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# Are morbid obese (class–III) patients at high risk for postoperative complications after robotic ventral hernia repair? A propensity score matching analysis

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## ABSTRACT

**Introduction:** Extreme obesity is an independent risk factor for many perioperative complications, as well as the development of ventral hernias. Many surgeons consider extreme obesity as a prohibitive factor for minimally invasive ventral hernia repair (VHR). To investigate whether robotic VHR (RVHR) has value in these high–risk patients, in this study, we aim to compare outcomes between class–III obese (BMI ≥40 kg/m$^2$) patients and non–obese (BMI <30 kg/m$^2$) patients.

**Materials and Methods:** A retrospective analysis of a database collected between 2012 and 2020 was performed. A 1: 2 propensity score match (PSM) analysis was implemented to obtain two balanced patient groups. Univariate analyses, in unmatched and matched samples, were performed between the two groups concerning preoperative, intraoperative, and postoperative variables. Postoperative complications and morbidity (up to 90–days) were assessed using the Clavien–Dindo classification and comprehensive complication index (CCI®) score system.

**Results:** Our initial cohort consisted of 598 patients, in which 287 unmatched patients were included. After 1: 2 PSM, 86 and 43 patients were assigned to the non–obese and class–III obese groups, respectively. Differences in unmatched patient demographics, hernia characteristics, and intraoperative variables between the two groups were resolved after matching. In an unmatched comparison, class–III obese patients experienced higher rates of Clavien–Dindo grade–II complications and cellulitis. However, the two matched groups experienced similar postoperative complication rates.

**Conclusion:** This study revealed that class–III obese patients can obtain similar benefits from RVHR as their non–obese counterparts. Surgeons should consider patient and hernia characteristics when planning to perform RVHR in these patients, rather than BMI alone.

**Keywords:** Class–III obesity; morbid obesity; robotic surgery; ventral hernia.

## Introduction

Obesity is a growing epidemic; therefore, surgeons are confronted with an increasingly complex patient population, that is frequently overweight, with more comorbidities. Obesity has considered an independent risk factor for a multitude of perioperative adverse events including medical and wound-related complications.[1] Obesity also contributes to the risk for the development of ventral and incisional hernia occurrence.[2]

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When compared to open herniorrhaphies, laparoscopic approaches have proved superior in terms of perioperative morbidity, postoperative complications, and recurrence rates among both obese and morbidly obese patients.[3–5] The robotic platform has been a promising addition to the available methods for herniorrhaphy. In a multicenter case series evaluating 368 patients undergoing RVHR, a large proportion of the study population was morbidly obese (20.9%) and postoperative complications, within a 30–day postoperative period, were within the ranges reported in the literature for open and laparoscopic VHR.[6] Several studies have also emerged demonstrating the safety and durability of robotic ventral hernia repair (RVHR).[6, 7] Given its relatively recent introduction, however, the value of RVHR in the morbidly obese population has yet to be well–established.

This study aims to compare the short–term outcomes of RVHR between non–obese and class–III obese patients. Based on similar studies comparing outcomes of laparoscopic ventral hernia repair (LVHR) in these two populations,[8, 9] we hypothesize that RVHR in class–III obese patients would have similar outcomes in their non–obese counterparts.

## Materials and Methods

A retrospective study was conducted evaluating consecutive patients who underwent robotic ventral hernia repair in a suburban teaching hospital between February 2012 and December 2019. The recommendations of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational cohort studies were followed.[10] The data for this study was obtained from both a prospectively maintained database and electronic medical records. The study was approved by the Institutional Review Board and signed consent was obtained.

### Study population, inclusion–exclusion criteria,

Patients were grouped according to their body mass index (BMI) at the time of the index operation. Non–obese and class–III obese patients were included. Non–obesity was defined as a BMI <30 kg/m$^2$ and class–III obesity was defined as a BMI ≥40 kg/m$^2$. Patients with a BMI between 30 kg/m$^2$ and 39.9 kg/m$^2$ were excluded from the analysis to understand the effects of extreme obesity in comparison to the non–obese population. Any non–hernia–related concomitant procedures were excluded to better elucidate hernia related postoperative complications. Patients with missing preoperative data were also excluded because the selected statistical method did not allow for inclusion.

### Variables

Preoperative, intraoperative, and postoperative variables were analyzed. Preoperative variables were the following: patient demographics, hernia etiology (primary ventral, incisional, or both), the localization of the hernia (midline, off–midline, or both), the American Society Anesthesiologists classification scores (ASA), comorbidities and risk factors such as smoking (defined as smoking within three months of operation), immunosuppression (defined as recent chemotherapy or immunosuppressants, a history of previous wound infections), and procedural setting (elective or emergency).

Intraoperative variables include hernia content, primary robotic hernia defect closure, surgical repair technique [intraperitoneal onlay mesh (IPOM), transabdominal preperitoneal (TAPP), retrorectus (Rives–Stoppa/RS), and transversus abdominis release (TAR)], the presence of concomitant inguinal hernia repair, mesh material, mesh fixation method, hernia defect and mesh dimensions, operative times, estimated blood loss (EBL), and intraoperative complications. The localization of the hernia, as well as the measurement of the hernia defect, was determined following recommendations of the European Hernia Society (EHS).[11] The defect area, the mesh area, and the ratio of mesh to defect size (M/D ratio) were determined using conventional mathematical formulas, which have been previously described.[12]

Postoperative variables were selected as follows; postoperative pain scores (0–to–10 verbal scale assessed immediately after surgery in the post–anesthesia care unit–PACU), the hospital length of stay (LOS), emergency department (ED) re–visit and hospital readmission within 30–days, the presence and type of postoperative complications during follow–up visits. Any ED visit within 30–days postoperatively was classified as a re–visit. Patients presenting to the ED requiring inpatient admission were classified as a re–admission. As part of routine care, all post–operative patients were clinically evaluated at mainly two intervals post–operatively; the first was performed within three weeks, and the second within three months. As necessary, select patients were evaluated on a semi–annual and annual basis. For this study, follow–up up to 90–days was chosen to assure the detection of postoperative surgical complications related to index procedures.

All postoperative complications were categorized according to the Clavien–Dindo classification system.[13] The morbidity score was measured using the Comprehensive Complication Index (CCI®, University of Zurich, Zurich, Switzerland).[14] Surgical site events (SSEs) were classified as surgical site infections (SSIs– including cellulitis, superficial, deep and organ–space infections), surgical site occurrences (SSOs– including fluid collections such as seroma and hematoma), and surgical site occurrence or infection requiring procedural interventions (SSO/SSI–PIs; SSOs or SSIs requiring any procedural intervention such as reopening a wound, placing a drain, percutaneous aspiration, or reoperation).[15, 16]

Follow–up of complications up to 90–days postoperatively was performed by reviewing prospectively maintained records, phone conversation records, medical records for both in– and outpatient clinic visits as well as emergency department visits. Patients who were lost to follow–up were not included in the statistical comparison of postoperative complications.

### Surgical Technique

The RVHR techniques have been previously described elsewhere.[12, 17–19] Following proper preparation, the trocars were inserted and the patient side cart of the da Vinci surgical robotic system (Intuitive Surgical, Sunnyvale, CA, USA) was docked. Adhesiolysis was performed as necessary. *For rIPOM–VHR*, the peritoneum surrounding the defect was dissected. After defect measurement, primary closure of the hernia defect was performed. The mesh was secured to the posterior fascia using absorbable sutures. *For rTAPP–VHR*, the preperitoneal plane was entered and dissected at least 5 cm circumferentially around the defect. After closing the hernia defect, the mesh was secured to the posterior fascia. The peritoneal flap was closed with an absorbable suture. *For rRM–VHR*, the posterior rectus fascia was cut and the retrorectus plane was entered and the mesh was placed in the retromuscular space. When required, a TAR was added. After completion of the dissection, primary closure of the anterior fascial defect was performed. The opening of the posterior rectus sheath was closed and the mesh was then deployed. Skin incisions were closed with absorbable sutures.

### Statistical Analysis

Categorical variables were presented as the frequency with percentage [n (%)] and continuous variables as mean±SD or median (interquartile range, IQR), as appropriate. Categorical variables were analyzed using Pearson Chi–Square or Fisher`s Exact Test, and continuous variables using the Independent–Sample t–test (for normal distributions) or Mann–Whitney U Test (for non–normal distributions). Statistical assessments were performed using SPSS software pack (Statistical Package for Social Sciences for Windows version 22 software) and R program (version 2.15.2 for Windows). To incorporate these programs and to perform propensity score matching (PSM) analysis, a developer–based software providing a custom dialog in the SPSS menu was used.[20] A p–value of less than 0.05 was considered statistically significant.

### Propensity Score Matching

Due to the study design, we expected potential imbalances between groups. A PSM analysis was planned to reduce potential bias and to attain comparable groups (non–obese and class–III obese groups). After estimation of the propensity scores using potential confounders such as demographics and preoperative risk factors, participants were matched using a simple 1:2 nearest neighbor matching, with a caliper of 0.2 of the standard deviation of the logit of the propensity score to obtain similar groups regarding the set of covariates. Standardized differences were examined to compare groups before and after matching, with an imbalance being defined as an absolute value greater than 0.25.

### Power Analysis

Due to the retrospective nature of the study, we performed a post hoc power analysis to calculate the power of the study using the G–Power program (version 3.1.9.4).[21]

## Results

From a total of 598 patients who underwent RVHR, patients with a BMI between 30–40 kg/m$^2$ (n=302) and patients with non–hernia concomitant procedures (n=5) were excluded. The unmatched study population consisted of 228 non–obese patients and 63 class–III obese patients. After exclusion of patients with missing data (n=4), a 1:2 PSM assigned 86 and 43 patients to the non–obese and morbidly obese study groups, respectively. These patients were balanced in terms of patient demographics and preoperative risk factors. A patient selection flowchart is provided (Fig. 1). The relative multivariate imbalance

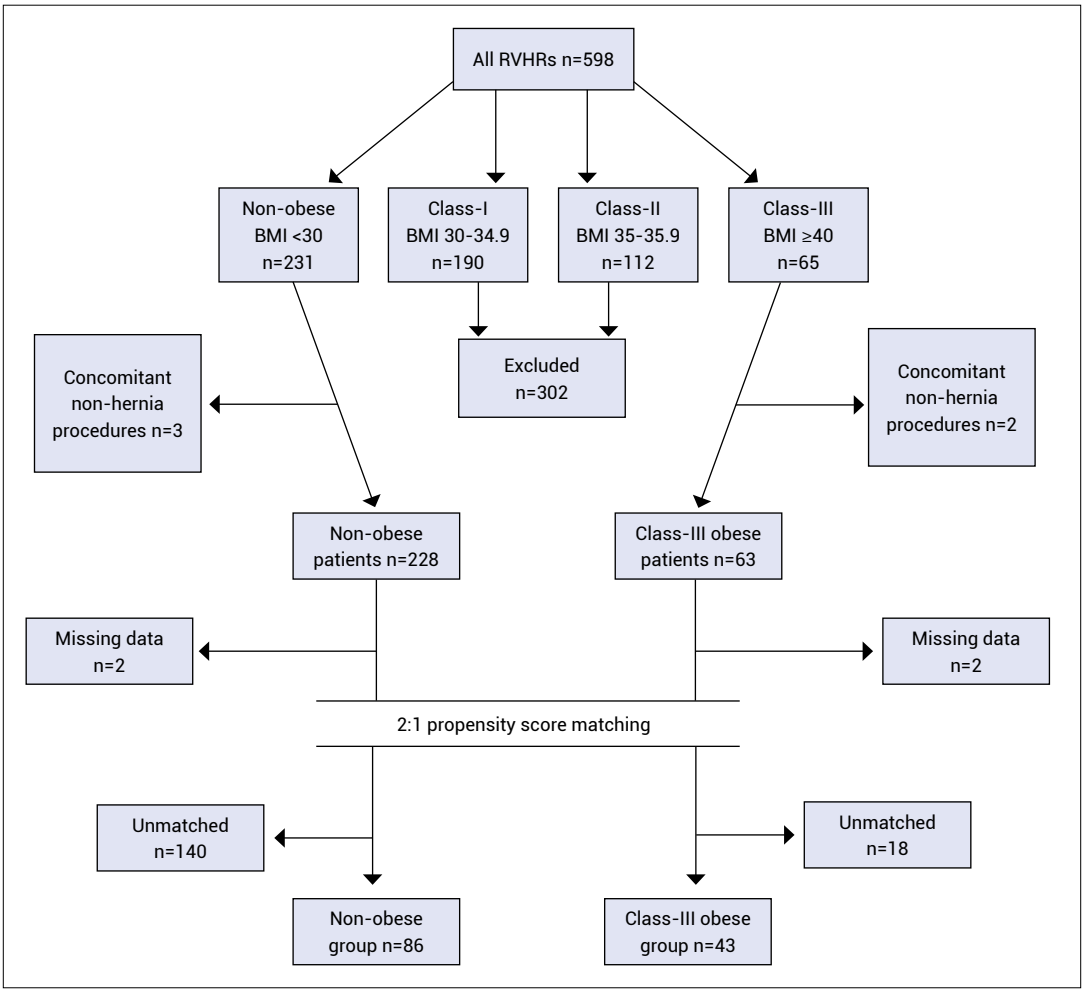


**Figure 1.** CONSORT diagram.

measure L1 test (before and after matching =0.969 >0.959) [22] confirmed the accuracy of the PSM. Post–hoc power analysis for 129 participants with a 0.3 effect size demonstrated that the present study has a power of 82.7%. Unmatched and matched groups were compared in terms of pre–, intra–, and postoperative variables.

A comparison between non–obese and morbidly obese patient demographics and preoperative risk factors is presented in Table 1. Before conducting a PSM analysis, the two groups differed significantly in terms of gender, ASA scores, diabetes prevalence, and hernia etiology. With regards to the intraoperative variables listed in Table 2, unmatched class–III obese patients had a significantly larger median defect and mesh sizes and significantly smaller median mesh–to–defect ratios than their non–obese counterparts. Primary defect closure rate did not differ statistically between two groups after matching (p=0.399; 89.5% in non–obese group, 83.7% in class–III obese group). Non–obese patients also underwent more concomitant inguinal hernia repairs, especially bilateral repair (14 vs. 0, p=0.046). Despite their increased rates of concomitant hernia repairs, skin–to–skin times for non–obese patients were lower than that of class–III obese patients, without statistical significance (91 vs. 69 minutes, p=0.087). Statistically significant differences that persisted after matching include a higher frequency of polypropylene mesh use and lower frequency of ePTFE mesh use in the non–obese group as compared to the class–III obese group (p=0.004 and p=0.001, respectively).

In terms of intraoperative complications, two serosal intestinal injuries were observed in 2 non–obese patients and were sutured. A closed suction drain was required in 2 (2.3%) non–obese patients who underwent rRM–VHR. No patients required conversion to an open or laparoscopic approach. However, a hybrid technique, requiring a skin incision to insert the mesh through the anterior fascial defect was utilized in 2 (2.3%) non–obese patients and in 1 (2.3%) class–III obese patient (p=1.000).

**Table 1. The comparison of study groups in terms of preoperative variables**

| | Unmatched comparisons | | | | | | Matched comparisons | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non-obese group (n=226) | | Class-III obese group (n=61) | | p | Std. diff* | Non-obese group (n=86) | | Class-III obese group (n=43) | | p | Std. diff* |
| | n | % | n | % | | | n | % | n | % | | |
| BMI (kg/m$^2$), mean±SD | 26.3±2.7 | | 44.8±4.6 | | <0.001 | -2.248 | 26.2±2.8 | | 44.1±4.8 | | <0.001 | -1.957 |
| Age (years), mean±SD | 54.6±16 | | 52.1±12.8 | | 0.267 | -0.192 | 51.9±15.6 | | 51.7±13.2 | | 0.943 | -0.036 |
| Sex, female | 110 | 48.7 | 39 | 63.9 | 0.043 | -0.315 | 49 | 57 | 24 | 55.8 | 1.000 | 0.112 |
| ASA Score, median (IQR) | 2 | 2-3 | 3 | 3-3 | <0.001 | 1.282 | 2 | 2-3 | 3 | 3-3 | 0.100 | 0.030 |
| HT, yes | 99 | 43.8 | 34 | 55.7 | 0.112 | 0.238 | 42 | 48.8 | 22 | 51.2 | 0.853 | 0.085 |
| CAD, yes | 15 | 6.6 | 7 | 11.5 | 0.274 | 0.151 | 9 | 10.5 | 5 | 11.6 | 0.841 | -0.024 |
| MI, yes | 1 | 0.4 | 0 | 0 | 0.603 | 0.075 | 1 | 1.2 | 0 | 0 | 0.478 | 0.012 |
| COPD, yes | 23 | 10.2 | 10 | 16.4 | 0.180 | 0.167 | 9 | 10.5 | 9 | 20.9 | 0.115 | 0.244 |
| Smoking, yes | 48 | 21.2 | 19 | 31.1 | 0.125 | 0.212 | 23 | 26.7 | 13 | 30.2 | 0.682 | -0.012 |
| DM, yes | 24 | 10.6 | 19 | 31.1 | <0.001 | 0.440 | 18 | 20.9 | 11 | 25.6 | 0.655 | 0.046 |
| Hx of wound infection, yes | 26 | 11.5 | 4 | 6.6 | 0.348 | -0.198 | 6 | 7 | 3 | 7 | 1.000 | 0.070 |
| Immunosuppression, yes | 4 | 1.8 | 1 | 1.6 | 0.945 | 0.010 | 3 | 3.5 | 1 | 2.3 | 0.719 | 0.012 |
| Hernia etiology | | | | | | | | | | | | |
| Primary ventral | 142 | 62.8 | 20 | 32.8 | <0.001 | 0.623 | 42 | 48.8 | 17 | 39.5 | 0.246 | 0.015 |
| Incisional | 83 | 36.7 | 40 | 65.6 | | | 44 | 51.2 | 25 | 58.1 | | |
| Both | 1 | 0.4 | 1 | 1.6 | | | 0 | 0 | 1 | 2.3 | | |
| Recurrent hernia | 43 | 19 | 17 | 27.9 | 0.156 | 0.196 | 19 | 22.1 | 10 | 23.3 | 1.000 | -0.090 |
| Hernia localization | | | | | | | | | | | | |
| Midline | 201 | 88.9 | 60 | 98.4 | 0.071 | -1.047 | 83 | 96.5 | 42 | 97.7 | 0.719 | 0.045 |
| Off-midline | 16 | 7.1 | 1 | 1.6 | | | 3 | 3.5 | 1 | 2.3 | | |
| Both | 9 | 4 | 0 | 0 | | | - | - | | | | |
| Procedure setting | | | | | | | | | | | | |
| Elective | 214 | 94.7 | 55 | 90.2 | 0.231 | -0.186 | 79 | 91.9 | 38 | 88.4 | 0.520 | -0.035 |
| Emergency | 12 | 5.3 | 6 | 9.8 | | | 7 | 8.1 | 5 | 11.6 | | |

BMI: body mass index; ASA: American society of anesthesiologist; HT: hypertension; CAD: coronary artery disease; MI: myocardial infarction; COPD: chronic obstructive pulmonary disease; DM: diabetes mellitus; SD: standard deviation; IQR: interquartile range; *Standardized difference: difference in means or proportions divided by the standard deviation; imbalance between groups was defined as an absolute value greater than 0.20 (small effect size). Note: variables that given with standardized difference were included in the propensity score matching analysis.

**Table 2. The comparison of intraoperative variables**

| | Unmatched comparisons | | | | | Matched comparisons | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Non-obese group (n=226) | | Class-III obese group (n=61) | | p | Non-obese group (n=86) | | Class-III obese group (n=43) | | p |
| | n | % | n | % | | n | % | n | % | |
| Hernia content | | | | | | | | | | |
| Omentum, yes | 122 | 54 | 37 | 60.7 | 0.386 | 40 | 46.5 | 25 | 58.1 | 0.263 |
| Small intestine, yes | 26 | 11.5 | 7 | 11.5 | 1.000 | 11 | 12.8 | 5 | 11.6 | 1.000 |
| Colon, yes | 6 | 2.7 | 3 | 4.9 | 0.368 | 3 | 3.5 | 3 | 7 | 0.275 |
| Adhesiolysis, >30min | 19 | 8.4 | 11 | 18 | 0.036 | 9 | 10.5 | 10 | 23.3 | 0.067 |
| Procedures | | | | | | | | | | |
| rIPOM repair | 69 | 30.5 | 21 | 34.4 | 0.641 | 28 | 32.6 | 15 | 34.9 | 0.844 |
| rTAPP repair | 63 | 27.9 | 12 | 19.7 | 0.250 | 18 | 20.9 | 10 | 23.3 | 0.822 |
| rRS repair | 49 | 21.7 | 9 | 14.8 | 0.283 | 23 | 26.7 | 7 | 16.3 | 0.269 |
| rTAR repair | 45 | 19.9 | 19 | 31.1 | 0.082 | 17 | 19.8 | 11 | 25.6 | 0.500 |
| Concomitant inguinal hernia repair | | | | | | | | | | |
| Unilateral, yes | 13 | 5.8 | 2 | 3.3 | 0.441 | 1 | 1.2 | 2 | 4.7 | 0.215 |
| Bilateral, yes | 14 | 6.2 | 0 | 0 | 0.046 | 7 | 8.1 | 0 | 0 | 0.054 |
| Defect width, cm, median (IQR) | 3 | 2–4 | 4 | 3-5 | <0.001 | 4 | 2–4 | 4 | 3–5 | 0.893 |
| Defect size, $cm^2$, median (IQR) | 7 | 3.1–15.1 | 12.6 | 7-28.2 | 0.001 | 12.6 | 3.1–23.6 | 12.6 | 7–25.5 | 0.446 |
| Mesh size, $cm^2$, median (IQR) | 176.7 | 63.6–240 | 225 | 113.1–300 | 0.023 | 225 | 113.1–300 | 198 | 113.1–300 | 0.856 |
| Mesh materials | | | | | | | | | | |
| Polypropylene | 68 | 30.1 | 7 | 11.5 | 0.003 | 28 | 32.6 | 4 | 9.3 | 0.004 |
| Polyester | 144 | 63.7 | 36 | 59 | 0.551 | 53 | 61.6 | 28 | 65.1 | 0.847 |
| ePTFE | 12 | 5.3 | 18 | 29.5 | <0.001 | 4 | 4.7 | 11 | 25.6 | 0.001 |
| Absorbable | 2 | 0.9 | 0 | 0 | 0.461 | 1 | 1.2 | 0 | 0 | 0.478 |
| Cranio-caudal overlap, cm, median (IQR) | 5 | 3.5–6.5 | 5 | 4.5–6 | 0.107 | 5 | 4-6.5 | 5 | 4.5–7.3 | 0.860 |
| Transverse overlap, cm, median (IQR) | 5 | 3.5–5.5 | 5 | 4.5–6 | 0.084 | 5 | 3.5-6 | 5 | 4–5.5 | 0.798 |
| Mesh/Defect ratio, median (IQR) | 20.2 | 11.5–25 | 16 | 8–25.4 | 0.039 | 16.9 | 9-23.4 | 16 | 8.3–29–8 | 0.563 |
| Mesh fixation | | | | | | | | | | |
| None/self-fix | 95 | 42 | 19 | 31.1 | 0.141 | 37 | 43 | 11 | 25.6 | 0.057 |
| Suture and/or tacker | 131 | 58 | 42 | 68.9 | | 49 | 57 | 32 | 74.4 | |

**Table 2. CONT.**

| | Unmatched comparisons | | | | | | Matched comparisons | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non-obese group (n=226) | | Class-III obese group (n=61) | | p | | Non-obese group (n=86) | | Class-III obese group (n=43) | | p | |
| | n | % | n | % | | | n | % | n | % | | |
| Console time, min., median (IQR) | 53 | 39–110 | 72 | 42–114 | 0.082 | | 57.5 | 42–120 | 74 | 41–112 | 0.489 | |
| Skin-to-skin time, min., median (IQR) | 69 | 51–124 | 91 | 59–131 | 0.087 | | 80.5 | 55–141 | 92 | 57.5–129.5 | 0.626 | |
| EBL, mL, median (IQR) | 5 | 5–5 | 5 | 5–7 | 0.135 | | 5 | 5–5 | 5 | 5–6 | 0.717 | |
| Intraoperative complication | 5 | 2.2 | 0 | 0 | 0.241 | | 2 | 2.3 | 0 | 0 | 0.314 | |

rIPOM: robotic intraperitoneal onlay mesh; rTAPP: robotic transabdominal preperitoneal; rRS: robotic Rives-Stoppa; rTAR: robotic transversus abdominis release; ePTFE: expanded polytetrafluoroethylene; EBL: estimated blood loss; IQR: interquartile range.

The median (IQR) pain score, assessed before leaving the PACU, was 4 (2–5) in the non–obese group and 4 (3–6) in the class–III obese group (p=0.195). The median (range) LOS was 0 (0–4) days for the non–obese group and 0 (0–5) days for the class–III obese group (p=0.465). Accordingly, the majority of patients were discharged on the same day of the procedure (74.4% vs. 65.1%, respectively). The rate of ED re–visits within 30–days postoperatively was 14% for both groups (p=1.000). However, the hospital readmission rate was 4.7% in the non–obese group and 0% in the class–III obese group (p=0.151).

The average follow–up period for the entire cohort was 30.1 (range=2.3–72.2) months. There was no difference between groups in terms of mean follow–up (p=0.957). 90.7% of patients in the non–obese group completed 90–day postoperative assessments versus 97.7% in the class–III obese group (p=0.143). Although class–III obese patients experienced a higher percentage of Grade–II complications as compared to non–obese patients (15.5 vs. 5.3, p=0.010), this difference did not persist after PSM analysis (p=0.387). Similarly, unmatched class–III obese patients experienced higher rates of cellulitis relative to their non–obese counterparts (5.2% vs. 1%, p=0.038), unlike matched patients, where no difference was found. Although a higher rate of seroma was observed in non–obese patients after matching, this was not statistically significant (p=0.082). This could be due to easier detection of seromas in lower BMI patients. CCI® scores and all postoperative complications, including SSEs, were similar across groups after matching. None of the patients experienced hernia recurrence throughout the study period. Postoperative complications were given in Table 3.

## Discussion

The relationship between extreme classes of obesity and postoperative outcomes is debated among the surgical community. A combination of physiological and anatomical perturbances place morbidly obese patients at increased risk of several diseases, such as ventral and incisional hernias.[23] A large proportion of hernia–related perioperative complications includes surgical site fluid collections, infections, and wound dehiscence. Obese patients often have extensive adipose tissue with limited vascularization and resistance to infection, and associated comorbidities such as diabetes contribute to impaired wound healing.[1] Class–III obesity has been shown to result in increased wound infections in patients undergoing open VHR (OVHR).[24] A study examined early out-

comes in 106.968 patients from the American College of Surgeons National Surgical Quality Improvement Program (ACS–NSQIP) database, across several BMI classes after elective VHR, and found that when compared with OVHR, LVHR minimizes both SSIs and SSOs.[4] However, they showed that there is an increasing trend of several complications as BMI increases in both OVHR and LVHR groups, and although LVHR decreased the risk of SSOs relative to OVHR in the majority of BMI classes, this risk did not decrease in patients with a BMI >40 kg/m$^2$. Moreover, the risk of infection after LVHR decreased for all patients except the morbidly obese.

The literature surrounding the relationship between higher BMI and VHR is not conclusive. Berger et al.[25] retrospectively reviewed 888 OVHRs and developed a risk–assessment tool for SSOs and SSIs. They found that a BMI ≥40 kg/m$^2$ was a predictor for the development of SSIs. Our study did not find any difference between non–obese and class–III obese patients in terms of SSEs, including SSO and SSI rates. This may be attributed to the advantages of minimally invasive hernia repair in this patient population. Notably, the previously mentioned studies involve open repair which may be a significant risk factor for the development of SSEs. The introduction of minimally invasive VHR showed promising results in such patient populations. The abovementioned database was examined by Fekkes et al.,[25] whereby 12,004 patients under-

**Table 3. The comparison of short-term postoperative outcomes**

| | Unmatched comparisons | | | | | | Matched comparisons | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non-obese group (n=206) | | Class-III obese group (n=58) | | p | | Non-obese group (n=78) | | Class-III obese group (n=42) | | p | |
| | n | % | n | % | | | n | % | n | % | | |
| CCI®, median (range) | 0 | 0–42.4 | 0 | 0–42.4 | 0.557 | | 0 | 0–42.4 | 0 | 0–42.4 | 0.993 | |
| Clavien-Dindo | | | | | | | | | | | | |
| Grade-I | 26 | 12.6 | 4 | 6.9 | 0.347 | | 12 | 15.5 | 3 | 7.1 | 0.254 | |
| Grade-II | 11 | 5.3 | 9 | 15.5 | 0.010 | | 8 | 10.3 | 7 | 16.7 | 0.387 | |
| Grade-IIIa | 3 | 1.5 | 0 | 0 | 0.355 | | 1 | 1.3 | 0 | 0 | 0.461 | |
| Grade-IIIb | 4 | 1.9 | 0 | 0 | 0.285 | | 0 | 0 | 0 | 0 | N/A | |
| Grade-IVa | 1 | 0.5 | 1 | 1.7 | 0.337 | | 1 | 1.3 | 1 | 2.4 | 0.654 | |
| SSEs, yes | 28 | 13.6 | 7 | 12.1 | 1.000 | | 11 | 14.1 | 5 | 11.9 | 1.000 | |
| SSIs, yes | 8 | 3.9 | 3 | 5.2 | 0.664 | | 4 | 5.1 | 3 | 7.1 | 0.653 | |
| Cellulitis | 2 | 1 | 3 | 5.2 | 0.038 | | 2 | 2.6 | 3 | 7.1 | 0.231 | |
| Superficial | 3 | 1.5 | 0 | 0 | 0.355 | | 1 | 1.3 | 0 | 0 | 0.461 | |
| Deep | 2 | 1 | 0 | 0 | 0.451 | | 1 | 1.3 | 0 | 0 | 0.461 | |
| Organ space | 1 | 0.5 | 0 | 0 | 0.206 | | 0 | 0 | 0 | 0 | N/A | |
| SSOs, yes | 22 | 10.7 | 4 | 6.9 | 0.465 | | 9 | 11.5 | 2 | 4.8 | 0.220 | |
| Seroma | 20 | 9.7 | 3 | 5.2 | 0.429 | | 9 | 11.5 | 1 | 2.4 | 0.083 | |
| Hematoma | 3 | 1.5 | 1 | 1.7 | 0.883 | | 0 | 0 | 1 | 2.4 | 0.171 | |
| Wound dehiscence | 1 | 0.5 | 0 | 0 | 0.595 | | 1 | 1.3 | 0 | 0 | 0.461 | |
| SSO/I-PI | 6 | 2.9 | 0 | 0 | 0.189 | | 1 | 1.3 | 0 | 0 | 0.461 | |

CCI®: Comprehensive Complication Index (University of Zurich, Zurich, Switzerland); SSEs: surgical site events; SSIs: surgical site infections; SSOs: surgical site occurrences; SSOPI: surgical site occurrence requiring procedural intervention.

going OVHR and LVHR were compared. They found that the mean hospital LOS increased significantly after OVHR for patients with a BMI ≥40 kg/m$^2$ (3.7 days) as compared to those with a BMI ≤25 kg/m$^2$ (2.4 days), and the opposite was observed with LVHR (1.9 and 3.2 days, respectively).[25] In contrast, we did not find any difference in LOS between our two study groups, with a mean LOS of 0.5 days (median=0 days) for both non–obese and class–III obese patients. In terms of operative times, laparoscopic repair is generally more time–consuming than open repair. In Fekkes et al.'s study,[25] mean operative times for extremely obese patients undergoing laparoscopic repair was found to be 106 minutes, while open repair resulted in a mean of 109 minutes. They attribute this to the need for extensive subcutaneous dissection during open repair in these patients. In our study, the mean operative time for class–III obese patients was 85 minutes (median=92 minutes). Another study about abdominal wall reconstruction showed that while class–III obesity was associated with return to OR and venous thromboembolic events, it did not contribute to the development of any major surgical, medical, or wound complications.[26] However, the authors found that operative times and LOS for the morbidly obese group were longer than that of the non–obese groups.[26] Contrarily, we did not find any difference between our study groups in terms of these variables. This could be attributed to the performance of abdominal wall reconstruction, which is a more invasive and time–consuming procedure. It is worth mentioning that studies evaluating the ACS–NSQIP database are limited to a 30–day follow–up period and are unreliable in deducing long–term outcomes such as recurrence, which is an important variable in these high–risk patients. In terms of early postoperative outcomes, our study confirmed previously published studies showing no difference in early outcomes after LVHR between non–obese and morbidly obese patients.[8, 9]

Similar data surrounding RVHR in extreme BMI classes is scarce. We previously conducted a study evaluating RVHR in the morbidly obese population alone. 50 patients with a median BMI of 42.9 kg/m$^2$ were included in the study with a mean follow–up period of 22.7 months. The majority of minor complications (Clavien–Dindo grade–I & –II) involved persistent pain or discomfort, and major complications (Clavien–Dindo grade–III & –IV) were noted in only 6% of patients. A short hospital LOS (0.32 days) and a recurrence rate of 2% supported the safety and efficacy of RVHR in this patient population. In the current study, all complication rates were comparable between non–obese and class–III obese patients, after PSM analysis. This indicates that the complications observed in our study are not attributed to an extreme BMI, and may instead be related to factors associated with higher BMIs in terms of patient demographics and hernia characteristics.

There are several technical challenges with performing RVHR in obese patients. Trocar access is a critical step that can have several downstream implications. For patients with normal BMI, a distance of 6–8 cm between trocars is generally sufficient. However, obese patients may require an increased distance between trocars since a large portion of the trocars has to traverse a thick layer of adipose tissue. This may result in robotic arm collision as well as interference between instruments inside the abdominal cavity. Furthermore, the use of longer trocars in this patient population can help create more leverage and ease instrument maneuverability. This is especially relevant for LVHR, where large abdomens place more torque on trocars and instruments leading to decreased control and fluidity of movements.[27] Robotic repair may offset these challenges by providing a stable platform and may reduce the risk of potential intraoperative injury. Trocar–related considerations play a big role in ensuring good quality repairs. Obtaining sufficient working space and dexterity are necessary for achieving adequate mesh overlap and fixation. Moreover, optimal trocar positioning reduces the need for re–docking and consequently operative times, which likely translates to decreased postoperative complications. In this study, the only difference in terms of intraoperative variables, which persisted after PSM, was the higher use of ePTFE mesh (Synecor Pre™, W.L. Gore & Associates Inc., Newark, DE, USA) in the class–III obese group. This a reflection of the surgeon's mesh selection for higher–risk patients, including extreme BMI classes. The similarity between the two study groups' complication rates may imply that factors other than BMI, such as patient selection and technical considerations, dictate repair outcomes.

We can highlight a few limitations of our study. In general, retrospective studies are criticized in terms of the introduction of selective bias. Several variables such as repair technique, mesh materials, and the performance of RVHR in high–risk individuals is subject to selective bias. Furthermore, extreme obesity is associated with several comorbidities and anatomical variations which make it difficult to compare these patients. We attempted to coun-

teract potential confounders with a PSM analysis to isolate the effects of higher BMI. Some literature suggests that high–risk patients should undergo preceding bariatric surgery with VHR and that deferring repair could increase the risk of bowel incarceration. However, there is a concern for contamination and subsequent complications after some of these weight loss procedures, especially those involving synthetic mesh. Convincing patients to undergo bariatric surgery when presenting for hernia repair is challenging and may not be practical in all clinical scenarios. All patients in this study were consulted about the risks and benefits of simultaneous bariatric surgery and were encouraged to adopt several methods for weight loss before their hernia repair. Patients in our study either chose to delay bariatric surgery or were not suitable candidates for such procedures. Our study also lacks data about other variables such as abdominal dimensions and quality of life measurements, which can better clarify the relationship between extreme obesity and its relevant postoperative complications. Lastly, our study cannot draw any conclusions about recurrence rates after RVHR due to the lack of long–term follow–up in this study's two groups.

Per our study hypothesis, non–obese and class–III patients experienced similar outcomes after RVHR. Surgeons can benefit from adopting a tailored and holistic approach with high–risk individuals, taking into consideration other patient demographics and hernia characteristics instead of BMI alone.

## Disclosures

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**Ethichs Committee Approval:** The study was approved by the Local Ethics Committee (IRB#:HW202, Good Samaritan Medical Center).

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## References

1. Flancbaum L, Choban PS. Surgical implications of obesity. Annu Rev Med 1998;49:215–34. [CrossRef]
2. Sugerman HJ, Kellum JM Jr, Reines HD, DeMaria EJ, Newsome HH, Lowry JW. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. Am J Surg 1996;171:80–4. [CrossRef]
3. Novitsky YW, Cobb WS, Kercher KW, Matthews BD, Sing RF, Heniford BT. Laparoscopic ventral hernia repair in obese patients: a new standard of care. Arch Surg 2006;141:57–61.
4. Regner JL, Mrdutt 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;210:1024–9. [CrossRef]
5. Froylich D, Segal M, Weinstein A, Hatib K, Shiloni E, Hazzan D. Laparoscopic versus open ventral hernia repair in obese patients: a long-term follow-up. Surg Endosc 2016;30:670–5.
6. Gonzalez A, Escobar E, Romero R, Walker G, Mejias J, Gallas M, et al. Robotic-assisted ventral hernia repair: a multicenter evaluation of clinical outcomes. Surg Endosc 2017;31:1342–9. [CrossRef]
7. Sharbaugh ME, Patel PB, Zaman JA, Ata A, Feustel P, Singh K, et al. Robotic ventral hernia repair: a safe and durable approach. Hernia 2019 Nov 27. [Epub ahead of print], doi: 10.1007/s10029-019-02074-9. [CrossRef]
8. Birgisson G, Park AE, Mastrangelo MJ Jr, Witzke DB, Chu UB. Obesity and laparoscopic repair of ventral hernias. Surg Endosc 2001;15:1419–22. [CrossRef]
9. 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;22:2244–50. [CrossRef]
10. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational StudiesSTROBE Statement. Annals of Internal Medicine 2007;147:573–7.
11. Muysoms FE, Miserez M, Berrevoet F, Campanelli G, Champault GG, Chelala E, et al. Classification of primary and incisional abdominal wall hernias. Hernia 2009;13:407–14.
12. Gokcal F, Morrison S, Kudsi OY. Short-term comparison between preperitoneal and intraperitoneal onlay mesh placement in robotic ventral hernia repair. Hernia 2019;23:957–67.
13. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205–13. [CrossRef]
14. Slankamenac K, Graf R, Barkun J, Puhan MA, Clavien PA. The comprehensive complication index: a novel continuous scale to measure surgical morbidity. Ann Surg 2013;258:1–7.
15. Petro CC, Novitsky YW. Classification of hernias. Hernia Surgery. Springer; 2016. p. 15–21. [CrossRef]
16. Bittner JGt, Alrefai S, Vy M, Mabe M, Del Prado PAR, Clingem-

peel NL. Comparative analysis of open and robotic transversus abdominis release for ventral hernia repair. Surg Endosc 2018;32:727–34. [CrossRef]

17. Gokcal F, Morrison S, Kudsi OY. Robotic ventral hernia repair in octogenarians: perioperative and long-term outcomes. J Robot Surg 2020;14:275–81. [CrossRef]
18. Gokcal F, Morrison S, Kudsi OY. Robotic retromuscular ventral hernia repair and transversus abdominis release: short-term outcomes and risk factors associated with perioperative complications. Hernia 2019;23(2):375–85. [CrossRef]
19. Kudsi OY, Gokcal F, Chang K. Propensity score matching analysis of short-term outcomes in robotic ventral hernia repair for patients with a body mass index above and below 35 kg/m2. Hernia 2019 Dec 16. [Epub ahead of print], doi: 10.1007/s10029-019-02108-2. [CrossRef]
20. Thoemmes F. Propensity score matching in SPSS. Tubingen: University of Tubingen; 2012.
21. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior research methods 2007;39:175–91. [CrossRef]
22. Iacus S, King G, Porro G. CEM: Coarsened exact matching software. Available at: https://gking.harvard.edu/files/gking/files/jss-paper.pdf. Accessed Jun 9, 2020.
23. Buckley FP, Vassaur HE, Jupiter DC, Crosby JH, Wheeless CJ, Vassaur JL. Influencing factors for port-site hernias after single-incision laparoscopy. Hernia 2016;20:729–33. [CrossRef]
24. Berger RL, Li LT, Hicks SC, Davila JA, Kao LS, Liang MK. Development and Validation of a Risk-Stratification Score for Surgical Site Occurrence and Surgical Site Infection after Open Ventral Hernia Repair. Journal of the American College of Surgeons 2013;217:974–82. [CrossRef]
25. 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;25:151–7. [CrossRef]
26. 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;48:305–11.
27. Alfalah H, Philippe B, Ghazal F, Jany T, Arnalsteen L, Romon M, et al. Intragastric Balloon for Preoperative Weight Reduction in Candidates for Laparoscopic Gastric Bypass with Massive Obesity. Obesity Surgery 2006;16:147–50. [CrossRef]