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The effect of increasing body mass index on wound complications in open ventral hernia repair with mesh

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ABSTRACT

Background: There is a paucity of data delineating the relationship between body mass index (BMI) and wound complications. We investigated the association between BMI and wound morbidity following open ventral hernia repair with mesh (OVHR).

Design: Patients undergoing elective OVHR were identified within the Americas Hernia Society Quality Collaborative. Multivariate logistic regression identified predictors of 30-day surgical site infection (SSI) and surgical site occurrences requiring procedural intervention (SSOPI). BMI was treated as a continuous variable in the models.

Results: 8949 patients were included (median age 58, median BMI 31.3 kg/m^2, median defect width of 7 cm). Repairs typically included synthetic mesh (89%), placed as a sublay (70%). SSI rate was 4.5% and SSOPI was 6.7%. BMI was associated with increased relative log-odds for SSI ($p = 0.01$) and SSOPI (<0.0001), with a proportional increase in relative log-odds for complications according to escalations in BMI.

Conclusion: Escalating BMI progressively increases relative log-odds for SSI and SSOPI after OVHR. Further studies are necessary to determine whether preoperative weight loss can reduce the impact of this association.

Introduction

Being overweight is now endemic in the United States (US). It is estimated that 40% of adult men and 30% of adult women have a body mass index ranging from 25 to 29.9 kg/m^2 and are therefore classified as overweight[1,2] The addition of the obese population (BMI≥30 kg/m^2) to this statistic estimates that the prevalence of overweight and obesity reaches 66–71% of adults in the US.[3] The problematic relationship between increased BMI and poor outcomes after ventral hernia repairs has been extensively reported in the literature. In addition to an increased risk of hernia formation after abdominal surgeries,[4–6] overweight patients are also prone to higher rates of hernia recurrence than their non-overweight counterparts.[7–10] Also, overweight patients have an elevated risk of medical complications, prolonged hospital length of stay, and augmented health care costs after hernia repair.[11–14]

As the overweight epidemic continues to progress worldwide, managing such patients with ventral hernias is becoming a dilemma which general surgeons now face with increasing frequency. While minimally invasive techniques have reduced rates of wound morbidity following ventral hernia repair (VHR),[15,16] there are many patients that are not candidates for a minimally invasive approach. Indeed, increased BMI is commonly associated with larger and more complex defects (15), often requiring an open approach.

Although increased BMI is associated with hernia recurrence and is linked to a variety of complications after VHR,[17,18] there is a

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paucity of data detailing whether there is a graded relationship between increasing BMI and odds for wound complications after ventral hernia repair. In this study, we sought to[1]: investigate the association between increasing BMI and 30-day surgical site infection (SSI) and surgical site occurrences requiring procedural intervention (SSOPI) following open ventral hernia repair with mesh (OVHR) adjusting for common confounders on clinical characteristics, hernia-specific variables and operative details and[2] delineate how increasing patient BMI impacts the odds for such wound complications.

Methods

Inclusion criteria, patient identification

Following Institutional Review Board (IRB) approval, all patients included in the Americas Hernia Society Quality Collaborative (AHSQC) database were initially identified. Patients who underwent elective OVHR and with 30-day follow-up completed were included for analysis. All ventral hernia types (incisional, parastomal, incisional + parastomal and primary ventral hernias: umbilical, epigastric, Spigelian and lumbar), as well as all Centers for Disease Control and Prevention (CDC) wound classes were included. We have excluded from our analysis: inguinal hernia repairs, VHRs without mesh placement, patients who have undergone ventral hernia repair (VHR) through a minimally invasive approach, and VHRs performed emergently. Also, we have excluded patients where BMI was not reported and patients without 30-day follow-up completed.

Data source

The AHSQC is a hernia-specific nationwide registry with the objective of continuous quality improvement, accomplished through patient-centered data collection, ongoing performance feedback to clinicians, and improvement based on analysis of collected data and collaborative learning. At the time of this study, the AHSQC had data available from 268 surgeons practicing in a variety of clinical settings, including academic, community, and academic-affiliated hospitals. Data on the AHSQC is collected prospectively, entered by the surgeon on a real-time basis during patient care. The AHSQC collects patient demographics information, hernia specific-variables and operative details, as well as patient-reported outcomes (PRO's) and postoperative follow up information at each patient contact. While demographic, follow-up and PRO's can be entered by the surgeon's staff (medical secretary, clinical nurses, fellows, or data abstractors), it is required that hernia variables and operative details are entered by the surgeon. For every surgeon joining the AHSQC, training is provided and educational videos showing best practices for data collection are available on the AHSQC website: www.ahsqc.org/faqs. A data quality assurance process is in place to ensure both completeness and accuracy of the data reported. To ensure data completeness, the number of operations entered in the database by the surgeon is compared to the number of operations that were eligible to be included over a specified time frame. This is performed with a cross-checking process using billing data for the specific surgeon during a pre-determined time frame. To ensure data accuracy, repeated data evaluations are performed targeting key exposure and outcome variables. For such, randomly selected cases entered by the surgeon are reviewed by the AHSQC staff and a local a non-AHSQC surgeon with access to the site's medical records. A recent review of the 5 highest volume centers contributing data to the AHSQC has shown mean completeness of 100% and accuracy of 98.5%. Upon every review, a minimum 90% completeness and accuracy are required or another review is scheduled after remediation. Other details regarding the AHSQC and registry structure, governance, and data assurance process have been previously reported.[19]

Outcomes definitions

Outcomes of interest included were SSI and SSOPI, and definitions of wound complications were based on the work by Haskins et al.[20] In summary, SSI is characterized as superficial, deep, or organ space infection according to the CDC.[21] SSOPI includes any SSI as well as wound cellulitis, non-healing incisional wound, fascial disruption, skin or soft tissue ischemia, skin or soft tissue necrosis, wound serous or purulent drainage, stitch abscess, seroma, hematoma, infected or exposed mesh, or development of an enterocutaneous fistula that requires a procedural intervention for treatment. Procedural interventions include any of the following: wound opening, wound debridement, percutaneous drainage, suture excision and partial or complete mesh removal.[22]

Statistical analysis

Patient demographics, clinical variables, hernia characteristics, operative details and outcomes information were abstracted from the AHSQC in a de-identified manner. Data were described using medians and interquartile ranges (IQR) for continuous variables and counts and percentages for categorical variables as appropriate. Single imputation was used in instances of missing data, which were found to be <1% missing in covariates and <3% for each individual covariates. Multivariate logistic regression models were built to identify predictors of each class of 30-day wound event (SSI and SSOPI) after adjusting for identified confounding factors. BMI was treated as a continuous variable in the models. For all models, the selection of covariates was based on clinical consensus and included: age, gender, diabetes, smoking, chronic obstructive pulmonary disease, immunosuppression, American Society of Anesthesiologists classification, hernia type, hernia width, recurrent hernia, indication for repair (bowel obstruction, enlarging hernia, pain, infected mesh or fistula), history of open abdomen, CDC wound classification, stoma present, mesh location, mesh type, subcutaneous flaps raised, myofascial release and concomitant procedure performed. Confidence intervals were calculated using the bootstrap percentile interval method. Age and hernia width were modeled using restricted cubic regression splines with 3 knots. Because BMI is the covariate of primary interest, it was modeled with a restricted cubic spline with 5 knots. Interactions between recurrent hernia and gender, recurrent hernia and age, and gender and hernia type were included in the model based on findings of prior analyses from our group. Relative log-odds of SSI and SSOPI were calculated for each given value of BMI. Relative log-odds can be interpreted as the log of the odds of obtaining a SSI (or SSOPI) for the given BMI minus the log of the odds of obtaining a SSI (or SSOPI) for a BMI equal to 23. Odds is the ratio of the probability of SSI (or SSOPI) to the probability of no SSI (or no SSOPI). A benefit of interpreting outcomes on the relative log-odds scale is that the predicted relative log-odds is accurate regardless of patient characteristics.

Results

Fig. 1 depicts criteria for study population identification. After exclusions, a total of 8949 patients met inclusion criteria and were included for analysis.

Table 1 reveals patient demographics, hernia variables and operative details of the studied population. The median age was 58

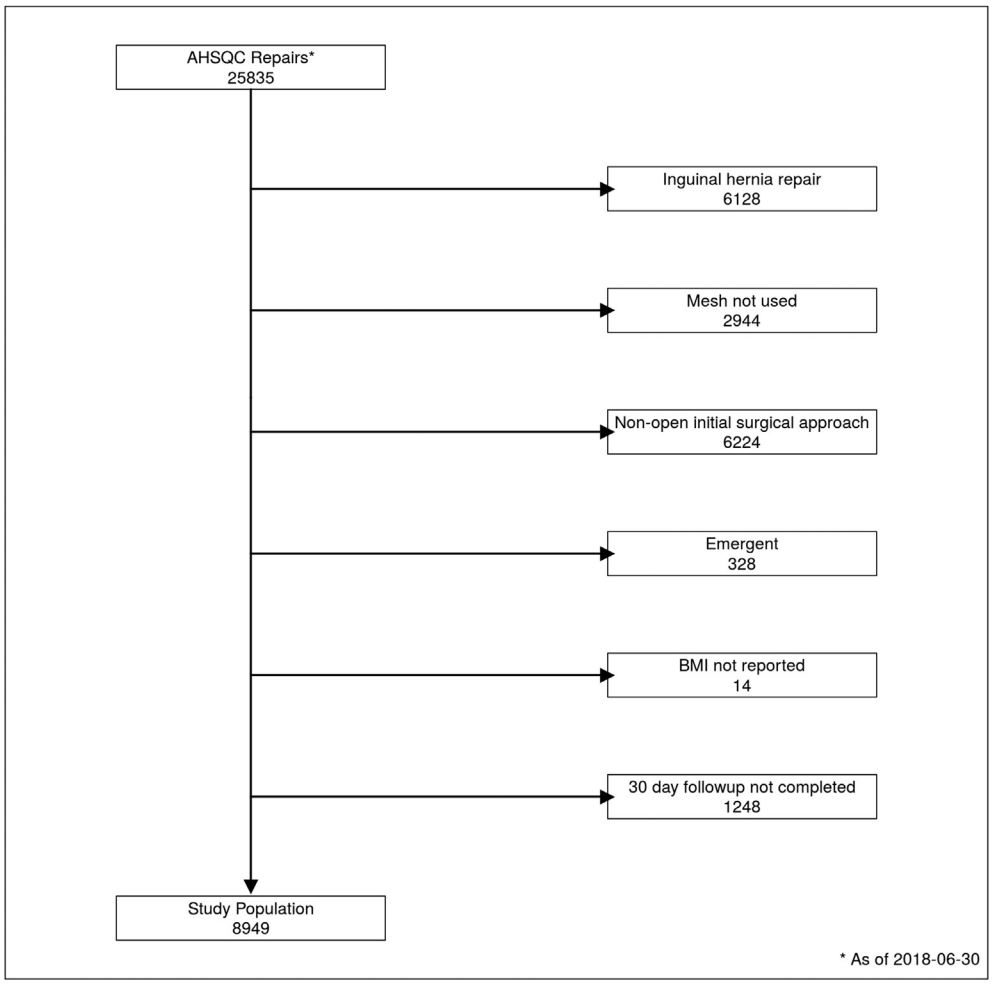

Fig. 1. Study population selection.

years (IQR 48–67), 53% were males, and the median BMI was 31.3 kg/m^2 [IQR 27.5–35.7]. The majority of cases were incisional hernias (70%), with a median defect width of 7 cm [IQR 3–12 cm] and performed in a clean wound (82%). Repairs typically included permanent synthetic mesh (89.4%), most commonly placed in the sublay position (70%), and 54% required a myofascial release. For the entire cohort, 30-day wound morbidity rates were 4.5% for SSI (n = 405) and 6.7% for SSOPI (n = 603).

Multivariate logistic regression models have shown that after adjusting for identified confounding factors, BMI was associated with increased odds for SSI (p = 0.01) and SSOPI (p = <0.0001). Full models can be seen as supplementary material for this work (SDC1).

Figs. 2 and 3 graphically represent the estimated relationship between patient BMI (x-axis) and relative log of odds for SSI and SSOPI (y-axis), respectively. Shading area in the graph represents 95% bootstrap confidence intervals. In both figures, the relative log-odds for wound complication progressively increases according to BMI escalations.

Discussion

Our study demonstrated the association between increasing BMI on 30-day SSI and SSOPI after OVHR while using data from a large nationwide database with hernia-specific variables and operative details. More importantly, this relationship could be graphically represented, illustrating that escalating BMI result in a progressive increase in the relative log-odds for wound complications. As such, our study could demonstrate a clear graded relationship between increasing BMI and odds for wound complications, reinforcing the importance of future research endeavors and quality improvement initiatives to determine whether weight loss, as part of preoperative optimization protocols, could have the ability to decrease complications rates and improve the short- and long-term outcomes of OVHR.

Wound complications following VHR can result in a more than 300% increase in total encounter costs over the short-term.[23] Additionally, as wound infection has also been demonstrated to double the risk for hernia recurrence,[24] an increase in the cost of care is also expected in the long-term. Indeed, Poulose et al.[25] estimated that a 1% reduction in hernia recurrence rates would result in $32 million of procedural cost savings. There is a significant body of literature detailing the deleterious effects of increased BMI on surgical outcomes after VHR, and the findings of our study are corroborated by previously published data originating from other large nationwide databases. For example, Kaoutzanis et al.[26] queried the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database and found that a BMI $\geq$ 30 kg/m^2 was associated with an increased risk of postoperative superficial SSI (OR 1.82), deep SSI (OR 2.87) and wound dehiscence (OR 4.50) after VHR. Mrdutt et al.[27] reviewed elective and emergent open ventral hernia repairs in the ACS-NSQIP

Table 1
Study population information.

Variables	Overall n = 8949	n (%)
Body mass index (BMI), kg/m2, median [IQR]		31.3 [27.5–35.7]
Age, years, median [IQR]		58 [48–67]
Gender		
	Male	4725 (53)
	Female	4224 (47)
Diabetes		1669 (19)
Chronic Obstructive Pulmonary Disease		631 (7)
Immunosuppression		493 (6)
Smoking		1031 (12)
Previous History of Abdominal Wall SSI		1533 (17)
ASA class		
	1	527 (6)
	2	3597 (40)
	3	4590 (51)
	4	226 (3)
Wound Class		
	Clean	7376 (82)
	Clean-Contaminated	915 (10)
	Contaminated	503 (6)
	Dirty	155 (2)
Hernia Type		
	Incisional	6283 (70)
	Parastomal	169 (2)
	Incisional + Parastomal	383 (2)
	Epigastric	371 (4)
	Umbilical	1672 (19)
	Spigelian	43 (0.5)
	Lumbar	27 (0.3)
Hernia width, cm, median [IQR]		7 [3–12]
Recurrent Hernias		3047 (34)
Operative Time (minutes)		
	0–59	1906 (21)
	60–119	1799 (20)
	120–179	1867 (21)
	180–239	1366 (15)
	240+	2011 (22)
Subcutaneous Flaps Raised		2604 (29)
Myofascial release Performed		4800 (54)
Mesh Type		
	Permanent Synthetic	8001 (89.4)
	Absorbable Synthetic	414 (4.6)
	Biologic	501 (5.6)
	Biologic/Synthetic Hybrid	7 (0.07)
	Unknown	26 (0.3)
Mesh Position		
	Onlay	743 (8)
	Sublay [a]	6289 (70)
	Intraperitoneal	1568 (18)
	Inlay	349 (4)
Fascial Closure		8430 (94)
Drains Used		5494 (61)
30-day SSI		405 (4.5)
30-day SSOPI		603 (6.7)

[a] Retromuscular or Preperitoneal.

database and found that overweight and obese patients are at increased risk of developing SSI, wound dehiscence, return to the operating room, and death when compared to normal weight individuals (NWI) undergoing elective open VHR. A trend in increasing odds ratios for complications was seen in linear relation to upscaling BMI classes (OR1.2 for overweight individuals up to OR 2.8 for class III obese individuals undergoing elective VHR when compared to NWI). Likewise, an ACS-NSQIP analysis by Owei et al.[28] found that obese individuals have increased odds for wound and medical complications when compared to NWI (OR 1.2 for BMI>30 kg/m^2). Similarly, the increase in odds for complications was proportional to BMI increase (OR 1.5 for BMI 35–39.9, OR 2.66 for BMI>50 kg/m^2). While the aforementioned studies are consistent in reporting overweight and obesity as risk factors for complications, there is controversy and significant paucity of data detailing at which BMI level this relationship starts to exist. While the study by Mrdutt et al.[27] reported that overweight individuals (BMI 25–30 kg/m2) undergoing elective open VHR experienced a 20% increase in the odds of all complications when compared to NWI in the same setting (OR1.2 95%CI1.0–1.5), the multivariable logistic regression from Owei[28] has not confirmed an independent association between a BMI 25–30 kg/m^2 and increased odds for complications (OR1.02 95%CI0.94-1.11). A more recent study by Pernar et al.[29] aimed to identify a BMI threshold for open VHR using single institution data including 922 patients. In this report, after adjusting for confounding factors, only a BMI≥40 kg/m^2 was shown to be independently associated with complications (OR3.4). When compared to NWI, the study revealed no difference in obese patients with a BMI below this threshold.

Our study differs from the previously mentioned studies, as all prior studies elected to analyze BMI either as a binary patient demographic (either less than or greater than 30 kg/m2) or by discretizing BMI into classes. In contrast, we avoided the negative consequences of discretization at arbitrary cutpoints by estimating a flexible (potentially non-linear) and smooth association between BMI and the relative log-odds of wound complications using restricted cubic splines. Another important distinction in our analysis is that while these reviews establish a graded relationship between obesity classes and wound or medical complications, key operative characteristics such as hernia dimensions, operative approach, mesh type and position are not captured by the ACS-NSQIP dataset, and therefore, are not accounted for. These variables have an established influence on wound complications. In our study, we used the AHSQC database, which collects these variables and consequently allowed us to adjust and control for them.

One important finding of our analysis is that we were unable to identify a particular inflection point when BMI began to negatively affect wound morbidity. This pattern supports the notion that there is no “magic cut point” at which it is either safe to operate or unsafe to operate on an obese patient. It is important for surgeons to understand this concept, as our data does not support surgeons refusing to offer elective hernia repairs to obese patients based on a specific BMI. Instead, we would encourage surgeons to share this information and wound morbidity curves with their patients during preoperative shared decision-making discussions to understand their risk for wound morbidity based on their current BMI.

To date, the optimal management of overweight patients with ventral hernias remains uncertain even among experts. For example, participants in a recent expert consensus panel agreed that elective VHR can be safely performed in patients with a BMI lower than 30 kg/m^2 and that elective repair is prohibitive when BMI is greater than 50 kg/m^2.[17] For those patients with a BMI between 30 kg/m^2 and 50 kg/m^2, the recommendation is that preoperative weight loss is indicated, but there is no agreement regarding the optimal weight loss goal or the best intervention to accomplish such a goal. While many hernia surgeons have embraced the concept of preoperative optimization, engagement and support in the form of shared patient decision-making has proven challenging due to the paucity of data directing these discussions. A focused discussion supported by real-world evidence can illustrate the impact associated with an increased BMI in surgical outcomes and should facilitate patient engagement and motivation for medically-supervised weight loss. On the other hand, clinical judgment remains important to select patients for whom a delay in hernia repair is not appropriate. Hernia size, symptom severity, socioeconomic considerations, the risk of incarceration/strangulation and feasibility of a minimally invasive repair are all factors that must be accounted for when evaluating patients for elective repair of ventral hernias.

It is important to note that the value of mandatory weight loss

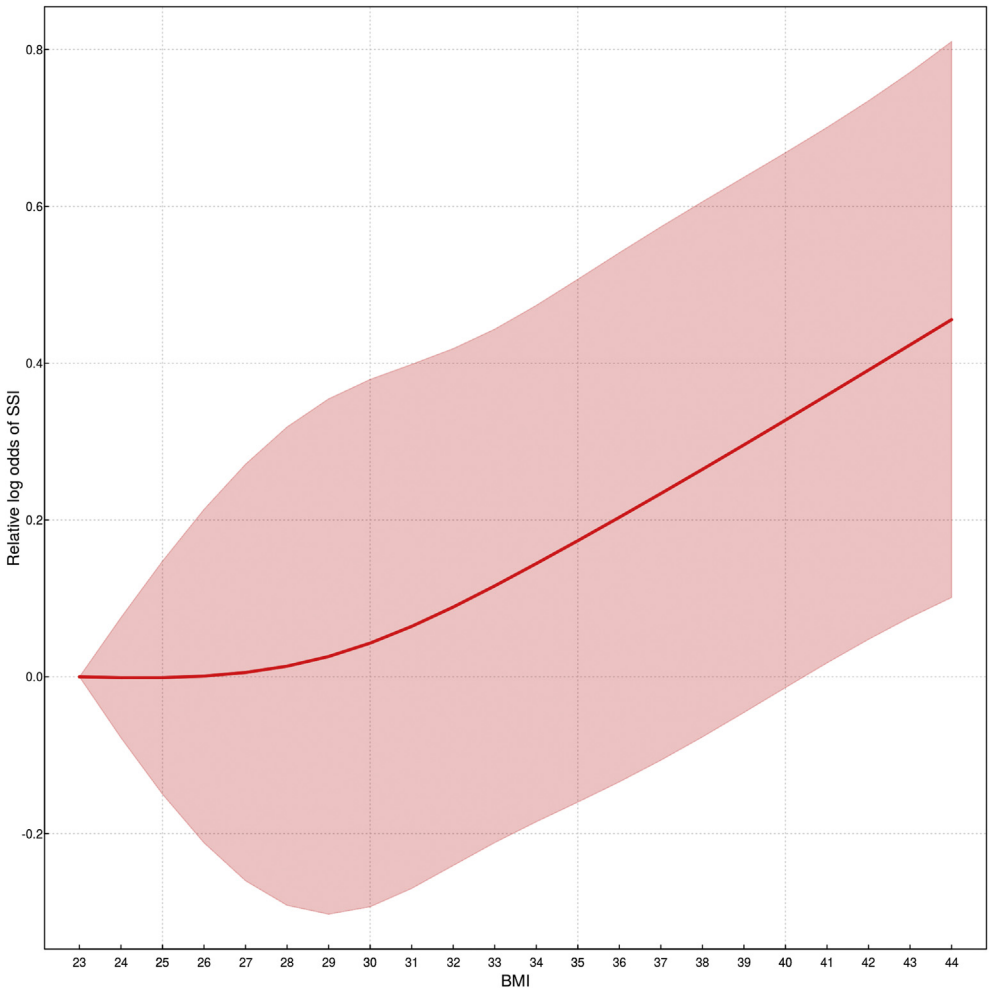

Fig. 2. Relationship between BMI (x-axis) and relative log-odds for SSI (y-axis). Shading represents 95% bootstrap confidence intervals.

prior to hernia surgery is a question that cannot be addressed by our analysis. We are unable to assess some of the negative consequences of delaying surgery to achieve that weight loss goal. Some of the unforeseen complications could include patient frustration, dissatisfaction, abandoning care and requiring an emergent repair. In addition, although endorsed by current expert consensus, there is a lack of data assessing if patients undergoing preoperative weight loss will in fact experience fewer complications as opposed to those undergoing upfront elective repair. Ultimately, further research is needed to determine the benefit of preoperative weight loss interventions on outcomes of hernia repair. It will be important that these studies evaluate weight loss across all levels of BMI to adequately interpret the potential benefits of weight loss on hernia outcomes.

Our study findings should be interpreted in light of several limitations that deserve mention. First, our study is a retrospective review of a prospectively maintained database. Therefore, while our analysis was able to identify an association between BMI and wound complications, the design of our study allows identifying correlation but not causation. The correct interpretation is that higher BMI is correlated with higher odds of wound complications in the AHSQC patient population. Second, our analysis is limited to OVHR only. Consequently, our findings do not apply to overweight patients undergoing a minimally invasive VHR, where the negative impact of increasing BMI on wound complications might be neutralized or at least decreased by the absence of an open incision and subcutaneous dissection. We elected to include only open repairs for our analysis because three-fourths of all ventral hernia repairs in the United States are performed using the open technique (25). The incidence of this approach to OVHR is similar to that found within the AHSQC. Another limitation is that our study is limited to 30-day outcomes, and the impact of BMI on longer-term SSI and SSOPI and hernia recurrence remains to be determined. It is important to note that at the moment that the AHSQC database was queried there were 1248 patients (12.2%) meeting inclusion criteria that did not have 30-day follow-up completed and were excluded from analysis. One could argue that this could lead to selection bias. Along the same lines is the fact that the data in the AHSQC is surgeon-entered, and there is an inherent risk for under-reporting 30-day wound complications. As a recent internal review of the AHSQC database has revealed that surgeons preferentially input their more complex cases, our suspicion of unrecorded adverse events is low.

Is important to highlight that even though our analysis supports that patient BMI is associated with increased odds for SSI and SSOPI after OVHR, our study does not have the ability to generate any conclusions whether weight loss could impact on wound morbidity rates. While it seems reasonable to hypothesize that weight loss could be beneficial for the majority of overweight patients, it should be noted that the inherent delay in hernia repair might result in increased incidence of incarceration and emergent repair and in fact worsen the outcomes of this challenging population. As stated before, further research is necessary to determine whether

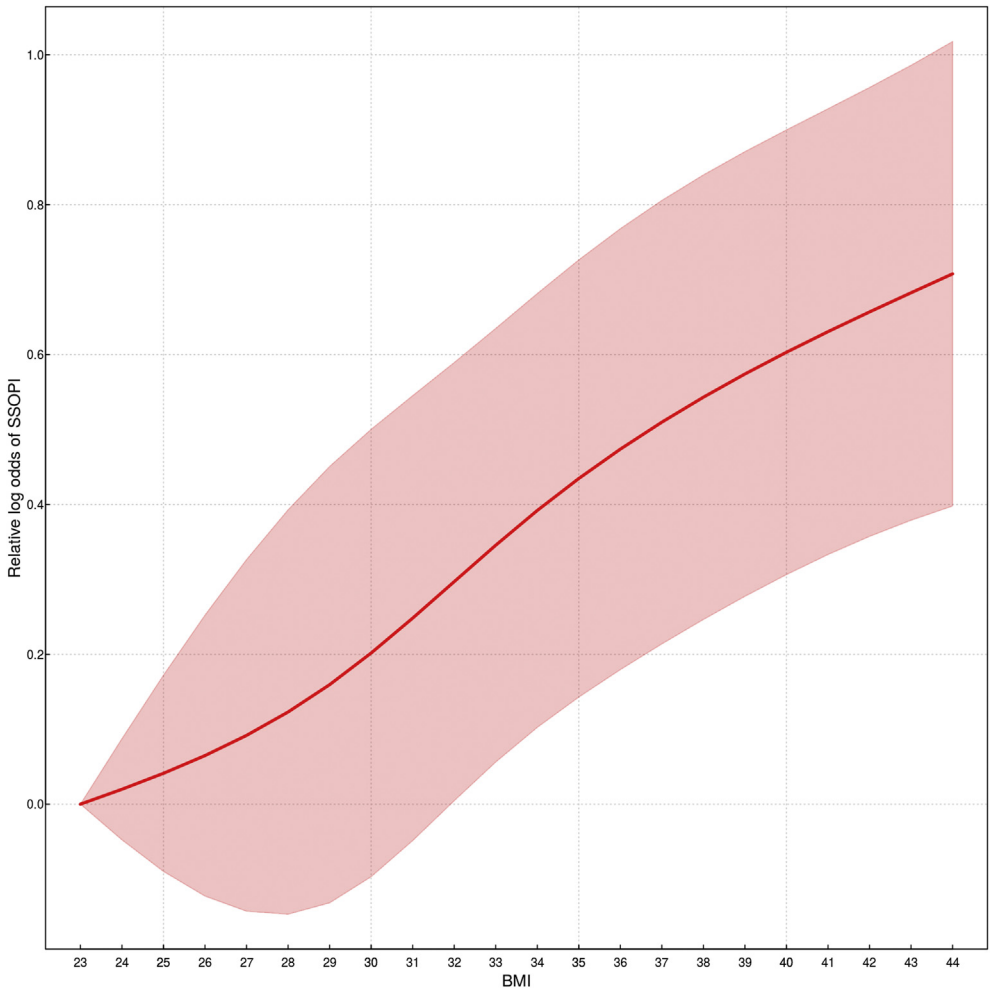

Fig. 3. Relationship between BMI (x-axis) and relative log]-odds for SSOPI (y-axis). Shading represents 95% bootstrap confidence intervals.

preoperative weight loss has the ability to ameliorate the effects of BMI on wound morbidity or not. We also acknowledge that anthropometric elements other than BMI may influence on wound complications in an obese patient, such as body fat distribution patterns.[5] For example, patients with a preponderance of peripheral fat deposition often have a thicker subcutaneous pannus when compared to patients with a predominance of visceral fat and therefore might be at a different risk despite having equivalent BMI's. Additional studies are also needed to determine if body morphology and predominant location of fat deposition are associated with complications of the overweight patient.

Conclusion

Escalating BMI is associated with increasing relative log-odds for 30-day SSI and SSOPI after OVHR with mesh. Further studies are necessary to determine whether preoperative weight loss confers any benefit on reducing such complications.

Conflicts of interest

Luciano Tastaldi and Ivy Haskins: have received resident research grants from the Americas Hernia Society Quality Collaborative that is not related to the submitted work.

David Krpata: has received an educational grant from W.L Gore that is not related to the submitted work.

Ajita S. Prabhu: receives compensation for consulting for Medtronic and has an ongoing research grant from Intuitive Inc. None of these conflicts of interest are related to the submitted work.

Michael J. Rosen: receives salary support for his role as the medical director of the Americas Hernia Society Quality Collaborative. Is a board member of Ariste Medical Inc., has ongoing research grants from Pacira Pharmaceuticals and Intuitive Inc. and has stocks from Ariste Medical. None of these conflicts of interest are related to the submitted work.

Jacob Greenberg: Receives payment for development of educational presentations from Medtronic, W.L Gore and Ariste Medical. None of these conflicts of interest are related to the submitted work.

Clayton Petro, Steven Rosenblatt, Molly Olson, Thomas G. Stewart have nothing to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.01.022.

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