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Robotic ventral hernia repair in morbidly obese patients: perioperative and mid-term outcomes

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Abstract

Background Obesity is a growing epidemic and it has been found to be an independent risk factor for a multitude of perioperative complications. We describe our experience with morbidly obese patients who underwent robotic ventral hernia repair (RVHR), examining factors affecting perioperative and mid-term outcomes.

Methods From a prospectively maintained database, all morbid obese (BMI $\geq$ 40 kg/m^2) patients who underwent robotic procedures between 2013 and 2018 were analyzed retrospectively including perioperative outcomes and the mid-term follow-up. Complications were assessed with validated grading systems and index. Univariate analyses and multivariate logistic regression analysis were performed to determine the factors associated with the development of any complication. Kaplan–Meier's time-to-event analysis was performed to calculate freedom-of-recurrence.

Results Fifty patients with median BMI 42.9 kg/m^2 were included. The median last pain score before leaving PACU was 4. The mean LOS of all cohorts was 0.32 day. The postoperative complication rate was 46%. The most frequent complication was persistent pain/discomfort (32%) in early postoperative period. Minor complications (Clavien–Dindo grade-I and II) were seen in 40% of patients while major complications (Clavien–Dindo grade-III and IV) were seen in 6%. The maximum comprehensive complication index® score was 42.9. In regression analysis, BMI, adhesiolysis, intraperitoneal mesh placement, and off-console time were found to be significantly associated with postoperative complications. Mean follow-up was 22.7 months. Hernia recurrence was seen in 2% and the mean freedom-of-recurrence was 57.4 months (95% CI 54.6–60.2).

Conclusions To our best knowledge, this study is the first to present outcomes of morbidly obese patients who underwent RVHR. The results indicate the safety and efficacy of RVHR in morbid obesity with a low recurrence rate as well as a long freedom-of-recurrence time. Further studies are needed to better elucidate the role of robotic surgery in morbidly obese patients.

Keywords Robotic ventral hernia repair · Incisional hernia · Morbid obesity

The repair of ventral hernias, either primary or incisional, is one of the most commonly performed surgical procedures. The number of incisional hernia repairs was estimated to be 300,000 annually in Europe and 400,000 annually in the US [1]. Hernia repairs are accomplished either via an open or minimally invasive approach. A variety of surgical techniques are currently in practice for both approaches. Laparoscopic ventral hernia repair (LVHR) has been reported to be associated with fewer perioperative complications, as well as a shorter hospital stay, when compared to the open equivalent [2–4]. However, the repair of hernias in patients with significant comorbidities often results in frustration for both surgeons and patients, even when performed laparoscopically. Obesity is one of the comorbidities with an increasing incidence worldwide. In the US, estimated prevalence was approximately 40% of the adult population between 2015 and 2016, according to the Center for Disease Control [5]. Obesity has been defined as an independent risk factor for numerous perioperative complications; including cardiac events, adverse pulmonary outcomes, thromboembolic events, wound complications, and infections. Many surgical textbooks describe higher morbidity and mortality in obese patients undergoing surgery [6]. Some studies have suggested that the use of minimally invasive techniques may reduce perioperative complication rates and decrease

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failure rates in obese patients undergoing ventral hernia repair (VHR) [7–10]. Morbid obesity, which is defined as a body mass index (BMI) of 40 kg/m^2 or greater, further complicates health management.

A developing technology in minimally invasive surgery, the growing use of robotic platforms can offer advantages over conventional laparoscopy. Dexterity and instrument precision are more refined allowing surgeons the ability to perform complex intracorporeal tasks effectively [11–13]. Particularly in highly elevated BMI patients, laparoscopic surgery becomes increasingly difficult secondary to the torque of the abdominal wall on standard laparoscopic instruments and trocars. The force and weight of the abdominal wall on the instruments as they pass through the trocars can destabilize the fluidity of the surgeon's motions resulting in a loss of control and precision [14]. In terms of postoperative recovery, it has been reported that robotic surgery might be associated with a faster recovery and reduced morbidity profile, especially in obese patients who underwent colorectal surgery [15, 16]. However, data is scarce regarding the use of robotic platforms in VHR for obese patients. In this study, we aim to share our experience with morbidly obese patients who underwent robotic VHR (RVHR) and to identify the factors affecting perioperative and mid-term outcomes in this particular patient population.

Methods

Study population and design

Institutional Review Board approved this study and written inform consent was received from all patients or their next of kin/patient representative. The data of this study was obtained from a prospectively maintained database of patients who underwent robotic procedures performed by a single surgeon (OYK) between February 2013 and November 2018. The database included demographics (age, sex), comorbidities, body mass index (BMI), American Society Anesthesiology (ASA) Classification, the type of hernia (primary ventral, incisional, or recurrent), the location of the hernia (midline, off-midline), the capability of the surgeon to close the anterior fascial defect of the hernia robotically (yes/no), the type of mesh used, the dimensions of the hernia defect and of the mesh itself, the requirement of adhesiolysis, the operative time in minutes (console and skin-to-skin), the estimated blood loss (EBL) in mL, and postoperative discharge day.

The measurements of the hernia defect were determined following the model outlined by the European Hernia Society [17]. The defect area (cm^2) was determined using a mathematical formula for an oval or circle. The mesh area (cm^2) and the ratio of mesh size to defect size (M/D ratio) were also calculated using conventional mathematical formulas. Transverse mesh overlap was recorded as the shortest radial distance between the edge of the defect and the edge of the mesh. Other calculations included determination of the off-console time (time required to place trocars, dock the robot, undock the robot and closing the trocar sites) where the console time is subtracted from the skin-to-skin time.

The medical records and clinical charts of the patients were reviewed for perioperative complications. Postoperative and final pain scores were determined by reviewing the 0–10 numeric rating scale (0: no pain, 10: the worst pain) performed by the anesthesiologist. The last pain score was determined at the time point just before the patient left the post anesthesia care unit (PACU). The pain score at postoperative day 1 (POD-1), which was documented by the unit nurse, was also determined in patients who stayed overnight following surgery. The length of hospital stay (LOS) in days was determined according to the dates of admission and hospital discharge.

Postoperative complications were reviewed from follow-up visit notes of the surgeon, as well as medical records and clinical charts of the patients. In patients with inadequate data retrieval, phone calls were made to gather information on perioperative complications. All unexpected complaints of the patients such as pain, nausea, and constipation have been regarded as a complication. All complications were categorized according to the Clavien–Dindo classification system [18]. Of these, surgical wound complications were categorized according to the previously published classification of surgical site occurrences [19]. The Morales-Conde classification was utilized to describe the severity of seroma complications [20]. To measure the morbidity score, the Comprehensive Complication Index (CCI®, University of Zurich, Zurich, Switzerland) was used as a continuous scale [21].

Phone calls were also made to assess mid-term outcomes. Patients or their surrogates were asked whether they had undergone another hernia surgery after their index VHR. Patients were then assessed for recurrence via the algorithm of ventral hernia recurrence inventory [17]. According to the inventory, patients were asked two questions regarding their hernia operation: (1) "Do you have physical symptoms or pain at the site?" and (2) "Do you feel or see a bulge?" When any of these questions were responded as "yes," the patient was invited to an office visit to perform a physical examination and a further imaging study, if necessary.

Surgical technique and postoperative plan

In brief, the patients were placed in the supine position on the operating room table. Following the preparation of National Surgical Quality Improvement Program protocols (including mechanical venous thromboembolism

prophylaxis options such as elastic stockings or intermittent pneumatic compression devices), the trocars were inserted in suitable places, and the patient side cart of the da Vinci surgical robotic system (Intuitive Surgical, Sunnyvale, CA) was docked. All abdominal wall adhesions were divided with the use of monopolar scissors and hernia contents were reduced into the abdominal cavity. For defects up to 5 cm authors prefer transabdominal preperitoneal (TAPP) repair, though intraperitoneal onlay mesh (IPOM) can be used as well, and may be an option if a TAPP is not feasible based on patient characteristics. For larger defects (> 5 cm), a retrorectus approach is preferred, with the addition of component separation wherever needed. If retromuscular repair is not feasible, IPOM can be another option.

Robotic intraperitoneal onlay mesh (rIPOM) VHR

The peritoneum surrounding the defect was dissected. Umbilical and falciform ligaments, if found in the field of mesh placement, were also dissected. After defect measurement, primary closure of the hernia defect was accomplished by running a long-lasting absorbable barbed suture (Stratafix 0™ on CT-1 needle, Ethicon, Somerville, NJ, USA) under reduced intraabdominal pressure (4–8 mmHg). The mesh was introduced to the abdominal cavity via one of the ports and secured to the posterior fascia using barbed absorbable sutures (2–0 V-Loc™; Medtronic, Minneapolis, MN, USA) in a running fashion, or with absorbable tackers (AbsorbaTack™; Medtronic, New Haven, CT, USA).

Robotic transabdominal preperitoneal (rTAPP) VHR

The preperitoneal plane was entered and dissected at least 5 cm circumferentially around the defect to provide space for adequate mesh deployment. After closing the hernia defect, mesh was deployed and secured to the posterior fascia. Any disruption of peritoneal integrity or tears that occurred during the development of the peritoneal pocket were repaired by absorbable sutures. The peritoneal flap was closed with a barbed absorbable suture (2–0 V-Loc™; Medtronic, Minneapolis, MN, USA).

Robotic retromuscular (rRM) VHR

The posterior rectus fascia was cut along the medial edge of the rectus muscle after performing adhesiolysis, as necessary. The dissection plane was carried out laterally towards the linea semilunaris to obtain the proper distance for mesh overlap. At the lateral border of the rectus sheath, a transversus abdominis release (TAR) was added as required. Neurovascular bundles of the rectus muscle were found and preserved during the TAR and the dissection plane was extended approximately to the anterior axillary line. The same steps were performed for the contralateral side of the patient as required. After completion of the dissection, primary closure of the anterior fascial defect was accomplished by running a long-lasting absorbable barbed suture (Stratafix 0™ on CT-1 needle, Ethicon, Somerville, NJ, USA) under reduced intraabdominal pressure (4–8 mmHg). The opening of the posterior rectus sheath was closed using barbed absorbable suture (2–0 V-Loc™; Medtronic, Minneapolis, MN, USA) in a running fashion. The mesh was then inserted, deployed, and secured in its correct position.

Drains were not used. Pneumoperitoneum was released under direct vision. Any fascial incision more than 10 mm was closed, along with skin incisions with absorbable sutures after local anesthetic (1% bupivacaine hydrochloride; Marcaine) infiltration at the trocar sites. Patients were transferred to PACU after surgery. All patients received IV ketorolac and fentanyl perioperatively, unless they had a contraindication. A low molecular-weighted heparin was ordered for patients who had a history of deep vein thrombosis or an operative time longer than 1 h. All the patients were prescribed Oxycodone-Acetaminophen 5/325 mg/30 tablets at the time of discharge.

Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences for Windows Version 22). 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) and Mann–Whitney U (for non-normal distributions). All variables were compared between patients who developed complications and in those without complications. Logistic regression analysis was performed to determine the factors associated with the development of any complication. The regression model included all the variables having a $p < 0.1$ value in univariate analysis. BMI has also been included in the regression model as a possible independent explanatory variable. Kaplan–Meier's time-to-event analysis was performed to calculate freedom-of-recurrence. A p value of less than 0.05 was considered statistically significant.

Results

There were 468 patients who underwent RVHR (primary and/or incisional). Of these, 52 hernia operations performed on 50 patients (10.6%) with a BMI ≥ 40 kg/m^2 were included into the study. The mean age of the patients was 50.14 ± 12.1 and the median BMI was 42.9 kg/m^2 (IQR: 41.8–46.1, min.-max.: 40.2–59.2). 31 (62%) patients were female. All patients (100%) had at least one comorbidity, in addition to morbid obesity. Comorbidities were categorized

as following (*n*, %): Cardiovascular (32, 64%), pulmonary (31, 62%), endocrine (18, 36%), neuropsychiatric (12, 24%). 11 (22%) patients reported taking a medication potentially associated with postoperative bleeding such as acetylsalicylic acid, clopidogrel, and coumadin. Median ASA class was 3 (IQR: 2–3).

Twenty-one (42%) patients had a primary ventral hernia. Of these, only one (2%) patient had diastasis recti. 29 (58%) patients underwent surgery for an incisional hernia, of these, 68% had a recurrence after a prior repair with mesh. 4 (8%) patients underwent surgery in an emergency setting. Almost all hernias (98%) were located in the abdominal mid-line. According to EHS classification [17], the localization of the hernias were as follows: M2 accounted for 22%, M3 94%, M4 12%, M5 4%, and L2 comprised 2%. 11 (22%) patients had multiple defects. 33(66%) patients had an incarcerated hernia at the time of repair. Of these, incarcerated viscera included omentum in 27 patients (54%), small bowel in 5 (10%), and colon in 3 (6%). Extensive adhesiolysis was required in 11 (22%) patients. Primary closure of the fascial defect was accomplished in 42 (84%) patients. Hernia and operative variables were summarized in Table 1. Detailed operative methods are presented in Table 2.

The distribution of the mesh types were as follows: 54% Symbotex™ (Medtronic, Minneapolis, MN, USA), 20% ProGrip™ (Medtronic, Minneapolis, MN, USA), 35.2% Parietene™ (Medtronic, Minneapolis, MN, USA), 12% Synecor Pre™ (W.L. Gore & Associates Inc., Newark, DE, USA), 10% Parietene™ (Medtronic, Minneapolis, MN, USA), 2% Synecor™ (W.L. Gore & Associates Inc., Newark, DE, USA), 2% Bard® Soft Mesh (Bard-Davol Inc., Warwick, RI, USA).

None of the procedures were converted to open or conventional laparoscopy. Intraoperative complications did not occur in any of the patients. The median (IQR) of the last pain score before leaving PACU was 4 (3–5) and POD-1 pain score (*n*:12) was 6 (IQR: 2.5–7.5). The mean LOS of all cohorts was 0.32 day (min–max: 0–3). Most of patients were discharged on the same day of surgery (76%). 26% of patients visited the emergency department (ED) following surgery, of these 4% required admission. The reasons given for ED revisits included pain, syncope, urinary tract infection, pneumonia, and wound concerns.

Table 1 Hernia and operative variables

Defect width (cm), median (min–max)	3 (1.5–12)
Mesh width (cm), median (min–max)	12 (9–30)
Mesh overlap, transverse (cm), median (min–max)	5 (2–12.5)
Defect area (cm^2), median (IQR)	9.62 (4.9–18.8)
Mesh area (cm^2), median (IQR)	176.7 (113.1–300)
Mesh/defect ratio, median (IQR)	18.7 (9–31.8)
Console time (min.), median (IQR)	60.5 (39–96)
Skin to skin time (min.), median (IQR)	71 (54–110)
Estimated blood loss (mL), median (IQR)	5 (5–5)

Min minimum, *max* maximum, *IQR* interquartile range

Table 2 Performed procedures

Surgery type	*n* (%)
rIPOM, *n* (%)	20 (40)
rTAPP, *n* (%)	11 (22)
rIPOM + rIPOM, *n* (%)	1 (2)
rIPOM + rTAPP, *n* (%)	1 (2)
rIPOM + cholecystectomy, *n* (%)	1 (2)
rTAPP + cholecystectomy, *n* (%)	1 (2)
rRM without TAR, *n* (%)	5 (10)
rRM without TAR + gastric band removal, *n* (%)	1 (2)
rRM with TAR, *n* (%)	8 (16)
Unilateral TAR, *n* (%)	3 (6)
Bilateral TAR, *n* (%)	5 (10)
rRM with TAR + unilateral inguinal hernia repair, *n* (%)	1 (2)

rIPOM robotic intraperitoneal onlay mesh, *rTAPP* robotic transabdominal preperitoneal, *rRM* robotic retromuscular, *TAR* transversus abdominis release

The rate of patients with any postoperative complication was 46%. The most frequent complication was persistent post-surgical pain or discomfort early postoperatively (32%). The presence of postoperative pain or discomfort was significantly higher in rIPOM repair subgroup ($p = 0.036$). However, all of these complaints had resolved by 2 months, and no patients reported chronic pain. Other complications included nausea (10%), pulmonary complications (6%), SSI (6%), seroma (6%), urinary tract infection, constipation, small bowel obstruction, and hematoma (2% each). According to Clavien–Dindo classification, minor complications (grade-I and II) were seen in 40% of patients while major complications (grade-III and IV) were seen in 6%. There were two Grade-III complications; one of which was a trocar site SSI that required drainage, and the other was a hernia recurrence. There was one Grade-IV complication; a patient with a history of obstructive sleep apnea was admitted to the ICU for CPAP delivery, secondary to CO2 retention in the PACU. The median CCI® score was 0 (IQR:0–12.2). The details of postoperative complications, as well as SSEs, are presented in Table 3.

The ventral hernia inventory questionnaire for recurrence was completed for 70% of patients via phone conversation. Mean follow-up time was 22.7 months (SD: 15.8). Hernia recurrence was seen in only 1 (2%) patient 14.1 months after surgery. A trocar site hernia developed in 1(2%) patient, likely secondary to a SSI reported by the patient at that site. 1(2%) patient expired secondary to a myocardial infarction,

Table 3 Postoperative complication grades and surgical site events

Complications	*n* (%)
Clavien–Dindo[a]	
Grade-I	14 (28)
Grade-II	6 (12)
Grade-IIIa	1 (2)
Grade-IIIb	1 (2)
Grade-IVa	1 (2)
SSEs	8 (16)
SSIs	3 (6)
Cellulitis[b,c]	2 (4)
Superficial infection[b,d]	1 (2)
SSOs	5 (10)
Seroma[e]	4 (8)
Hematoma[b]	1 (2)
SSOPI	0 (0)

SSEs surgical site events, *SSIs* surgical site infections, *SSOs* surgical site occurrences, *SSOPI* surgical site occurrence procedural intervention

[a]Patients who had two or more complications were given the highest grade

[b]Observed at trocar site away from hernia site

[c]Treated with antibiotics

[d]Drainage was needed

[e]3 were Morales-Conde class-0b, 1 patient was Morales-Conde class-1

14.5 months postoperatively. Comparison of patients with and without complication was shown in Table 4.

In a multivariate regression model, intraperitoneal placement of the mesh was an independent risk factor for increased postoperative pain or discomfort ($p = 0.030$, OR 4.65, 95%CI 1.15–18.7). In a logistic regression model, BMI, the performance of adhesiolysis, intraperitoneal mesh placement, and prolonged off-console time were found to be significantly associated with the development of any complication. Data are shown in Table 5. There was also a weak correlation between the required off-console time in min and CCI® score (Spearman's rho correlation coefficient: 0.301, $p = 0.034$).

The outcome of time-to-event data for hernia recurrence is shown in Fig. 1 as a Kaplan–Meier plot. According to this analysis, the mean freedom-of-recurrence was found to be 57.4 months (95% CI 54.6–60.2).

Discussion

Obesity was previously considered a relative contraindication for conventional laparoscopic surgery [7, 22]. On the contrary, today, for several procedures, laparoscopy seems to be superior to open approaches in these patients such as cholecystectomy, appendectomy, and bariatric surgery [7]. In a survey study among surgeons in 2012, morbid obesity was considered a contraindication to VHR by 43.3% of surgeons [23]. However, with the increasing incidence of obesity in the adult population, surgeons are re-evaluating outcomes of this patient subset in order to better address the feasibility of VHR. In terms of postoperative outcomes, numerous studies have shown superior results after laparoscopic repair of ventral hernias in an obese population [7–10]. It has been proven that RVHR is safe and feasible [24–26], but no prior studies have specifically examined the outcomes of RVHR in morbidly obese patients.

In a study of 64 patients undergoing LVHR, where 16 patients were morbidly obese, mean operative time was reported to be 161.5 min [8]. In another study, mean operative time was found to be 154 min for 134 morbidly obese patients [10]. We found that the mean operative (skin-to-skin) time was 72 min for our rIPOM subgroup (*n*:23), which was considerably shorter than others reported. The mean operating time was 70.5 min for rTAPP and 156 min for rRM. Length of stay can differ from patient to patient, however, in our study group most patients were discharged on the same day of surgery (76%, mean LOS: 0.32 day). For similar class obese patients (BMI > 40 kg/m^2), LOS was 2.1 days in Birgisson et al.'s study and 3.6 days in Tsereteli et al.'s study. These differences could be due to the difference in the average defect size between studies. While the mean defect size was 156 cm^2 and 171 cm^2, respectively for those studies, the mean defect size was 13.6 cm^2 for our rIPOM subgroup, 11.3 cm^2 for rTAPP, and 26.8 cm^2 for rRM subgroups. The average defect size of our cohort is smaller than those previously published laparoscopic series. This huge difference could be due to the method of defect measurement. We measured the defect size intracorporeally. It is possible that other researchers measured defect size extracorporeally. This would create a large discrepancy particularly in a morbidly obese patient as the innermost layer may be considerably narrower that the exterior surface. The difference could also be the result of the formula used to calculate the hernia defect area; our study used an oval or circle shape formula. We are not able to comment on their method of defect measurement or the formula used to calculate defect area, as this was not reported.

Most surgeons do not close the hernia defect primarily as this maneuver is prohibitively difficult in conventional laparoscopic hernia repair. For this purpose, the robotic platform offers a better opportunity to the surgeon secondary to EndoWrist® technology [11, 13]. In a multicenter study, which reviewed the outcomes of 368 patients who had undergone robotic VHR from 5 different centers, the achievement rate of defect closure was 69.3% for all patients, of whom 20.9% were morbidly obese [27]. The rate of primary closure in our study group was 84%. The real impact

Table 4 Characteristics of the patients with or without complications (univariate analysis)

	Complication (−)	Complication (+)	*p*
Age, mean ± SD	48.9 ± 13.5	51.6 ± 10.5	0.442
Sex, female *n* (%)	16 (59.3)	15(65.2)	0.773
BMI, kg/m^2, median (IQR)	42.4 (41.7–45)	43.5 (42.1–48.7)	0.280
ASA class III, *n* (%)	20 (74.1)	17 (73.9)	1.000
Comorbidities, yes, *n* (%)			
Cardiovascular	18 (66.7)	14 (60.9)	0.771
Pulmonary	17 (63.0)	14 (60.9)	1.000
Endocrine	9 (33.3)	9 (39.1)	0.771
Neuropsychiatric	7 (25.9)	5 (21.7)	1.000
Medication that might cause bleeding	4 (14.8)	7 (30.4)	0.305
Hernia etiology, incisional, *n* (%)	15 (55.6)	14 (60.9)	0.778
Recurrent incisional, *n* (%)	4 (14.8)	6 (26.1)	0.480
Incarcerated hernia, yes, *n* (%)	18 (66.7)	15 (65.2)	1.000
Omentum	17 (63.0)	10 (43.5)	0.255
Small intestine	1 (3.7)	4 (17.4)	0.167
Colon	1 (3.7)	2 (8.7)	0.558
Adhesiolysis, yes, *n* (%)	2 (7.4)	10 (43.5)	0.006
Defect closure, yes, *n* (%)	24 (88.9)	18 (78.3)	0.444
Defect width (cm), median (IQR)	3 (3–4)	3.5 (2.25–5.5)	0.513
Mesh width (cm), median (IQR)	12 (12–15)	12 (12–15)	0.659
Mesh overlap, transverse (cm), median (IQR)	5 (4.5–5.9)	5 (4–5.8)	0.357
Defect area (cm^2), median (IQR)	9.6 (7.1–12.7)	9.6 (4.8–29.1)	0.524
Mesh area (cm^2), median (IQR)	176.7 (113.1–225)	113.1 (113.1–300)	0.905
Mesh/defect ratio, median (IQR)	17.4 (12.1–25.2)	19.6 (8–30.8)	0.792
Mesh position, intraperitoneal*, *n* (%)	9 (33.3)	14 (60.9)	0.087
Console time, min., median (IQR)	55 (39–71.5)	86 (40–119.5)	0.144
Skin-to-skin time, min., median (IQR)	63 (56.5–90.5)	105 (55.5–138.5)	0.080
Off-console time, min., median (IQR)	12 (9–15)	15 (12–24)	0.008
EBL, mL, median, (IQR)	5 (5–5)	5 (5–10)	0.108

BMI body mass index, *ASA* American society of anesthesiologists, *EBL* estimated blood loss, *IQR* interquartile range

*Patients with preperitoneal and retromuscular of mesh were collapsed into a group as extraperitoneal

Table 5 Risk factors for any postoperative complications (multivariate analysis)

Risk factors	*p* value	OR	95% CI	
			Lower	Upper
BMI	0.037	1.172	1.010	1.361
Adhesiolysis	0.005	16.055	2.270	113.574
Intraperitoneal mesh	0.049	4.625	1.006	21.262
Off-console time	0.033	1.139	1.010	1.285

BMI body mass index, *OR* odds ratio, *CI* confident interval

of defect closure on mesh overlap is unclear in the literature. The mesh overlap is calculated according to the size of the defect before it is closed. Closure of the hernia defect, however, may allow for realignment and reconstruction of the abdominal wall and wider contact between the mesh and abdominal wall, additionally, it may prevent the development of seromas, cosmetic bulging, and recurrence [28].

Dense adhesions may be present in recurrent hernia cases or after previous surgeries such as hysterectomy, requiring extensive lysis. As an intraoperative complication, intestinal injury is one of the most commonly reported complications in LVHR, with the incidence of 1% to 3.5% [29]. In the event of an intestinal injury, laparoscopic repair of enterotomies can be technically challenging. One of two patients, whose case was complicated by an enterotomy during LVHR in Birgisson et al.'s series [8], required delayed VHR secondary to enteric spillage into the abdominal cavity. In a study comparing morbidly obese and non-morbidly obese groups, Tsereteli et al. [10] concluded that morbid obesity was not a risk factor for the occurrence of an enterotomy (0.7% vs. 1.8%, respectively). In Novitsky et al.'s series [9], 5 patients (3.1%) required conversion to an open approach.

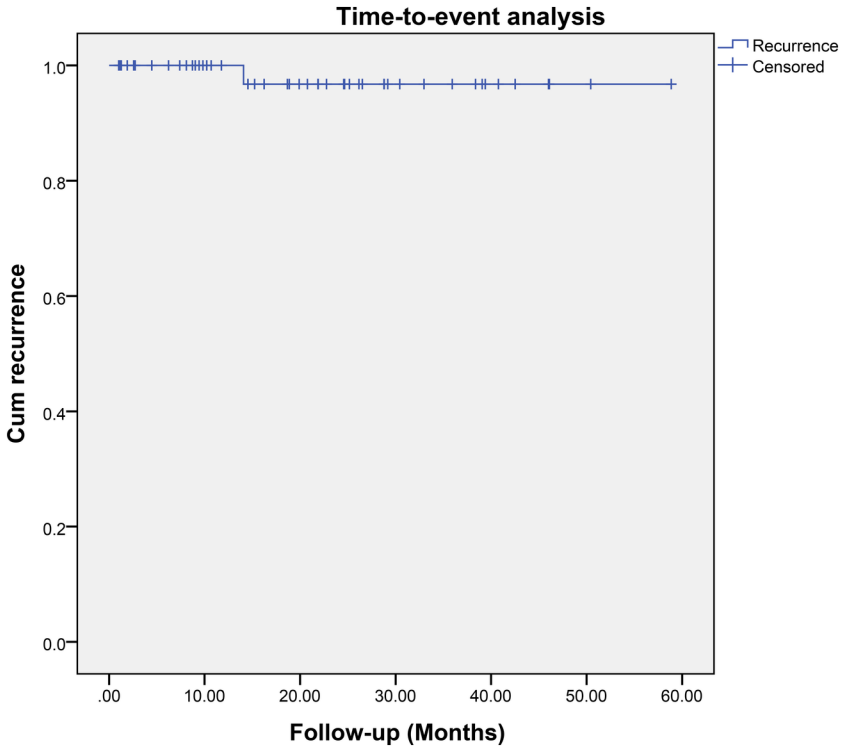

Fig. 1 The Kaplan–Meier plot for time-to-event analysis. The ticks refer to censored cases, representing the time of follow-up in months of individual patients at analysis. A step down refers to a recurrence, only one case in this study

One of these cases involved an inadvertent enterotomy. In the present study, we did not have to convert to open nor did we have any enterotomies. However, we did find a relationship between the requirement of extensive adhesiolysis and the development of postoperative complications, according to our regression analysis. This may have been due to prolonged operative times or represent cases of higher anatomic complexity.

Conventional LVHR is largely performed with intraperitoneal mesh placement. To secure the mesh to abdominal wall, tacks and transfascial sutures are commonly used by surgeons. Transfascial sutures are particularly painful for patients. Admittedly, in our study group, even without transfascial sutures, 32% of patients complained of postoperative pain or discomfort. Increased postoperative pain or discomfort was reported at a significantly higher rate in the rIPOM subgroup. Furthermore, a multivariate regression model confirmed that intraperitoneal placement of the mesh was an independent risk factor for increased postoperative pain or discomfort.

In terms of SSEs, Tsereteli et al. [10] reported a 5.9% incidence of a prolonged seroma, 1.5% wound infection, and 1.5% mesh infection in the morbidly obese group. In our study group, 16% of our patients developed SSEs. Of those, seromas made up 8%, but all of these resolved within 4 weeks (6%, Moreles Conde class-0b; 2%, Moreles Conde class-1). We did not encounter any incidence of mesh infection but did have SSIs (6%), all of which occurred at the trocar site. In a recent study on open VHR, a risk-assessment tool for SSOs and SSIs was developed and used to assess the outcomes [30]. According to the study results, factors associated with SSO included the use of a mesh implant, concomitant hernia repair, extensive dissection of skin flaps, and a wound class of 4. Predictors of SSI included concomitant repair, extensive development of skin flaps, ASA class ≥ 3, wound class 4, and BMI ≥ 40 kg/m^2. Concomitant hernia repairs were defined as those repaired during a procedure for a separate indication. In our study, we had four concomitant repairs; two of which were done synchronously with an elective cholecystectomy, and unfortunately both of these patients developed a complication postoperatively. One case developed a seroma that resolved without intervention. The other developed a SSI, that later resulted in a trocar hernia at the gallbladder extraction site. The other two cases done synchronously with their hernia repair were a gastric band removal and an inguinal hernia repair. These were clean cases, in contrast to the synchronous cholecystectomies that would be classified as clean-contaminated cases, and this is perhaps an explanation for the differing complication rates.

In terms of hernia recurrence, Tsereteli et al. [10] reported a recurrence rate of 8.3% in the morbidly obese group and a 2.9% recurrence rate in the non-morbidly obese group. The reason for this difference was interpreted by authors as being due to the fact that morbidly obese patients often have a significantly greater hernia defect initially. In addition, according to a Kaplan–Meier analysis, they found that the time to hernia recurrence was shorter for the morbidly obese group. In our study, there was only one hernia recurrence at

14 months postoperatively, and thus we could not perform a statistical analysis for recurrence risk. In a review of that patient, we believe that the recurrence could possibly be secondary to a technical error. Although, we generally assure at least a 5 cm mesh overlap between the defect edge and edge of the mesh, in this instance, the overlap was only 2.75 cm. Leblanc, in his studies, requires that the mesh overlap the defect by at least 3 cm, irrespective of the biomaterial used [29, 31]. Furthermore, he recommended that a larger overlap be used in hernias that are located either very high or very low on the abdominal wall and for all hernias in significantly obese individuals. It has become a common practice in hernia surgery to aim for a mesh overlap of at least 5 cm; however, some authors point out that this has become dogma without ample supporting data in the literature. Moreover, it is reported that the ratio of mesh area to defect area is more useful in predicting the risk of hernia recurrence [32, 33]. It was also reported that a ratio of 13 appears to be the threshold under which the risk of recurrence becomes prohibitive and 16 as the threshold over which the risk of recurrence is virtually nil with the use of a bridging technique [33]. In the present study, the median M/D ratio of 18.7 was found; however, in the case of the patient with recurrence, it was 6.61.

Overall complication rate was reported as 31% for the morbidly obese group by Birgisson et al. [8] and as 19% by Tsereteli et al. [10]. We report the complication rate in our study to be 42%. This reported rate is high due to the fact that increased postoperative pain and discomfort were assumed as a complication as opposed to other studies. We determined that pain was increased secondary to the patients' requirement for pain medication beyond what is routinely prescribed. Overall, pain was found as a complication in 32% of the study population. The high levels of pain after robotic hernia repair may in part be due to primary closure of the defect and resulting abdominal wall tension. In addition, obese patients will be more likely to have increased intraabdominal pressure after closure as a result of their habitus. The off-console time was independently associated with the presence of postoperative complications. Time in this interval might be prolonged secondary to dense adhesions to the anterior abdominal wall from prior surgery, requiring laparoscopic adhesiolysis to allow for safe visualization and entry of trocars into the abdomen. As mentioned, there was a weak correlation between this duration and CCI®. We also found that a higher BMI was an independent risk factor for postoperative complications. The body habitus of these patients poses technical challenges to conventional laparoscopy secondary to the torque of the abdominal wall on the trocars and instruments. While robotic surgery facilitates the ease of operating for the surgeon in these patients, properly angled trocar placement can still be challenging, and the force of the robotic arms against the abdominal wall during the surgery could cause significant compression of the subcutaneous tissue leading to exacerbated postoperative pain, as well as trocar site events. Authors prefer to place trocars further away than routine position with a minimum distance of 8–10 cm apart and to be inserted at a perpendicular angle to the abdominal wall, so as to create the shortest possible path through the wall, and subsequently minimize torque on the tissue from the equipment. Longer trocars exist and could be of benefit for selected patients where they may be needed in order to avoid collisions from the robotic arms with bony structures of the patient; however, we have not required longer trocars in this case series. A comparative study highlighting morbidly obese and non-morbidly obese patients is needed in order to make a precise comment on how morbid obesity effects the execution of robotic surgery.

This study has several limitations. This was a single center study of procedures performed by one surgeon, which admittedly may limit its generalizability. Multicenter studies that represent more diverse surgeon experience could provide additional value. The main limitations of the study design include small sample size, descriptive study, uncontrolled design, and the retrospective nature of follow-up data. In future studies, we believe the addition of hernia specific quality-of-life assessments would be helpful to better interpret patient reported outcomes. Similarly, pain assessment during postoperative visits would be more accurate and reproducible if we used a specific pain assessment tool, such as the visual analog system, rather than simply a subjective report of whether or not pain was experienced. We did observe a high rate of early postoperative pain. It is possible that addition of "Enhanced Recovery After Surgery" based non-narcotic agents might improve these complaints. We are currently working to implement such a protocol for our future patients. A critique of this study could be made of our decision to operate electively on high BMI patients with a known elevated risk of failure. All patients in our study were encouraged to lose weight in order to optimize their outcomes prior to hernia repair and were referred for evaluation and entry into a bariatric program for surgical weight loss. Patients may have chosen not to pursue this option, or perhaps were determined by the evaluating team not to be a good candidate for weight loss surgery for other reasons. More effort in the future could be invested pre-operatively to focus on additional weight loss by a variety of methods, however, given the high BMI of our subset, our recurrence rates were still admittedly low, and setting aside increased pain as a complaint, our complication rates were otherwise similarly low.

In conclusion, this study represents the first report of RVHR in morbidly obese individuals. Our results support the safety and feasibility of RVHR in morbid obesity. Elevated BMI, extensive adhesiolysis, off-console time, and intraperitoneal mesh placement, were associated with higher rates of complications and specifically high rate of early

postoperative pain/discomfort. Further prospective studies are needed to better elucidate the role of robotic surgery in morbidly obese patients.

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Compliance with ethical standards

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