Published in final edited form as:

Plast Reconstr Surg. 2017 May ; 139(5): 1234–1244. doi:10.1097/PRS.0000000000003264.

The Impact of Body Mass Index on Abdominal Wall Reconstruction Outcomes: A Comparative Study

Salvatore A Giordano, MD, PhD, Patrick B Garvey, MD, FACS, Donald P Baumann, MD, FACS, Jun Liu, PhD, and Charles E Butler, MD, FACS

Department of Plastic Surgery, The University of Texas MD Anderson Cancer Center, Houston, TX

Abstract

Background—Obesity and higher body mass index (BMI) may be associated with higher rates of wound healing complications and hernia recurrence rates following complex abdominal wall reconstruction (AWR). We hypothesized that higher BMI's result in higher rates of postoperative wound healing complications but similar rates of hernia recurrence in AWR patients.

Methods—We included 511 consecutive patients who underwent AWR with underlay mesh. Patients were divided into three groups on the basis of preoperative BMI: $<30 \text{ kg/m}^2$ (non-obese), $30\text{--}34.9 \text{ kg/m}^2$ (class I obesity) and $\geq 35 \text{ kg/m}^2$ (class II/III obesity). We compared postoperative outcomes among these three groups.

Results—Class I and class II/III obesity patients had higher surgical site occurrence rates than non-obese patients (26.4% vs. 14.9%; $p=0.006$ and 36.8% vs. 14.9%; $p<0.001$, respectively) and higher overall complication rates (37.9% vs. 24.7%; $p=0.007$ and 43.4% vs. 24.7%; $p<0.001$, respectively). Similarly, obese patients had significantly higher skin dehiscence (19.3% vs 7.2%; $p<0.001$ and 26.5% vs 7.2%; $p<0.001$, respectively) and fat necrosis rates (10.0% vs 2.1%; $p=0.001$ and 11.8% vs 2.1%; $p<0.001$, respectively) than non-obese patients. Obesity class II/III patients had higher infection and seroma rates than non-obese patients (9.6% vs 4.3%; $p=0.041$ and 8.1% vs 2.1%; $p=0.006$, respectively). However, class I and class II/III obesity patients experienced hernia recurrence rates (11.4% vs. 7.7%; $p=0.204$ and 10.3% vs. 7.7%; $p=0.381$, respectively) and freedom from hernia recurrence (overall log-rank $p=0.41$) similar to non-obese patients.

Conclusions—Hernia recurrence rates do not appear to be affected by obesity on long-term follow-up in AWR.

Corresponding author: Charles E Butler, MD, The University of Texas MD Anderson Cancer Center, 1400 Pressler St., Unit 1488, Houston, TX 77030, cbutler@mdanderson.org.

Level of Evidence: III

Financial Disclosure Statement:

Financial Support: This research was supported in part by the National Institutes of Health through MD Anderson's Cancer Center Support Grant CA016672.

Products Mentioned: AlloDerm and Strattice, Acelity Corp, Bridgewater, NJ. Surgimend, TEI Biosciences, Inc., Boston, MA.

Financial Disclosure: No author has a relevant financial conflict with the material presented in this manuscript.

Keywords

Obesity; BMI; hernia; abdominal wall; surgical mesh; acellular dermis; postoperative complications; component separation; strattice; surgimend

INTRODUCTION

The number of abdominal wall reconstruction (AWR) procedures, including ventral hernia repair, has been growing annually in the United States over the past several years, with over 350,000 such surgeries performed in 2014. [1] Obesity (body mass index [BMI] ≥ 30 kg/m²) has also been rising continuously in the United States over the past several years and has a current prevalence of 35.0% among men and 40.4% among women. [2] Furthermore, the prevalence of class II and III obesity (BMI 35–39.9 kg/m² and ≥ 40 kg/m², respectively) increased significantly between 2005 and 2014. [2]

It is well known that obese patients are more likely to have comorbid medical conditions, which compound their peri-operative risk. [2, 3] Obesity complicates surgical treatment by increasing the risk of surgical adverse events, including nosocomial infections, readmissions, blood transfusion, wound healing problems, surgical site infections, and abscess formation. [4, 5]

AWR can be particularly challenging in obese patients, independent of the size of the hernia/defect. [3] Recent studies suggest that obesity increases the rates of complications after AWR, and elevated BMI is associated with rates of wound healing complications and hernia recurrence up to 48.7% and 41.7%, respectively, after AWR. [6, 7, 8] Further complicating this issue, over 54% of Americans have a centralized abdominal distribution of subcutaneous fat, or “abdominal obesity.” [3]

Therefore, surgical technique modifications have been described and proposed in order to improve surgical field exposure and limit postoperative wound healing complications in obese patients undergoing AWR. [9, 10] However, to date, only a few studies have compared AWR outcomes in obese and non-obese patients, and the data available are confounded by significant heterogeneity within cohorts, particularly regarding the type of the study population, the abdominal hernia/defect size and short duration of follow-up. [7, 11–14]

Some studies have analyzed the degree of obesity as an independent risk factor in abdominal surgical outcomes. [9, 10] Although AWR outcomes are worse in patients with BMI ≥ 30 kg/m², the relationship between the degree of obesity and postoperative complications in these procedures has not yet been clearly defined. [6–8] Quantifying the risk factors among different obesity classes could help to optimize the outcomes and minimize both complication and recurrence rates associated with AWR. It could also help surgeons properly screen and counsel patients preoperatively about AWR procedures.

The aim of this study was to assess the impact of the degree of BMI on AWR complications and hernia recurrence outcomes in an attempt to quantify the differences between patients with class I or class II/III obesity compared with non-obese patients. We hypothesized that

obese patients experience higher wound healing complication rates but similar hernia recurrence rates after AWR compared with non-obese patients.

METHODS

Patients

We queried the institutional database for consecutive patients who had undergone midline complex AWR with underlay (i.e. preperitoneal or intraperitoneal) or sublay (i.e. retro-rectus) acellular dermal matrix (ADM) for an abdominal wall ventral hernia and/or oncologic resection defect [15] at The University of Texas MD Anderson Cancer Center from March 2005 through October 2015. We followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational cohort studies. [16] We conducted this clinical investigation in accordance with the ethical principles of the World Medical Association Declaration of Helsinki and the laws of the United States of America. The Institutional Review Board approved this study, and individual informed consent was waived because the source data were de-identified.

For the purpose of the present study, patients were divided into three groups on the basis of preoperative BMI: <30 (non-obese), 30 – <35 (class I obesity), and ≥ 35 kg/m² (class II/III obesity). The outcomes of these groups of patients were compared.

Patients with lateral defects not involving the midline, primary closure of their abdominal wall fascia without mesh, onlay mesh reconstructions other than ADM, defects reconstructed or bridged with tissue from free or local musculocutaneous or fasciocutaneous flaps or fascial grafts, or follow-up less than 6 months were excluded from the study. We excluded synthetic mesh AWRs because the number of cases in our database was too small for a meaningful statistical comparison.

Patients had been followed up with physical examination and computed tomographic (CT) imaging (88.8% of cases had a postoperative CT scan at follow-up). The AWR follow-up was robust since our institution serves an oncologic population; both clinical and radiologic surveillance were accomplished according to each patient's tumor protocol, typically quarterly for the first year and then annually thereafter. Data were accurately collected both from a prospectively maintained departmental database and from the patients' electronic medical records.

Patient, treatment, and defect characteristics were analyzed, and surgical outcomes were directly compared between the different groups. A medical comorbidity was defined as having one or more of the following conditions: coronary artery disease, diabetes mellitus, hypertension, pulmonary disease, or renal disease. Wounds were considered contaminated if they met the American College of Surgeons' National Surgical Quality Improvement Program definition of contaminated or infected (class 3–4). [17] Patients who smoked tobacco within 1 month of surgery were considered to be active smokers.

Recurrent hernia was a contour abnormality associated with a fascial defect detected by physical examination and/or CT scan; bulging was a contour abnormality without a fascial

defect. Hernia and bulge were considered mutually exclusive conditions and were diagnosed by physical examination and/or CT imaging. The surgical techniques in AWR have been previously described. [15, 18] Surgical site occurrence (SSO) was defined as any complication involving the abdominal wall. Wound dehiscence was defined as a skin breakdown with full-thickness skin separation extending over 2-cm with or without infection, while skin necrosis involved clearly demarcated necrotic skin edges over 1-cm in width. Fat necrosis was a palpable firmness 1-cm or greater in diameter that persisted beyond 3 months postoperatively. Infection was an infectious process (cellulitis/abscess) requiring treatment with intravenous or oral antibiotics with or without surgery. Hematoma and seroma were subcutaneous collections of blood or serous fluid, respectively, requiring percutaneous or operative drainage.

The primary outcome measure was SSO after AWR. Secondary outcome measures were hernia recurrence, abdominal wall bulge, time to recurrence at follow-up, overall complications, surgical site infections (SSI), and incidences of the following postoperative complications: bulging or laxity of the abdominal wall and specific wound healing complications (skin dehiscence, skin necrosis, fat necrosis, cellulitis, abscess, hematoma, and seroma).

Statistical Analysis

Continuous variables were reported as the mean $\pm$ standard deviation. Pearson's chi-square test or Fisher's exact test was used to assess association between categorical variables as appropriate. Two sample t-test was used for pairwise comparisons of continuous variables among the three BMI groups. The correlation between preoperative BMI and other continuous variables were evaluated with Pearson's or Spearman's correlation coefficient.

The Youden index was used to determine the best cutoff value of the BMI value for SSO and the relative risk (RR) was calculated.

Time to hernia recurrence was defined as the time interval from the reconstructive surgery date to the first hernia recurrence date or the last follow-up date if a hernia recurrence had not yet occurred by that date. Hernia recurrence-free probability were estimated using Kaplan-Meier product limit method that accounted for censoring. - The differences in time to hernia recurrence among the three groups were evaluated by using the log-rank test.

Logistic regression and Cox proportional hazard regression models were used to estimate the odds ratios (ORs) and hazard ratios (HRs) for risk factors associated with SSO and hernia recurrence. A stepwise model selection method was used to fit a multivariate regression model.

P-values less than 0.05 were considered statistically significant. All tests were two-sided. All analyses were carried out using SPSS statistical software (IBM SPSS Statistics, version 23, Armonk, NY).

RESULTS

Patient Demographics and Reconstructions

We identified 511 consecutive patients who underwent AWR with underlay or sublay ADM during the period of the study, with a mean follow-up for the overall series of 31.4 ± 22.4 months. The mean BMI was 31.4 ± 6.8 kg/m². Two hundred and seventy-six (54.2%) of the patients were obese (BMI ≥ 30 kg/m²). Patients' baseline characteristics and risk factors are outlined in Table 1, showing that obese patients had significantly higher rates of diabetes and hypertension, worse American Society of Anesthesiologists (ASA) status and larger abdominal hernia defect sizes, as well as higher rates of pulmonary disease. Mean follow-up was similar among the groups.

Operative time was significantly longer in patients with BMI ≥ 30 mg/kg² than in non-obese patients, but there was no difference between obesity class I and class II/III (Table 2). Likewise, our surgeons employed a component separation technique more often in patients with obesity class II/III than in non-obese patients (77.9% vs 62.1%; $p=0.002$). Bridged repairs, panniculectomies, and tissue flaps were used in similar proportions among the groups. No differences between the BMI groups were detected in the type of bioprosthetic used, including non-cross-linked porcine ADM (Strattice, Acelity Corp, Bridgewater, NJ), non-cross-linked bovine ADM (Surgimend, TEI Biosciences, Inc., Boston, MA), and human cadaveric ADM (AlloDerm, Acelity Corp, Bridgewater, NJ).

BMI Class and Patient Outcomes

We detected a significant positive correlation between the patients' BMIs and the incidence of SSO ($r=0.22$, $p<0.001$), operative time ($r=0.18$, $p<0.001$), and estimated blood loss ($r=0.05$, $p<0.001$). In contrast, we did not find any significant correlation between BMI and hospital stay ($r=0.03$, $p=0.564$) or hernia recurrence ($r=0.04$, $p=0.418$).

Patients with a BMI ≥ 30 had a more than 2-fold higher SSO rate and patients with a BMI ≥ 35 had a more than 3-fold higher SSO rate compared to non-obese patients (26.4% versus 14.9%, odds ratio [OR] 2.2, 95% confidence interval [CI] 1.2–3.4, $p=0.006$ and 36.8% versus 14.9%, OR 3.3, 95% CI 2.0–5.5, $p<0.001$, respectively, Table 3). The percentages of patients with and without SSO in each BMI category are shown in Fig. 1. Similar significant differences were observed in overall complications, with lower rates corresponding to lower BMI. In particular, patients with both class I and II/III obesity had significantly higher skin dehiscence and fat necrosis rates compared with non-obese patients. Infection and seroma rates were significantly higher in class II/III obese patients than in non-obese patients. No significant differences were detected between obesity class I and class II/III patients in the rates of SSO or any complication. The best BMI break point identified by the ROC curve with respect to SSO was 31.9 kg/m².

Mesh exposure occurred more often in obesity class I patients compared with non-obese ones, but we observed no other differences in mesh-related complications. All three groups had similar rates of re-operation, re-admission, and intensive care unit admission.

At follow-up there was no difference in the hernia recurrence rates among the three groups. Time to recurrence was, however, shorter in class II/III obese patients than in class I obese patients. Kaplan-Meier curves did not show a significant difference in freedom from hernia recurrence between the three groups (Fig. 2). The percentage of patients with and without hernia recurrence in each BMI category is shown in Fig. 3.

Univariate analysis showed BMI ≥ 30 kg/m², stoma presence, comorbidity, diabetes, hypertension, wound contamination grade 3 or 4, defect width ≥ 15 cm, and panniculectomy to be associated with SSO (Table 4). These factors were then analyzed with multivariate logistic regression, which confirmed that both stoma presence (adjusted OR 2.4, 95% CI 1.5–3.8, $p<0.001$), comorbidity (adjusted OR 2.2, 95% CI 1.1–4.2, $p=0.021$) and BMI ≥ 30 kg/m² (adjusted OR 2.5, 95% CI 1.6–3.9, $p<0.001$) were significant independent predictors of SSO (Table 4).

Multivariable Cox proportional hazard regression models identified bridged repair (adjusted HR 7.4, 95% CI 4.0–13.7, $p<0.001$), human ADM (adjusted HR 3.2, 95% CI 1.5–7.1, $p=0.003$), coronary artery disease (adjusted HR 2.9, 95% CI 1.4–5.7, $p=0.002$), smoking (adjusted HR 2.9, 95% CI 1.2–6.5, $p=0.013$), and wound dehiscence (adjusted HR 2.5, 95% CI 1.3–4.9, $p=0.006$) to be factors significantly associated with the development of hernia recurrence (Table 4). Component separation was demonstrated to be an independent protective factor with almost a three-fold reduction against hernia recurrence (adjusted HR 0.4, 95% CI 0.2–0.7, $p<0.001$).

DISCUSSION

Many surgeons view obesity as a contraindication to performing AWR, yet denying obese patients AWR excludes a significant portion of the patient population suffering from the consequences of an abdominal incisional hernia. Our data support our hypothesis that obesity is associated with higher rates of complications compared to those in non-obese patients. Indeed, we identified a BMI cutoff of 31.9 kg/m², using an ROC curve, above which the rate of SSO was significantly higher. However, although the rate of overall complications was higher and the length of surgery was longer, the rate of hernia recurrence was not found to be higher with increasing degree of obesity. Thus, although obese patients do appear to experience higher rates of wound healing complications, they do not necessarily experience higher rates of reconstruction failure or hernia recurrence.

Our finding that the incidence of the wound healing complications skin dehiscence, fat necrosis, infection, and seroma increased with increasing BMI corroborates results from previous studies on this topic. Many recent studies have shown a significantly higher complication rate among patients with higher BMI. [8, 9, 18–24] However, these studies were limited by small patient study populations, [19, 20] short postoperative follow-up, [19] or data obtained from the National Surgical Quality Improvement Program register, which only includes follow-up data occurring within 30 days of surgery. [8, 20–24] Our obesity class III (BMI ≥ 40 kg/m²) population was limited ($n=46$ patients) and did not allow us to corroborate a previous study showing that complications are most likely to occur in patients with BMI over 40 kg/m². [24]

Our data showing higher rates of wound healing complications among obese patients are also supported by recent experimental and epidemiological studies demonstrating that there is a high degree of association between metabolic regulation and the immune response. [25, 26]

As is widely known, low-grade chronic inflammation is present in obesity, where white adipose tissue and adipose tissue-derived macrophages secrete several cytokines, so-called “adipokines,” including tumor necrosis factor- α , interleukin (IL)-1, and IL-6. [25] The signals related to metabolic surplus in obese patients are similar to those present in response to injury and tissue repair, such as that caused by major surgical procedures like AWR. [26] However, morbidly obese patients experience inefficient energy use because this extreme metabolic excess leads to hypermetabolic inflammatory responses, oxidative stress, and immunosuppression. [25, 26] For all these reasons, these patients are potentially not fully prepared to deal with high physiologic stress and may experience more postoperative complications and other adverse events than non-obese patients.

An excess of subcutaneous fat, which is relatively poorly perfused with low oxygen tension, in obese patients might predispose them to impaired wound healing and its associated complications. [27] Furthermore, obese patients have higher incidences of diabetes, insulin resistance, and poor glycemic control, all of which are known to increase the risk of postoperative complications. Although, we did not observe significant differences in complications between class I and class II/III obesity, we did notice a trend towards a progressive increase in complications with greater obesity (Table 3).

In contrast to most of the previous studies, [8, 28, 29] we did not find significant differences in hernia recurrence among the different obesity classes. It has been speculated that patients with higher BMIs have greater intra-abdominal pressure, which might affect the fascial integrity after reconstruction and, thus, predispose the patients to recurrences, particularly patients with visceral obesity. [8] Our similar hernia recurrence rates among the different obesity classes may be explained by the surgical technique adopted by our surgeons. Component separation was included in the majority of cases, and it was more common among obese patients likely because the parallel increase in BMI and hernia/defect size (Table 1) made component separation necessary in order to obtain a fascial coaptation. [29–31]

Mesh choice is another important issue in these procedures. The use of bioprosthetic mesh has been shown to be associated with a low incidence of mesh-related infection, adhesion, and enterocutaneous fistulae [32]; lower rates of infection, mesh exposure leading to explantation, and reconstruction failure [31–36]; and fewer infectious wound complications, [32, 33] but it has similar hernia recurrence rates compared to synthetic mesh [34] and is more expensive. [31–36]

In our study, we found that mesh exposure seemed to be greater in class II/III obese patients compared with the non-obese group; however, this difference did not persist with mesh infection or removal rates, and it probably reflects the higher skin dehiscence rates detected among the obese patients. The fact that ADM was typically placed in an underlay position to

facilitate mesh revascularization from the posterior sheath may explain why ADM exposure did not appear to lead to serious sequelae such as mesh explantation. This placement allows for conservative wound management like negative-pressure wound therapy in the case of delayed wound healing, avoids further procedures in the operating room such as new mesh implantation, and, therefore, reduces morbidity. [37, 38]

Preoperative optimization of obese patients undergoing AWR is important in order to mitigate the risk of complications. Glucose control, smoking cessation, and nutritional therapy have shown significant promise. A recent study demonstrated that medically supervised weight loss prior to AWR can significantly reduce postoperative complications among morbidly obese patients and it can be considered a possible additional strategy to minimize SSO. [7] In contrast, non-surgical weight loss before AWR can lead to a delay of the AWR procedure. [7, 39] Nonetheless, the effects of preoperative weight loss on AWR outcomes, particularly hernia recurrence, are still not clear, and further research on this topic is warranted. [39]

On the other hand, if AWR cannot be delayed or preoperative weight loss is not achievable, laparoscopic AWR might be considered, as it has been shown to be associated with lower rates of complications (8.8%) and hernia recurrences (3.8%). [40] Laparoscopic AWR seems also to be associated with fewer surgical site infections and reoperations [8] and with a shorter hospital stay. [9] Nevertheless, in morbidly obese patients, a staged or concomitant bariatric surgery has been shown to be safe and feasible. [41, 42] Given the possible additional wound healing risk, panniculectomy can also be performed with drain placement to minimize seroma formation in selected patients. [7, 20, 43, 44]

The strengths of this study include its large sample size, consistent surgical technique, long-term follow-up, and relatively large defect/hernia sizes. We considered a large number of variables in order to minimize confounders. Also, our center's routine tumor recurrence surveillance protocols with both clinical examination and CT scans (in 88.8% of cases) confer very high sensitivity and specificity for hernia recurrence detection that is unmatched in the medical literature. [45]

Limitations include a retrospective study design and lack of randomization, which introduce the possibility of selection bias. Another important limitation is the illness severity and complexity of the patients in our unique oncological practice setting, which exceeds those usually encountered in AWR practices. This complexity of our patients and need for postoperative adjuvant therapy influenced our surgeons to prefer ADM over synthetic mesh. This differs from many other practitioners who use synthetic mesh primarily due to lesser patient complexity and initial cost pressures. Nevertheless, component separation was performed more often among obese patients with higher BMI. This fact may have further influenced the outcomes, particularly because component separation was found to be a protective factor against hernia recurrence. Lastly, the BMI cutoff we identified is specific to our data set. Therefore, external validation is needed.

Further studies on this topic are warranted and, the effect of preoperative weight loss among obese patients, as well as that of bariatric surgery, should be further investigated as a measure to reduce postoperative complications and hernia recurrence in the long term.

CONCLUSIONS

Our results show that a BMI $\geq 30 \text{ kg/m}^2$ is associated with significantly higher rates of wound healing complications but not with higher rates of hernia recurrence on long-term follow-up in complex AWR. Obese patients should be carefully counseled about the longer operative time and increased risk of wound healing complications.

References

1. Poulose BK, Shelton J, Phillips S, et al. Epidemiology and cost of ventral hernia repair: making the case for hernia research. *Hernia*. 2012; 16:179–183. [PubMed: 21904861]
2. Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in obesity among adults in the United States, 2005 to 2014. *JAMA*. 2016; 315:2284–2291. [PubMed: 27272580]
3. Ford ES, Maynard LM, Li C. Trends in mean waist circumference and abdominal obesity among US adults, 1999–2012. *JAMA*. 2014; 312:1151–1153. [PubMed: 25226482]
4. Manilich E, Vogel JD, Kiran RP, Church JM, Seyidova-Khoshknabi D, Remzi FH. Key factors associated with postoperative complications in patients undergoing colorectal surgery. *Dis Colon Rectum*. 2013; 56:64–71. [PubMed: 23222282]
5. Wick EC, Hirose K, Shore AD, et al. Surgical site infections and cost in obese patients undergoing colorectal surgery. *Arch Surg*. 2011; 146:1068–1072. [PubMed: 21576597]
6. Kaoutzanis C, Leichtle SW, Mouawad NJ, et al. Risk factors for postoperative wound infections and prolonged hospitalization after ventral/incisional hernia repair. *Hernia*. 2015; 19:113–123. [PubMed: 24030572]
7. Rosen MJ, Aydogdu K, Grafmiller K, Petro CC, Faiman GH, Prabhu A. A multidisciplinary approach to medical weight loss prior to complex abdominal wall reconstruction: Is it Feasible? *J Gastrointest Surg*. 2015; 19:1399–1406. [PubMed: 26001369]
8. Regner JL, Mordant MM, Munoz-Maldonado Y. Tailoring surgical approach for elective ventral hernia repair based on obesity and National Surgical Quality Improvement Program outcomes. *Am J Surg*. 2015; 210:1024–1029. [PubMed: 26455523]
9. Fekkes JF, Velanovich V. Amelioration of the effects of obesity on short-term postoperative complications of laparoscopic and open ventral hernia repair. *Surg Laparosc Endosc Percutan Tech*. 2015; 25:151–157. [PubMed: 25222715]
10. Tsereteli Z, Pryor BA, Heniford BT, Park A, Voeller G, Ramshaw BJ. Laparoscopic ventral hernia repair (LVHR) in morbidly obese patients. *Hernia*. 2008; 12:233–238. [PubMed: 18064399]
11. Desai KA, Razavi SA, Hart AM, Thompson PW, Losken A. The Effect of BMI on outcomes following complex abdominal wall reconstructions. *Ann Plast Surg*. 2016; 76(Suppl 4):S295–297. [PubMed: 26808768]
12. Mullen JT, Moorman DW, Davenport DL. The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. *Ann Surg*. 2009; 250:166–172. [PubMed: 19561456]
13. Doyle SL, Lysaght J, Reynolds JV. Obesity and post-operative complications in patients undergoing non-bariatric surgery. *Obes Rev*. 2010; 11:875–886. [PubMed: 20025695]
14. Ching SS, Sarela AI, Dexter SP, Hayden JD, McMahon MJ. Comparison of early outcomes for laparoscopic ventral hernia repair between nonobese and morbidly obese patient populations. *Surg Endosc*. 2008; 22:2244–2250. [PubMed: 18622552]
15. Butler CE, Campbell KT. Minimally invasive component separation with inlay bioprosthetic mesh (MICSIB) for complex abdominal wall reconstruction. *Plast Reconstr Surg*. 2011; 128:698–709. [PubMed: 21572378]

16. von Elm E, Altman DG, Egger M, et al. STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014; 12:1495–1499. [PubMed: 25046131]
17. American College of Surgeons National Surgical Quality Improvement Program. User Guide for the 2011 Participant Use Data File. Chicago, IL: Available at: http://site.acsnsqip.org/wp-content/uploads/2012/03/2011-User-Guide_Final.pdf [Accessed January 21, 2016]
18. Garvey PB, Bailey CM, Baumann DP, et al. Violation of the rectus complex is not a contraindication to component separation for abdominal wall reconstruction. *J Am Coll Surg*. 2012; 214:131–139. [PubMed: 22169002]
19. Hultman CS, Clayton JL, Kittinger BJ, Tong WM. Learning curves in abdominal wall reconstruction with components separation: one step closer toward improving outcomes and reducing complications. *Ann Plast Surg*. 2014; 72:S126–131. [PubMed: 24835871]
20. Fischer JP, Wink JD, Nelson JA, Kovach SJ 3rd. Among 1,706 cases of abdominal wall reconstruction, what factors influence the occurrence of major operative complications? *Surgery*. 2014; 155:311–319. [PubMed: 24433774]
21. Nelson JA, Fischer JP, Cleveland EC, Wink JD, Serletti JM, Kovach SJ 3rd. Abdominal wall reconstruction in the obese: an assessment of complications from the National Surgical Quality Improvement Program datasets. *Am J Surg*. 2014; 207:467–475. [PubMed: 24507860]
22. Stey AM, Russell MM, Sugar CA, et al. Extending the value of the National Surgical Quality Improvement Program claims dataset to study long-term outcomes: Rate of repeat ventral hernia repair. *Surgery*. 2015; 157:1157–1165. [PubMed: 25731782]
23. Qin C, Hackett NJ, Kim JY. Assessing the safety of outpatient ventral hernia repair: a NSQIP analysis of 7666 patients. *Hernia*. 2015; 19:919–926. [PubMed: 26508500]
24. Pernar LI, Pernar CH, Dieffenbach BV, Brooks DC, Smink DS, Tavakkoli A. What is the BMI threshold for open ventral hernia repair? *Surg Endosc*. 2016 Jul 20. [Epub ahead of print].
25. Gil A, María Aguilera C, Gil-Campos M, Cañete R. Altered signalling and gene expression associated with the immune system and the inflammatory response in obesity. *Br J Nutr*. 2007; 98:S121–126. [PubMed: 17922949]
26. Gregor MF, Hotamisligil GS. Inflammatory mechanisms in obesity. *Annu Rev Immunol*. 2011; 29:415–445. [PubMed: 21219177]
27. Karapanagioti EG, Assimopoulou AN. Naturally occurring wound healing agents: An evidence-based review. *Curr Med Chem*. 2016 May 17. [Epub ahead of print].
28. Sauerland S, Korenkov M, Kleinen T, Arndt M, Paul A. Obesity is a risk factor for recurrence after incisional hernia repair. *Hernia*. 2004; 8:42–46. [PubMed: 13680307]
29. Ko JH, Wang EC, Salvay DM, Paul BC, Dumanian GA. Abdominal wall reconstruction: lessons learned from 200 “components separation” procedures. *Arch Surg*. 2009; 144:1047–1055. [PubMed: 19917942]
30. Booth JH, Garvey PB, Baumann DP, et al. Primary fascial closure with mesh reinforcement is superior to bridged mesh repair for abdominal wall reconstruction. *J Am Coll Surg*. 2013; 217:999–1009. [PubMed: 24083910]
31. Nelson JA, Fischer JP, Wink JD, Kovach SJ 3rd. A population-level analysis of abdominal wall reconstruction by component separation in the morbidly obese patient: can it be performed safely? *J Plast Surg Hand Surg*. 2014; 48:305–311. [PubMed: 24495185]
32. Garvey PB, Martinez RA, Baumann DP, Liu J, Butler CE. Outcomes of abdominal wall reconstruction with acellular dermal matrix are not affected by wound contamination. *J Am Coll Surg*. 2014; 219:853–864. [PubMed: 25440025]
33. Darehzereshki A, Goldfarb M, Zehetner J, et al. Biologic versus nonbiologic mesh in ventral hernia repair: a systematic review and meta-analysis. *World J Surg*. 2014; 38:40–50. [PubMed: 24101015]
34. Montgomery A, Kallinowski F, Köckerling F. Evidence for replacement of an infected synthetic by a biological mesh in abdominal wall hernia repair. *Front Surg*. 2016; 2:67. [PubMed: 26779487]
35. Rosen MJ, Krpata DM, Ermlich B, Blatnik JA. A 5-year clinical experience with single-staged repairs of infected and contaminated abdominal wall defects utilizing biologic mesh. *Ann Surg*. 2013; 257:991–996. [PubMed: 23426340]

36. Guerra O. Noncrosslinked porcine-derived acellular dermal matrix for single-stage complex abdominal wall herniorrhaphy after removal of infected synthetic mesh: a retrospective review. *Am Surg*. 2014; 80:489–495. [PubMed: 24887729]
37. Holihan JL, Nguyen DH, Nguyen MT, Mo J, Kao LS, Liang MK. Mesh location in open ventral hernia repair: a systematic review and network meta-analysis. *World J Surg*. 2016; 40:89–99. [PubMed: 26423675]
38. Albino FP, Patel KM, Nahabedian MY, Attinger CE, Bhanot P. Immediate, multistaged approach to infected synthetic mesh: outcomes after abdominal wall reconstruction with porcine acellular dermal matrix. *Ann Plast Surg*. 2015; 75:629–633. [PubMed: 24667884]
39. Chan G, Chan CK. A review of incisional hernia repairs: preoperative weight loss and selective use of the mesh repair. *Hernia*. 2005; 9:37–41. [PubMed: 15503240]
40. Marx L, Raharimanantsoa M, Mandala S, D'Urso A, Vix M, Mutter D. Laparoscopic treatment of incisional and primary ventral hernia in morbidly obese patients with a BMI over 35. *Surg Endosc*. 2014; 28:3310–314. [PubMed: 25007972]
41. Schuster R, Curet MJ, Alami RS, Morton JM, Wren SM, Safadi BY. Concurrent gastric bypass and repair of anterior abdominal wall hernias. *Obes Surg*. 2006; 16:1205–1208. [PubMed: 16989705]
42. Newcomb WL, Polhill JL, Chen AY, et al. Staged hernia repair preceded by gastric bypass for the treatment of morbidly obese patients with complex ventral hernias. *Hernia*. 2008; 12:465–469. [PubMed: 18493715]
43. Fischer JP, Tuggle CT, Wes AM, Kovach SJ. Concurrent panniculectomy with open ventral hernia repair has added risk versus ventral hernia repair: an analysis of the ACS-NSQIP database. *J Plast Reconstr Aesthet Surg*. 2014; 67:693–701. [PubMed: 24525270]
44. Janis JE, Khansa I. Evidence-Based Abdominal Wall Reconstruction: The Maxi-Mini Approach. *Plast Reconstr Surg*. 2015; 136:1312–1323. [PubMed: 26291701]
45. Baucom RB, Beck WC, Holzman MD, Sharp KW, Nealon WH, Poulouse BK. Prospective evaluation of surgeon physical examination for detection of incisional hernias. *J Am Coll Surg*. 2014; 218:363–366. [PubMed: 24559951]

Figure 1.

The percentage of patients with and without surgical site occurrence (SSO) in each body mass index (BMI) class.

Figure 2. Kaplan-Meier curves of hernia recurrence among the three different classes of body mass index (BMI).

Figure 3.

The percentage of patients with and without hernia recurrence in each body mass index (BMI) class.

Table 1

Baseline characteristics of patients who underwent abdominal wall reconstruction with acellular dermal matrix according to BMI groups.

	BMI <30	BMI 30 – <35	BMI 35	p-value ^a	p-value ^b	p-value ^c
	235	140	136			
Age (years)	59.5±13.5	59.6±11.3	58.1±11.0	0.922	0.248	0.296
Females	123 (52.3%)	60 (42.9%)	79 (58.1%)	0.076	0.011	0.284
BMI (mg/kg ²)	25.5±3.1	31.8±1.4	39.8±5.2	< 0.001	< 0.001	< 0.001
Comorbidity	188 (80.0%)	114 (81.4%)	118 (86.8%)	0.735	0.226	0.099
Coronary artery disease	28 (11.9%)	10 (7.1%)	17 (12.5%)	0.139	0.134	0.868
Diabetes	23 (9.8%)	33 (23.6%)	32 (23.5%)	< 0.001	0.993	< 0.001
Hypertension	96 (40.9%)	85 (60.7%)	91 (66.9%)	< 0.001	0.284	< 0.001
Pulmonary disease	14 (6.0%)	17 (12.1%)	15 (11.0%)	0.035	0.773	0.079
Renal disease	33 (14.0%)	12 (8.6%)	14 (10.3%)	0.115	0.624	0.296
ASA status	2.8±0.5	2.9±0.4	3.0±0.3	0.022	0.065	< 0.001
Smoking	27 (11.5%)	5 (3.9%)	10 (7.4%)	0.008	0.166	0.200
Preoperative abdominal wall XRT	71 (30.2%)	29 (20.7%)	30 (22.1%)	0.044	0.785	0.089
Preoperative chemotherapy	138 (58.7%)	89 (63.6%)	84 (61.8%)	0.353	0.756	0.565
Stoma presence	46 (19.6%)	37 (26.4%)	35 (25.7%)	0.122	0.896	0.166
Complex hernia	129 (54.9%)	75 (53.6%)	63 (46.3%)	0.804	0.229	0.111
Extrurpative defect	91 (38.7%)	59 (42.1%)	61 (44.9%)	0.513	0.650	0.247
Recurrent hernia	32 (13.6%)	15 (10.7%)	18 (13.2%)	0.412	0.519	0.917
Defect width, cm	10.4±5.2	11.6±4.9	12.7±5.9	0.026	0.114	< 0.001
Defect area, cm ²	196.2±173.9	247.4±189.7	265.1±210.0	0.008	0.465	0.001
Contamination grade 3 or 4	39 (16.6%)	25 (17.9%)	33 (24.3%)	0.753	0.191	0.072
Prior abdominal surgery	224 (95.3%)	135 (96.4%)	131 (96.3%)	0.607	0.963	0.646
History of hernia repair	52 (22.1%)	37 (26.4%)	37 (27.2%)	0.344	0.884	0.270
Follow-up (months)	31.5±23.0	31.3±22.1	32.1±22.1	0.874	0.310	0.470

BMI, body mass index

ASA, American Society of Anesthesiologists

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

XRT, radiotherapy
BMI <30 vs BMI 30 – <35
BMI 30 – <35 vs BMI 35
BMI <30 vs BMI 35

Reconstruction characteristics and perioperative data on patients who underwent abdominal wall reconstruction with acellular dermal matrix according to BMI groups

Table 2

	BMI <30	BMI 30 – <35	BMI 35	p-value ^d	p-value ^b	p-value ^c
	235	140	136			
Operative time (minutes)	340.9±183.5	386.1±192.2	426.6±211.4	0.024	0.097	<0.001
Estimated blood loss (mL)	493.4±1212.2	442.8±632.7	631.8±1375.5	0.649	0.186	0.382
Component separation	146 (62.1%)	100 (71.4%)	106 (77.9%)	0.067	0.214	0.002
Minimally invasive	42 (28.8%)	35 (35.0%)	32 (30.2%)	0.286	0.524	0.704
Bioprosthetic mesh type						
HADM	12 (5.1%)	5 (3.6%)	9 (6.6%)	0.490	0.249	0.544
PADM	117 (49.8%)	72 (51.4%)	60 (44.1%)	0.758	0.224	0.292
BADM	100 (42.5%)	61 (43.6%)	61 (44.9%)	0.785	0.830	0.610
Bridged repair	21 (8.9%)	15 (10.7%)	14 (10.3%)	0.572	0.909	0.666
Panniculectomy	98 (41.7%)	61 (43.6%)	68 (50.0%)	0.723	0.285	0.121
Flap use	15 (6.4%)	15 (10.7%)	8 (5.9%)	0.135	0.146	0.847
Hospital stay (days)	9.9±12.4	9.8±10.3	12.7±32.1	0.881	0.310	0.248

BMI, body mass index

HADM, human acellular dermal matrix

PADM, porcine acellular dermal matrix

BADM, bovine acellular dermal matrix

^aBMI <30 vs BMI 30 – <35

^bBMI 30 – <35 vs BMI 35

^cBMI <30 vs BMI 35

Table 3

Postoperative outcomes of patients who underwent abdominal wall reconstruction with acellular dermal matrix according to BMI groups.

	BMI <30	BMI 30 – <35	BMI 35	p-value ^a	p-value ^b	p-value ^c
	235	140	136			
Hernia recurrence	18 (7.7%)	16 (11.4%)	14 (10.3%)	0.204	0.763	0.381
Time to recurrence *	19.7±14.8	21.6±13.7	13.8±5.6	0.673	0.034	0.128
Bulging/laxity	9 (3.8%)	6 (4.3%)	6 (4.4%)	0.817	0.969	0.784
Recurrent hernia/bulging correction **	7 (25.0%)	5 (23.8%)	8 (42.1%)	0.924	0.217	0.217
Overall complications	58 (24.7%)	53 (37.9%)	59 (43.4%)	0.007	0.350	< 0.001
Surgical site occurrence (SSO)	35 (14.9%)	37 (26.4%)	50 (36.8%)	0.006	0.065	< 0.001
Wound healing complications						
Skin dehiscence	17 (7.2%)	27 (19.3%)	36 (26.5%)	< 0.001	0.155	< 0.001
Fat necrosis	5 (2.1%)	14 (10.0%)	16 (11.8%)	0.001	0.638	< 0.001
Infection cellulitis	10 (4.3%)	11 (7.9%)	13 (9.6%)	0.142	0.616	0.041
Infection abscess	13 (5.5%)	11 (7.9%)	10 (7.4%)	0.374	0.874	0.483
Hematoma	4 (1.7%)	1 (0.07%)	2 (1.5%)	0.420	0.545	0.865
Seroma	5 (2.1%)	7 (5.0%)	11 (8.1%)	0.126	0.299	0.006
Enterocutaneous fistula	5 (2.1%)	1 (0.7%)	1 (0.7%)	0.291	0.984	0.306
Anastomosis leak	5 (2.1%)	3 (2.1%)	1 (0.7%)	0.992	0.328	0.306
Mesh exposure	2 (0.9%)	6 (4.3%)	4 (2.9%)	0.026	0.550	0.124
Mesh infected	3 (1.3%)	1 (0.7%)	1 (0.7%)	0.608	0.984	0.627
Mesh removal	2 (0.9%)	3 (2.1%)	1 (0.7%)	0.291	0.328	0.905
Re-operation	20 (8.5%)	16 (11.4%)	10 (7.4%)	0.354	0.247	0.693
Necessity of ICU	8 (3.4%)	3 (2.1%)	7 (5.1%)	0.484	0.182	0.412
Re-admission (<30 days)	19 (8.1%)	9 (6.4%)	8 (5.9%)	0.555	0.850	0.431

* Calculated among patients who had hernia recurrence after abdominal wall reconstruction during the follow-up period.

** Calculated among patients who had hernia recurrence and bulging during the follow-up period.

BMI; Body Mass Index

ICU; Intensive Care Unit

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

35
BMI <30 vs BMI 30 – <35 vs BMI 35
q
BMI <30 vs BMI 30 – <35 vs BMI 35
p

Table 4

Univariate and multivariable logistic regression models of SSO and Cox PH regression model of hernia recurrence.

	Odds ratio*	95% Confidence interval	<i>p-value</i>
Surgical site occurrence			
	Univariate Analysis		
BMI 30	2.6	1.7–4.0	<0.001
Stoma presence	2.5	1.6–3.9	<0.001
Comorbidity	2.3	1.2–4.4	0.008
BMI 35	2.1	1.3–3.4	0.002
Diabetes mellitus	1.9	1.1–3.1	0.013
Contamination grade 3 or 4	1.8	1.1–2.9	0.019
Hypertension	1.8	1.2–2.7	0.007
Panniculectomy	1.5	1.0–2.3	0.041
Defect width 15 cm	1.5	1.0–2.4	0.042
	Multivariable Analysis		
Stoma presence	2.4	1.5–3.8	<0.001
BMI 30	2.5	1.6–3.9	<0.001
Comorbidity	2.2	1.1–4.2	0.021
	Hazard ratio		
Hernia recurrence			
	Univariate Analysis		
Bridged repair	7.2	3.9–13.2	<0.001
Enterocutaneous fistula	4.3	1.0–17.7	0.045
Coronary artery disease	3.0	1.5–6.0	0.001
Human ADM	2.7	1.3–5.8	0.010
Hematoma	2.7	0.6–11.0	0.174
Wound dehiscence	2.1	1.1–4.0	0.020
Smoking	1.9	0.9–4.3	0.108
Defect width 15 cm	1.7	0.9–3.0	0.082
History of hernia repair	1.7	0.9–3.1	0.091
Stoma presence	1.6	0.9–2.9	0.144
Contamination grade 3 or 4	1.6	0.8–3.3	0.159
Panniculectomy	1.5	0.8–2.6	0.176
Surgical site occurrence	1.5	0.8–2.8	0.165
Component separation	0.5	0.3–0.9	0.188
	Multivariable Analysis		
Bridged repair	7.4	4.0–13.7	<0.001
Human ADM	3.2	1.5–7.1	0.003
Coronary artery disease	2.9	1.4–5.7	0.002

	Odds ratio*	95% Confidence interval	<i>p-value</i>
Smoking	2.9	1.2–6.5	0.013
Wound dehiscence	2.5	1.3–4.9	0.006
Component separation	0.4	0.2–0.7	0.001

SSO, surgical site occurrence; BMI, Body Mass Index; ADM, acellular dermal matrix