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ORIGINAL ARTICLE

Role of tissue expanders in patients with loss of abdominal domain awaiting intestinal transplantation

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Summary

Abdominal closure is a complex surgical problem in intestinal transplant recipients with loss of abdominal domain, as graft exposure results in profound morbidity. Although intraoperative coverage techniques have been described, this is the first report of preoperative abdominal wall augmentation using tissue expanders in patients awaiting intestinal transplantation. We report on five patients who received a total of twelve tissue expanders as a means to increase abdominal surface area. Each patient had a compromised abdominal wall (multiple prior operations, enterocutaneous fistulae, subcutaneous abscesses, stomas) with loss of domain and was identified as high risk for an open abdomen post-transplant. Cross-sectional imaging and dimensional analysis were performed to quantify the effect of the expanders on total abdominal and intraperitoneal cavity volumes. The overall mean increase in total abdominal volume was 958 cm^3 with a mean expander volume of 896.5 cc. Two expanders were removed in the first patient due to infection, but after protocol modification, there were no further infections. Three patients eventually underwent small bowel transplantation with complete graft coverage. In our preliminary experience, abdominal tissue expander placement is a safe, feasible, and well-tolerated method to increase subcutaneous domain and facilitate graft coverage in patients undergoing intestinal transplantation.

Introduction

Abdominal closure is a challenging aspect in the management of intestinal failure patients with a compromised abdominal wall who require intestinal transplantation. Many of these patients have lost substantial domain due to prior enterectomy resulting in reduced compliance of the skin and abdominal wall from multiple operations, stomas, abscesses, and enterocutaneous fistulae (ECF). This discrepancy between domain and abdominal content is intensified at the time of transplantation when the graft becomes edematous due to ischemia–reperfusion injury [1]. Inadequate graft coverage is associated with significant post-transplant morbidity and mortality, as well as decreased graft survival with a higher rate of retransplantation and death when primary closure is not achieved [2].

Various surgical techniques have been described to facilitate abdominal closure including the use of prosthetic mesh [3,4], component separation [5], rotation/free flap coverage [6,7], cadaveric and biologic fascia [8,9], and in extreme cases abdominal wall transplantation [10,11]. However, all these techniques have focused on intraoperative management of challenging closures, and no report in the literature has explored the role of preoperative abdominal wall augmentation in this complex patient population.

Tissue expanders have been extensively used in general, pediatric, and plastic surgery [12–18] and have been shown to be safe and efficacious. They can provide skin expansion

and progressive subcutaneous volume gain that can be used to cover large defects. Concerns related to the use of a foreign body in patients at risk for infection as well as the space limitations caused by ECF, scar tissue, and stomas have thus far limited their use in intestinal transplant candidates. Here, we describe our experience using tissue expanders and abdominal wall reconstruction to achieve abdominal closure, as well as the medical and technical modifications that made this approach feasible and effective.

Patients and methods

Between October 2008 and September 2011, 20 patients were listed for intestinal transplant at our institution. Of these, five patients presented with a compromised abdominal wall resulting from ECF ($n = 2$), recurrent subcutaneous abscesses ($n = 2$), multiple laparotomies, and loss of abdominal domain ($n = 5$) and were identified as high risk for having an open abdomen post-transplant (Table 1). Clinical criteria that factor into our patient selection for tissue expander placement include compliance of the abdominal wall, distance from abdominal skin to abdominal aorta, thickness of the subcutaneous tissues, and the ability to predict skin flap creation for coverage of the graft (based on presence of and amount of scar tissue, prior incision lines and skin grafts, large areas at risk for devascularization, etc.) In our early transplant experience, we identified abdominal wall closure as one of the most important predictors of short-term outcome. We therefore implemented an aggressive strategy in collaboration with our plastic surgery department to maximize the likelihood of achieving primary abdominal wall closure.

Three of the five patients received two tissue expanders, and two patients received a total of three. We utilized 17×8 cm and 18×8 cm low-profile, rectangular expanders (Specialty Surgical Products, Victor, MT, USA) for each patient. The goal of placement was to be as close as possible to the midline, while avoiding any pre-existing fistulae or stomas, to gain the most volume in this coverage-limiting area. Inflation of the expanders occurred weekly or biweekly beginning 1 week after surgery, until the goal expansion volume was obtained or transplantation became available. CT scans of the abdomen and pelvis were obtained before and after the placement of subcutaneous tissue expanders and were reconstructed with 1-mm thick slices on a dedicated postprocessing workstation. After encountering infection in our first patient, we made two modifications to the method. First, we began to utilize iodophor impregnated, antimicrobial drapes (Ioban; 3M, St. Paul, MN, USA) during expander placement. Secondly, we placed our patients on prophylactic IV antibiotics (vancomycin) for 10 days postoperatively.

Total abdominal volume (TAV) was defined as the abdominal volume outlined by the skin or most external layer of soft tissue. Total abdominal cavity volume (TACV) was defined as the abdominal cavity contents, including intraperitoneal and retroperitoneal structures contained by the abdominal wall musculature and the anterior paraspinal musculature. A graphical depiction of TAV and TACV is shown in Fig. 1a. TAV, TACV, and tissue expander volumes were calculated prior to expander placement and at the end of the expansion process (Fig. 1b). Postplacement volume calculations were not performed on Patient #2 because CT imaging could not be obtained before the patient underwent intestinal transplantation. In three of four patients, the volumes of two expanders were calculated. While three expanders were placed in Patient #1, only one was present at the time of volume calculation, as the others had been removed due to infection. The length of abdominal wall along the craniocaudal axis including the entirety of the distended tissue expanders was used for volume calculations. In three patients, abdominal volumes were calculated from the level of the superior mesenteric artery origin to the pubic symphysis. In Patient #1, abdominal volumes were calculated between the superior endplates of the L1 and S1 vertebral bodies to ensure adequate coverage of the tissue expanders. This patient had extensive fistulae, which precluded placement of the expanders in the same location as the other patients.

To calculate volumes, two board-certified radiologists specialized in abdominal imaging traced the perimeter of each desired area on sequential CT slices. The total number and position of slices contoured for a given patient were the

Table 1. Intestinal failure patients identified as high risk for post-transplant open abdomen that were selected to undergo tissue expander placement.

Patient	Age	Gender	Etiology of intestinal failure	Number of expanders	Fistulae	Stoma
1	35	M	Crohn's disease	3	Yes	Jejunostomy
2	32	F	Mesenteric ischemia	2	No	Jejunostomy
3	47	M	Mesenteric ischemia	3	No	Jejunostomy
4	56	M	Crohn's disease	2	Yes	Jejunostomy
5	44	F	Mesenteric ischemia	2	No	Jejunostomy

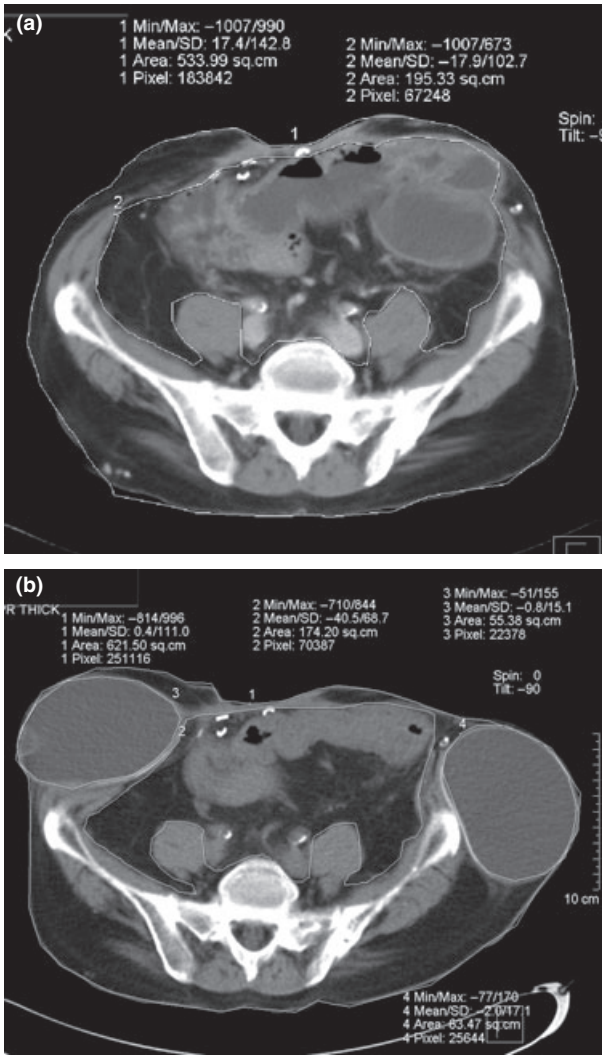

Figure 1 (a) Volumetric analysis prior to tissue expander placement. Total abdominal volume is the area outlined by line #1. Total abdominal cavity volume is the area outlined by line #2. (b) Volumetric analysis after tissue expander placement and expansion. Tissue expander volumes are defined by lines #3 and #4.

same on pre- and post-tissue expander CT scans. However, the number of slices varied between patients, ranging from 20 to 29, due to differences in patient height. To calculate volumes for each parameter, the volumes of the individual slices (i.e., the product of the reconstruction interval and the area of the manually traced region) were added together.

Patients

Patient #1 is a 35-year-old man with severe Crohn's disease with aggressive fistulization. He underwent multiple laparotomies with small bowel resections and abdominal wall reconstructions including mesh placement, component separation twice, muscle flap preparation, and multiple skin grafts. He was referred to our transplant center in June 2009 and underwent near total enterectomy with jejunostomy and split thickness skin graft placement. He later developed TPN-induced liver failure. He then underwent placement of three subcutaneous tissue expanders. He tolerated expansion without difficulty, but developed an infected hematoma necessitating removal of two of the three expanders. Since he has received a simultaneous liver and abdominal wall transplant, however, he developed primary liver graft nonfunction, requiring emergency retransplantation. The abdominal wall graft also failed due to vascular thrombosis likely secondary to profound hemodynamic instability associated with primary nonfunction of the transplanted liver. He has recovered and is currently awaiting both intestinal and abdominal wall transplantation.

Patient #2 is a 32-year-old woman who required a total enterectomy at an outside hospital due to superior mesenteric artery (SMA) thrombosis and was transferred to our institution for management. Six months after initial evaluation, two expanders were placed. The surgical technique differed from our first patient in that we utilized iodophor impregnated drapes and prophylactic IV antibiotics. She underwent serial expansion in the outpatient clinic weekly with 60–120 cc at a time until the expanders each reached approximately 480 cc. She had one episode of discomfort that resolved with removal of 50 cc from one expander. She successfully underwent intestinal transplant 2 years after initial referral with removal of expanders at the time of transplantation. Complete soft tissue coverage was obtained, and fascial closure was achieved after component separation and placement of Alloderm mesh (LifeCell, Branchburg, NJ, USA).

Patient #3 is a 47-year-old man who developed a spontaneous SMA dissection resulting in mesenteric ischemia. He underwent small bowel resection at another institution and was subsequently transferred to our institution for management. Upon arrival, he was febrile and had peritonitis, and he immediately underwent a near total enterectomy with end jejunostomy. He recovered well, and after evaluation by our transplant center, he had three tissue expanders placed. He tolerated weekly expansions without difficulty; however, one of the expanders malfunctioned necessitating removal 3 months later. Five months after initial expander placement, he underwent intestinal transplantation in which primary graft coverage was obtained.

Patient #4 is a 56-year-old man with a history of Crohn's disease with extensive fistulae, transferred for evaluation and management. He underwent a near total enterectomy followed by placement of two tissue expanders 1 year later. He is currently on the list awaiting intestinal transplantation.

Patient #5 is a 44-year-old woman who developed superior mesenteric vein thrombosis necessitating a near total

enterectomy at an outside hospital. She was transferred to our transplant center and underwent small bowel transplantation in January 2010. Her transplant was complicated by rejection, which required graft enterectomy 2 months later. In September 2010, she had two tissue expanders placed and underwent subsequent weekly injections without difficulty. She then received a second intestinal transplant in December 2012 with primary abdominal closure. She recovered well from the operation but unfortunately died from complications of intra-abdominal sepsis three and a half months postoperatively.

Results

A total of 12 tissue expanders were placed in our series. Two were removed in Patient #1 due to infection, and one was removed in Patient #3 due to port misplacement in the subcutaneous tissue that led to accidental puncture of the expander.

Total abdominal volume, TACV, and expander volumes were calculated for the four patients with postplacement CT imaging (Table 2). The overall mean increase in TAV was 958 cc. The overall mean decrease in TACV was 269 cc, although this does not include Patient #3, who obtained an increase of 853 cc. Patient #1 had a decrease in both TAV and TACV (−1510 and −101 cc, respectively). This was likely due to worsening nutrition with his concurrent liver failure leading to a decrease in both subcutaneous and intraperitoneal fat concentrations.

The mean expander volume was 896.5 cc. This was generally obtained over the course of 3 months from insertion (Fig. 2). Patient #2 required a reduction in expander volume due to discomfort; however, 2 weeks after removal of 50 cc, she was able to continue scheduled expansions without difficulty. She was then successfully transplanted with primary closure. Results of tissue expansion at the time of transplant are shown in Fig. 3.

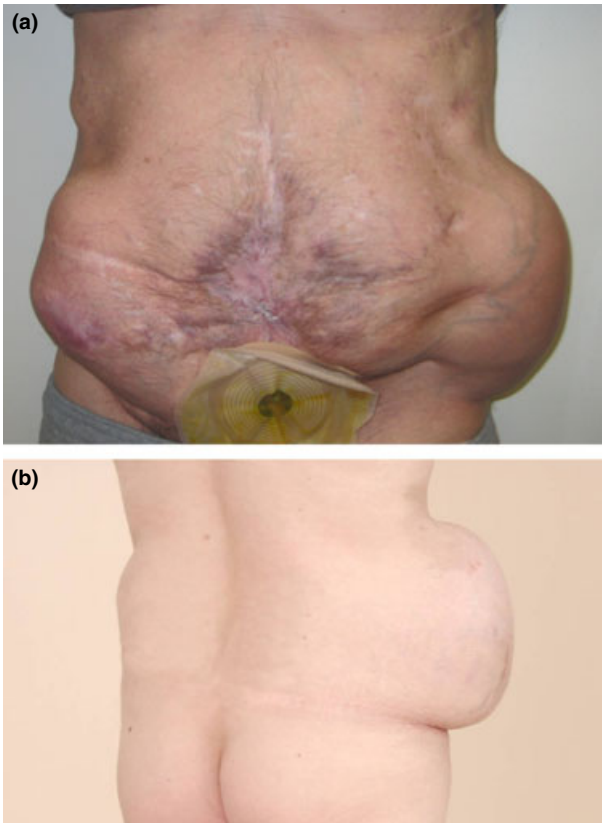

Figure 2 Patient photographs depicting location and extent of expansion of the tissue expanders.

Discussion

Management of abdominal wall defects continues to be an integral yet challenging component of surgical patient care. The open abdomen has become a common occurrence in trauma and general surgery, with various techniques described for damage control and delayed abdominal closure [19,20]. While there exists extensive experience regarding management of the open abdomen in general surgery patients, there is a paucity of data regarding this issue in intestinal transplantation. Loss of domain is a common problem in patients with intestinal failure, and primary closure after intestinal transplantation is frequently not possible. Lack of adequate coverage for the graft results in significant patient morbidity and mortality, as well as in decreased graft survival. These patients are at increased risk

Table 2. Pre- and postexpansion abdominal and tissue expander volumes (cc).

Patient	Baseline TAV	Baseline TACV	Right TEV	Left TEV	Postexpansion TAV	Postexpansion TACV
1	13 505	5819		284	12 995	5018
3	11 191	4160	532	118	15 622	5015
4	13 883	5626	545	746	14 303	5222
5	18 688	4998	753	608	21 983	4696

TAV, total abdominal volume; TACV, total abdominal cavity volume; TEV, tissue expander volume.
Postplacement volume calculations were not performed on Patient #2 because CT imaging could not be obtained before the patient underwent intestinal transplantation.

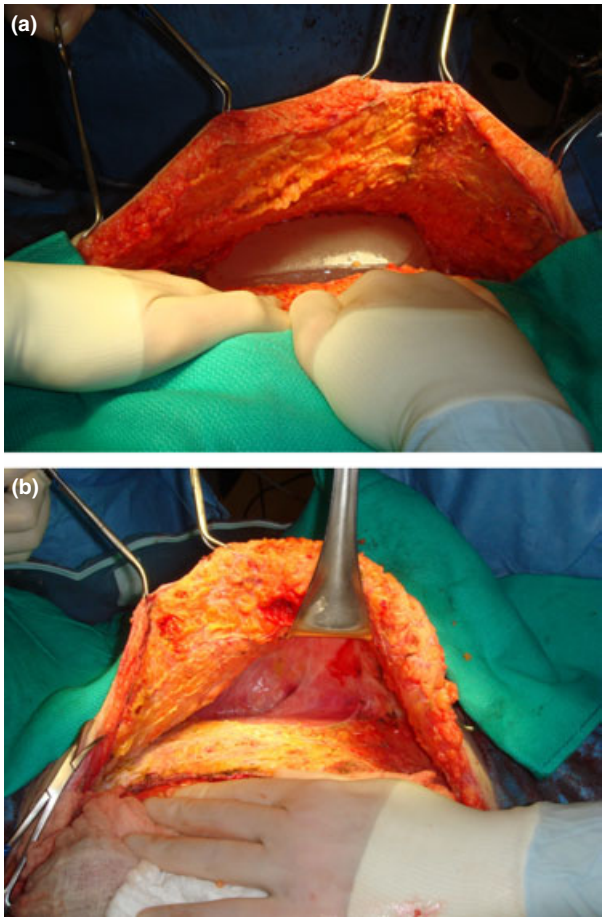

Figure 3 Intraoperative photographs of tissue expander removal at the time of intestinal transplantation. The expander is seen *in situ* in the subcutaneous space (a), and the expanded tissue compartment is visualized after its removal (b).

for significant fluid and electrolyte loss, enteroatmospheric fistula, intra-abdominal infection and sepsis [21]. The vascular reconstruction is particularly vulnerable to infection, and the development of mycotic aneurysms can lead to life-threatening hemorrhage. Therefore, prevention of an open abdomen after transplant is critical to a successful outcome.

Current methods for abdominal wall closure after intestinal transplant include bridging with prosthetic or biologic mesh, component separation, regional rotation or free flap coverage, or a combination of these techniques. Use of prosthetic mesh has been a dependable option for closure of fascial defects in nontransplant patients; however, there is increased risk of infection and ECF formation when immunosuppression is necessary [22], and multiple operations are often required for down-sizing and eventual removal [2,23]. In the intestinal failure population in particular, the success of these techniques is limited by lack of skin to cover the defect. Additionally, in these patients with fistulae, intra-abdominal infections, bacteremia, etc., leaving prosthetic material *in situ* is to be avoided post-transplant. Biologic mesh has the advantage of absorbability and allowing for subsequent skin grafting on a granulating wound bed without residual foreign material [24,25]. However, the period of time with an exposed open wound can be several months before definitive skin closure [26]. Component separation is an effective and frequently used technique for facilitating primary fascial closure; however, it allows coverage of midline defects only up to 10 cm. It is of limited utility in intestinal transplant patients with prior laterally extending abdominal incisions and stomas, and it can further compromise abdominal wall blood supply. Flap closure is advantageous, in that it is a one-stage procedure and avoids placement of foreign material, but it is technically challenging and can create large wounds elsewhere in immunocompromised, nutritionally deficient patients.

While there are replacements for fascia in abdominal closure after intestinal transplant, there is no immediate substitute for skin to create a truly closed wound. Primary fascial closure is ideal, but it is often not possible in these recipients. Complete skin coverage, providing physiologic graft protection even in the context of large fascial defects, is therefore the most important aspect of wound management. For this reason, we investigated preoperative placement of tissue expanders to facilitate gaining sufficient skin and subcutaneous tissue for definitive skin closure at the time of transplant. Initially described by Byrd and Hobar [12], adjunctive abdominal wall tissue expansion has been utilized in a number of scenarios for complex reconstruction. Livingston *et al.* [16] obtained satisfactory results utilizing tissue expanders placed in the subcutaneous tissues of abdomens affected by trauma. Jacobsen *et al.* [27] described the use of expanders between muscle layers of the abdominal wall to facilitate fascial closure of giant ventral hernias. Tissue expanders are now readily available and have been used extensively in many types of reconstructive surgery with great success. Subcutaneous placement is a relatively benign procedure, does not violate the abdominal cavity, and can be performed with low morbidity. Expansion is generally well tolerated, and large volume increases can be achieved in a relatively short period of time.

The use of tissue expanders is not without risk. While infection is a well-known complication of abdominal tissue expander placement [28], our series shows that it is a safe procedure in this population. In clean cases (i.e., breast reconstruction), the incidence of wound infection is approximately 5.6% [29]. Given this complex patient population at greater risk for infection, our incidence of 16% is acceptable. Moreover, after implementing a specific topical and systemic antimicrobial prophylaxis protocol, we

avoided infection in the subsequent four patients. Secondly, there is no significant expansion of the fascia with subcutaneous tissue expanders, and a decrease in intraperitoneal volume can occur with aggressive expansion. Additionally, this method can be inconvenient as serial injections require weekly visits to the clinic. We propose the use of tissue expanders not as an alternative to other techniques, but rather as an adjunct to increase the amount of skin and subcutaneous tissue available for closure.

In our patients, we found that, as expected, abdominal circumference was increased with the use of expanders due to a significant expansion of the cutaneous and subcutaneous tissue. There was some degree of compensatory intraperitoneal volume loss, but it did not compromise the ability to perform intestinal transplantation as fascia can be easily replaced with biologic/cadaveric tissue, while skin cannot. Moreover, skin is more extensible than fascia and easier to stretch on top of edematous intra-abdominal organs, a critical quality especially when a skin-only closure is performed. Placement of expanders between the fascial layers may have increased the fascial compartment while diminishing intraperitoneal volume loss. However, our goal was to obtain maximal skin growth, and we achieved good expansion with a low complication rate. Even when patient factors (such as ECF) necessitated placement more laterally, there was a noticeable benefit. Other techniques to obtain fascial closure, such as component separation and biologic mesh placement, were performed to reconstruct the abdominal wall in conjunction with primary skin closure.

These expanders are readily available at our institution, and we found that the low-profile rectangular expanders contoured well and were well tolerated. While we did not routinely reach the maximal available volume, the expansion process is currently ongoing.

A limitation of this report is its retrospective nature as it did not allow standardization regarding imaging timeframes, and one patient did not have a postplacement CT scan prior to transplantation. Additionally, the small number of patients does not allow for formal statistical analyses. Moreover, patient nutritional status—and more specifically the amount of subcutaneous fat present—may act as a confounding factor in calculation of the total body circumference. Additional prospective studies with standardized imaging intervals and surgical protocol are needed for further investigation of the technique in this specific patient population.

In our experience, abdominal wall subcutaneous tissue expansion was safe, feasible, and effective in providing abdominal wall augmentation prior to intestinal transplantation. This method can play a critical role in complex abdominal reconstruction to achieve full graft coverage at the time of transplant.

Authorship

MJW: Participated in performance of the research, data collection and analysis, writing of the paper, manuscript revision. NK: Participated in research design, performance of the research, writing of the paper. CC: Participated in performance of the research, data analysis. RD, KH, BE, NG and KAE: Participated in research design, performance of the research. MF and TDU: Contributed to the care of the patients, manuscript revision. AN: Participated in literature review. CQ: Participated in research design, performance of the research, data analysis, writing of the paper.

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