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Acellular Dermal Matrix in Abdominal Wall Reconstruction

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Abstract
Abdominal wall reconstruction is a complex and challenging surgical undertaking. While permanent prosthetic mesh is considered the gold standard for minimizing hernia recurrence, placement of synthetic mesh is sometimes imprudent due to contamination or risk of infection. Acellular dermal matrices (ADM) offer an exciting biologic alternative. This article provides a historical perspective on the evolution of complex ventral hernia repair leading up to and including the placement of ADM, an explanation of the biology of ADM as it relates to ventral hernia repair, and a description of the current indications, techniques, benefits, and shortcomings of its use in the abdominal wall.

Keywords
hernia, abdominal wall reconstruction, AlloDerm, Strattice, Permacol, acellular dermal matrix, ADM, component separation, open abdomen

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It has clearly been established through prospective, randomized, controlled data that the placement of synthetic mesh is superior to primary ventral hernia repair alone.¹ This concept has generally been adopted by surgeons. Unfortunately, there are many circumstances in which synthetic mesh is either absolutely contraindicated (such as in the setting of active infection) or suboptimal (such as in cases where contamination is a concern or where the risk for infection is higher). For these patients, surgeons require an alternative to synthetic mesh, and acellular dermal matrices (ADM) are increasingly playing this role.

The historical alternative to synthetic materials in abdominal wall reconstruction is autologous tissue. Tissue expansion remains a viable option but is seldom utilized due to the need for multiple surgeries, the inconvenient process of tissue expansion, and the risk for extrusion/infection of the expanders themselves. Pedicled flaps (including the tensor fascia lata flap and the rectus femoris flap) have certainly been described in the literature but are limited by their arc of rotation and their donor site morbidity.² Microvascular free tissue transfer is also possible but remains fairly limited in frequency due to the technical complexity of the operation as well as donor site morbidity.³ Disa et al popularized free fascia lata grafts for abdominal wall reconstruction by showing that these grafts obtain a blood supply when placed as a free graft in the abdominal wall and can successfully repair a defect even in the setting of bacterial contamination.⁴ Although fascia lata grafts are technically much easier and faster to perform than flap reconstructions, they still have the problem of limited size and donor site morbidity. In light of these challenges, the ideal material would be something “off the shelf” that could become fully revascularized (and thereby able to resist infection) without donor site morbidity.

Human ADM (AlloDerm, LifeCell Corporation, Branchburg, New Jersey) is well known to surgeons from its successful use in burns as well as for soft tissue replacement in the head and neck. AlloDerm is processed in a way that does not damage or alter the structural architecture of the dermal matrix, and this process allows the material to be readily accepted by the body without an immunological or significant foreign body response, readily supporting cellular repopulation and revascularization. Animal studies have confirmed AlloDerm’s ability to rapidly revascularize (specifically in the abdominal wall) and

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also demonstrated its ability to resist visceral adhesions. A longer-term, larger porcine study also showed that this allogenic ADM persisted and functioned well for reconstructing large fascial defects over a nine-month period.

By the mid-2000s, many surgeons began placing AlloDerm for ventral hernia repair in cases in which synthetic mesh was contraindicated, and several clinical series were published with excellent results. The series with the longest follow-up was recently presented at the Hernia Update 2008 conference by Vargo. This series consisted of 100 patients undergoing complex ventral hernia repair with AlloDerm, with a mean follow-up of two years. Vargo’s data showed a 17% recurrence rate, which is certainly acceptable in this complex group of patients.

PATIENT GRADING FOR ABDOMINAL WALL RECONSTRUCTION

Based on the published and presented studies, it became quite standard for surgeons in the United States to place AlloDerm for abdominal wall reconstruction in cases where bacterial contamination was clearly present. As these most difficult of cases began to show lasting results, surgeons began to consider whether biologic materials should be utilized in other, less severe cases. A scale was recently published categorizing patients who require ventral hernia repair into four grades based on their risk for infection (Table 1).

<table>
<thead>
<tr>
<th>Grade I (Low Risk)</th>
<th>Grade II (Co-Morbid)</th>
<th>Grade III (Potentially Contaminated)</th>
<th>Grade IV (Infected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low risk of complications</td>
<td>Smoker</td>
<td>Previous wound infection</td>
<td>Infected mesh</td>
</tr>
<tr>
<td>No history of wound infection</td>
<td>Obese</td>
<td>Stoma present</td>
<td>Septic dehiscence</td>
</tr>
<tr>
<td></td>
<td>Diabetic</td>
<td>Violation of the gastrointestinal tract</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Immunosuppressed</td>
<td>COPD</td>
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</tbody>
</table>


who are undergoing emergency hernia repair in the setting of peritonitis.

Clearly, for Grade 3 and 4 patients, synthetic mesh is contraindicated, and most surgeons agree that a biologic material should be placed in those patients. Grade 1 patients are generally treated with synthetic mesh unless there are specific issues such as a concern about mesh palpability or the likelihood for a repeat laparotomy in the future. (Repeat laparotomy in the setting of synthetic mesh is associated with a significantly higher rate of bowel injury.) Grade 2 is the most controversial category of patients because they are not infected at the time of the surgery but have a higher risk for infection based on their comorbidities. Surgeons should consider biologic materials in these patients, keeping in mind their specific circumstances and comorbidities. Personally speaking, it has generally become my practice to place biologic materials in Grade 2 patients. To that end, our group has presented retrospective data on a specific subset of Grade 2 cases: immune-suppressed transplant patients. Our data showed a significantly higher rate of mesh explantation and hernia repair failure in the synthetic mesh group compared to the group that received ADM.

ELASTICITY OF BIOLOGIC MATERIALS

The most common biologic material for abdominal wall reconstruction, until very recently, was AlloDerm. As more surgeons began placing the material, certain ease of use issues were noted, most notably with regard to the material’s natural elasticity. This elasticity, which is a normal quality of human dermis, remains beneficial in certain applications (such as breast reconstruction) but was less desirable in the abdominal wall. In particular, surgeons expressed concern about the risk of bulging or laxity of the abdominal wall when bridging large fascial defects. This issue of bulging was managed by many experienced surgeons with specific surgical techniques for minimizing the fascial defects and appropriately setting the tension on the AlloDerm at the time of inset by removing all of the elasticity under physiological tension. Nevertheless, it was
important to find a more permanent and reliable solution to this problem, and a porcine ADM (Strattice, LifeCell Corporation) was developed as a result. Strattice is also processed to minimize damage to the extracellular matrix, thereby preserving normal dermal architecture, but it is less elastic than AlloDerm by virtue of the denser collagen matrix and lower elastin content in the porcine donor tissue. This quality allows for a technically-easier inset. Although care must still be taken to place the material under physiological tension to avoid bulging, this is much easier and more predictable with Strattice.

It should be noted that Strattice was extensively studied in a primate abdominal wall model to be certain that it did not elicit a xenogeneic immunological response. The polysaccharide that is responsible for xenogeneic immunological rejection (galactose-alpha-1,3-galactose (alphaGal)) is enzymatically cleaved during processing. Humans have preformed antibodies to the alphaGal, but after the processing, neither humoral nor cellular immune responses were detectable in the primate model with six-month follow-up.22 Revascularization, cellular repopulation, and resistance to adhesions were also noted in the primate study.

At the time this article was prepared, a multicenter, prospective clinical trial was also underway studying the long-term outcomes of 80 patients with ventral hernias in the setting of infected, contaminated, or clean-contaminated operative fields. This is a very complex group of patients in whom synthetic mesh is generally contraindicated. The 12-month data were presented with excellent results.18 At 12 months, none of the patients required explantation of the Strattice despite the contaminated nature of the wounds. One patient required a small amount of surface debridement for a piece of Strattice that had become exposed. The recurrence rate at this early time point was 18.8%; again, this is a reasonable rate considering the complicated nature of treating this contaminated group of patients. One might expect, there was a high rate of surgical site infections (28%) and a 5% rate of clinically-relevant seromas. These complications are not unexpected in this group of patients and make the fact that there were no explantations even more remarkable. Now, Strattice has superseded AlloDerm as the most commonly-used biologic material for abdominal wall reconstruction, and it is the material of choice in my own practice.

It should be noted that there are over a dozen biologic materials on the market. The vast majority of the products have very little in the way of supportive peer-reviewed studies. It is important that surgeons not assume how a given material will behave; rather, clinical decisions must be based on the best-available published data. Many materials have been shown to elicit an inflammatory response and ultimately are broken down and resorbed, while other materials have been shown to resist revascularization and simply become encapsulated like a foreign body.19-23 It is important to understand each material’s manufacturing process and, when dealing with animal-derived products, the immunological implications. The best-available comparative data to date are from a six-month primate abdominal wall resection model. Three available porcine-derived formulas (Permacol [Covidien, Dublin, Ireland], Surgisis [Cook Medical Inc., Bloomington, Indiana], and Strattice) were studied. The Surgisis group was characterized by an immediate inflammatory response and eventual scar formation and contraction. The Permacol group did not demonstrate vascular ingrowth or cellular repopulation even at six months, presumably due to its cross-linked collagen bundles. The Strattice group did demonstrate early vascular ingrowth without a significant inflammatory or immunological response.19,22,23

**OPERATIVE TECHNIQUE**

It is important to recognize that the abdominal wall is a complex functional motor unit involved in many important functions such as maintaining good posture, rotation and flexion/extension of the trunk, ventilation, coughing, urination and defecation, emesis, and childbirth. It is therefore important to restore the abdominal wall muscularity to its normal position when repairing an abdominal wall defect such as a ventral hernia.

**Component Separation**

The component separation technique (which takes advantage of the redundant myofascial layers lateral to the rectus abdominis muscles) allows medial advancement of the rectus abdominis muscles toward the midline and, in the vast majority of cases, allows for reapproximation of the two rectus muscles in the midline. The first step involves incising the external oblique fascial layer just lateral to the rectus abdominis. This maneuver alone often allows for up to 8 cm of rectus advancement on each side. If that is inadequate, undermining in the plane between the external and internal oblique fascial layers (as well as lifting the rectus abdominis muscle off its posterior rectus sheath) can provide an additional 2 to 3 cm of advancement on each side. This repair alone, however, is essentially nothing more than a primary suture repair of the ventral hernia, which has been associated with unacceptably-high recurrence rates.1,24 Therefore, many surgeons have advocated for additional reinforcement at the time of component separation repair.

There is some evidence to support the efficacy of biologic reinforcement in separation repairs.25 Surgeons have described placing this additional support as either an underlay deep to the rectus abdominis muscles (either in the retrorectus or intraperitoneal position) or as an onlay superficial to the rectus abdominis muscles.6,26 Clearly, if the rectus abdominis muscles cannot be reapproximated in the midline without undue tension, an onlay is inappropriate, and a bridging underlay technique should be utilized. The underlay should be placed at least 3 to 5 cm back from the fascial edge but ideally should proceed all the way to the lateral edge of the rectus abdominis muscle (Figure 1). When the muscles can be reapproximated in
the midline, my preferred technique is to reinforce the repair with a Strattice onlay placed anterior to the fascia, spanning from the lateral, cut edge of the released external oblique fascia across the midline to the other lateral, cut edge of the external oblique fascia. The material should be placed under some tension in order to off-load the tension on the midline primary repair. It is important to place multiple quilting sutures though the Strattice and down to the anterior rectus sheath so as to obliterate the dead space in this plane but also to widely distribute the tension on the abdominal wall (Figures 2-4).

This technique has the added benefit of reconstructing the site where the external oblique muscle has been divided, reinforcing that area of relative weakness as well as refunctonalizing the external oblique motor unit. Our group recently presented a series of 60 consecutive patients who were treated with this technique (component separation with Strattice onlay), showing a 7% recurrence rate with one-year follow-up.26 There are many excellent surgeons who have described placing the reinforcing material deep to the rectus muscles, even in cases where the muscles can be reapproximated. A study directly comparing the underlay and overlay positioning of the reinforcing material has not been performed to date. Both procedures remain a viable option, so the selection is made according to the individual surgeon’s preference.

**Trauma Patients**

The trauma patient with an open abdomen requires a separate discussion. There is an increasing number of trauma patients who have had their abdominal cavity opened either due to a damage-control laparotomy or concerns over abdominal compartment syndrome. In the past, these patients were left open until adequate granulation tissue formed over the bowel, at which time a skin graft would be placed. Ultimately, the patients were brought back into the operating room approximately a year later. The skin graft would then be removed, and the fascial defect was repaired in some way, often with a synthetic mesh, which required that the skin be advanced over the top of the mesh.27 This historical technique was an important life-saving advancement when it was described. However, in light of the technological advancements associated with ADM, there is a growing shift in the treatment of these difficult patients. It is now recommended that an early definitive closure of the fascia be performed, ideally within the first 10 days after trauma. With each return trip to the operating room for a wash out or exploration (or even for an unrelated procedure), an attempt should be made to gradually close the fascial defect. These attempts may be as minor as placing a single stitch at the superior and inferior aspects of the fascia, or they may mean completely closing the fascia. Negative pressure therapy should be instituted during this time to help reduce edema, control wound exudates, and maintain the abdominal domain while encouraging abdominal fascial closure.28 It is important to protect the bowel from direct contact with the foam from the negative pressure therapy, and it is also important to direct the negative pressure therapy deep into the paracolic gutters in order to prevent pooling of the exudate and provide the benefits of the negative pressure as deep into the abdomen as possible. For these reasons, I utilize the Abthera open-abdomen negative pressure system (KCI, San Antonio, Texas), which has a built-in protective layer over the foam and allows easy placement of negative pressure deep into the paracolic gutters.

Once the open abdomen is the only issue keeping the patient in the intensive care unit (ICU), the fascia should be definitively closed. If the fascia cannot be closed primarily, then the defect should be bridged with ADM.28 The skin can then generally be advanced over the top of the material easily, with some undermining in the subcutaneous plane over drains. Having a closed wound improves the overall condition of the patient, often quite dramatically. Fluid, heat, and protein loss are significantly reduced, and ambulation becomes much easier. This shift in the treatment algorithm allows beds in the ICU to be available for more acute patients and allows patients to return home more quickly.29 Furthermore, patients do not
need to wait for definitive hernia repair, and they therefore avoid the inevitable loss of domain that occurs over time with an unrepaired hernia.

In those rare circumstances where it is impossible to advance the skin over the ADM, or in situations where the skin suture line separates due to wound breakdown or infection, it is important to appropriately manage the exposed material. Strattice is able to tolerate exposure, even prior to being vascularized, provided it does not become overwhelmed with bacteria or desiccated. In order to protect the exposed Strattice, I generally recommend placing a nonadherent, porous dressing directly on it, followed by a VAC foam (either standard black Granufoam or Granufoam Silver if available; KCI). I continue the VAC therapy until there is confluent granulation tissue, at which time I place a skin graft. Alternatively, a delayed primary closure can be performed over drains, provided there is adequate skin and the wound is clean enough.

CONCLUSIONS

Placement of ADM materials during abdominal wall reconstructions has resulted in a major advancement in the care of these often-challenging patients. The algorithm shift that has taken place very rapidly over the past decade has resulted in lower morbidity for patients in terms of flap donor sites and synthetic mesh complications as well as a reduction of multistaged repairs.

Disclosures

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REFERENCES


