

Human Acellular Dermal Matrix for Repair of Abdominal Wall Defects: Review of Clinical Experience and Experimental Data

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ABSTRACT: The use of prosthetic mesh for the tension-free repair of incisional hernias has been shown to be more effective than primary suture repair. Unfortunately, prosthetic materials can be a suboptimal choice in a variety of clinical scenarios. In general, prosthetic materials should not be implanted into sites with known contamination or infection because they lack an endogenous vascular network and are thus incapable of clearing bacteria. This is of particular relevance to the repair of recurrent hernias, which are often refractory to repair because of indolent bacterial colonization that weakens the site and retards appropriate healing. Although fascia lata grafts and muscle flaps can be employed for tension-free hernia repairs, they carry the potential for significant donor site morbidity. Recently, a growing number of clinicians have used human acellular dermal matrix as a graft material for the tension-free repair of ventral hernias. This material has been shown to become revascularized in both animal and human subjects. Once repopulated with a vascular network, this graft material is theoretically capable of clearing bacteria, a property not found in prosthetic graft materials. Unlike autologous materials such as fascial grafts and muscle flaps, acellular dermal matrix can be used without subjecting the patient to additional morbidity in the form of donor site complications. This article presents a thorough review of the current literature, describing the properties of human acellular dermal matrix and discussing both animal and human studies of its clinical performance. In addition to the review of previously published clinical experiences, we discuss our own preliminary results with the use of acellular dermal matrix for ventral hernia repair in 46 patients.

KEY WORDS: alloderm, abdominal wall reconstruction, ventral hernia, biological prosthesis

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INTRODUCTION

Restoring abdominal wall integrity is a challenging problem faced by surgeons. Deficiencies of the abdominal wall can be the result of infection, abdominal compartment syndrome, trauma, or primary herniation. The resultant defects include the loss of skin, muscle, and/or fascia in varying combinations and degrees. Of the causes of abdominal wall defects, incisional hernia is the most common, with incidences as high as 11–20% of patients post-laparotomy.^{1–3} When the primary repair of incisional hernias fail, the surgeon faces an increasingly difficult task as each subsequent attempt to repair becomes less likely to persist. Luijendijk et al.⁴ demonstrated the advantages of a tension-free technique in a study comparing suture repair of incisional hernias to the interpositional placement of synthetic mesh. Nonetheless, while several large studies have reported recurrence rates near 50% for primary suture repair,^{5–7} others have noted a rate of recurrence as high as 34% for those repairs done with synthetic mesh.^{8–10}

Although the use of synthetic materials may decrease reherniation rates, there are many clinical situations in which the use of these materials is ill-advised. These situations include, but are not limited to, enterocutaneous fistulae, recent intra-abdominal infections, sites with previous wound infections, areas with unstable wound coverage, operative fields in which an ostomy will be located near the suture line, and in patients who are immunocompromised. Furthermore, it has been demonstrated that patients with incisional hernias, as a group, have higher rates of postoperative wound infections, even when their previous incision sites appear to have healed completely without signs of infection. Specifically, Houck et al.¹¹ found that patients undergoing abdominal hernia repair had a postoperative wound infection rate of 16%, compared to an infection rate of 1.5% for patients undergoing other “clean” procedures. The authors suggest that subclinical bacterial contamination may play a significant role in the development of the initial hernia. When hernias are repaired at the site of a previously documented infection, the rate of

postoperative wound infection rises to over 40%. In addition, Rodgers et al.¹² have noted that the implantation of synthetic nonabsorbable prostheses into the diaphragm and abdominal wall leads to encapsulation and large fibrotic conglomerates, which can be a nidus for infection.

In addition to their inability to clear infection, synthetic materials have been associated with serious complications such as adhesion formation, bleeding, fistulae, erosion, and seroma formation in as many as 15% of cases.^{13,14} Surgeons must consider not only possible contraindications for the use of synthetics, but also the fact that failure and the need to explant these materials may render the hernia larger and harder to repair in the future. Despite these drawbacks, reconstruction with prosthetic materials continues to be the most common technique employed.¹⁵ Given the ease of use, abundant availability, perceived low cost, and familiarity with these materials, this trend is likely to continue until a better solution is proven.

Angiogenesis is recognized as an essential step in wound healing.¹⁶ Tissue that is vascularized is clearly more capable of resisting infection than synthetic materials. Vascularity allows tissue to resist or fight infection by delivering inflammatory cells as well as nutrients and oxygen. Synthetic graft materials cannot elicit angiogenesis or produce growth factors and are therefore plagued by an inability to clear infection. Once they are infected, synthetic materials should be removed. Accordingly, the use of autologous tissue in the form of muscle flaps, myocutaneous flaps, fascial grafts, or de-epithelialized dermal grafts traditionally has been favored over synthetic graft materials when there is concern for infection. Using a rabbit model, Disa et al.¹⁷ demonstrated that free autologous fascia lata grafts retain their native cellular architecture and become vascularized when used for the repair of abdominal wall defects. Furthermore, they demonstrated that these fascial grafts were more capable than synthetic mesh of resisting infection. However, the use of autologous tissue in the form of muscle flaps, myocutaneous flaps, or fascial grafts may result in significant donor site morbidity in the form of pain, seroma, hematoma, wound dehiscence,

and lateral knee instability from the disruption of the ilio-tibial tract. Autologous tissues are not always available in sufficient quantity, and their use can greatly increase operative times and complexity and are generally outside the scope of practice of many general surgeons.¹⁸⁻²³ Similarly, the component separation technique generally allows the surgeon to close a defect with local autologous tissue but necessitates extensive dissection and is not always sufficient when the repair is located near an ostomy or when the operative field contains severe scarring from previous procedures.²⁴

As a result of the inherent drawbacks of synthetic and autologous graft materials, significant effort has been spent on the identification of new techniques and materials for use in hernia repair. Among the biological materials investigated, several have been produced from animal sources. These xenogenic materials, including porcine small intestinal submucosa, even when rid of cells, are prone to immunologic rejection over time.²⁵ Xenogenic acellular dermal matrix (XADM) implants also have been studied in an animal model and were shown to elicit a chronic humoral and cell-mediated immune response that resulted in poor wound healing when compared to allogenic tissue.²⁶ Recently, human acellular dermal matrix (HADM) has been used by surgeons for a number of aesthetic and reconstructive indications. Lauded initially for its ability to improve wound healing in burn patients, it has been used with great success for the repair of complex abdominal wall hernias.

HUMAN ACELLULAR DERMAL MATRIX

Human acellular dermal matrix (AlloDerm®, LifeCell, Branchburg, New Jersey) is processed from human cadaver skin obtained from AATB guideline-compliant tissue banks. To limit the possibility of disease transmission, donors are rigorously screened by social and medical history. In addition, they undergo serological testing for RPR, VDRL, HBsAg, anti-HCV 2.0, anti-HIV-1 and 2, anti-HTLV-1, and bacterial and fungal organisms. Because it is an acel-

lular product, HADM is also presumably incapable of transmitting Creutzfeldt-Jakob and other prion diseases. Furthermore, prion diseases have never been transmitted through skin; only neural tissues have been implicated in the transmission of these diseases.

Partial-thickness sheets of skin are harvested from these cadavers using a dermatome. Because a dermatome is used to harvest the skin, commercially available sheets of AlloDerm® are available in pieces currently no larger than 4 × 16 cm. For defects larger than this, surgeons must suture two or more sheets of AlloDerm® together (see Figs. 1a-c). The manufacturer of AlloDerm® uses a proprietary method to separate the epidermis from the dermis, which employs a high-ionic-strength solution to uncouple the bonds between the layers. Sodium deoxycholate is then used to remove cells from the dermis. This process eliminates the potential for graft rejection mediated by host macrophages, fibroblasts, endothelial cells, dendritic cells, and Langerhans' cells. This same step simultaneously eradicates donor major histocompatibility class I and II antigens.²⁷ The acellular dermis is then freeze-dried by a unique proprietary method, which creates an amorphous ice that retains the structural integrity of the complex microarchitecture of the dermis. During conventional freeze-drying, hexagonal ice crystals form, disrupting the normal architecture of this layer and rendering the damaged matrix susceptible to inflammation and rejection, because the hosts immune system regards the fragmented subunits as individual foreign bodies.

This three-step process ultimately yields a biomaterial containing a structurally intact basement membrane with overlying matrix. The remaining matrix contains glycosaminoglycans; intact human dermal collagen fibers and bundles of types I, III, IV, and VII; and intact elastin and laminin.^{28,29} The normal dermal architecture supports angiogenesis and host cellular migration, while the collagen and elastin provide biomechanical strength.³⁰

HADM shares many favorable characteristics with other allograft materials. Like fascial grafts, HADM develops a vascular supply, a quality that allows the

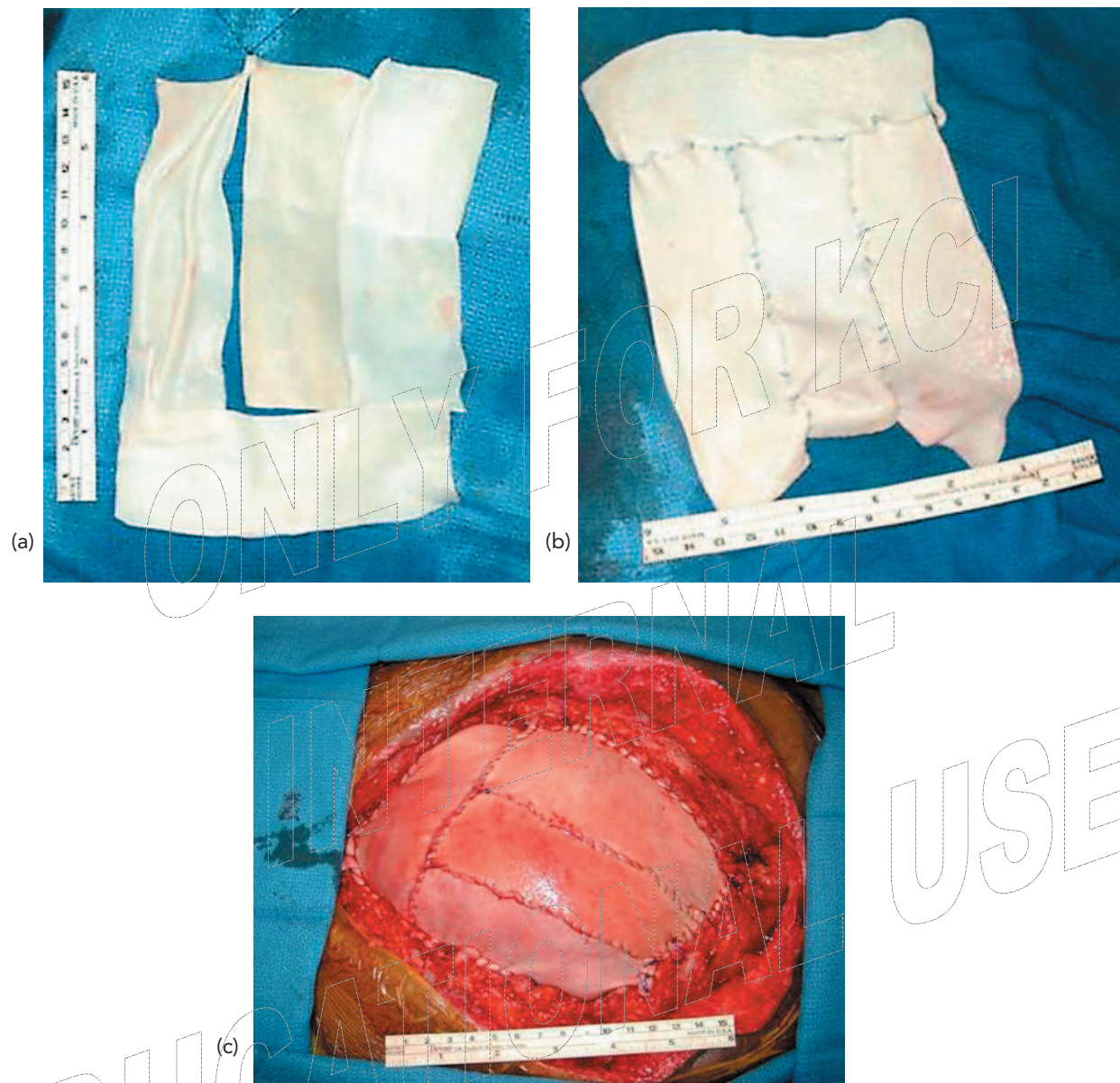


FIGURE 1. Creation of a large AlloDerm[®] patch. (a) Four 4 x 12 cm pieces of AlloDerm[®] arranged into a rectangular configuration in preparation for use as an interpositional graft. (b) AlloDerm[®] pieces sutured together with nonabsorbable suture material. (c) Customized AlloDerm[®] patch after implantation as an interpositional graft.

material to better resist infection. In addition, HADM is stronger than fascia and is as resistant to stretch and suture pull-through.^{31,32} Although HADM is an allograft material that becomes incorporated into

and invested by native tissue, it has been shown to persist after implantation. In a study of the performance of HADM as a soft-tissue filler, Costantino et al.³³ demonstrated that 80–85% of this material had

persisted after 22 months of implantation in a human patient. In contrast to autograft materials, HADM does not expose the patient to extended operative time or donor site morbidity and exists in a nearly unlimited supply.

Animal Data

Several recent animal studies have investigated the use of acellular dermal matrices for the repair of abdominal wall defects. Gamba et al.³⁴ repaired full-thickness abdominal wall defects in a rabbit model using homologous acellular dermal matrix. Specifically, this group investigated whether ADM would serve as a matrix for the incorporation of organized skeletal muscle. Histologic and EMG analysis of the tissue at several time points revealed evidence of fibroblast migration, deposition of new collagen, and neovascularization. No signs of necrosis or skeletal muscle ingrowth were seen. Evaluation by EMG demonstrated minimal muscular electrophysiologic activity, which was attributed to muscle underlying the patch.

Our group has conducted two animal series to evaluate the performance of ADM for the repair of ventral hernias. The first study, which used New Zealand White rabbits, was designed to compare the performance of human ADM to ePTFE (Micro-mesh®) implants.³⁵ In this study, all animals survived and none developed hernias. Fluorescein dye injection and histologic analysis confirmed neovascularization of all ADM implants. Visceral adhesions to the graft were found in all of the animals repaired with Micro-mesh® but in none of the animals repaired primarily or with ADM. This finding is supported by the recently published data of Butler and Prieto.³⁶ In a study designed to evaluate the ability of HADM to prevent visceral adhesions, these researchers compared polypropylene grafts to polypropylene grafts married to sheets of HADM and found that the HADM prevented adhesions.

In our study, two of the ADM patches increased in size by 1 cm in the transverse dimension. This increase

in width was found to be statistically insignificant ($p=0.17$) when compared to the change in size of the ePTFE. Tensiometry testing revealed that the mean breaking strength of the primary closure group was significantly higher than that of the two groups repaired with a patch. There was, however, no significant difference in breaking strength between the ADM/fascia interface and the porous micromesh/fascia interface. This study was able to demonstrate that ADM becomes vascularized when implanted into the abdominal wall and has mechanical effectiveness similar to ePTFE (Micro-mesh®) but without the formation of visceral adhesions.

In order to follow the encouraging results of the rabbit study, our group performed a longer follow-up study in swine.³⁷ By using porcine ADM furnished by LifeCell Corporation, we were able to conduct a 9-month evaluation of the performance of ADM for repair of ventral hernias. Use of allogenic ADM allowed us to evaluate this material without the confounding effects of a xenogenic rejection of the implants. Using a similar study design we randomized 22 Yucatan miniature pigs to two groups. After creation of 12 × 4 cm full-thickness abdominal wall defects, the pigs were repaired with either homologous ADM ($n=12$) or ePTFE ($n=10$). Animals were terminated at either 3 or 9 months. At the time of termination, the surgical sites were evaluated for the presence of hernias. The grafts were then excised and evaluated for stretching of the implant, visceral adhesions, vascularity, and biomechanical strength.

Ultimately, two hernias developed with each material. However, minimal stretching or adhesion was found in any implant. Fluorescein dye testing and histologic analysis demonstrated vascular ingrowth within all ADM grafts. Tensiometry testing revealed no statistical difference in the mean breaking strength between the ADM/fascia interface (106.5 N ±SD 40.1), the ADM/ADM interface after suture removal (149.1 N ±SD 76.7), and primary fascial repair (108.1 N ±SD 20.9) at 9 months. The ADM/fascia interface, however, was found to be significantly stronger than that of the ePTFE/fascia interface (66.1 N ±SD 30.1) ($p=0.017$).

Clinical Experience

Previous to its use in abdominal wall reconstruction, ADM was used successfully for numerous reconstructive and aesthetic applications. It was first used by Wainwright et al.³⁸ for the treatment of full thickness burns. They found that the application of ADM between a well-debrided burn surface and a split-thickness skin graft lead to less contracture, as well as improved soft tissue volume and greater durability of the skin graft. Other early applications of HADM have included its use as a soft-tissue filler in aesthetic surgery^{33,39} for the correction of periodontal disease⁴⁰ and as a dural replacement in neurosurgery.^{41,42}

More recently, HADM has been used by clinicians for repair of abdominal fascial defects. Surgeons have reported using HADM for indications such as TRAM flap donor site closure, ventral hernia repair (see Figs. 2a-e), and as a replacement for infected synthetic mesh. Operative techniques for the implantation of HADM range from interpositional grafts, onlay, sublay, and even interpositional graft material used in conjunction with the component separation technique.

Several groups have reported success with the use of HADM for abdominal wall reconstruction. Hirsch⁴³ has reported a case in which HADM was used to repair a large abdominal wall fascial defect in the setting of significant local wound sepsis. Several days after this procedure, the patient developed a wound infection. The HADM graft was left in place even after the development of a frank enterocutaneous fistula. This fistula closed after several weeks of bowel rest, TPN, octreotide, and local wound care. This patient ultimately healed and was without evidence of hernia by physical examination at 3 and 6 months. At 9 months he had a CT scan, which failed to demonstrate a hernia, and at the time of publication, the patient had returned to work without disability.

Guy et al.⁴⁴ recently published their experience with the use of HADM for early one-stage closure of fascial defects resulting from abdominal compartment syndrome. Whereas the standard method of repair for these patients has historically required three-

stage closure, Guy's group was able to repair fascial defects with HADM and provide adequate coverage with bilateral bipedicle advancement flaps. Using this technique, they were able to decrease greatly the length of hospitalization for these patients, as well as minimize the period in which patients have large and debilitating hernias while they await definitive repair. Although the patients profiled in this study were all trauma victims, several with frankly perforated viscus, complications were noted in only three of the nine patients and were limited to one flap hematoma, one recurrent hernia, and a wound infection that was cleared by drainage and local wound care. It is important that no patients developed postoperative fistulae, and no patient required explantation of the HADM implant.

In 2004, Buinewicz and Rosen⁴⁵ published a retrospective review of their clinical experience using HADM to repair TRAM flap sites ($n=18$), incisional hernias ($n=21$), and abdominal wall defects of various etiologies ($n=5$). Their series of 44 patients started with a single case in which a TRAM flap site herniated by the second postoperative week and was repaired with ePTFE. Intraoperative cultures revealed the presence of methicillin-resistant *Staphylococcus aureus* (MRSA), which persisted despite a 6-week course of Vancomycin therapy. This patient was ultimately repaired with HADM, and the surgeon elected not to reimplant synthetic graft material into the colonized site. Although the MRSA wound infection was an unforeseen complication, the incidence of TRAM flap harvest site hernias is known to be as high as 10% (Carlson, 1994). After initial success with this patient, Buinewicz and Rosen⁴⁵ abandoned the use of synthetic graft material and began to use HADM preferentially for all patients. This proclivity for the use of HADM included clinical situations ($n=8$) in which gross wound infection existed at the time of HADM implantation. Postoperative wound complications in this series included two patients with seroma, three patients with postoperative infection, and two with wound dehiscence. All of these patients were treated conservatively, and no patients graft required explantation. Furthermore, graft biopsies



FIGURE 2. 20-year old patient for whom AlloDerm[®] was used to repair a large abdominal wall defect that developed secondary to a trauma-related abdominal compartment syndrome. **(a)** Anterior view of ventral hernia covered with a skin graft. **(b)** Lateral view of ventral hernia. **(c)** Interpositional AlloDerm[®] graft repair of ventral hernia. **(d)** Anterior view of patient 2 months post-operative. **(e)** Lateral view of patient 2 months postoperative.

taken 8 months post-implantation revealed clear evidence of cellular repopulation and neovascularity and no signs of inflammation or scar formation around the HADM implant. In addition, histologic

analysis of the graft biopsies showed areas deficient in elastin. This was thought to represent an ongoing remodeling of the graft into tissue that resembled fascia histologically.

Our preliminary experience with the use of HADM for repair of abdominal wall defects consists of 49 repair sites in 46 patients. From November of 2001 to June of 2004, four surgeons in our division used HADM to repair a variety of defects. Although no absolute indications for the use of HADM have been identified, this material generally has been selected as the implant material when there is either suspicion for, or incontrovertible evidence of, infection at the defect site. In addition, HADM was employed frequently when the patient was immunocompromised and/or deemed prone to poor wound healing (see Table 1). HADM was used in a variety of techniques, including as an interpositional graft and in a variety of tension-free methods (see Table 2). Demographic characteristics of the patients in our series include

an average age of 51.8 years (range 18–71), a gender ratio of approximately two females to three males (18:28), and an average body mass index (BMI) of 32.7 (range 18.1–58.5). Of the sites repaired, 20 were initial repairs, whereas 18 sites had had one previous repair, and the remaining 11 sites had had two or more previous repairs.

Ultimately, 11.9% of the sites reherniated (mean follow-up for all patients 184 days [17–918] vs. 232 days [115–482] for patients with reherniation). Seven patients either died or were lost to follow-up. Other complications included ten wound infections, of which only two were associated with reherniation and one led to the explantation of the HADM. A second explantation was performed but was not associated with wound infection or reherniation (this

TABLE 1. Comparison of Independent Indications Cited by our Group for Implantation of HADM*

Independent indications for using AlloDerm	Repairs per indication <i>n</i> = 92*	Reherniations per indication <i>n</i> = 8*
Contaminated area		
Bowel resection	14	1
Enterocutaneous fistulae	6	0
Enterotomies	14	1
Bowel perforation	1	0
Concurrent colostomy reversal	5	0
Immunosuppression		
Diabetes Mellitus	15	0
Chronic steroid dependence	9	2
Solid-organ transplant	7	2
Unstable skin coverage	1	0
Infection		
Infected mesh	4	0
History of infected hernia site	4	1
Peristomal	8	0
Failed mesh and planned transplant	1	0
Unknown	3	1

*The number of indications and the associated number of reherniations outnumbers the total number of patients and repair sites. This relates to the fact that several patients had more than one cited indication for the use of HADM.

TABLE 2. Correlation Between Process of Reherniation and HADM Implantation Technique

Technique of hernia repair using AlloDerm	Repairs <i>n</i> = 49	Reherniations <i>n</i> = 5
Interpositional		
Interpositional AlloDerm	7	1
Interpositional AlloDerm with Vicryl onlay	4	0
Interpositional and onlay AlloDerm (2 layers of AlloDerm)	2	0
Interpositional AlloDerm and TFL graft	1	0
Onlay		
AlloDerm onlay	4	0
Underlay		
AlloDerm underlay	7	1
Component separation with		
AlloDerm onlay	18	1
AlloDerm underlay	2	0
Interpositional AlloDerm	2	0
Interpositional AlloDerm and AlloDerm onlay (2 layers)	1	1
Interpositional AlloDerm and Vicryl onlay	1	1
Interpositional Vicryl and AlloDerm onlay	1	0

patient became septic after surgery and the graft was removed empirically). Five sites had seroma, two of which required incision and drainage, two of which had one-time percutaneous aspiration, and one of which necessitated multiple percutaneous aspirations for resolution. None of the seromas were in sites that ultimately failed. One patient had an acute fascial dehiscence and was taken urgently to the operating room, where the HADM was covered with Marlex. Placement of HADM near a stoma was not associated with reherniation or wound complications.

In general, the patients who reherniated were younger (42.6 years) and less obese (BMI = 24.8). It is interesting that no patients with reherniation were diabetic, and only one was an active smoker. Of the five patients with documented reherniation, two were solid-organ transplant recipients on immune suppression regimens consisting of steroids, tacrolimus, and mycophenolate mofetil.

CONCLUSIONS

Abdominal wall defects, including incisional hernias, are a common problem faced by the reconstructive and general surgeon. Tension-free repair using synthetic materials has been shown to provide a better long-term success rate than primary fascial repair. This improved success rate- however, is tempered by complications associated with the inability to resist and clear infection. Because many hernias are thought to recur as a result of indolent bacterial contamination, the use of synthetics can be a precarious option. Unlike synthetics, autologous tissues such as fascial grafts have the advantage of developing a native blood supply, which can participate in the host's efforts to clear infection. Unfortunately, the use of autologous tissues is related to significant potential cost in the form of donor site morbidity, time of harvest, and a generally limited supply. For patients prone to infec-

tion and poor wound healing and in patients who are critically ill or metabolically taxed, the use of HADM will certainly reduce the stress currently associated with the harvest of autologous tissues.

Like autologous tissues, HADM is well tolerated by the host immune system, has the capacity to revascularize and therefore clear infection, and has mechanical properties conducive to repairing fascial defects. Animal research demonstrates that HADM fuses with native fascia and develops a connection that is stronger than the connection between fascia and synthetic materials. Both animal and human data suggest that a large percentage of implanted ADM persists over time. Finally, even in situations in which HADM does become contaminated by infection, clinical data suggest that because of its development of an endogenous vascular supply this material can be safely left in place and treated conservatively with

local wound care and antibiotics. Our research group is currently conducting animal research to assess and quantify the ability of ADM to clear contamination caused by organisms commonly associated with wound infections.

Like all promising new materials and innovations, the theoretical advantages and early encouraging results of this material need to withstand the test of time. To that end, we look forward to reporting on the long-term performance of HADM.

CONFLICT OF INTEREST STATEMENT

Drs. Silverman, Singh, and Goldberg have received honoraria from LifeCell corporation as speakers. Drs. Silverman and Goldberg have received research support from LifeCell Corporation.

REFERENCE LIST

- Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. *Br J Surg.* 1985;72(1):70-1.
- Santora TA, Roslyn JJ. Incisional hernia. *Surg Clin North Am.* 1993;73(3):557-70.
- Sugerman HJ, Kellum JM Jr, Reines HD, DeMaria EJ, Newsome HH, Lowry JW. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. *Am J Surg.* 1996;171(1):80-4.
- Luijendijk RW, Hop WC, van den Tol MP, de Lange DC, Braaksma MM, IJzermans JN, Boelhouwer RU, de Vries BC, Salu MK, Wereldsma JC, Bruijninx CM, Jeekel J. A comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med.* 2000;343(6):392-8.
- Langer S, Christiansen J. Long-term results after incisional hernia repair. *Acta Chir Scand.* 1985;151(3):217-9.
- George CD, Ellis H. The results of incisional hernia repair: a twelve year review. *Ann R Coll Surg Engl.* 1986;68(4):185-7.
- Ellis H, Gajraj H, George CD. Incisional hernias: when do they occur? *Br J Surg.* 1983;70(5):290-1.
- Paul A, Korenkov M, Peters S, Kohler L, Fischer S, Troidl H. Unacceptable results of the Mayo procedure for repair of abdominal incisional hernias. *Eur J Surg.* 1998;164(5):361-7.
- Anthony T, Bergen PC, Kim LT, Henderson M, Fahey T, Rege RV, Turnage RH. Factors affecting recurrence following incisional herniorrhaphy. *World J Surg.* 2000;24(1):95-100.
- Leber GE, Garb JL, Alexander AI, Reed WP. Long-term complications associated with prosthetic repair of incisional hernias. *Arch Surg.* 1998;133(4):378-2.
- Houck JP, Rypins EB, Sarfeh IJ, Juler GL, Shimoda KJ. Repair of incisional hernia. *Surg Gynecol Obstet.* 1989;169(5):397-9.
- Rodgers BM, Maher JW, Talbert JL. The use of preserved human dura for closure of abdominal wall and diaphragmatic defects. *Ann Surg.* 1981;193(5):606-11.
- Bauer JJ, Harris MT, Kreel I, Gelernt IM. Twelve-year experience with expanded polytetrafluoroethylene in the repair of abdominal wall defects. *Mt Sinai J Med.* 1999;66(1):20-5.

14. Trupka AW, Schweiberer L, Hallfeldt K, Waldner H. Management of large abdominal wall hernias with foreign implant materials (Gore-Tex patch) *Zentralbl Chir.* 1997;122(10):879–84.
15. Bauer JJ, Salky BA, Gelernt IM, KreeI I. Repair of large abdominal wall defects with expanded polytetrafluoroethylene (PTFE). *Ann Surg.* 1987;206(6):765–9.
16. Folkman J, Shing Y. Angiogenesis. *J Biol Chem.* 1992;267(16):10931–4.
17. Disa JJ, Klein MH, Goldberg NH. Advantages of autologous fascia versus synthetic patch abdominal reconstruction in experimental animal defects. *Plast Reconstr Surg.* 1996;97(4):801–6.
18. Disa JJ, Goldberg NH, Carlton JM, Robertson BC, Slezak S. Restoring abdominal wall integrity in contaminated tissue-deficient wounds using autologous fascia grafts. *Plast Reconstr Surg.* 1998;101(4):979–86.
19. Bostwick J 3rd, Hill HL, Nahai F. Repairs in the lower abdomen, groin, or perineum with myocutaneous or omental flaps. *Plast Reconstr Surg.* 1979;63(2):186–94.
20. Brown RG, Vasconez LO, Jurkiewicz MJ. Transverse abdominal flaps and the deep epigastric arcade. *Plast Reconstr Surg.* 1975;55(4):416–21.
21. Houston GC, Drew GS, Vazquez B, Given KS. The extended latissimus dorsi flap in repair of anterior abdominal wall defects. *Plast Reconstr Surg.* 1988;81(6):917–24.
22. Caffee HH. Reconstruction of the abdominal wall by variations of the tensor fasciae latae flap. *Plast Reconstr Surg.* 1983;71(3):348–53.
23. Hein KD, Morris DJ, Goldwyn RM, Kolker A. Dermal autografts for fascial repair after TRAM flap harvest. *Plast Reconstr Surg.* 1998;102(7):2287–92.
24. Ramirez OM, Ruas E, Dellon AL. “Components separation” method for closure of abdominal-wall defects: an anatomic and clinical study. *Plast Reconstr Surg.* 1990;86(3):519–26.
25. Franklin ME Jr, Gonzalez JJ Jr, Michaelson RP, Glass JL, Chock DA. Preliminary experience with new bioactive prosthetic material for repair of hernias in infected fields. *Hernia.* 2002;6(4):171–4.
26. DeSagun EZ, Botts JL, Srivastava A, Hanumadass M, Walter RJ. Long-term outcome of xenogenic dermal matrix implantation in immunocompetent rats. *J Surg Res.* 2001;96(1):96–106.
27. Wainwright D, Madden M, Luterma n A, Hunt J, Monaf o W, Heimbach D, Kagan R, Sittig K, Dimick A, Herndon D. Clinical evaluation of an acellular allograft dermal matrix in full-thickness burns. *J Burn Care Rehabil.* 1996;17(2):124–36.
28. Eppley BL. Experimental assessment of the revascularization of acellular human dermis for soft-tissue augmentation. *Plast Reconstr Surg.* 2001;107(3):757–62.
29. Adhikary S, Beniker HD, Garfield J, Griffey ES, Harper JA, Livesey SA, McQuillan DJ, Ott D, Owens RT. Biochemical and ultrastructural characterization of an acellular extracellular matrix scaffold (AlloDerm® and Cymetra™): utility in tissue regeneration and potential for gene delivery. *American Society for Matrix Biology.* 2002.
30. Livesey SA, Herndon DN, Hollyoak MA, Atkinson YH, Nag A. Transplanted acellular allograft dermal matrix. Potential as a template for the reconstruction of viable dermis. *Transplantation.* 1995;60(1):1–9.
31. Choe JM, Kothandapani R, James L, Bowling D. Autologous, cadaveric, and synthetic materials used in sling surgery: comparative biomechanical analysis. *Urology.* 2001;58(3):482–6.
32. Silverman RP, Singh NK, Li EN, Disa JJ, Giroto JA, Slezak S, Goldberg NH. Restoring abdominal wall integrity in contaminated tissue-deficient wounds using autologous fascia grafts. *Plast Reconstr Surg.* 2004;113(2):673–5.
33. Costantino PD, Govindaraj S, Hiltzik DH, Buchbinder D, Urken ML. Acellular dermis for facial soft tissue augmentation: preliminary report. *Arch Facial Plast Surg.* 2001;3(1):38–43.
34. Gamba PG, Conconi MT, Lo Piccolo R, Zara G, Spinazzi R, Parnigotto PP. Experimental abdominal wall defect repaired with acellular matrix. *Pediatr Surg Int.* 2002;18(5–6):327–31.
35. Menon NG, Rodriguez ED, Byrnes CK, Giroto JA, Goldberg NH, Silverman RP. Revascularization of human acellular dermis in full-thickness abdominal wall reconstruction in the rabbit model. *Ann Plast Surg.* 2003;50(5):523–7.
36. Butler CE, Prieto VG. Reduction of adhesions with composite AlloDerm/polypropylene mesh implants

- for abdominal wall reconstruction. *Plast Reconstr Surg.* 2004;114(2):464-43.
37. Silverman RP, Li EN, Holton LH 3rd, Sawan KT, Goldberg NH. Ventral hernia repair using allogenic acellular dermal matrix in a swine model. *Hernia.* 2004 (in press).
38. Wainwright DJ. Use of an acellular allograft dermal matrix (AlloDerm) in the management of full-thickness burns. *Burns.* 1995;21(4):243-8.
39. Jones FR, Schwartz BM, Silverstein P. Use of a nonimmunogenic acellular dermal allograft for soft-tissue augmentation. *Aesthetic Surg Q.* 1996;16:196-201.
40. Silverstein LH, Duarte CF. Use of an acellular dermal allograft for soft-tissue augmentation. *Dent Implantol Update.* 1998;9(8):61-4.
41. Chaplin JM, Costantino PD, Wolpoe ME, Bederson JB, Griffey ES, Zhang WX. Use of an acellular dermal allograft for dural replacement: an experimental study. *Neurosurgery.* 1999;45(2):320-7.
42. Costantino PD, Wolpoe ME, Govindaraj S, Chaplin JM, Sen C, Cohen M, Gnoy A. Human dural replacement with acellular dermis: clinical results and a review of the literature. *Head Neck.* 2000;22(8):765-71.
43. Hirsch EF. Repair of an abdominal wall defect after a salvage laparotomy for sepsis. *J Am Coll Surg.* 2004;198(2):324-8.
44. Guy JS, Miller R, Morris JA Jr, Diaz J, May A. Early one-stage closure in patients with abdominal compartment syndrome: fascial replacement with human acellular dermis and bipedicle flaps. *Am Surg.* 2003;69(12):1025-8.
45. Buinewicz B, Rosen B. Acellular cadaveric dermis (AlloDerm): a new alternative for abdominal hernia repair. *Ann Plast Surg.* 2004;52(2):188-94.

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