstructed. Tissue expanders may be placed endoscopically anywhere a soft tissue pocket may be created.

Equipment

The instruments needed for endoscopic tissue expander placement consist of a camera, light source, cables, video display, and the surgical instruments themselves. Specific equipment needed for endoscopic tissue expander placement include an endoscope with an accompanying endoretractor. The endoscopes employed for these operations are either 5 mm or 10 mm in diameter, depending on the location of the dissection. In the scalp, face, and occasionally neck, a 5-mm endoscope is used to help reduce the size of the surgical wound. The scopes are angled at 0, 30, or 45 degrees. The angle of the endoscope required depends on the ease of visualization when creating the tissue expander pocket. In general, when the dissection is being performed over a convex surface, the 45-degree endoscope allows improved visualization "around the curve." When tissue expanders are being placed on a flat surface like the back or abdomen, a 10-mm endoscope with 0-degree or 30-degree lenses allows excellent visualization of the dissection planes. It should be noted that the optical cavity for these endoscopic operations is manually maintained with retraction. As a result, a retractor must be used in combination with the endoscope to allow visualization of the dissection. There are several commercially available retractors that allow maintenance of the optical cavity while at the same time holding the scope in position for visualization. The endoscope is then connected to a conventional endoscopic video cart and light source. The dissection instruments used for endoscopic tissue expander placement consist of graspers, scissors, cautery hooks, and dissectors, which are also readily available in a standard laparoscopic cholecystectomy instrument set.^{37,38} There are a couple of additional items that may help with the endoscopic dissection that are not included in most standard laparoscopic cholecystectomy sets: one is a curved cautery and the other is a blunt dissector. These instruments are also available from several vendors and can be selected based on surgeon preference.

Technique

The patient is evaluated preoperatively in the holding room where the location of the tissue expanders is marked and the location of the incisions is defined. The access ports are usually 2 to 3 cm in length and

positioned remotely from the area of intended expansion, typically 8 to 10 cm from the border of the tissue expander. The specific incision site is selected with the following criteria in mind: minimize the aesthetic impact of the incision; maximize the number of expanders that can be placed through the minimal number of incisions; minimize the length of the incision; and locate the incision to permit optimal endoscopic visualization.

The placement of the tissue expander through a remote incision is accomplished with a combination of open and endoscopic techniques. The initial dissection is performed under direct visualization, and all subsequent dissection is performed with endoscopic techniques. Typically, we are able to perform approximately half of the dissection under direct visualization until the visualization becomes inadequate. At that point, we introduce the endoscope into the access port and complete the remainder of the dissection. An endoscopic retractor is used to provide the optical cavity for visualization of the dissection. Several commercially available endoretractors have been designed to accomplish several different functions. In general, the retractors have been designed to perform multiple functions simultaneously, allowing single-surgeon operation. In addition to providing an optical cavity for performance of the operation, the endoretractor also secures the light source and camera for enhanced visualization and has a smoke evacuation port to ensure that the smoke does not obscure the view. During performance of the dissection, arteries and veins can be easily identified, clamped with an endoscopic grasper or right angle, and either cauterized directly or secured with hemoclips. Meticulous hemostasis needs to be maintained during the dissection to optimize visualization of the perforating vessels. Using current technology, small areas of bleeding are optically magnified and addressed more precisely or avoided altogether. The extent of the subcutaneous pocket is limited only by anatomic boundaries and the length of the instruments. Through use of endoscopic approaches, the number of tissue expanders that can be placed through each small incision is increased; typically we have been able to place two to three tissue expanders through each incision. All sizes and shapes of tissue expanders have been placed through this approach. Technical considerations such as those encountered in scarred tissue or previous expansion (as in serial expansions) have not created any substantial difficulties with this procedure. Because the incision is placed at a distance from the tissue expander, the tissue expansion can begin immediately and continue postoperatively on a weekly basis without any delay.

Outcomes

We have recently published data retrospectively comparing open versus endoscopic placement of tissue

expanders in a large academic medical center.³⁸ Our results demonstrate that the endoscopic placement of tissue expanders leads to a significant reduction in the major complication rate, defined as any complication requiring either an operation or hospitalization to treat (43.3% versus 9.5%; $p < 0.00052$). The minor complication rate was similar in both experimental groups, 11.7% versus 23.8% in the open and endoscopic groups, respectively ($p = 0.25$). If the complications are evaluated per expander, the major complication rate per expander was significantly reduced from 22.0% to 2.7% ($p = 0.000056$) using an endoscopic approach. In addition, there was a significant reduction in the time from tissue expander placement to tissue expander removal and reconstruction, from 128.8 ± 81.7 days to 99.9 ± 32.6 days ($p = 0.032$). The length of hospital stay was significantly reduced in the endoscopic tissue expander placement group from 1.4 ± 1.6 days to 0.5 ± 0.9 days ($p = 0.0037$); however, whether this reduction in length of hospital stay is clinically significant is debatable. There was also a significant reduction in the time it took to place each tissue expander when an endoscopic approach was used: 49.2 ± 23.3 minutes for the open approach and 34.0 ± 12.2 minutes for the endoscopic approach ($p = 0.000030$). The overall operative time for placement of the tissue expanders was similar in the two groups, but that was because more tissue expanders were placed for each endoscopic operation (3.6 ± 1.5 tissue expanders) than in the open operations (2.1 ± 1.0 tissue expanders). Serial expansion of a site for staged treatment did not create any technical difficulties, nor did it increase the complication rate during endoscopic placement of the tissue expanders.

CASE 1

The patient is a 3-year-old Jamaican boy who sustained an 8% total body surface area (TBSA) burn at the age of 1 year. All burn injuries were allowed to heal by secondary intention after the injury. It has been 2 years since the original injury, and the patient has been referred to us for further evaluation and treatment. The areas of greatest concern to the family were the forehead, left cheek, and chest burns (Fig. 1A–C). After extensive discussions regarding the potential treatment options, the decision was made to proceed with endoscopic tissue expander reconstruction. Two tissue expanders were placed endoscopically through a 2.5-cm incision over the left deltoid. A 300-mL rectangular tissue expander was placed into the neck and a 400-mL tissue expander placed into the chest through this single incision using endoscopic techniques. The tissue expander ports were placed over the anterior shoulder. Tissue expansion was begun during the first week postoperatively and continued weekly for 3 months. A

total of 450 mL was placed into the neck expander and 550 mL was placed into the chest expander. Nearly 3.5 months after the initial tissue expander placement, the patient was taken back to the operating room where the tissue expanders were removed, the burn scar was resected, and the expanded skin was used for reconstruction of the resultant defects. Figure 1D–F demonstrates nice correction of the forehead, left cheek, and chest burn scar deformity 1 month postoperatively. Unfortunately, we were unable to get additional postoperative photos since the child returned to Jamaica.

CASE 2

The patient is a 52-year-old woman who sustained a 60% TBSAB at the age of 36 years. She underwent numerous operative procedures to debride the devitalized tissue and reconstruct the burn wounds. Thereafter, she underwent multiple burn reconstructive operations to release burn scar contractures and optimize her functional outcome. She ultimately presented to our clinic with concerns regarding a severe left neck burn scar contracture, right neck burn deformity, and lower-lip burn ectropion (Fig. 2A–D). After discussions with the patient regarding the options, we elected to proceed with endoscopic tissue expander placement for burn reconstruction. A 2.5-cm incision was made in the region of a sternal burn scar through which the tissue expanders were placed. Two 800-mL rectangular tissue expanders were endoscopically placed through the single incision. The tissue expansion was initiated during the first week postoperatively and continued weekly for 3 months. The patient was taken back to the operating room, and the burn tissue was removed from the left neck and right mandibular border. The expanded skin was then used to reconstruct the defects and also used to correct the lower-lip burn ectropion. Figure 2E–H demonstrates the result 1 year postoperatively. There has been nice release of the left neck burn scar contracture, right mandibular border scar, and correction of the lower-lip ectropion.

CONCLUSION

Tissue expansion is an excellent technique for reconstruction of large and difficult wounds in situations where other techniques are not suitable. Unfortunately, tissue expander reconstruction has been plagued with high complication rates, reducing the utility and appeal of this reconstructive approach. Minimally invasive approaches have been adapted to the placement of tissue expanders to address this issue. Compared with traditional open approaches, minimally invasive endoscopic tissue expander placement has the benefit of reducing operative time, reducing the major complication rate, reducing the time to full expansion, and

Figure 1 Photos of a 3-year-old boy who sustained an 8% TBSA burn at the age of 1 year. (A) Preoperative frontal face, (B) preoperative lateral face, (C) preoperative chest, (D) postoperative frontal face, (E) postoperative lateral face, (F) postoperative chest.

Figure 2 Photos of a 52-year-old woman who sustained a 60% TBSA burn at the age of 36 years. (A) Right lateral face 10 years after the burn injury, (B) preoperative frontal face, (C) preoperative left lateral face, (D) preoperative left lateral neck close-up demonstrating scar contracture,

potentially shortening hospital stays. A minimal amount of readily available equipment is needed to perform the operation. In addition, the technique of endoscopic tissue expander placement can be easily

mastered by any plastic surgeon. As a result, we believe that endoscopic placement of tissue expanders is a safe and effective method for plastic surgical soft tissue reconstruction.

Figure 2 (Continued) (E) postoperative frontal face, (F) postoperative left lateral face, (G) postoperative right lateral face, (H) postoperative right lateral face; note the position of the lower lip.

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