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Retro-rectus placement of bio-absorbable mesh improves patient outcomes

Juliann E. Cho[1] · Melissa C. Helm[2] · Joseph H. Helm[2] · Neil Mier[2] · Andrew S. Kastenmeier[2] · Jon C. Gould[2] · Matthew I. Goldblatt[2]

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Abstract

Background There is little consensus on the ideal anatomical placement of bio-absorbable mesh. We hypothesized that retro-rectus placement of bio-absorbable mesh would significantly reduce recurrence rates when compared to intraperitoneal mesh placement.

Methods A retrospective review was conducted of patients who underwent open complex ventral hernia repair using bio-absorbable mesh (Bio-A, Gore, Flagstaff, AZ). Patient demographics and Centers for Disease Control wound type were collected.

Results A total of 81 patients were included. Seventy-four (91.4%) of these hernia repairs had mesh in the retro-rectus position, while 7 (8.6%) had intraperitoneal mesh placement. Patient demographics, including preoperative comorbidities, did not differ between groups. The retro-rectus group trended to have larger hernia defects (156.2 cm^2) compared to the intraperitoneal group (63.9 cm^2) ($p=0.058$). Overall complications (e.g., dehiscence, wound drainage, cellulitis, sepsis) were also similar in both groups of patients. Recurrence rates in the retro-rectus and intraperitoneal group were 8.1% and 42.9%, respectively ($p=0.005$). When evaluating only patients with CDC class 1 wounds, the recurrence rate in the retro-rectus group was 8.2% and the intraperitoneal group was 50% ($p=0.02$). Overall, the average patient follow-up was 22 months and did not differ between groups. Both the retro-rectus and intraperitoneal groups indicated a significant ($p<0.05$) improvement in quality of life from baseline. No long-term (> 7 days) antibiotics were used and no mesh implants were removed during the study.

Conclusion Patients who underwent open complex ventral hernia repairs with bio-absorbable mesh in the retro-rectus position experienced lower overall complication rates than those with intraperitoneal mesh placement. Despite a larger hernia defect in the retro-rectus group, recurrence rates were significantly reduced with retro-rectus placement of mesh compared to intraperitoneal placement. In addition, recurrence rates using bio-absorbable mesh in clean wounds are comparable to previously published recurrence rates with permanent mesh.

Keywords Open complex ventral hernia repair · Bio-absorbable mesh · Retro-rectus placement

As the incidence of obesity and diabetes continues to reach epidemic proportions, hernia surgeons are increasingly repairing abdominal walls with infected fields or with wounds that are considered high-risk for infection. With the increased risk of infection of permanent synthetic meshes in these high-risk wounds, the need for new reinforcement materials has driven this market [1]. For years, biologic implants were used to avoid the long-term problems of permanent mesh infections [2]. A recent prospective, multicenter study reported low recurrence rates and low surgical site infections with the use of synthetic absorbable mesh in complex ventral hernia repair [3]. Such findings suggest absorbable synthetic mesh as a safe alternative to biologic or permanent synthetic mesh for contaminated and high-risk wounds in open complex ventral hernia repairs.

✉ Matthew I. Goldblatt
mgoldbla@mcw.edu

[1] Department of Anesthesia, University of California Davis, Davis, CA, USA

[2] Division of General Surgery, Department of Surgery, Medical College of Wisconsin, 8701 W Watertown Plank Rd, Milwaukee, WI 53226, USA

Complex abdominal wall reconstruction is typically performed through an open midline incision. However, multiple anatomical positions exist for placement of reinforcing materials for successful abdominal wall reconstruction [4]. The most common options available to surgeons for placing the mesh are the onlay, intraperitoneal, preperitoneal, or retro-rectus positions. However, there are limited data regarding outcomes in the various mesh positions in complex hernia repairs. The primary objective of our study was to determine the long-term surgical outcomes of various positions of mesh placement. We hypothesized that retro-rectus placement of bio-absorbable mesh would significantly reduce complications and recurrence rates when compared to repairs with intraperitoneal mesh placement.

Methods

After Institutional Review Board (Medical College of Wisconsin; Milwaukee, WI) approval, a retrospective review of prospectively maintained data was undertaken of patients who underwent open complex ventral hernia repair with bio-absorbable mesh at the Medical College of Wisconsin between September 2011 and January 2015. All but one procedure was performed by a single surgeon (MG).

Surgical technique—retro-rectus

Through a midline incision, a laparotomy was performed and the hernia sac was dissected from the surrounding tissues. After adhesiolysis and removal of previous mesh (if present), the posterior rectus sheath was incised just lateral to the linea alba and the retro-rectus space was created. This space was opened to just medial to the neuro-vascular bundles at the semi-lunar line and was taken at least 5 cm beyond the hernia defect in both a cranial and caudal direction. At the discretion of the surgeon, in some patients when tension on the abdominal wall was judged to be too great to allow a primary closure of the fascia, a transversus abdominis release component separation was performed to allow closure of the posterior sheath.

Once the posterior sheath was closed with a running 0 PDS (Ethicon; Cincinnati, OH), the retro-rectus space was measured and the absorbable synthetic implant (Bio-A, WL Gore; Flagstaff, AZ) was trimmed to fit. The implant was secured to the anterior rectus sheath with interrupted #1 PDS. Typically, one suture each was placed in the cranial and caudal position, and 2–3 sutures were placed on each lateral side. The lateral sutures were positioned to draw the linea alba back to the midline and, therefore, place the tension on the implant. For some hernias, the tension on the implant was significant and so a small 1×2 cm piece of leftover implant was used to reinforce the suture under the implant to avoid pulling through. The anterior sheath was closed with a running #1 PDS. Drains were placed in both the retro-rectus space and subcutaneous space and were kept in until output was less than 20 ml per day for two consecutive days.

Intraperitoneal

After midline laparotomy, hernia sac resection and adhesiolysis, the hernia defect was measured and a bio-absorbable implant was chosen that was at least 5 cm larger than the hernia defect in all directions. Intraperitoneal placement of the implant was typically performed due to a lack of posterior rectus sheath often damaged from previous intraperitoneal mesh repairs. The mesh was then sewn to the anterior abdominal wall using interrupted 0 PDS suture. The sutures were placed 1 cm from the edge of the mesh every cm to avoid bowel eventration. Placement of the sutures was performed to take tension off the midline and transfer it to the implant. Midline closure was achieved with a running #1 PDS. Drains were placed between implant and fascia, as well as in the subcutaneous space.

Perioperative details and postoperative complications were collected for up to 49 months. Furthermore, the Center for Disease Control surgical wound classifications and Ventral Hernia Working Group grading were determined for all patients [3]. Hernia-related quality-of-life (HerQLes) surveys were also used to assess quality of life from baseline to 48 months after surgery [5]. The HerQLes six-point scale was used to compare pre-and post-operative scores. Follow-up was obtained either in person or by a validated phone questionnaire [6].

Statistical analysis

Statistical analysis was conducted using SPSS, version 21 (IBM Corp). Chi square and Fisher's exact tests were used for categorical variables. Results of categorical data were expressed as n (%). Continuous variables were analyzed using Mann–Whitney U and independent samples t-tests. Results of continuous data were expressed as mean ± standard deviation. All analyses were two-sided. A p-value < 0.05 was considered statistically significant.

Results

A total of 81 patients met inclusion criteria. Seventy-four (91.4%) of these hernia repairs had mesh in the retro-rectus position, while 7 (8.6%) had intraperitoneal mesh placement. Patient demographics, preoperative body mass index (BMI), and comorbidities did not differ between groups, except there were more women in the retro-rectus group (Table 1).

Table 1 Patient demographics

Variable	IP	RR	Cumulative	*p* value
Subjects *N* (%)	7 (8.6%)	74 (91.4%)	81	–
Female	3 (42.9%)	51 (68.9%)	54 (66.7%)	0.16
Age (years)	60.1 ± 6.1	56.2 ± 12.0	56.5 ± 11.7	0.17
Pre-op body mass index (kg/m^2)	36.1 ± 8.7	34.7 ± 8.4	34.9 ± 8.4	0.69
Race				
African American	2 (28.6%)	4 (5.4%)	6 (7.4%)	0.03*
Caucasian	4 (57.1%)	68 (91.9%)	72 (88.9%)	0.005*
Hispanic	1 (14.3%)	1 (1.4%)	2 (2.5%)	0.04*
Other	0 (0%)	1 (1.4%)	1 (1.2%)	0.76
Former smoker	2 (28.6%)	23 (31.1%)	25 (30.9%)	0.89
Current/recent smoker	0 (0%)	9 (12.2%)	9 (11.1%)	0.33
Diabetes mellitus	3 (42.9%)	20 (27.0%)	23 (28.4%)	0.38
American Society of Anesthesiologists (ASA) classification*				
Class 1	0 (0%)	0 (0%)	0 (0%)	–
Class 2	0 (0%)	18 (25.0%)	18 (23.1%)	0.16
Class 3	6 (100%)	53 (73.6%)	59 (75.6%)	0.15
Class 4	0 (0%)	1 (1.4%)	1 (1.3%)	0.77

*ASA classification was missing in three patients

Table 2 Hernia and wound characteristics

Variable	IP	RR	Cumulative	*p* value
Recurrent hernia	5 (71.4%)	32 (43.2%)	37 (45.7%)	0.15
Number of previous repairs	1.1 ± 1.1	0.74 ± 1.6	0.78 ± 1.6	0.52
CDC wound class				
Class 1	6 (85.7%)	49 (66.2%)	55 (67.9%)	0.42
Class 2	1 (14.3%)	13 (17.6%)	14 (17.3%)	1.00
Class 3	0 (0%)	1 (1.4%)	1 (1.2%)	1.00
Class 4	0 (0%)	11 (14.9%)	11 (13.6%)	1.00
Ventral Hernia Working Group grade				
Grade 1	0 (0%)	3 (4.1%)	3 (3.7%)	0.59
Grade 2	5 (71.4%)	50 (67.6%)	55 (67.9%)	0.83
Grade 3	2 (28.6%)	10 (13.5%)	12 (14.8%)	0.28
Grade 4	0 (0%)	11 (14.9%)	11 (13.6%)	0.27

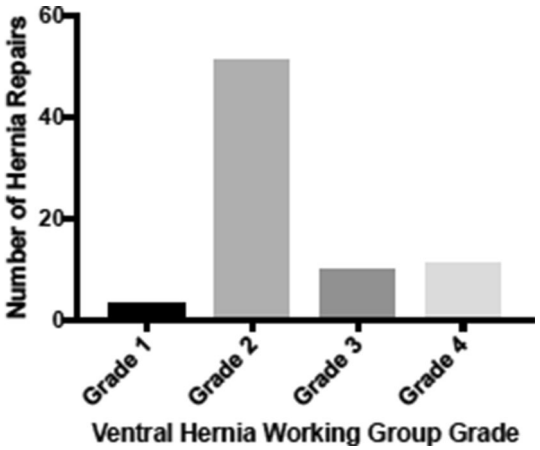

Fig. 1 Retro-rectus mesh placement—Ventral Hernia Working Group (VHWG) classification

The CDC and Ventral Hernia Working Group wound classifications are depicted in Table 2 (Figs. 1, 2). There were no significant differences in wound types between the intraperitoneal hernias compared to the retro-rectus mesh placement hernias. There was also no significant difference in the size of the mesh used in the repairs. The procedures that utilized retro-rectus placement of mesh had a larger defect size compared to those that had intraperitoneal placement (156.2 ± 125 vs. 63.9 ± 59.3; $p = 0.058$) (Table 3). Furthermore, there was no statistically significant difference in the length of stay between the two groups (Table 4).

Patients with retro-rectus mesh placement were analyzed for recurrence based on the fact that if their repair was recurrent or primary. Through 5 months post-op, none of the 42 patients who had with retro-rectus mesh placement for a primary hernia repair experienced a recurrence. The two recurrences took place at 6 and 9 months post-op. In contrast, in the 32 patients with a recurrent hernia repair that had retro-rectus mesh placement, recurrences took place at 1 month (in two patients), 16 months, and 24 months post-op ($p = 0.23$).

Surgical outcomes are depicted in Table 4. The overall incidence of 30-day perioperative complications were similar in both patient populations. These complications included four patients with prolonged ileus, one patient requiring re-intubation, one patient with hepatic artery

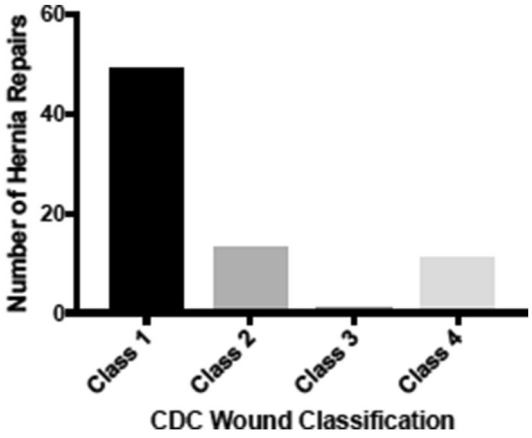

Fig. 2 Retro-rectus mesh placement—CDC wound classification

thrombosis, and one patient with a partial wound dehiscence managed with a wound VAC which ultimately became one of the recurrences. In addition, five patients required a short course of post-operative antibiotics (≤ 7 days) for wound cellulitis. None of the patients required re-operation due to their complication and no mesh explants were necessary throughout the study. Recurrence rates were significantly lower in the retro-rectus group compared to the intraperitoneal group (8.1% vs. 42.9%; $p = 0.005$) with a mean follow-up of 22 months. All recurrences were evaluated clinically and confirmed with a CT-scan if applicable. Post-operative quality of life assessed with the HerQLes survey improved after surgery in both the retro-rectus and intraperitoneal groups compared to baseline (Table 5).

Sub-group analysis of patients with clean wounds (CDC class 1) were evaluated (Table 6). There were 55 patients in this sub-group with six patients in the intraperitoneal cohort and 49 who had a retro-rectus repair. The IP patients were older by about 6 years. The RR group had larger hernia defects than the IP group. Recurrence rates were 50% for the IP placement and 8.2% for the RR group.

Table 5 Symptomatic outcomes

HerQLes (6 pt scale)	Time frame	Mean (*n*)	*p* value
IP	Baseline	43.5 ($n=2$)	–
	2-week	n/a ($n=0$)	–
	6-week	n/a ($n=0$)	–
	3-month	37.5 ($n=2$)	0.87
	6-month	41.5 ($n=2$)	< 0.0001
	12-month	n/a ($n=0$)	–
	24-month	12 ($n=1$)	–
RR	Baseline	47.3 ($n=23$)	–
	2-week	47.3 ($n=10$)	0.08
	6-week	45.8 ($n=10$)	0.15
	3-month	33.5 ($n=14$)	0.01
	6-month	34.6 ($n=21$)	0.09
	12-month	33.9 ($n=15$)	0.16
	24-month	30.8 ($n=6$)	–

Discussion

This retrospective study evaluated the use of a bio-absorbable mesh in 81 open complex ventral hernia repairs with an average of 22 months follow up. Seven patients had their mesh placed in the intraperitoneal position, resulting in a 42.9% recurrence rate. Seventy-four patients had their mesh placed in the retro-rectus position with an 8.1% rate of hernia recurrence. This study suggests that placing the mesh in the retrorectus space has better long-term outcomes than

Table 3 Operative data

Variable	IP	RR	Cumulative	*p* value
Size of defect (cm^2)	63.9 ± 59.3	156.2 ± 125.0	148.2 ± 123.3	0.058
Size of mesh (cm^2)	346.1 ± 265.9	420.4 ± 196.2	414.0 ± 202.2	0.50
Operative time (min)	304.7 ± 131.1	293.4 ± 94.2	294.2 ± 96.5	0.79

Table 4 Surgical outcomes

Variable	IP	RR	Cumulative	*p* value
Length of stay	7.9 ± 5.8	6.3 ± 2.6	6.4 ± 3.0	0.50
Perioperative complications	0 (0%)	1 (1.3%)	1 (1.2%)	1.0
DC to 30-days complications	1(14.3%)	9 (12.2%)	10 (12.3%)	0.87
31-days to 12 months complications	0 (0%)	3 (4.1%)	3 (3.7%)	0.59
12–24 months complications	0 (0%)	0 (0%)	0 (0%)	–
Overall complications	1 (14.3%)	12 (16.2%)	13 (16.0%)	0.89
Recurrent midline hernia	3 (42.9%)	6 (8.1%)	9 (11.1%)	0.005

Table 6 Patient demographics for CDC class 1 wounds

Variable	IP	RR	*p* value
Subjects *N* (%)	6 (10.9%)	49 (89.1%)	–
Age (years)	62 ± 3.9	56.1 ± 12.3	0.02
Pre-op BMI (kg/m^2)	34.9 ± 8.9	34.4 ± 8.3	0.89
Size of mesh (cm^2)	303.8 ± 264.2	404.5 ± 206.6	0.28
Size of defect (cm^2)	50.0 ± 51.0	163.1 ± 133.7	0.047
Operative time (min)	268.8 ± 89.9	275.1 ± 87.1	0.87
Length of stay (days)	6.0 ± 3.3	6.0 ± 2.6	0.97
Recurrent midline hernia	3 (50%)	4 (8.2%)	0.003

intraperitoneal mesh. This is not the first study to suggest that the retro-rectus space is an advantageous place to put mesh. The earliest study to investigate the impact of mesh positioning used Chinchilla rabbit models and found favorable results in the retro-rectus placement of synthetic mesh compared to an onlay technique [7]. Furthermore, subsequent studies observed a clear trend that suggested the benefits of retro-rectus placement of biologic or biosynthetic mesh compared to an intraperitoneal position [2, 8].

Fifty-five (67.9%) of the patients had a clean wound per the CDC wound classification (Fig. 1) and were considered high-risk for wound complications (Ventral Hernia Working Group Grade II) (Fig. 2). Many surgeons would use permanent synthetic mesh in these patients. The use of a bio-absorbable mesh in clean wounds was mostly driven by patient preference and concern for a permanent product in their body. The risk of wound complications and possibly mesh complications are not avoided in clean wounds. The greatest risk of wound complications is likely due to the surgical technique. Anterior component separation (external oblique) with its large skin flaps is highly associated with wound complications. In the randomized controlled trial conducted by de Vries Reilingh et al. 53% of patients with a CDC class I or II ventral hernia repair had a wound complication or recurrence at 36-months [9]. The retro-rectus group in our study with a CDC Class I wound, had a 10.9% complication rate through 30-days post-op which subsequently decreased to 1.8% through 12-months post-op. CDC Class II wounds had a decreased rate of wound complications through 30-days post-op (7.1%), but revealed no complications after 30-days. When analyzed with Ventral Hernia Working Group grades, patients classified as VHWG Grade I experienced no complications through 12-months post-op. Patients classified as VHWG Grade II had a 12% complication rate through 30-days post-op and 16% complication at 12-months post-op.

The prospective Complex Open Bioabsorbable Reconstruction of the Abdominal Wall (COBRA) study reported similar findings and demonstrated the influence of mesh placement on post-operative outcomes [8]. In the COBRA study, the primary endpoint was ventral hernia recurrence and 90% of patients underwent repair with retro-rectus mesh placement, while the remaining 10% received intraperitoneal mesh placement. The overall recurrence rate using the bio-absorbable mesh was 17%. In fact, a significantly higher rate of recurrence was seen when the mesh was placed intraperitoneally as compared to the retro-rectus position ($p = 0.04$) [8, 10]. This current study confirms the findings of the COBRA study in that the retro-rectus position is the best position to place a prosthetic material, or that the intraperitoneal mesh patients represented the most complex hernias. Neither this study nor the COBRA study was designed to determine the reason for the higher recurrence rate in the intraperitoneal patients. The intraperitoneal mesh patients in our study had smaller hernia defects which leads one to conclude that the success of retro-rectus repairs may indeed be related to the retro-rectus position of the mesh.

Alternatives to bio-absorbable mesh that have been used in similar procedures include permanent or biologic mesh. In the Repair of Infected and Contaminated Hernias (RICH) trial, a prospective, multicenter study was undertaken to evaluate the clinical outcomes of contaminated open ventral hernia repairs using a biologic porcine dermal matrix [2]. The placement of mesh was left to the discretion of the surgeon. Reported hernia recurrence rate was 28% at 24 months, while the complication rate from infection-related events was 30% [2]. The RICH trial also demonstrated that the position of the reinforcing material is an important factor for recurrence, with retro-rectus placement of the reinforcing material leading to lower recurrence rates compared to intraperitoneal placement.

Carbonell, et al. investigated the effects of synthetic, polypropylene mesh on surgical outcomes of contaminated ventral hernia repairs [11]. In this retrospective study, 94% of the procedures had retro-rectus placement of mesh, while the remaining 1% and 5% of mesh were placed in the onlay and preperitoneal positions, respectively. With a mean follow-up of 63 months, there was a 7% overall recurrence rate, suggesting that even with a permanent implant, recurrence rates range from 5 to 10%. That study did not differentiate the mesh location in their recurrences.

In a more recent study, recurrence and complication rates were evaluated using multiple types of mesh. The overall complication rate was reported as 37.7%. Furthermore, recurrence rates using synthetic, bio-absorbable, and biologic mesh were 16.2%, 17.1%, and 25%, respectively. In fact, the recurrence rate after retro-rectus polypropylene mesh repairs was significantly higher with lightweight (22.9%) compared to midweight mesh (10.6%). With respect to mesh placement, the recurrence rate was lower in patients whose graft was placed in the retro-rectus position (10%) rather than the intraperitoneal position (30%). In comparison to these findings, our study demonstrated a similar overall

recurrence rate using bio-absorbable mesh (11.1%) and a lower recurrence rate in the retro-rectus position (8.1%). These results suggest that perhaps the benefits of utilizing bio-absorbable mesh in open complex ventral hernia repairs is more related to the technique of the repair rather than the longevity of the material [12]. Although not the scope of this study, the recurrences that occurred in this patient cohort were typically smaller than the original hernia and were repaired by either laparoscopic approach or redo retro-rectus repair with a bio-absorbable mesh. Also, regardless of whether or not the patient experienced a recurrence, the patients were satisfied with their outcome as evidenced by the HerQLes results. This is similar to other studies [5, 8].

A limitation of this study, as with many hernia studies, is the long-term follow up. With continued contact both in person and by telephone survey, we were able to achieve an average of 22 months follow up. The potential for missed recurrences exists because patients may elect to have their hernia repaired elsewhere, or they are not aware of a recurrence due to lack of pain or a bulge. In other studies assessing hernia recurrence, many of the recurrences do not manifest clinically until 2 years [13]. Thus, this current study has a similar follow-up length compared to other studies, and further follow-up would likely reveal additional recurrences.

A potential limitation to this retrospective cohort study is that there may have been a potential bias in the peritoneal placement of the bio-absorbable mesh. Although the placement of mesh was at the discretion of the attending surgeon, retro-rectus placement was the preferred position, and thus more complex cases with greater posterior sheath destruction likely necessitated the intraperitoneal placement of mesh. It is difficult to determine if the higher recurrence rate of intraperitoneal mesh is merely due to either the more complex hernia or anatomical position of the mesh. In addition, since there were only seven patients in the intraperitoneal group, versus 74 in the retro-rectus group, there is the possibility of a type 1 error.

As the populations of most Western societies continue to have increasing rates of obesity, type 2 diabetes, and other co-morbidities, the risk for significant wound complications in open hernia repair remains high. Wound-related complications are associated with worse hernia outcomes, including mesh infection and recurrence. At the same time, current teaching suggests that long-term durable hernia repair requires permanent prosthetic reinforcement. However, this study adds to the growing body of literature suggesting that absorbable synthetic mesh, when placed in the retro-rectus position, has similar long-term recurrence rates as permanent synthetic mesh. Therefore, in patients with a high risk for wound or mesh related complications, absorbable synthetic mesh placed in the retro-rectus space provides a safe and durable hernia repair.

Compliance with ethical standards

Disclosures Andrew Kastenmeier, MD has received personal fees from WL Gore. Jon Gould, MD has received personal fees from WL Gore and Grant funding and personal fees from Torax Medical. Matthew Goldblatt, MD has received personal fees from WL Gore, grant funding and personal fees from Medtronic, grant funding from Merck, personal fees from Allergan, and grant funding from BD. Juliann Cho, Melissa Helm, Joseph Helm and Neil Mier no conflicts of interest or financial ties to disclose.

References

1. Chung J, Tse GH, O'Dwyer PJ (2014) Outcome of patients with chronic mesh infection following abdominal wall hernia repair. Hernia 18:701–704
2. Itani KM, Rosen M, Vargo D, RICH Study Group et al (2012) Prospective study of single-stage repair of contaminated hernias using a biologic porcine tissue matrix: the RICH Study. Surgery 152:498–505
3. Breuing K, Butler CE, Ferzoco S, Franz M et al (2010) Incisional ventral hernias: review of the literature and recommendations regarding the grading and technique of repair. Surgery 148(3):544–558
4. Rosen MJ, Denoto G, Itani KM et al (2013) Evaluation of surgical outcomes of retro-rectus versus intraperitoneal reinforcement with bio-prosthetic mesh in the repair of contaminated ventral hernias. Hernia 17:31–35
5. Krpata DM, Schmotzer BJ, Flocke S et al (2012) Design and initial implementation of HerQLes: a hernia-related quality-of-life survey to assess abdominal wall function. Am Coll Surg 215(5):635–642
6. Baucom RB, Ousley J, Feurer ID et al (2016) Patient reported outcomes after incisional hernia repair—establishing the ventral hernia recurrence inventory. Am J Surg 212(1):81–88
7. Binnebosel M, Klink CD, Otto J et al (2010) Impact of mesh positioning on foreign body reaction and collagenous in growth in a rabbit model of open incisional hernia repair. Hernia 14:71–77
8. Rosen MJ, Bauer JJ, Harmaty M et al (2017) 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 study. Ann Surg 265:205–211
9. De Vries Reilingh TS, van Goor H, Charbon JA et al (2007) Repair of giant midline abdominal wall hernias: "components separation technique" versus prosthetic repair: interim analysis of a randomized controlled trial. World J Surg 31:756–763
10. Helgstrand F, Rosenberg J, Kehlet H et al (2013) Nationwide prospective study of outcomes after elective incisional hernia repair. J Am Coll Surg 216:217–228
11. Carbonell AM, Criss CN, Cobb WS et al (2013) Outcomes of synthetic mesh in contaminated ventral hernia repairs. J Am Coll Surg 217:991–998
12. Cobb WS, Warren JA, Ewing JA et al (2015) Open retromuscular mesh repair of complex incisional hernia: predictors of wound events and recurrence. J Am Coll Surg 220(4):606–613
13. Rosen MJ, Krpata DM, Ermlich B, Blatnik JA (2013) A 5-year clinical experience with single-staged repairs of infected and contaminated abdominal wall defects utilizing biologic mesh. Ann Surg 257:991–996