



# Is there an advantage to laparoscopy over open repair of primary umbilical hernias in obese patients? An analysis of the Americas Hernia Society Quality Collaborative (AHSQC)

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## Abstract

**Purpose** The most common techniques used to repair umbilical hernias are open and laparoscopic. As the obesity epidemic in the United States is growing, it is essential to understand how this morbidity affects umbilical hernia repairs. This study compares laparoscopic versus open umbilical hernia repairs in obese patients.

**Methods** All patients with body mass index (BMI)  $\geq 30$  kg/m<sup>2</sup> who underwent elective, open or laparoscopic repair of a primary umbilical hernia with mesh were identified from the Americas Hernia Society Quality Collaborative (AHSQC). A retrospective review of the prospectively collected data was conducted. Outcomes of interest included surgical site infections (SSI), surgical site occurrences requiring procedural intervention (SSOPI), hernia-related quality-of-life survey (HerQles), and long-term recurrence. A logistic regression model was used to generate propensity scores.

**Results** Of 1507 patients who met the inclusion criteria, 322 were laparoscopic, and 1185 were open cases. The laparoscopic group had higher mean BMI ( $37 \pm 6$  vs.  $35 \pm 5$  kg/m<sup>2</sup>,  $P < 0.001$ ) and mean hernia width ( $3$  cm  $\pm 1$  vs.  $2$  cm  $\pm 2$ ,  $P < 0.001$ ). Using a propensity score model, we controlled for several clinically relevant covariates. Propensity score adjustment showed no differences in the 30-day HerQles score (OR 0.93, 95% CI 0.58–1.49), SSI (OR 1.57, 95% CI 0.52–4.77), SSOPI (OR 2.85, 95% CI 0.84–9.62) or hernia recurrence (hazard ratio 0.86, 95% CI 0.50–1.49).

**Conclusion** In obese patients with primary umbilical hernias, there is likely no benefit to laparoscopy over open umbilical hernia repair with mesh with regard to wound morbidity. Although, the long-term recurrence also showed no difference between these two approaches, overall follow up was lacking.

**Keywords** Umbilical hernia · Laparoscopic · Obese · Wound morbidity · Recurrence

## Introduction

In the adult population in the United States, the incidence of umbilical hernias is as high as 2% [1]. The most common approaches used to repair these defects are open and

laparoscopic. Although the laparoscopic technique has gained increased acceptance amongst general surgeons since its development in the 1990s, the majority of umbilical hernias are repaired in a traditional open fashion [2]. This is likely due to the small incision size required to perform an open repair and shorter operative time. However, the obese population offers a unique set of challenges. Open repairs may be complicated by body habitus [3]. In addition, there is an inherently higher risk of postoperative morbidity in this patient population [4, 5]. These considerations present a treatment dilemma as to which approach will offer better outcomes to this patient population.

Previous studies have shown a potential decrease in wound morbidity, postoperative pain, and lower recurrence rates associated with laparoscopic repair when compared with open umbilical hernia repair [6–8]. However, the

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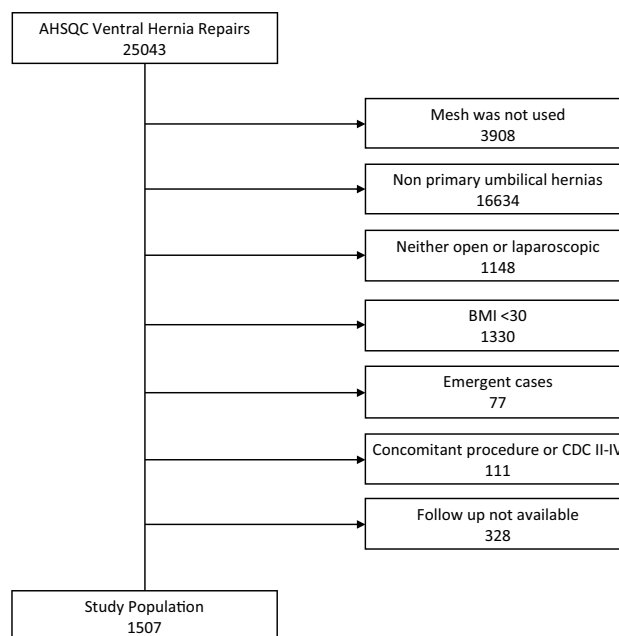
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majority of these studies include the general population. To date, there are limited long-term data available that compare laparoscopic versus open techniques for repairing umbilical hernias in obese patients. As the obesity epidemic in the United States grows, it is essential to understand how this morbidity affects umbilical hernia repairs because of associated higher risk for umbilical hernia recurrence in patients with BMI > 30 [7]. Furthermore, it is expected that there will be an increase in obese patients who will require this procedure [3]. Thus, we aim to study short- and long-term outcomes of umbilical hernia repair in obese patients by comparing laparoscopic and open techniques. Our study was a retrospective review of prospectively surgeon-entered data. The hypothesis was that in well-matched groups, the laparoscopic approach would be associated with a lower risk of short-term wound morbidity and hernia recurrence.

## Methods

After Institutional Review Board approval, the patients were identified using the Americas Hernia Society Quality Collaborative (AHSQC). This registry is a prospective, surgeon-entered quality improvement effort that aims to improve outcomes through sharing the data transparently and collaborative learning. Using standardized preoperative, operative, and postoperative definitions, information is collected prospectively at the point-of-care. At the time of this study, AHSQC had data available from over 300 surgeons nationally, practicing in a variety of clinical settings, including academic, community, and affiliated hospitals. Details regarding the design, implementation, and data quality assurance of the registry have been previously published [9].

The study population included all patients with body mass index (BMI)  $\geq 30$  kg/m<sup>2</sup>, who underwent elective, open or laparoscopic repair of a primary umbilical hernia with mesh between 2013 and 2019. Figure 1 illustrates the inclusion and exclusion criteria used to identify the study population. All mesh positions were included in the study. We then performed a retrospective review of the prospectively collected data. The variables of interest included demographics, comorbidities, operative technique, mesh use, and position, wound events, and recurrence. The primary outcome was 30-day wound events, and the secondary outcome was hernia recurrence. Postoperative wound events included surgical site infection (SSI), and surgical site occurrence requiring procedural intervention (SSOPI). SSI was classified as superficial, deep, or organ space, according to the Centers for Disease Control and Prevention (CDC) standards [10]. Surgical site occurrence (SSO) included all SSI, in addition to wound cellulitis, non-healing incisional wound, fascial disruption, skin or soft tissue ischemia, skin or soft tissue necrosis, serous or purulent wound drainage,



**Fig. 1** Study population showing inclusion and exclusion criteria

stitch abscess, seroma, and hematoma, infected or exposed mesh, or development of an enterocutaneous fistula. Procedural interventions to be considered SSOPI included wound opening, wound debridement, suture excision, percutaneous drainage, partial mesh removal, and/or complete mesh removal.

Descriptive statistics were used to analyze the data, while the Pearson Chi-square test was used to compare mesh placement for categorical variables, and the Kruskal–Wallis test was used for continuous variables. When expected cell counts for categorical variables were small, Fisher’s exact test was used instead. Missing data were imputed using single imputation, where data were missing < 3% in covariates. To account for covariate imbalance between the mesh placement groups, we generated propensity scores using a logistic regression model with several covariates hypothesized to be associated with surgical mesh placement. We fit logistic regression models for 30-day SSI and SSOPI, Cox proportional hazards model for recurrence at any time, and a proportional-odds regression model for HerQLes scaled scores. The HerQLes survey is a validated 12-question, hernia-specific quality of life instrument with a focus on abdominal wall function and the impact of ventral hernia repair on quality of life [11]. This patient-reported tool was found to correlate with abdominal wall physiology and function. A higher score indicates a better quality of life [12]. Of note, recurrence in the AHSQC is measured through a composite score. This score is comprised of two tools for assessing recurrence: (1) radiologic or clinical examination evidence, and (2) patient-reported Ventral Hernia Recurrence

Inventory (VHRI). If either tool is positive, the composite score marks the patient with a recurrence.

## Results

Inclusion criteria were met by 1507 patients: 322 had laparoscopic repair, and 1185 had open repair. Patient demographics are presented in Table 1. The laparoscopic group had a higher body mass index ( $37 \pm 6$  vs.  $35 \pm 5$ ,  $P < 0.001$ ). Also, in the laparoscopic group, there were more women (25% vs 16%,  $P < 0.001$ ), and the mean hernia width was greater ( $3 \text{ cm} \pm 1$  vs  $2 \text{ cm} \pm 2$ ,  $P < 0.001$ ). Table 2 shows the operative characteristics and intra-operative complications. A higher rate of patients had fascial closure in the open group (92% vs 72%,  $P < 0.001$ ). Mesh fixation type was also different between the groups. In the open group in 7% of cases had no mesh fixation vs. 3% in the laparoscopic group,  $P = 0.029$ . There were more suture fixation cases in the open group and more fixation with tacks in the laparoscopic group. Two laparoscopic cases were converted to open and analyzed as intent-to-treat. The open group was associated with higher rates of SSI (2% vs 1%) and SSOPI (3% vs 1%), however these differences did not reach statistical significance (Table 3).

**Table 1** Patient demographics and hernia characteristics

	Laparoscopic	Open	<i>p</i> value
<i>N</i>	322	1185	
Age (Mean $\pm$ SD)	$52 \pm 12$	$53 \pm 12$	0.333
Gender (Female), <i>N</i> (%)	79 (25)	192 (16)	0.001
BMI ( $\text{kg}/\text{m}^2$ ; Mean $\pm$ SD)	$37 \pm 6$	$35 \pm 5$	<0.001
ASA <sup>a</sup> class, <i>N</i> (%)			0.056
1	14 (4)	105 (9)	
2	194 (60)	699 (59)	
3	109 (34)	366 (31)	
4	5 (2)	14 (1)	
None assigned	0 (0)	1 (<1)	
Prevalence of comorbidities	201 (62)	715(60)	
Immunosuppressant	5	21	
Smoking (within 1 year)	46	141	
Nicotine use (within 1 year)	51	160	
Hypertension	148	525	
Diabetes mellitus	56	165	
Dyspnea	10	21	
COPD <sup>b</sup>	8	39	
Current steroid use	1	11	
Hernia width (cm; Mean $\pm$ SD)	$3 \pm 1$	$2 \pm 2$	<0.001

<sup>a</sup>American Society of Anaesthesiologists Classification

<sup>b</sup>Chronic obstructive pulmonary disease

**Table 2** Operative characteristics and intra-operative complications

	Laparoscopic	Open	<i>p</i> value
<i>N</i>	322	1185	
Fascial closure	231 (72)	1093 (92)	<0.001
Mesh used, <i>N</i> (%)	322 (100)	1185 (100)	
Mesh type, <i>N</i> (%)			1.000
Permanent synthetic	319 (99)	1170 (99)	
Resorbable synthetic	3 (1)	13 (1)	
Biological tissue-derived	0 (0)	2 (<1)	
Mesh location			0.722
Inlay	7 (2)	34 (3)	
Onlay	14 (4)	58 (5)	
Sublay	301 (93)	1093 (92)	
Sublay mesh position			
Retrorectus	13 (4)	49 (4)	
Preperitoneal	37 (12)	589 (54)	
Intraperitoneal	251 (83)	459 (42)	
Mesh fixation	311 (97)	1106 (93)	0.029
Mesh fixation type			
Adhesives	1	16	
Staples	3	12	
Sutures	185	1083	
Tacks	293	22	
Intraoperative complications	1 (<1)	2 (<1)	0.514
Bowel injury	1	1	
Other	0	1	
Conversion to open	2 (1)	0 (0)	
Length of stay (median, interquartile range)	0 (0–0)	0 (0–0)	

Similarly, there was no significant difference in composite recurrence rates for up to 3 years for both study groups.

A logistic regression model was created to account for differences between the two groups. Figure 2 shows the standardized mean difference (SMD) of several baseline covariates deemed to be significant predictors of (a) the operation approach and/or (b) baseline risk of readmission, recurrence, infection, complication, and occurrence.

Adjusted odds ratios for wound events and hazard ratio were then calculated, which are shown in Fig. 3. This model showed no differences in the rates of SSOPI (OR 2.85, 95% CI 0.84–9.62), and SSI (OR 1.57, 95% CI 0.52–4.77). After the adjustment, the hazard ratio (HR) for developing recurrence at any time showed no differences between laparoscopic versus open techniques (HR 0.86, 95% CI 0.50–1.49). Figure 4 shows the adjusted laparoscopic vs. open odds ratios (OR) of HerQles scores at 30-day (OR 0.93, 95% CI 0.58–1.49). No short-term quality-of-life differences were found between the two groups.

**Table 3** 30-day wound morbidities, mean follow-up and the recurrence rates

	Laparoscopic	Open	<i>p</i> value
SSI <sup>a</sup> <i>N</i> (%)	4 (1)	20 (2)	0.571
Superficial	4	18	
Deep incisional	0	3	
Organ space	0	0	
SSO <sup>b</sup> excluding SSI	24 (7)	77 (6)	0.543
Hematoma	3	11	
Seroma	21	40	
Skin/soft tissue ischemia or necrosis	0	3	
Wound cellulitis	1	9	
Wound purulent drainage	0	3	
Wound serous drainage	0	11	
Fascial disruption	0	1	
Infected hematoma	0	1	
Infected seroma	0	1	
SSOPI <sup>c</sup>	3 (1)	33 (3)	0.054
Procedural intervention			
Wound opening	0	12	
Wound debridement	0	7	
Suture excision	1	1	
Percutaneous drainage	2	18	
Partial mesh removal	0	1	
Complete mesh removal	0	2	
1 year composite recurrence	5 of 29 (17)	12 of 111 (11)	0.347
2 year composite recurrence	6 of 32 (19)	5 of 62 (8)	0.129
3 year composite recurrence	3 of 12 (25)	4 of 25 (16)	0.519

<sup>a</sup>Surgical site infection<sup>b</sup>Surgical site occurrence<sup>c</sup>Surgical site occurrence requiring procedural intervention

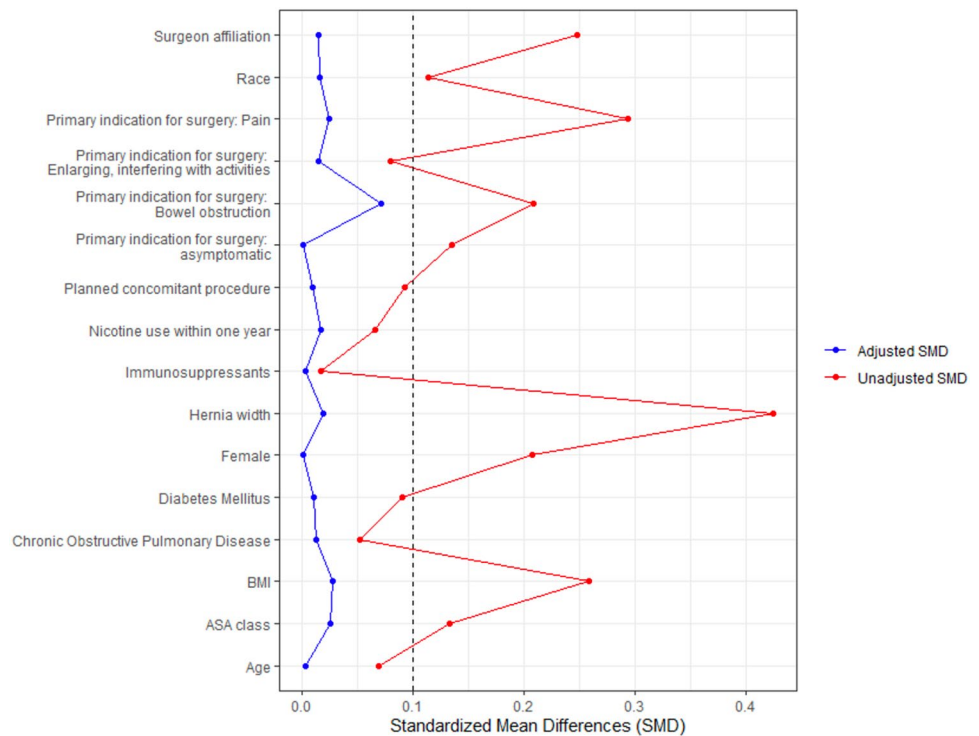
## Discussion

The effect of increasing BMI on surgical outcomes has been well established in the literature. An American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) analysis by Kaoutzanis et al. showed that BMI  $\geq 30$  kg/m<sup>2</sup> was a significant risk factor for superficial (OR 1.82, CI 1.35–2.45,  $p < 0.01$ ) and deep SSIs (OR 2.87, CI 1.74–4.74,  $p < 0.01$ ) [13]. Tastaldi et al. analyzed open ventral hernia repairs in the AHSQC and showed proportional increases in relative log-odds for SSIs and SSOPIs according to increasing BMI. These findings are significant because of the increased risk for recurrence [14] when patients have wound infections and the increased cost associated with treatment [15]. Thus, it is essential to determine the optimal approach when repairing an umbilical hernia in obese patients, especially since they have an inherently higher risk for complications. Our study is the first to show that in well-matched groups, there are no differences in the rates of wound events when laparoscopic umbilical hernia repair with mesh was compared with the open approach.

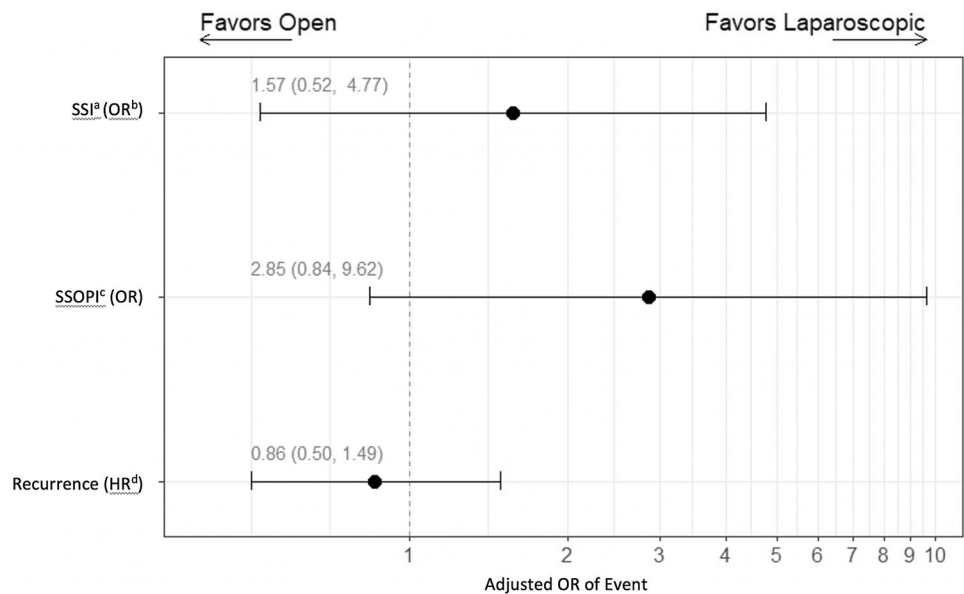
These results differ from previously published works, which have demonstrated improved outcomes with the laparoscopic approach. A systematic review of 16,549 patients conducted by Hajibandeh et al. showed that open repair was associated with a higher risk of wound infection (OR 2.35, 95% CI 1.23–4.48,  $p = 0.010$ ) [2]. However, in this review, the BMI of the population studied was not reported by over half of the studies analyzed. Looking at obese patients specifically, Colon et al. retrospectively reviewed 123 umbilical hernia repairs in patients with BMI  $> 30$  [3]. They found a significant increase in wound infection in the open group when compared with laparoscopy (26% vs. 4%,  $p < 0.05$ , respectively). The lower risk of wound complications was theorized to be due to tissue handling and less contact with the umbilicus. This study was limited by a relatively small sample size and significant loss of follow up, almost 40% of the population. In our larger series, the differences could not be demonstrated.

Additionally, current surgical literature suggests that laparoscopy has reduced rates of recurrence after umbilical hernia repair [2, 16, 17]. The work by Colon et al. showed

**Fig. 2** Standardized Mean Difference (SMD) of several baseline, clinically relevant covariates. The blue line indicates the SMD of the cohort without adjustment, and the red line indicates the SMD after adjustment. Values less than or around 0.1 indicate good balance (color figure online)



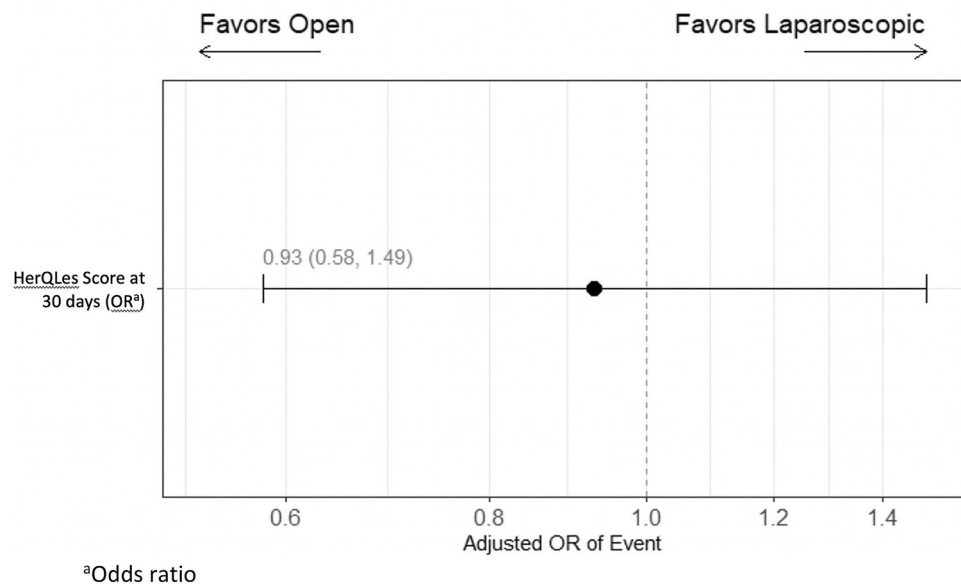
**Fig. 3** Adjusted recurrence Hazard Ratio (HR) and odds ratios (OR) for SSI and SSOPI. <sup>a</sup>Surgical site infection. <sup>b</sup>Odds ratio. <sup>c</sup>Surgical site occurrence requiring procedural intervention. <sup>d</sup>Hazard ratio



no recurrences in the laparoscopic group, and there was a 4% recurrence in the open group after a mean follow-up of 15 and 20 months in the laparoscopic and open groups, respectively [3]. Identification of additional defects that can be repaired at the same time, as well as wide mesh overlap, are often cited as the contributing factors to these findings. Previous publications have associated the development of surgical site infections with increased rate of recurrence [18, 19]. Since we hypothesized that

there would be a higher rate of wound infections, we also expected a higher risk of recurrence. Nonetheless, in our study, no differences were found in long-term recurrence rates between the two study groups. Interestingly, even though the differences in fascial closure rates were significant, this did not translate in differences in recurrence rates. These results should be interpreted with caution, however, given the lack of long-term follow-up data.

**Fig. 4** Adjusted odds ratios (OR) of HerQles scores at 30-day follow up. <sup>a</sup>Odds ratio



Finally, hernia repair in patients with obesity has been associated with worse outcomes. Compared with patients with normal BMI, umbilical hernia repair in patient with obesity have been shown to have higher risk of wound complications and recurrence regardless of which repair technique is employed [8, 20, 21]. Although there is no consensus on the management of hernia repair in obese patient, weight loss options should be considered for all patients with obesity. In particular, patient with severe obesity present challenging treatment dilemma [21]. The hernia can be repaired before, after or at the same time as bariatric surgery. Rather than a one-size-fits, treatment plans should be individualized after taking into consideration BMI, patient comorbidities, symptoms and hernia characteristics [22].

The strength of this study is that it is the first large multi-center study comparing laparoscopic and open umbilical hernia repairs performed by surgeons practicing in various settings. However, there are some limitations that deserve mention. First, this is a retrospective review of prospectively collected data, and it may be associated with bias inherent to this type of research. Second, as previously mentioned, recurrence in the AHSQC is measured through a composite score, which is comprised of clinical or radiologic evidence, and the Ventral Hernia Recurrence Inventory (VHRI). Because the VHRI is a patient-reported outcome where they answer Yes vs. No to “Do you see a bulge?” it may not portray the true recurrence rate. However, the same tool is used for both study groups. Third, mesh position was different between the two groups. The laparoscopic group had more intraperitoneal mesh, while the open group had more preperitoneal mesh. Although a subgroup analysis was done in this study, comparison of different mesh positions should be addressed in future studies. Fourth, as is it typical

for hernia research in the United States, long-term follow up was not complete. However, this is the largest study to date to compare the short- and long-term effects of these two surgical techniques in obese patients. Finally, there could be an inherent selection bias for the surgeon to select one approach over the other. This may depend on the hernia size, BMI and surgeon training, which cannot be measured or adjusted in the retrospective study.

## Conclusion

Our study is the first to show that there is likely no benefit to laparoscopy over open umbilical hernia repair with mesh with regard to wound morbidity in the obese population. Although recurrence rates were also similar for both groups, long-term data was lacking. Further prospective studies are needed to determine the best surgical approach for repairing umbilical hernias in this challenging population.

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## Compliance with ethical standards

**Conflict of interest** Ajita Prabhu reported receiving honoraria for speaking and a research grant paid to her institution from Intuitive Surgical, serving on an advisory board and receiving honoraria from Medtronic and from BD. Michael Rosen reported receiving salary support for his role as Medical Director of the Americas Hernia Society Quality Collaborative and grant support paid to his institution from Pacira. No other disclosures were reported. David Krpata reports education grants from W.L. Gore.



**Research involving human participants and/or animals** This article does not contain any studies with human participants or animals performed by any of the authors.

**Ethical approval** This project was approved by the IRB.

**Informed consent** For this type of study, formal consent was not required.

## References

- Rutkow IM (2003) Demographic and socioeconomic aspects of hernia repair in the United States in 2003. *Surg Clin N Am* 83:1045–1051. [https://doi.org/10.1016/S0039-6109\(03\)00132-4\(v-vi\)](https://doi.org/10.1016/S0039-6109(03)00132-4(v-vi))
- Hajibandeh S, Hajibandeh S, Sreh A, Khan A, Subar D, Jones L (2017) Laparoscopic versus open umbilical or paraumbilical hernia repair: a systematic review and meta-analysis. *Hernia* 21:905–916. <https://doi.org/10.1007/s10029-017-1683-y>
- Colon MJ, Kitamura R, Telem DA, Nguyen S, Divino CM (2013) Laparoscopic umbilical hernia repair is the preferred approach in obese patients. *Am J Surg* 205:231–236. <https://doi.org/10.1016/j.amjsurg.2012.02.022>
- Tastaldi L, Krpata DM, Prabhu AS, Petro CC, Rosenblatt S, Haskins IN et al (2019) The effect of increasing body mass index on wound complications in open ventral hernia repair with mesh. *Am J Surg* 218:560–566. <https://doi.org/10.1016/j.amjsurg.2019.01.022>
- Bamgbade OA, Rutter TW, Nafiu OO, Dorje P (2007) Postoperative complications in obese and nonobese patients. *World J Surg* 31:556–560. <https://doi.org/10.1007/s00268-006-0305-0>
- Cassie S, Okrainec A, Saleh F, Quereshey FS, Jackson TD (2014) Laparoscopic versus open elective repair of primary umbilical hernias: short-term outcomes from the American College of Surgeons National Surgery Quality Improvement Program. *Surg Endosc* 28:741–746. <https://doi.org/10.1007/s00464-013-3252-5>
- Shankar DA, Itani KMF, O'Brien WJ, Sanchez VM (2017) Factors associated with long-term outcomes of umbilical hernia repair. *JAMA Surg* 152:461–466. <https://doi.org/10.1001/jamasurg.2016.5052>
- Williams KN, Hussain L, Fellner AN, Meister KM (2019) Updated outcomes of laparoscopic versus open umbilical hernia repair in patients with obesity based on a National Surgical Quality Improvement Program review. *Surg Endosc*. <https://doi.org/10.1007/s00464-019-07129-7>
- Poulose BK, Roll S, Murphy JW, Matthews BD, Todd Heniford B, Voeller G et al (2016) Design and implementation of the Americas Hernia Society Quality Collaborative (AHSQC): improving value in hernia care. *Hernia* 20:177–189. <https://doi.org/10.1007/s10029-016-1477-7>
- CDC. Surgical Site Infection (SSI) Event n.d. <https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscscscurrent.pdf>. Accessed 14 May 2019
- Krpata DM, Schmotzer BJ, Flocke S, Jin J, Blatnik JA, Ermlich B et al (2012) Design and initial implementation of HerQLes: a hernia-related quality-of-life survey to assess abdominal wall function. *J Am Coll Surg* 215:635–642. <https://doi.org/10.1016/j.jamcollsurg.2012.06.412>
- Criss CN, Petro CC, Krpata DM, Seafiler CM, Lai N, Fiutem J et al (2014) Functional abdominal wall reconstruction improves core physiology and quality-of-life. *Surgery* 156:176–182. <https://doi.org/10.1016/j.surg.2014.04.010>
- Kaoutzanis C, Leichtle SW, Mouawad NJ, Welch KB, Lampman RM, Wahl WL et al (2015) Risk factors for postoperative wound infections and prolonged hospitalization after ventral/incisional hernia repair. *Hernia* 19:113–123. <https://doi.org/10.1007/s10029-013-1155-y>
- Holihan JL, Alawadi Z, Martindale RG, Roth JS, Wray CJ, Ko TC et al (2015) Adverse events after ventral hernia repair: the vicious cycle of complications. *J Am Coll Surg* 221:478–485. <https://doi.org/10.1016/j.jamcollsurg.2015.04.026>
- Plymale MA, Ragulojan R, Davenport DL, Roth JS (2017) Ventral and incisional hernia: the cost of comorbidities and complications. *Surg Endosc* 31:341–351. <https://doi.org/10.1007/s00464-016-4977-8>
- Funk LM, Perry KA, Narula VK, Mikami DJ, Melvin WS (2013) Current national practice patterns for inpatient management of ventral abdominal wall hernia in the United States. *Surg Endosc* 27:4104–4112. <https://doi.org/10.1007/s00464-013-3075-4>
- Helgstrand F, Rosenberg J, Kehlet H, Jorgensen LN, Bisgaard T (2013) Nationwide prospective study of outcomes after elective incisional hernia repair. *J Am Coll Surg* 216:217–228. <https://doi.org/10.1016/j.jamcollsurg.2012.10.013>
- Cobb WS, Warren JA, Ewing JA, Burnikel A, Merchant M, Carbonell AM (2015) Open retromuscular mesh repair of complex incisional hernia: predictors of wound events and recurrence. *J Am Coll Surg* 220:606–613. <https://doi.org/10.1016/j.jamcollsurg.2014.12.055>
- Tubre DJ, Schroeder AD, Estes J, Eisenga J, Fitzgibbons RJ (2018) Surgical site infection: the “Achilles Heel” of all types of abdominal wall hernia reconstruction. *Hernia* 22:1003–1013. <https://doi.org/10.1007/s10029-018-1826-9>
- Donovan K, Denham M, Kuchta K, Denham W, Linn JG, Haggerty SP et al (2019) Predictors for recurrence after open umbilical hernia repair in 979 patients. *Surg (United States)* 166:615–622. <https://doi.org/10.1016/j.surg.2019.04.040>
- Lo ME, Hinojosa M, Carbonell A, Krpata D, Carter J, Rogers AM (2018) American Society for Metabolic and Bariatric Surgery and American Hernia Society consensus guideline on bariatric surgery and hernia surgery. *Surg Obes Relat Dis*. 14:1221–1232. <https://doi.org/10.1016/j.soard.2018.07.005>
- Eid GM, Wikiel KJ, Entabi F, Saleem M (2013) Ventral hernias in morbidly obese patients: a suggested algorithm for operative repair. *Obes Surg* 23:703–709. <https://doi.org/10.1007/s11695-013-0883-5>

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