Surgical Literature Compendium

Review of Clinical and Pre-Clinical Research
ACell’s proprietary core technology – MatriStem UBM™ (Urinary Bladder Matrix) is an extracellular matrix (ECM) derived from porcine urinary bladder and differentiated from other ECM products by its intact acellular epithelial basement membrane. MatriStem UBM technology is the only commercially available form of UBM, and is utilized in the manufacturing of the Gentrix® Surgical Matrix portfolio and devices.

UBM has been found to facilitate remodeling of biomechanically functional, site-appropriate tissue. As a result, ACell’s surgical devices are often used in complex cases. UBM has a considerable breadth of research supporting its unique biologic characteristics, as well as its value in clinical settings. The extensive body of research includes more than 100 pre-clinical and 50 clinical peer-reviewed articles. Several of the most relevant publications in the area of surgical soft tissue reinforcement are summarized in this compendium. A more extensive list of articles about UBM can be found at www.acell.com/publications.

Thomas W. Gilbert, Ph.D.*
Chief Science Officer

The publications presented in this compendium contain the opinions of and personal techniques practiced by the treating physician(s). The techniques presented herein are for informational purposes only. The decision of which techniques to use in a particular clinical application lies with the treating physician(s) based on patient profile, particular circumstances surrounding the procedure, and previous clinical experiences.

Cases presented involving Veterans Administration facilities or physicians do not reflect the opinion of the United States military or Veterans Affairs office.

Note: MatriStem® Surgical Matrix has been rebranded as Gentrix® Surgical Matrix.

The authors of certain publications presented in this compendium may make claims that are not made by ACell or its representatives. In these publications, the underlying use of the ACell surgical devices falls within the current indications for use of these devices, and therefore these publications are summarized within this compendium.

† Consultant | ‡ ACell Sponsored Research Agreement | * ACell Employee


This retrospective study assessed the long-term outcomes of complex ventral incisional hernia repair using UBM graft reinforcement in patients at a single center over a five year period.

A total of 64 patients were identified that had undergone complex ventral incisional hernia repairs that were reinforced with a UBM graft (Gentrix Surgical Matrix Thick). All of the patients were classified as either moderate or severe cases according to the patient severity classification published by Slater et al. Approximately 59% of the patients had a previously failed repair and 66% had concomitant procedures including bowel resection, evacuation of infection, cholecystectomy, or panniculectomy. The average BMI was 33 and 25% of patients had an existing stoma present.

The average time to follow up was 36 months (12-70 months). A total of nine patients required surgical repair in the cohort while a tenth patient had the recurrence managed non-surgically (15.6% recurrence rate). Median time to recurrence was 32 months. A Kaplan-Meier estimate of the data predicted a 4% recurrence rate at 24 months. The rate of seroma was 19%. There were no signs of graft infection, fistulization, or any need for graft explantation. Forty-five patients completed a Carolina Comfort Scale survey to assess quality of life after repair of their hernia with Gentrix reinforcement, with a median score of 16 out of a possible 115.

In 28 patients, abdominal ultrasound or CT scan revealed an intact fascia of the abdominal wall at least 24 months post-surgery. In three patients, biopsies of the repaired fascia (retrorectus and intraperitoneal Gentrix placement) were histologically analyzed. In all cases, a remodeling response characterized by cell infiltration and absence of inflammatory response was observed.

The use of Gentrix reinforcement following complex ventral incisional hernia repair showed successful long-term outcomes, with a low recurrence rate and limited complications. Uniquely, this study also included histological analysis at extended time points, highlighting the positive host response and site-appropriate remodeling of Gentrix devices.

Figure 1: H&E stains at 14 months post-retrorectus Gentrix placement (patient 1), at three years post-intraperitoneal repair with Gentrix (patient 2) and at 32 months post-retrorectus Gentrix repair showed incorporation of the graft and a remodeling response at the interface between the host and the graft.

The aim of this retrospective study was to evaluate the safety and effectiveness of laparoscopic hiatal hernia repair (LHHR) with porcine UBM reinforcement.

The study included 62 patients who had LHHR reinforced with a UBM graft (Gentrix Surgical Matrix) over a five year period at a single center. Seventeen of these patients (27%) also had a concomitant bariatric procedure (Roux-en-Y gastric bypass, sleeve gastrectomy, or anastomosis revision). After a minimum of three months post-surgery, patients completed an upper GI series to evaluate for recurrences of hernia, intra- and post-operative complications, pre- and post-operative gastroesophageal reflux (GERD) or dysphagia, and cessation of proton pump inhibitor (PPI) use.

There were no intra-operative complications noted from the use of Gentrix in reinforcement of LHHR. Incidence of GERD with PPI use was reduced from 98% of patients pre-operatively to only 16% post-operatively. Three patients (4.8%) did develop dysphagia post-operatively, which was successfully resolved with endoscopic balloon dilation without the need for reoperative intervention. Radiographic recurrence was identified in nine patients, however, only one became symptomatic and required revision at 22 months post-operatively.

The use of Gentrix as reinforcement following LHHR was shown to be effective and safe in this study. Patients experienced a dramatic improvement in GERD symptoms post-operatively with limited complications. This study supports the use of Gentrix devices in laparoscopic procedures and highlights the reduced risk of complications in a challenging intraperitoneal anatomy.


The goal of this retrospective study was to evaluate the short-term outcomes of using UBM as reinforcement following paraesophageal hiatal hernia repairs.

All patients from a single center that underwent hiatal hernia repairs over a period of five years were evaluated. Excluding patients undergoing concomitant bariatric procedures, a total of 56 patients had hernia repairs reinforced with a UBM graft (Gentrix Surgical Matrix or Gentrix Surgical Matrix Plus) whereas another 65 patients were treated with a primary repair (without any device reinforcement). All procedures were performed either laparoscopically or robotically. Post-operative complications in patients that received Gentrix reinforcement versus patients treated with primary repair only were classified according to the Clavien-Dindo grading system

Patient demographics were similar between the two cohorts, with the exception of age which was significantly higher in the Gentrix group. The length of stay of patients at the hospital and the 30-day readmission rate were not significantly different between patients with or without Gentrix reinforcement. The rate of post-operative complications was also similar between Gentrix-reinforced and non-reinforced (suture only) patients.

This study highlighted the safe use of Gentrix devices in laparoscopic and robotic repairs of paraesophageal hiatal hernias. While limited by the retrospective nature and limited follow up time in this study, these results show that utilizing Gentrix devices to reinforce hiatal hernia repairs did not increase the risk of complications in a sensitive anatomy.

The goal of this retrospective study was to compare two modalities of paraesophageal hernia (PEH) repair; primary suture repair and Gentrix Surgical Matrix.

The study covered patients who underwent PEH repair over a five year period. The study included patients with types II, III, and IV PEH with any type of repair. 65 patients out of 120 that met the inclusion criteria agreed to participate in this study. Patients were divided into 32 cases were reinforced with Gentrix devices and 33 cases that were not reinforced (suture only). The patients in the Gentrix group were more likely to have a history of recurrent hernias. The Gentrix devices were cut in a U-shape pattern to fit the area of repair.

While recurrence of PEH occurred in 20 patients, and was distributed equally between both groups, the primary operating surgeon attributed the recurrence in the Gentrix group to the placement of the graft and lack of reinforcement on the anterior aspect of the repair. The severity of symptoms in patients with or without recurrence was similar in the Gentrix group whereas the severity of symptoms in the control group was significantly higher in the recurrent patients versus non-recurrent patients.

In both groups, the rate of short-term post-operative complications was low. The quality of life of patients measured by SF-36 instrument and the severity of symptoms measured by the GERD-HRQL questionnaire showed no significant differences between both groups.

This study demonstrated the safety of using Gentrix in PEH repair. Gentrix reinforcement did not cause any increased complications or recurrence rate. Gentrix was associated with decreased symptom severity as compared to a non-reinforced control group.

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In this retrospective case series, the authors described 15 cases involving hiatal hernia repair with primary crural repair, which were reinforced with urinary bladder matrix (UBM) using Gentrix® Surgical Matrix Thin 10 cm x 15 cm and subsequent fundoplication. Hernia diameters averaged 6 cm. Patients were followed for an average of three years (24-56 months) and were assessed with upper gastrointestinal (GI) series, endoscopy, and assessments of subjective symptoms of gastroesophageal reflux disease (GERD).

This series reported no evidence of erosion, infection, or recurrence at a minimum of 24 month follow-up. One patient presented with post-operative stenosis unrelated to the graft which resolved following endoscopic dilation. At 24-56 months follow-up, the 15 patients had little reflux symptomology as evidenced by GERD-HRQL scores ranging from 0-12 (4 patients reported scores of 0) with a median score of 6 (range of scoring instrument is 0-50).

The authors noted that the handling properties of the Gentrix Surgical Matrix Thin device were favorable, including ease of insertion via a 12-mm trocar, maneuvering into position, and suturing to the crura. It was concluded that UBM material is potentially advantageous in the reinforcement of large hiatal hernias.

The study is a single-surgeon retrospective review of eleven patients who underwent laparoscopic repair of large hiatal hernia in a rural community hospital using a standardized laparoscopic technique. Six patients had the reinforcement of the crura with AlloMax™ (Bard Davol), one patient with Permacol™ (Covidien-Medtronic), and four patients with Gentrix Surgical Matrix. The author notes that all products were easy to work with, however Gentrix demonstrated “higher pliability.”

It was also noted that the Gentrix Surgical Matrix devices were secured with absorbable tacks, which were less traumatic than the titanium tacks required for use with the other grafts.


In this retrospective case series, the authors presented eight cases of parastomal hernia reinforcement with Gentrix Surgical Matrix grafts. Patients were followed for an average of 23 months.

Three of the cases were performed laparoscopically, with intraperitoneal placement of a keyhole-shaped Gentrix device. Five cases were performed through open laparotomy: one case utilized component separation and placement of the Gentrix Surgical Matrix device in the retrorectus plane; one repair utilized primary fascial closure reinforced with Gentrix Surgical Matrix Thick; and in the remaining three cases, the Gentrix Surgical Matrix device was placed in the intraperitoneal position.

All repairs were deemed successful, with only one late stricture requiring surgical revision six months post-op. At a median 23 months of follow up, all patients showed intact repairs.


This retrospective study conducted at Memorial Sloan Kettering Cancer Center compared the incidence of esophagojejunal junction (EJ) anastomotic leaks and strictures in total gastrectomy (TG) patients whose anastomoses were reinforced, Gentrix Surgical Matrix Thin, versus consecutive control patients identified from a historical database of TG surgeries at the sponsoring center who had primary EJ anastomoses without ECM reinforcement.

EJ anastomotic leaks occurred in 3% (1/37) of Gentrix patients as compared to 12% (4/33) in the control patients. Strictures occurred in 8% (n = 3) of Gentrix patients as compared to 15% (n = 5) of control patients. The authors concluded that use of Gentrix Surgical Matrix Thin may be helpful in reducing the incidence of these complications following TG.
Clinical Research


This published case study reviews the treatment of a 53-year-old female with a large type IV hiatal hernia with the stomach and colon herniated into the chest measuring 9 cm x 6 cm. Following hernia reduction and closure of the hiatal defect, a Gentrix Surgical Matrix device was used to reinforce the diaphragmatic crura. The author notes the Gentrix device was “easy to work with and had great pliability.” The patient showed no recurrence at 24 months post-op.

Pre-Clinical Research


The aim of this pre-clinical study was to evaluate the host response and mechanical performance of two extracellular matrix-derived materials in a sheep model of fascial repair.

Bilateral 4 cm x 4 cm defects were created in the fascia lata on both sides of the sheep. One side was repaired with a UBM device (Gentrix Surgical Matrix Plus) and the contralateral side was repaired with an acellular dermal matrix (ADM) device (Strattice® Firm, LifeCell Inc., NJ, USA). Animals were sacrificed at one month (n=3) and three months (n=4). An additional animal that underwent the defect without repair was sacrificed at three months and served as control.

As early as one month post-implantation, Gentrix had been partially remodeled and was nearly indistinguishable from the surrounding fascia. At the three month time point, Gentrix devices were completely remodeled and replaced with an organized, vascularized tissue that resembled native fascia. However, at three months, ADM devices were still readily identified with a clear boundary between the edge of the device and the surrounding fascial tissue. Histologically, there was limited cell infiltration into the device and negligible vascularization in the ADM group (see Figure 2).

The strength of UBM devices was similar to native fascia pre-operatively. As the device facilitated remodeling, the strength of the repair site increased until it was significantly higher than native fascia at three months post-op. In contrast, the strength of ADM devices was significantly higher than Gentrix and native fascia pre-implantation, but steadily decreased throughout the study. By three months, there was no difference in the strength between Gentrix and ADM devices. Gentrix devices showed comparable stiffness to native fascia throughout the study, however, ADM devices had increased stiffness at one month but then returned to baseline at three months.

The results of this study showed that despite initial strength differences between Gentrix and ADM, both materials resulted in similar mechanical performance at three months. However, at three months Gentrix devices were completely remodeled into site-appropriate tissue and maintained strength similar to native fascia. In contrast, ADM showed a foreign body response, with diminishing structural properties and limited tissue incorporation.

This pre-clinical study evaluated the mechanical and tissue remodeling characteristics of the abdominal wall following reinforcement with UBM in a large animal ventral hernia model.

An acute midline abdominal defect model was utilized in adult female Yucatan minipigs with a classic Rives-Stoppa-Wantz retromuscular approach to simulate a hernia repair. The repairs were reinforced with either Gentrix Surgical Matrix Plus or Gentrix Surgical Matrix Thick, or left as a primary suture repair control without reinforcement. Animals were then recovered and survived for time points of 3 or 8 months, with four animals per treatment group per time point.

Eight months post-op, animals reinforced with UBM-derived surgical devices showed remodeling of site-appropriate, biomechanically functional tissue at the defect site. Reinforcement of ventral incisional hernias with UBM-derived surgical devices prevented hernia recurrence throughout the course of observation, compared with 50% recurrence in non-reinforced controls. Furthermore, all UBM devices showed full remodeling at 8 months, evidenced by the deposition of vascularized tissue mimicking that of natural, uninjured posterior fascia. This resulted in the strength of the UBM-reinforced abdominal wall being similar to that of uninjured tissue, suggesting that it was the healthy, remodeled host tissue – not the reinforcement device – that was supporting the mechanical load of the abdominal wall.

Study results provide evidence that Gentrix Surgical Matrix devices are capable of reinforcing ventral hernia repairs by facilitating site-appropriate tissue remodeling of biomechanically functional tissue that corresponds with the mechanical strength of the abdominal wall pre-injury.


This study detailed the use of several forms of Urinary Bladder Matrix as a reinforcement graft for abdominal wall repair in a rodent model. One hundred and thirty rats were implanted with 6-layer UBM devices, either: commercially available Gentrix Surgical Matrix (manufactured by ACell), a chemically cross-linked version of the Gentrix graft, laboratory-prepared non-cross-linked UBM devices, laboratory-prepared crosslinked UBM devices, or laboratory-prepared 14C-proline labeled UBM devices. Grafts were explanted at 7, 14, 21, 90, and 180 days post-implantation and analyzed for strength and cell infiltration.

In all subgroups, the UBM biologic meshes were 50% degraded by 16 days and complete degraded by 90 days. The UBM device, which was stronger and stiffer than the native tissue at the time of implantation, was rapidly remodeled and exhibited mechanical behavior that mimicked the native tissue, and the remodeled tissue showed increasing strength and stiffness over time.
Pre-Clinical Research


This pre-clinical study evaluated the efficacy of Gentrix Surgical Matrix for reinforcing laparoscopic repair of surgically created hiatal hernias in an experimental porcine model.

Eight weeks after surgery, animals reinforced with Gentrix Surgical Matrix (6-Layer) (n = 7) had a robust crural repair with no signs of graft erosion, esophageal fibrosis, or intrusion. The Gentrix grafts were remodeled by the body into vascularized connective tissue, while animals in the control group had histologically thinner, less organized tissue at the repair site characteristic of scar tissue. When repaired tissues were explanted and tested for uniaxial tensile strength, hiatoplasty samples taken from animals in the Gentrix reinforcement group withstood significantly greater mechanical loads and had significantly greater stiffness compared to samples taken from non-reinforced control animals (see Figure 3). Study results provide evidence that when used to reinforce a hiatal hernia repair, Gentrix Surgical Matrix facilitates a healing response that may improve the likelihood of a favorable, long-term outcome.

Results of hiatal closure at eight weeks: (A) remodeled Gentrix Surgical Matrix-reinforced hiatoplasty site (arrow), (B) defect at histoplasty site in non-reinforced control animal (arrow).

Host tissue remodeling response in representative histologic samples from Gentrix Surgical Matrix treated and control animals is compared at 8 weeks. Hematoxylin and eosin stained histology samples at 40x and Masson’s trichrome stained samples at 200x are shown, respectively, for a treated animal (A and B) and control animal (C and D). The histoplasty in the treated animal shows abundance of well organized collagen fibers and no signs of fibrosis. The control sample has clear gaps in tissue structure (C) and disorganized, loose connective tissue and a strong mononuclear infiltrate (D) indicative of fibrosis and scar tissue formation.

Figure 3

The study describes the tissue remodeling response to 14 different commercially available biologic surgical mesh devices in a rat model of abdominal wall repair. Remodeling of these ECMs was measured using a histologic assessment at 14 and 35 days after surgery, and the histologic scoring was then correlated to the macrophage phenotype. Each material elicited a distinct host tissue remodeling response that could be characterized as falling into one of three general (quantitative) groups (Figures 4 and 5): Encapsulation, (Group 1), Integration, (Group 2), or Remodeling (Group 3).

In Figure 4, white bars represent materials from the Encapsulation Group, grey bars represent materials from the Integration Group, and blue bars represent materials from the Remodeling Group. Higher scores are more indicative of a constructive remodeling response while low scores are more indicative of a scar tissue or foreign body response. This remodeling response was correlated with an early, elevated presence of the M2 macrophage phenotype, and a higher ratio of M2:MI macrophages, which leads to immune modulation and may be a predictor for site-appropriate tissue formation.

Figure 5 illustrates photomicrographs of hematoxylin and eosin stained slides that show examples of the host remodeling response to test articles in Group 1 (Collamend), Group 2 (InteXen), and Group 3 (MatriStem UBM technology) at 35 days post-implantation.

MatriStem UBM technology showed evidence of favorable host remodeling response at both 14 and 35 days, including the presence of islands of skeletal muscle at the surgical site at 35 days. Of the 14 different commercially available ECMs tested, MatriStem UBM technology had the most favorable host remodeling response at both 14 and 35 days post-implantation.
The current indications for use for ACell’s family of surgical devices are as follows:

**Gentrix® Surgical Matrix Thin (3-Layer)** is intended for implantation to reinforce soft tissue where weakness exists in patients requiring urological, gastroenterological, or plastic & reconstructive surgery. Reinforcement of soft tissue within urological, gastroenterological, and plastic & reconstructive surgery includes, but is not limited to, the following procedures: hernia and body wall repair, colon and rectal prolapse repair, tissue repair, and esophageal repair.

**Gentrix® Surgical Matrix (6-Layer)** is intended for implantation to reinforce soft tissue where weakness exists in patients requiring gastroenterological or plastic & reconstructive surgery. Reinforcement of soft tissue within gastroenterological and plastic & reconstructive surgery includes, but is not limited to, the following procedures: hernia and body wall repair, colon and rectal prolapse repair, tissue repair, and esophageal repair.

**Gentrix® Surgical Matrix Plus (8-Layer)** is intended for implantation to reinforce soft tissue where weakness exists in patients requiring gastroenterological or plastic & reconstructive surgery. Reinforcement of soft tissue within gastroenterological and plastic & reconstructive surgery includes, but is not limited to, the following procedures: hernia and body wall repair, colon and rectal prolapse repair, tissue repair, and esophageal repair.

**Gentrix® Surgical Matrix Thick** is intended for implantation to reinforce soft tissue where weakness exists in patients requiring gastroenterological or plastic & reconstructive surgery. Reinforcement of soft tissue within gastroenterological and plastic & reconstructive surgery includes, but is not limited to, the following procedures: hernia and body wall repair, colon and rectal prolapse repair, tissue repair, and esophageal repair.