



Mesh sutured repairs of contaminated incisional hernias



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ABSTRACT

Background: We sought to evaluate the results of a new mesh sutured repair technique for closure of contaminated incisional hernias.

Methods: 48 patients with contaminated hernias 5 cm wide or greater by CT scan were closed with mesh sutures. Surgical site occurrence, infections, and hernia recurrence were compared to similar patient series reported in the literature.

Results: Of the 48 patients, 20 had clean-contaminated wounds, 16 had contaminated wounds, and 12 were infected. 69% of the patients underwent an anterior perforator sparing components release for hernias that averaged 10.5 cm transversely (range 5 cm–25 cm). SSO occurred in 27% of patients while SSI was 19%. There were no fistulas or delayed suture sinuses. With a mean follow-up of almost 12 months, 3 midline hernias recurred (6%). In these same patients, three parastomal hernias repaired with mesh sutures failed out of 4 attempted for a total failure rate of 13%.

Conclusion: Mesh sutured closure represents a simplified and effective surgical strategy for contaminated midline incisional hernia repair.

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1. Introduction

Contamination of the operative field at the time of hernia repair presents a significant challenge for the operating hernia surgeon. The perceived risk of infection leading to a need for mesh removal is high enough that many surgeons are reluctant to utilize permanent planar mesh for Center for Disease Control (CDC) Class 2 and 3 wounds, opting instead for a biologic mesh, absorbable mesh, or a simple suture repair.¹ There are few recommendations for treatment of “dirty” CDC Class 4 hernias for patients undergoing laparotomy other than possibly to perform a delayed closure when the surgical site becomes cleaner. As a result, long-term hernia recurrence rates in CDC 2, 3, and 4 patients are higher than those achieved for clean CDC grade 1 abdominal hernias, where dependable repairs using prosthetic mesh have been reported for open retrorectus repairs.²

Thus, hernia repair in the face of contamination is not usually

undertaken electively. However, the abdominal wall surgeon is often faced with the need to perform a hernia closure in the face of contamination following a laparotomy performed for unrelated indications on patients with pre-existing defects. These cases may involve a planned bowel resection, unexpected bowel injury, intra-abdominal infection, enterocutaneous fistulae and open wounds, or the need to remove infected mesh from prior failed hernia repairs. In addition to concerns about infection, the added time required to elevate tissue planes to place and secure a planar mesh may be ill advised for patients who have already undergone a sizeable surgical procedure. Thus, a rational approach in these difficult cases is to “get out of Dodge,” and to perform a safe repair that minimizes complications and protects tissue planes for another day, while still effectively achieving a closed abdomen.

We recently described a technique called a “mesh sutured repair” using strips of light-weight macroporous polypropylene mesh passed through the abdominal wall and tied like sutures to achieve closure.³ Mesh sutured repairs aim to capitalize on the biomechanical benefits of force distribution to reduce tearing, while minimizing the drawbacks of the total volume of implanted material and the required tissue dissection. Pre-clinical studies

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demonstrated the biomechanical benefits over conventional suture repair, with decreased suture pull-through and increased early tensile strength.^{4–6} We expanded its clinical use in our practice primarily because of its ease of implementation, cost effectiveness, and the minimal time required for closure even in difficult surgical cases. Given these considerations, we hypothesized that mesh sutured repairs would offer an efficient solution to contaminated incisional hernia repair with a 30-day surgical site occurrence and infection rate comparable to those reported for treatment of similar patients with existing techniques and products.

2. Methods

2.1. Mesh sutured technique

As previously described,³ a light-weight, macroporous, uncoated polypropylene mesh (PROLENE[®] Soft Prolene Mesh, Ethicon, Somerville, NJ) 10 × 14 inches in size (30.5 cm × 35.6 cm) was cut along the blue lines into 2 cm wide pieces in order to fabricate mesh strips in this off-label use of the product. Subcutaneous tissue was elevated off of the abdominal wall only as necessary in order to achieve a 1 cm wide bite of unscarred abdominal wall. The mesh strips were placed in interrupted fashion and spaced 1 cm from each other. A number 1 polypropylene suture is tied to the end of the strip, with the attached needle used to help introduce and guide the mesh passage through the abdominal wall. When there is significant scarring, a sharp right-angled clamp can be used to pierce the abdominal wall and pass the mesh strip, with care made to minimize the size of the hole. Both techniques are visible at <https://www.youtube.com/watch?v=dbezjvllUyQ&feature=youtu.be> during the repair of an umbilical hernia. Tension is then applied to multiple strips simultaneously to approximate the abdominal wall and facilitate tension-free knot tying (Figs. 1–5). One square knot is required, with one additional throw to reduce the chance of knot slippage. One or more suction drains are placed in the subcutaneous tissue and removed when collecting less than 25 cc per day. Hernia sac and redundant skin are excised liberally as a vertical panniculectomy. Antibiotics are used perioperatively, but are stopped within 24 h for CDC 2 and 3 wounds, and continued for 5 days for CDC 4 wounds or longer as required for clinical signs of infection. Anterior components release with perforator



Fig. 1. A 35 year old man with a skin grafted midline hernia presents for an ostomy takedown.

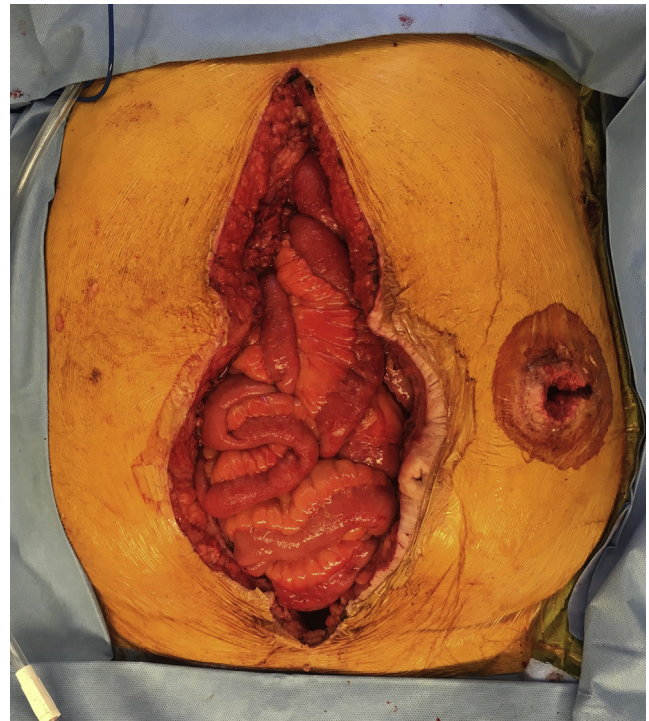


Fig. 2. Appearance after removal of skin graft and ostomy takedown.

preservation is performed for larger defects through laterally placed incisions.⁷ The decision to perform a components release was made intraoperatively based on an inability to bring the medial borders of the rectus muscle with simple finger traction.

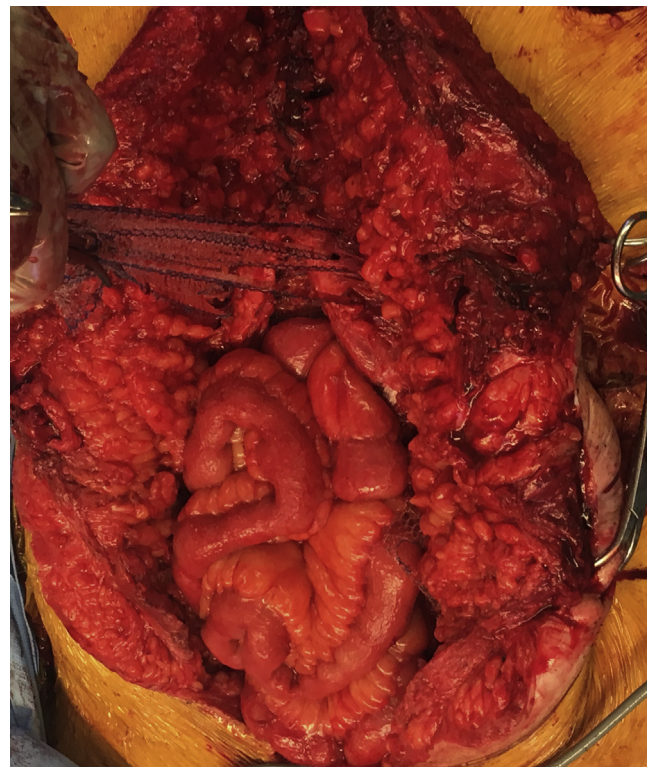


Fig. 3. Abdominal wall closure with mesh sutured technique underway. Lateral incisions for perforator preserving anterior components release are just visible.



Fig. 4. Midline appearance after abdominal wall closure. Note total of 5 cm of tissue elevation off of the midline.

2.2. Clinical experience

All of the senior author's hernia patients are entered into a prospectively maintained database for baseline characteristics and operative details. A retrospective review of this prospectively maintained database was performed to include consecutive patients who underwent a mesh sutured repair of a contaminated abdominal wall defect between Nov 2013 and February 2017. Exclusion criteria included clean surgical cases, the use of planar mesh, defect size measured less than 5 cm transversely by preoperative CT scan, or no hernia preoperatively (infected mesh removal with no preoperative hernia, closure of abdominal flap harvest



Fig. 5. Final intraoperative appearance. Note the medial movement of ostomy site.

sites, and abdominal wall dehiscence cases). All hernias wider than 5 cm in this study were located in the midline except for a single large parastomal defect, and all were repaired through a midline skin incision. This study was approved by the Northwestern University Institutional Review Board (IRB).

The decision to perform a mesh sutured repair was made by the attending surgeon based on a relative contraindication to the use of planar mesh and an expected high hernia occurrence risk with suture closure alone. The cases were drawn from the Division of Colorectal Surgery, the Department of Urology, and the Division of Plastic Surgery with its tertiary abdominal wall reconstruction practice. Demographics, comorbidities, surgical history and outcomes were collected for all patients. Midline hernia defect size was measured based on the widest separation of the medial aspect of the rectus muscles on CT scan. Operative records were used to classify patients into CDC wound classification,⁸ and patient factors were utilized to assign patients to a Ventral Hernia Working Group (VHWG)⁹ category (Table 1). A recurrent hernia was defined as any defect in the abdominal wall fascia as diagnosed by physical examination or CT scan. Palpable intraabdominal contents (bowel or fat) on physical examination, fascial defects, and localized bulges anterior to the level of the rectus muscles were recorded as hernias. Surgical site occurrence (SSO) was defined as any surgical site infection (SSI), seroma, hematoma, delayed wound healing, enterocutaneous fistula, reoperation, or dehiscence. SSI was defined as a clinical diagnosis of wound infection based on the appearance of wound erythema, drainage, and or decision to initiate therapeutic postoperative antibiotics. Seroma was defined as any appreciable subcutaneous fluid collection in the postoperative period that was opened to accelerate healing and did not require antibiotics for treatment. A suture sinus was defined as a delayed area of drainage arising through the tissues and leading to a surgical foreign body found after incisional healing has taken place. All readmissions and returns to the operating room for any reason within 30 days were recorded. Length of follow-up was defined as the time from surgery to the last documented abdominal wall examination in the electronic medical record, or by CT/MRI scan. Patients were followed on a yearly basis for evidence of hernia formation (see Figs. 6 and 7).

Demographic differences between cohorts that did experience complications and those that did not were tested for statistical correlation. Pearson's Chi-Square test was used for nominal variables, except in cases where the expected value in one of the cells was less than 5, in which case Fischer's Exact Test was used. Continuous ordinal variables were assessed by Student's t-test.

3. Results

3.1. Patient cohort description

48 patients underwent mesh sutured closure of an abdominal wall hernia. There were 16 men and 32 women, with a mean age of 62 (range 14–84) and an average BMI of 29.8. The majority of patients (29, 60%) required closure of their abdominal wall hernia following necessary colorectal and gastrointestinal surgery. Twelve patients (25%) had a contaminated complication of a prior incisional hernia repair (infected mesh, open gastrointestinal tract), and seven (15%) underwent urologic procedures with a pre-existing hernia. All patients had midline hernias measured by CT scan to have a mean of 10.5 cm (range 5–25 cm), though a single patient had a sizeable 7 cm parastomal defect. All patients had mesh strip closure of the midline abdominal wall, though 4 had additional repairs of parastomal hernias with mesh sutures. Anterior components release employing lateral incisions for perforator preservation was performed in 69% of the patients.

Table 1
CDC and VHWG classifications.

CDC 1: Clean	An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfected urinary tract is not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operative incisional wounds that follow nonpenetrating (blunt) trauma should be included in this category if they meet the criteria.
CDC 2: Clean-contaminated	An operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered.
CDC 3: Contaminated	Open, fresh, accidental wounds. In addition, operations with major breaks in sterile technique (e.g., open cardiac massage) or gross spillage from the gastrointestinal tract, and incisions in which acute, nonpurulent inflammation is encountered are included in this category.
CDC 4: Dirty	Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation.
VHWG 1: Low risk	Low risk of complications. No history of wound infection.
VHWG 2: Comorbid	Smoking, obesity, diabetes, immunosuppression
VHWG 3: Potentially Contaminated	Previous wound infection, presence of ostomy, violation of the GI tract
VHWG 4: Infected	Actively infected patients, with infected mesh or dehiscence

CDC: Centers for Disease Control.

VHWG: Ventral Hernia Working Group.

GI: Gastrointestinal.

3.2. CDC wound classification and Ventral Hernia Working Group classification

20 patients were CDC class 2, 16 were CDC class 3 (including cases of ostomy re-siting), and 12 cases CDC 4. All of the patients were Ventral Hernia Working Group 3 ($n = 37$) and 4 ($n = 11$).

3.3. Outcomes

Five of the 48 patients (10%) in our series experienced an unexpected return to the operating room within 30 days. Three cases were directly attributable to the abdominal wall closure, with 1 subcutaneous hematoma and 2 infected fluid collections being

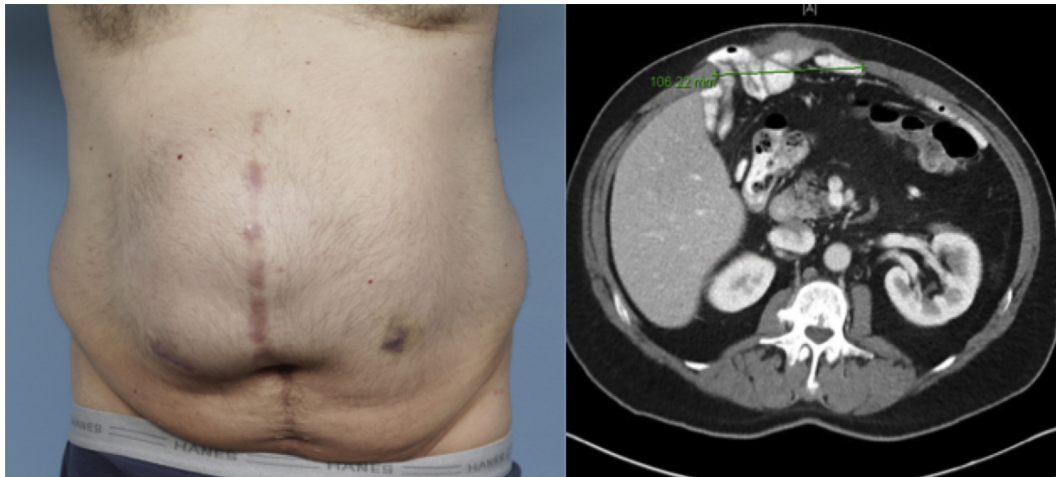


Fig. 6. Patient with 10.6 cm hernia to have abdominoperineal resection for recurrent rectal cancer.

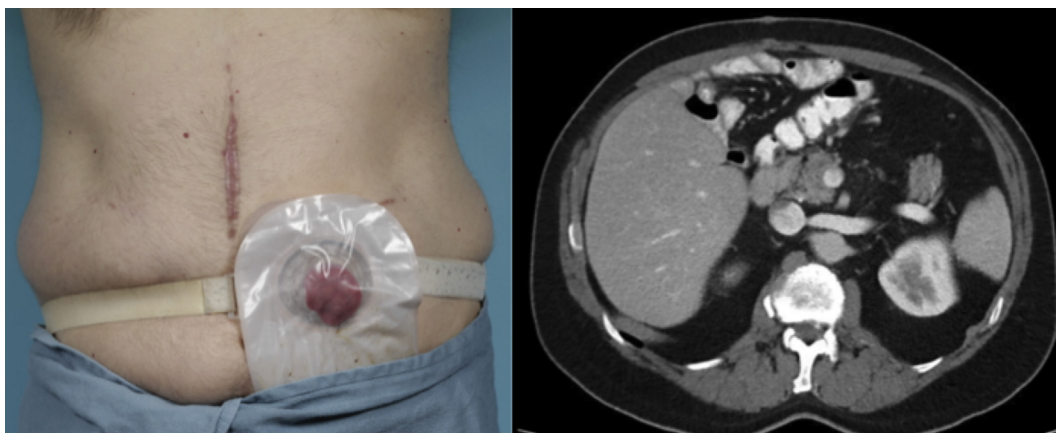


Fig. 7. Same patient 21 months later after successful abdominoperineal resection, permanent colostomy, anterior components release with perforator preservation, and mesh sutured closure.

managed operatively with wash-outs. These three patients did not require revision of the abdominal wall closure and the strips were left in place. The two remaining patients returned to the operating room for complications related to the intra-abdominal procedure, one for management of a small bowel leak after enterostomy and the other for leakage of his large bowel colonic anastomosis. One was reclosed with new mesh strips, and the second, *in extremis*, was closed with a running standard suture. This latter patient expired the following day.

Three patients (6%) were readmitted within 30 days though only one for the abdominal wall closure due to a superficial cellulitis treated with IV antibiotics. The remaining two patients had issues of hyponatremia and a urinoma.

The overall SSO rate (including infections, hematomas, reoperation, and delayed healing) was 27%. Seven patients had superficial infections, 3 had deep SSI, and one of these patients was common to both groups for an overall SSI of 19% (9 patients). While two superficial infections were treated in the operating room with soft tissue irrigation and debridement, the other 5 superficial SSI patients healed with conservative management that consisted of local wound care and oral antibiotics. None of these patients required mesh strip removal. There was one hematoma, and one patient had a skin opening that resolved with dressing changes. No patient developed a postoperative enterocutaneous fistula. In 7 patients who were perceived to be high risk of SSI by the surgeon due to the local quality of the tissues, primary skin closure was not performed during the initial procedure, predominantly at the ostomy site closure. None of these patients developed a local infection and all healed with local wound care. There were no infected knots that presented as delayed sinuses emerging from an intact and previously healed abdominal incision. One knot was removed after drainage of a subcutaneous abscess, and one knot found at the bottom of a seroma cavity was similarly excised. The “body” of these two sutures remained in the abdominal wall. Finally, a single patient with a massive contaminated hernia and loss of domain had partial abdominal wall approximation with mesh strips, followed by two additional trips to the operating room for serial staged closures. Her skin was left open to granulate closed. At 4 months, two exposed knots were removed at bedside. Follow-up at 16 months showed a clinically intact abdominal wall.

Three patients developed a hernia recurrence (6%) at their midline closure with a mean follow up of 358 days (11.8 months). Additionally, three of four patients (75%) who had simultaneous attempted repair of a parastomal hernia without relocation have

had parastomal recurrences, yielding a total recurrence rate of 6 out of 47 surviving patients (13%). Two patients have had a repeat hernia repair with a planar mesh, and the reoperative dissection was not unusual in any way. Biopsies of the mesh sutures showed a mild chronic foreign body reaction by pathology. The longest duration of follow up is over 2.4 years in a patient who has not developed a recurrence.

Statistical analysis did not correlate any complications of SSO or SSI with any defined variable including BMI, diabetes, smoking, immunosuppressive medications, or CDC wound classification. Hernia recurrence was statistically correlated to BMI with a $p = 0.011$ (Table 2).

4. Discussion

Mesh sutured closures of contaminated abdominal hernias defies two surgery doctrines. It neither avoids prosthetic material in contaminated abdominal wall closures, nor does it employ a reinforcing planar mesh for treatment of an established hernia. Blending the advantages of suture and mesh repairs, our results indicate that a mesh sutured repair is associated with a 30 day complication profile not worse than established treatments for complex hernia patients published in the literature. Importantly, the majority of our complications were managed expeditiously at the bedside or in an office setting, without the need for removal of foreign material in the operating room. Furthermore, we have utilized mesh sutured repairs even under hostile situations where surgeons may have traditionally opted to leave the abdomen open, use retention sutures, perform a staged repair, close with skin grafts, or commit the patient to eventual hernia with a spanning absorbable or bioprosthetic mesh.

Standard suture closure of hernia defects is technically straightforward and minimizes the amount of implanted foreign material, but results in an undesirably high rate of hernia recurrence.¹⁰ The tension required to re-approximate the retracted fascial edges becomes unacceptable at the suture/tissue interface. This excessive pressure causes tissue necrosis within the suture loop that results in suture pull-through and can cause either acute disruption of the closure (dehiscence) or chronic failure (incisional hernia formation).¹¹ We and others have shown in animal models that the mesh sutured technique is less likely to pull through at each suture-tissue interface compared to relatively narrow caliber conventional “sharp” sutures that inadvertently slice through tensioned tissue.^{4–6} We believe that this illustrates the key technical consideration is not the presence of a planar mesh *per se*, but

Table 2
Demographics and relationship to complications.

Characteristic	Frequency (n = 48)	p Value (SSI)	p Value (sSSI)	p Value (dSSI)	p Value (SSO)	p Value (Recurrence)
Age (Mean ± SD)	62.2 ± 14.2	0.229	0.442	0.383	0.383	0.590
BMI (Mean ± SD)	29.8 ± 7.7	0.954	0.749	0.670	0.670	0.011^a
Male	16 (33%)	0.138	0.664	0.735	0.735	1.000
COPD	5 (10%)	0.277	0.529	0.644	0.644	1.000
Diabetes	15 (31%)	0.199	0.157	0.140	0.140	0.157
Current Smoker	5 (10%)	1.000	1.000	0.085	0.085	0.125
Immunosuppressants	7 (15%)	0.587	1.000	0.355	0.355	0.576
ASA Class >2	33 (69%)	1.000	1.000	0.509	0.509	1.000
Ostomy at Time of Operation	22 (46%)	0.470	0.428	0.478	0.478	1.000
# Prior Operations	3 (1–10)	0.270	0.300	0.726	0.726	0.692
CDC Wound Classification		0.423	0.503	0.493	0.493	0.259

BMI: body mass index.

COPD: chronic obstructive pulmonary disease.

#: Number.

ASA: American Society of Anesthesia.

SD: standard deviation.

^a Statistically significant at 95% confidence level.

Table 3
Comparison to the literature.

Author, year	Dumanian, 2017	Carbonell, 2013	Slater, 2013	Rosen, 2017	Itani, 2012	Atema, 2017
Number of subjects	48	100	81	104	80	60
Technique	Mesh Suture	Retro-rectus polypropylene	Polypropylene	BioA	Strattice	Strattice
CDC 2	20 (40%)	42 (42%)	34 (43%)	24 (23%)	39 (48.7%)	NR
CDC 3	16 (36%)	58 (58%)	19 (23%)	80 (77%)	39 (48.7)	NR
CDC 4	12 (24%)	0	28 (35%)	0	2 (2.6%)	NR
VHWG 3	37 (77%)	NR	NR	NR	69 (75%)	66 (83%)
VHWG 4	11 (23%)	NR	NR	NR	20 (25%)	14 (17%)
Age	62.4 ± 14.5	60 ± 13	58.6	58	57 ± 14	63
BMI	29.5 ± 7.4	32 ± 9.3	26.6	28	NR	27.8 ± 5.9
Components separation	69%	49%	100	65%	65%	68%
SSO	27%	31%	52%	28%	66%	NR
SSI	19%	18%	19%	18%	35%	45%
Return to operating room	10%	12%	11.7	NR	NR	4%
30-day readmission	6%	NR	NR	NR	NR	28%
Hernia recurrence	13%	7%	NR	17%	28%	13%
Mean follow-up (months)	11.8	10.8	NR	24	24	7

CDC: Centers for Disease Control.

VHWG: Ventral Hernia Working Group.

BMI: body mass index.

SSO: Surgical site occurrence.

SSI: Surgical site infection.

rather the utilization of a technique that improves force distribution along the fascial closure. This is consistent with the recent STITCH trial that demonstrates improved outcomes via the distribution of forces along the length of a longer suture.¹² By better distributing tensile closure forces at the suture line, mesh sutured repairs offer the durability of a planar mesh repair, while minimizing the total volume of implanted foreign material that can reach over 1000 cm² for large planar mesh repairs.¹³

Mesh sutured repairs utilize permanent macroporous material, resulting in a lasting foreign body reaction and persistent scar tissue. It is unclear if scar around an absorbable foreign body will persist over time.¹⁴ Our ability to manage complications conservatively without revision of the abdominal wall repair questions the dogma that permanent materials are to be avoided in contaminated situations and must be removed when exposed. Rather, the character of material including its total volume, surface area, filament size, and location are likely important factors. Mesh strips are located predominantly within the abdominal wall muscles where they are rapidly incorporated, in comparison to sheet meshes that lie along surface planes where fluid collections occur. Longer-term follow-up is required to evaluate the ultimate performance of mesh strip closures. Nonetheless, this short-term analysis proves feasibility of a safe, simple, and inexpensive “get out of Dodge” strategy for surgeons faced with difficult closure situations. While not a subject of this manuscript, this versatile technique has proven successful in other contaminated defects such as fascial dehiscence, abdominal wall tumor resection, and abdominal flap harvest sites.

A meta-analysis of contaminated incisional hernia repairs determined a 24.3% recurrence rate at 26.7 months follow-up. However, as the preoperative hernia size was not provided in this study, we selected from the literature several more recent series of closure technique for a better qualitative comparison. The 5 similarly sized cohorts included conventional lightweight macroporous polypropylene meshes (UltraPro and Soft Prolene, Ethicon, Somerville NJ and Bard Soft Mesh, Davol, Warwick RI),^{15,16} a bioabsorbable prosthetic mesh (Gore Bio-A Tissue Replacement, Flagstaff AZ),¹⁷ and two with porcine acellular dermis (Strattice Reconstructive Tissue Matrix, Allergan, Parsipanny NJ),^{18,19} Our study was located midway between the comparison 5 studies for mean age and BMI (Table 3). Overall hernia recurrence rates as well as markers for 30 day complications are quite similar, despite the

mesh sutured technique requiring less dissection and implantation of decreased foreign material in comparison to the other surgical strategies. For midline approximation, our recurrence rate of 6% would be as low or lower than any of these other treatments. Our hernia recurrence rate could be underestimated as the majority of follow-up examinations for hernia were performed by physical examination. We had 3 of 4 failures of tightening of parastomal defects, for a total recurrence rate of 13% (6 of 47 surviving patients). Of the 5 comparison papers, only Carbonell described the site of hernia recurrences, and he too had several failures of repairs adjacent to permanent ostomies. Longer follow-up is underway to study hernia recurrence rates, but we reemphasize that for these clinical situations the goal is an early successful closure with minimized complications, rather than for a perfect long-term outcome. Our results are especially notable for CDC class 4 infected wounds. While the literature reports SSO to be 80% and SSI to be greater than 50% for these patients after open hernia repair,²⁰ our results were that only 3 of 12 CDC grade 4 patients had a surgical site occurrence. Of these, 2 had superficial infections, and 1 had both superficial and deep infections. We attribute our relatively low rate of complications not only to the mesh sutured technique and perforator preservation to maintain soft tissue vascularity,^{8,21} but also to the *en bloc* removal of inflamed tissue.^{22,23} SSO and SSI occurred sporadically, not even correlating to CDC wound class, though this study was designed to illustrate surgical technique and is underpowered to definitely correlate complications with preoperative conditions. Mesh sutured repairs were not effective at tightening of parastomal defects, perhaps due to the lack of a created “kink” or directional change in the ostomy bowel loop thought important in the Sugarbaker repair. However, the technique is still effective (at least temporarily) at solving an ostomy related issue.

The challenges posed by contaminated hernia defects require that any strategy for closure permits complications to be managed easily. Permanent wide meshes are potentially the most problematic, requiring a difficult surgical explantation if they become infected or require reoperative surgery as occurred for 4 patients of Carbonell et al. and 5 of Slater et al. Bioprosthetic and bioabsorbable meshes are touted to have the ability to resist infection, and are not thought to require complete removal when ongoing infections occur. However, these two materials require an invasive surgical approach for placement, they are costly, and do they do not prevent

the development of a later hernia. Mesh sutured repairs have an advantage over planar meshes that all of the foreign material is immediately under the surgical incision if there is need for removal. In the two patients who returned to the operating room for management of infected fluid collections, all mesh sutures were salvaged with soft tissue irrigation alone, and both patients went on to heal primarily. It has been our experience that patients with open wounds and exposed mesh suture knots heal successfully with local wound care/moist dressings. Our explanation is that the mesh is manufactured with filaments one quarter to one third the diameter of a 0-polypropylene suture. Small filaments elicit a more biocompatible foreign body response in comparison to larger filaments of the same material composition in laboratory animal studies.²⁴ While complications occur frequently in this challenging patient population, management of soft tissue complications in this series was remarkably straightforward.

Mesh sutured closures can be placed faster than can a planar mesh in the retro-rectus plane, and we have not found a contraindication to their use. We still perform planar meshes for clean cases, where the risks of removal of the mesh are lower, and the hernia outcomes in our hands are better than in the mesh sutured outcomes presented here.² While a formal cost-analysis has yet to be performed, the economic advantage of this technique over bioprosthetic or bioabsorbable repair is self-evident, given the comparable outcomes achieved with markedly lower direct costs. At our institution, the macroporous polypropylene mesh used in this study is 1/5th to 1/10th the institutional cost of the synthetic bioabsorbable Bio A and 1/35th to 1/54th the cost of the bioprosthetic Strattice, depending on the size of the mesh used. Demonstrating the penetrance of this mesh suture repair concept, only 3 pieces of bioprosthetic mesh were used for abdominal wall reconstruction at Northwestern Memorial Hospital for the last 12 months.

In conclusion, mesh sutured repairs achieved comparable patient outcomes to those reported in other large series when used in the contaminated setting. Early hernia recurrence rates are encouraging and comparable to more extensive hernia repairs that are more invasive or utilize more expensive absorbable mesh products, and continued follow-up is ongoing. Force distribution at the level of the suture may offer a new paradigm for the management of high-tension internal closures.

Funding for clinical review

Internal.

Conflict of interest

Dr. Dumanian has financial interest in the Advanced Suture Co and the Mesh Suture Co. He could potentially benefit from the outcomes of this research. None of the other authors have any conflicts of interest. No author has any relationship to any products or companies mentioned in this report.

References

- Hodgkinson JD, Maeda Y, Leo CA, et al. Complex abdominal wall reconstruction in the setting of active infection: a systematic review of hernia and fistula recurrence rates. *Colorectal Dis.* 2017;19:319–330.
- Lanier ST, Fligor JE, Miller KR, Dumanian GA. Reliable complex abdominal wall hernia repairs with a narrow well-fixed retrorectus polypropylene mesh: a review of over 100 consecutive cases. *Surgery.* 2016;160:1508–1516.
- Lanier ST, Dumanian GA, Jordan SW, et al. Mesh sutured repairs of abdominal wall defects. *PRS GO.* 2016;28:e1060.
- Souza JM, Dumanian Z, Gurjala D, Dumanian GA. In vivo evaluation of a novel mesh suture design for abdominal wall closure. *Plast Reconstr Surg.* 2015;135:322e–330e.
- Dumanian GA, Tulaimat A, Dumanian Z. Experimental study of the characteristics of a novel mesh suture. *Br J Surg.* 2015;102:1285–1292.
- Zhang T, Hatta T, Thoreson AR, et al. Rotator cuff repair with a novel mesh suture: an ex vivo assessment of mechanical properties. *J Ortho Res.* 2017. <https://doi.org/10.1002/jor.23668>.
- Saulis AS, Dumanian GA. Periumbilical rectus abdominus perforator preservation significantly reduces superficial wound complications in 'Separation of Parts' hernia repairs. *Plast Reconstr Surg.* 2002;109:2275–2280.
- <http://www.cdc.gov/hicpac/SSI/table7-8-9-10-SSI.html>. Accessed 3/24/2016.
- Ventral Hernia Working Group, Breuing K, Butler CE, Ferzoco S, et al. Incisional ventral hernias: review of the literature and recommendations regarding the grading and technique of repair. *Surgery.* 2010;148:544–558.
- Burger JW, Luijendijk RW, Hop WC, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. *Ann Surg.* 2004;240:578–583, 2004.
- Hoes J, Fischer L, Schachtrupp A. Laparotomy closure and incisional hernia prevention—what are the surgical requirements. *Zentralbl Chir.* 2011;136:42–49.
- Deerenberg EB, Harlaar JJ, Steyerberg EW, et al. Small bites versus large bites for closure of abdominal midline incisions (STITCH): a double-blind, multi-centre, randomised controlled trial. *Lancet.* 2015;386:1254–1260.
- Majumder A, Winder JS, Wen Y, et al. Comparative analysis of biologic versus synthetic mesh outcomes in contaminated hernia repairs. *Surgery.* 2016;160:828–838.
- Jordan SW, Fligor BS, Janes LE, Dumanian GA. Implant porosity and the foreign body response. *Plast Reconstr Surg.* 2017 Sep 15. <https://doi.org/10.1097/PRS.0000000000003930> [Epub ahead of print].
- Carbonell AM, Criss CN, Cobb WS, et al. Outcomes of synthetic mesh in contaminated ventral hernia repairs. *J Am Coll Surg.* 2013;217:991–998.
- Slater NJ, Knaapen L, Bokkerink WJV, et al. Large contaminated ventral hernia repair using component separation technique with synthetic mesh. *Plast Reconstr Surg.* 2015;136:796e.
- Rosen MJ, Bauer JJ, Harmaty M, et al. Multicenter, prospective, longitudinal study of the recurrence, surgical site infection, and quality of life after contaminated ventral hernia repair using biosynthetic absorbable mesh. The Cobra trial. *Ann Surg.* 2017;265:205–211.
- Atema JJ, Furnee EJ, Maeda Y, et al. Major complex abdominal wall repair in contaminated fields with use of a non-cross-linked biologic mesh: a dual institutional experience. *World J Surg.* DOI 10.1007/s00268-017-3962-2 [Epub ahead of print].
- Itani KM, Rosen M, Vargo D, et al. Prospective study of single-stage repair of contaminated hernias using a biologic porcine tissue matrix: the RICH study. *Surgery.* 2012;152:498–505.
- Berger RL, Li LT, Hicks SC, et al. Development and validation of a risk-stratification score for surgical site occurrence and surgical site infection after open ventral hernia repair. *J Am Coll Surg.* 2013;217:974–982.
- Ghali S, Turza KC, Baumann DP, Butler CE. Minimally invasive component separation results in fewer wound-healing complications than open component separation for large ventral hernia repairs. *J Am Coll Surg.* 2012;214:981–989.
- Szczerba SR, Sukkar SM, Dumanian GA. Definitive surgical treatment of infected or exposed mesh. *Ann Surg.* 2003;237:437–441.
- Janis JE, Khansa I. Evidence-based abdominal wall reconstruction: the max-mini approach. *Plast Reconstr Surg.* 2015;136(6):1312–1323. PMID: 26291701.
- Klink CD, Binnebosel M, Kaemmer D, et al. Comet-tail-like inflammatory infiltrate to polymer filaments develops in tension-free conditions. *Eur Surg Res.* 2011;46:73–81.