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Total Laparoscopic Hysterectomy: Making It Safe and Successful for Obese Patients

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ABSTRACT

Objective: To investigate outcomes and ascertain the safety and efficacy on patients having total laparoscopic hysterectomy (TLH), stratified by body mass index (BMI), focusing on high-BMI patients.

Methods: This was a retrospective cohort study that reviewed 2,266 patients with benign gynecologic diagnoses, early cervical, endometrial, and ovarian carcinoma from September 1996 to October 2017. BMI was from 14.5 to 74.2 and were classified as normal or underweight (<24.9); overweight (25.0–29.9); class I obese (>30.0–34.9); class II obese (35–39.9); or class III obese (>40.0). All patients underwent TLH.

Results: Patients' characteristics were similar across all BMI classes except for age, postoperative pathological diagnoses, and whether a cystoscopy was performed. Surgical duration, and estimated blood loss were similar across BMI classes. Overweight and obese class III patients had lower odds of staying >1 day compared to patients of normal BMI (OR = 0.65, P = .015). Obese class II patients had fewer complications compared to normal BMI patients (OR = 0.27, P = .013), but patients from other high BMI categories did not show any difference compared to patients with normal BMI. The rate of unplanned laparotomy was statistically, but not clinically, higher in obese class III patients (1.8% versus .7%, P = 0.011), most often due to large fibroids. The mean reoperation rate was 2.7%, with the lowest rate (.5%) among obese class II patients, and the highest rate (3.9%) among the normal BMI patients.

Conclusion: TLH is feasible and safe for obese women, regardless of BMI. Obesity is not a contraindication to good outcomes from laparoscopic surgery.

Key Words: Obesity, Minimally invasive hysterectomy, Laparoscopy, Total laparoscopic hysterectomy, Hysterectomy.

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INTRODUCTION

A laparoscopic approach for nearly every benign and most malignant gynecological diagnosis is feasible and preferred over laparotomy because of the associated reduced pain, blood loss, postoperative disability, hospital stay, and recovery time.[1–3] Currently, gynecologists employ laparoscopic approaches in only about 50% of hysterectomy cases nationally,[4] and even less often for higher body mass index (BMI) patients.[5]

Seeking to quantify the morbidity associated with minimally invasive hysterectomy in the highest BMI patients, it is hypothesized that increasing obesity would associate with longer surgeries, more blood loss, longer hospital stays, more total and reoperative complications, and unplanned conversions to laparotomy.

MATERIALS and METHODS

Sample

Data from all cases of total laparoscopic hysterectomy, performed in a referral surgical practice were abstracted from patients' office and hospital charts from September 1996 to October 2017. Office charts were abstracted onto an Excel spreadsheet, and confidentially stored in the

Figure 1. Patient with BMI 53, positioned in modified lithotomy with arms tucked at her side, shoulder support, panniculus in dependent position.

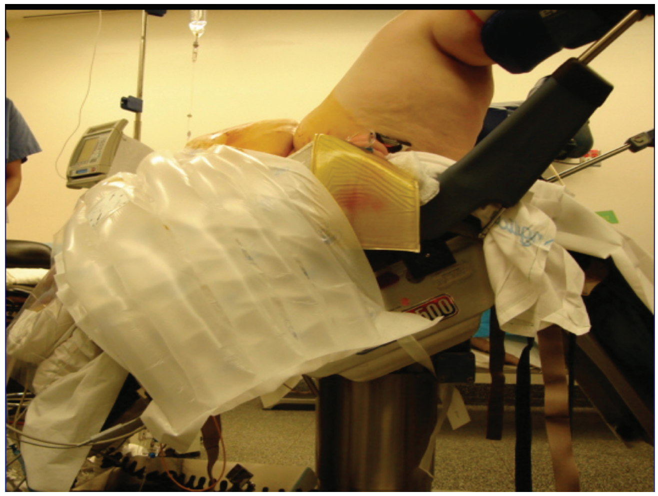

Figure 2. Patient with BMI of 53, in trial of maximal Trendelenburg, demonstrating both cardiopulmonary and positional stability in steep tilt prior to draping.

office computer under Investigational Review Board approval.

Cases included all consecutive benign gynecologic indications (endometriosis, chronic pelvic pain, adenomyosis, fibroid uterus), microinvasive cervical and early endometrial cancer, and occult ovarian cancer, treated with total and radical laparoscopic hysterectomy (TLH) and related procedures. Unless severe abdominal adhesions/intestinal adhesions were documented in a prior operative report, or clinical or radiographic evidence of metastatic ovarian or endometrial carcinoma were present, all patients, in sequence, requiring hysterectomy, received a laparoscopic approach. No patient was refused a laparoscopic approach for cardiopulmonary comorbidities, diabetes, senior age, illness, or on the basis of high BMI, after appropriate medical optimization and clearance. Patients and their support people were required to read a 13-page surgical educational pamphlet describing their anticipated hospitalization and recovery.

Follow-up of all patients was obtained by phone at 3 days, and by examination at 6 weeks in the office, or earlier if indicated by telephone with the patient and/or the referring physicians when patients lived several hours away.

Surgical Procedures

General anesthesia was administered to all patients. Each patient's arms were padded and tucked at her side with hands pronated. Both legs were placed in stirrups, with knee high SCDs, knees flexed at 45–90°, and hips lowered to nearly 180° (**Figure 1**). After induction of anesthesia but before draping, very high-BMI patients were tilted to 40° and observed for stability of position and sufficiency of respiration (**Figure 2**). The panniculus was also assessed during steep tilt, confirming utility of the diamond configuration of four trocars, to enable surgery from both sides of the patient (**Figure 3**). Then all

Figure 3. Assessment of abdomen in steep Trendelenburg shows that the trocar sites (star) in the umbilicus, 2 cm above and medial to both anterior superior iliac crests, and one suprapubic trocar (called the "diamond configuration") would be adequate for hysterectomy/oophorectomy, allowing surgery from both sides of the patient.

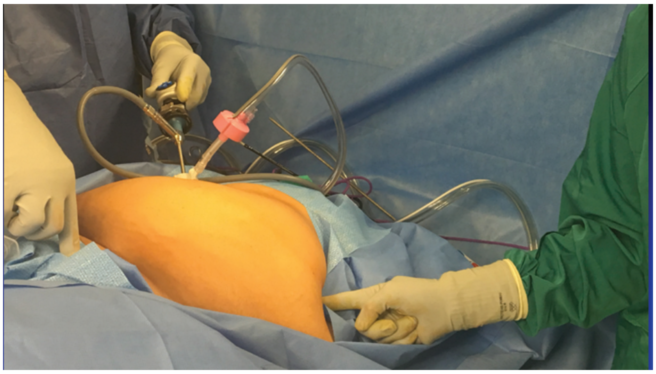

Figure 4. The assistant on the right in photo, is pointing posteriorly to the cervix as the surgeon on the left side of photo, is pointing to the cervix with forearm in straight line from elbow to cervix. The incision in the abdominal wall is located where the finger touches the abdominal wall, usually a few centimeters above the anterior superior iliac crest, and medial by about 2 cm.

patients were prepped and draped in a single-field fashion.[6]

A direct trocar entry technique at the apex of the umbilicus was used.[7] All trocar sites were injected with 10 cc of marcaine at the fascia and skin levels. All trocars were Kii Advanced Fixation trocars (CTR05, Applied Medical, Rancho Santa Margarita, CA, USA) 5 mm diameter, and 55 mm in length, for all four sites, always in the diamond configuration as shown in **Figures 3** and **4**. Longer trocars were never needed or used since these trocars have a nonlatex balloon at the distal end for retention of the trocar tip in the abdominal cavity, and an external retention disk to reduce trocar slippage into the abdomen. When there were concerns for periumbilical adhesion, a similar trocar was first placed in the left upper quadrant (Palmers point) after gastric deflation by orogastric tube suction. The two secondary lateral port locations were established by standing adjacent to the patient, and pointing in a straight line from the surgeon's elbow at her side to the patient's cervix, with the skin incision being located where the finger touched the abdominal wall skin along the imaginary line from elbow to cervix (**Figure 4**). The fourth trocar was placed in a standard suprapubic position. The technique for total laparoscopic hysterectomy with bilateral salpingo-oophorectomy (TLH/BSO) entails all surgical procedures, including vaginal closure, having been executed exclusively via laparoscopic ports.[8] Whenever the uterus was too large to be removed intact through the vagina, vaginal morcellation was undertaken. Whenever malignancy was present, possible or not ruled out, the uterus and adnexa were placed in a bag that was brought out through the vagina for morcellation. Planned mini-pfannensteil laparotomy for tumor removal was used for large masses when the vagina was too narrow or too long for vaginal morcellation.

Measures

The primary exposure variable was BMI, the ratio of the patient's weight in kilograms divided by the square of the patient's height in meters utilizing the standard World Health Organization (WHO) classification.[9] Patients were classified as ideal or underweight (BMI <24.9 kg/m2); overweight (BMI 25.0–29.9 kg/m2); class I obesity (BMI >30.0–34.9 kg/m2); class II obesity (BMI 35–39.9); and class III obesity (BMI > 40.0).[10]

The primary study outcomes comprised of surgical duration, estimated blood loss during surgery, postsurgical inpatient length of stay, and any surgical complication within 30 days of surgery. Surgical duration was abstracted from the hospital charts from time of incision to end of closing and was measured in minutes. Estimated blood loss in cc was measured from the graduated cylinder into which it was collected. Inpatient length of stay was measured as ≤1 day (the reference category) or >1 day. The complication outcome was assessed as any complication (including reoperation, any unplanned conversion to open) that occurred.

The following patient characteristics were abstracted from patient records and controlled for in all statistical models: age in years, parity (nulliparous versus parous), procedure category (total versus radical hysterectomy), postoperative diagnosis (benign adnexal, uterine, or cervical diagnosis; malignant adnexal, uterine, or cervical diagnosis; or other), enlarged adnexal size (mass diameter >10 cm), uterine weight in grams, and whether the procedure was considered "complex" (defined as requiring a node dissection, support procedure, or whether endometriosis was resected) or simple.

Statistical Analysis

Descriptive statistics were used to describe patients' clinical diagnoses and other characteristics by BMI category. Outcomes of laparoscopic hysterectomy were assessed across BMI categories. Logistic regression was used for binary outcome variables (i.e., hospital stay for > 1 day) and presence of any postoperative complication and linear

Table 1.
Demographic Characteristics of Patient Sample, According to BMI Category

	Normal weight n = 873 mean (SD)	Overweight n = 654 mean (SD)	Class I obesity n = 322 mean (SD)	Class II obesity n = 194 mean (SD)	Class III obesity n = 223 mean (SD)	Total n = 2266 mean (SD)	*p* values for ANOVA
Age, in years	51.8 (12.3)	53.6 (13.5)	54.1 (12.8)	53.6 (12.5)	52.7 (11.9)	52.9 (12.7)	0.030
Height, in	64.6 (2.6)	64.3 (2.8)	63.8 (2.9)	64.0 (2.7)	64.2 (3.0)	64.3 (2.8)	<0.001
Weight, lbs	132.8 (15.1)	160.7 (15.8)	186.7 (19.6)	217.5 (20.1)	279.3 (42.5)	170.1 (48.8)	<0.001
BMI (kg/m2)	22.3 (1.8)	27.3 (1.4)	32.1 (1.4)	37.3 (1.5)	47.7 (7.0)	28.9 (8.2)	<0.001
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	*p* values for Chi-square[a] or Fisher's exact test*
Parity > = 1	558 (63.9%)	440 (67.3%)	201 (62.4%)	130 (67.0%)	141 (63.2%)	1469 (63.2%)	0.580[a]
Diagnosis							<0.001*
Benign cervical	12 (1.4%)	8 (1.2%)	2 (0.6%)	6 (3.1%)	2 (0.9%)	30 (1.3%)	
Benign uterine	349 (40.0%)	265 (40.5%)	110 (34.2%)	61 (31.4%)	85 (38.1%)	870 (38.4%)	
Benign adnexal	221 (25.3%)	147 (22.5%)	70 (21.7%)	32 (16.5%)	36 (16.1%)	506 (22.3%)	
Malignant cervical	24 (2.8%)	13 (2.0%)	13 (4.0%)	5 (2.6%)	4 (1.8%)	59 (2.6%)	
Malignant uterine	119 (13.6%)	115 (17.6%)	80 (24.8%)	69 (35.6%)	79 (35.4%)	462 (20.4%)	
Malignant adnexal	43 (4.9%)	27 (4.1%)	18 (5.6%)	8 (4.1%)	4 (1.8%)	100 (4.4%)	
Prolapse	99 (11.3%)	73 (11.2%)	28 (8.7%)	11 (5.7%)	10 (4.5%)	221 (9.8%)	
Other categories	6 (0.7%)	6 (0.9%)	1 (0.3%)	2 (1.0%)	3 (1.4%)	18 (0.8%)	

regression for continuous outcome variables (surgical duration and volume of blood loss). Assumption of multivariate normality and multicollinearity were tested before running linear regression models. The rate of missing data was less than 5%. Therefore, listwise deletion was used to handle missing data. Significance was set at $P < .05$. All analyses were conducted using Stata 150.1.

RESULTS

A total of 2,266 sequential patients were included in this study: 873 with a normal BMI, and 1,393 with BMI greater than 25: 654 were overweight, 322 were obese class I, 194 were obese class II, and 223 were obese class III individuals. Patients' mean ages were clinically similar, but the highest mean age was in obese class I (mean = 54.1, SD = 12.8), followed by overweight (mean = 53.6, SD = 13.5), obese class II (mean = 53.6, SD = 12.5), and class III (mean = 52.7, SD = 11.9) patients (**Table 1**). Parity, surgical procedure, adnexal size uterine weight, experiences with complex procedure, and use of lymph node dissection were similar across all BMI groups.

Pathological diagnoses differed significantly by BMI class ($p < .01$). Patients with normal weight had the highest rate of benign adnexal (25.3%) and prolapse (11.3%) diagnoses, and the lowest rate of malignant uterine diagnoses (13.6%). Overweight patients (40.5%) and obese class II patients (35.6%) experienced the highest rates of both benign uterine and malignant uterine diagnoses, respectively.

Procedures did not differ between BMI categories, but cystoscopy was performed most often for patients with normal weight (40.1%), followed by patients in class I

Table 2.
Operational Procedures Stratified by BMI Category

Procedures Category	Normal weight n = 873 n (%)	Overweight n = 654 n (%)	Class I obesity n = 322 n (%)	Class II obesity n = 194 n (%)	Class III obesity n = 223 n (%)	Total n = 2266 n (%)	*p* values for Chi Square Test
LH	836 (95.8%)	631 (96.5%)	299 (92.9%)	184 (94.9%)	217 (97.3%)	2166 (97.3%)	0.082
RLH	37 (4.2%)	23 (3.5%)	23 (7.1%)	10 (5.1%)	6 (2.7%)	100 (4.4%)	
Complex procedure	181 (20.7%)	125 (19.1%)	71 (22.1%)	32 (16.5%)	34 (15.3%)	443 (19.6%)	0.206
Cystoscopy performed	350 (40.1%)	246 (37.6%)	123 (38.2%)	66 (34.0%)	62 (27.8%)	848 (37.4%)	0.013
Lymph node dissection performed	92 (10.5%)	62 (9.5%)	39 (12.1%)	19 (9.8%)	14 (6.3%)	226 (10.0%)	0.237
Endometriosis resection	67 (7.7%)	42 (6.4%)	20 (6.2%)	12 (6.2%)	9 (4.0%)	150 (6.6%)	0.530
Appendectomy performed	519 (59.5%)	390 (59.6%)	190 (59.0%)	115 (59.3%)	134 (60.1%)	1348 (59.5%)	0.999

Table 3.
Pathologic Data Stratified by BMI Category

	Normal weight n = 873 mean (SD)	Overweight n = 654 mean (SD)	Class I obesity n = 322 mean (SD)	Class II obesity n = 194 mean (SD)	Class III obesity n = 223 mean (SD)	Total n = 2266 mean (SD)	*p* values for ANOVA
Uterine length, cm	10.0 (30.1)	9.2 (3.4)	9.1 (3.2)	9.1 (3)	9.5 (3.1)	9.5 (18.8)	0.900
Uterine width, cm	6.2 (2.7)	6.3 (2.9)	6.1 (2.4)	6.2 (2.6)	6.5 (2.6)	6.2 (2.7)	0.408
Uterine depth, cm	5.3 (17.3)	5.0 (4.3)	5 (2.2)	4.8 (1.8)	5.2 (2.0)	5.1 (11.0)	0.974
Uterine weight, grams	205.1 (226.5)	215.9 (250.1)	220 (263.8)	195.4 (208.7)	237.1 (267.7)	212.8 (242.1)	0.352
Ovarian mass, cm	7.1 (4.1)	7.8 (4.2)	9.1 (6.2)	9.2 (6.7)	8.3 (5.3)	7.8 (4.8)	0.006
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	*p* values for chi square test
Enlarged adnexal size	244 (28.0%)	161 (24.6%)	84 (26.1%)	40 (20.6%)	46 (20.6%)	573 (25.3%)	0.130

obesity (38.2%), overweight (37.6%), class II (34.0%) and class III (27.8%) (**Table 2**). There were 1361 appendectomies, performed in 60% of patients across all BMI categories. Additionally, 131 Burch procedures, 8 cholecystectomies, 108 excisions of endometriosis were undertaken, but not further analyzed due to small numbers.

Mean uterine size of 242 grams was similar across BMI categories, whereas ovarian masses, when present, were largest, at an average of 6.7 cm, in obesity class II (**Table 3**).

Duration of surgery mean of 117 minutes, and estimated blood loss of 129 cc were similar across all BMI categories (**Table 4**).

Table 4.
Surgical Data Stratified by BMI Category

	Normal weight n = 873 mean (SD)	Overweight n = 654 mean (SD)	Class I obesity n = 322 mean (SD)	Class II obesity n = 194 mean (SD)	Class III obesity n = 223 mean (SD)	All n = 2266 mean (SD)	*p* values for ANOVA
Duration of surgery, min	119 (61.5)	114 (60.0)	118.4 (61.7)	117.3 (57.4)	118.2 (55.3)	117.3 (60.2)	0.593
Estimated blood loss, cc	122.3 (169.8)	125.9 (178.4)	137.4 (195)	148.2 (232.8)	140.4 (215.1)	129.5 (186.8)	0.305
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	*p* values for Chi-square[a] or Fisher's exact test*
Hospital stay >1 day	125 (14.3%)	63 (9.6%)	36 (11.2%)	24 (12.4%)	19 (8.5%)	267 (11.8%)	0.029[a]
Complication:							
Any surgical complication	76 (8.7%)	42 (6.4%)	17 (5.3%)	4 (2.1%)	15 (6.7%)	154 (6.8%)	0.010[a]
Urologic	20 (2.3%)	12 (1.8%)	2 (0.6%)	1 (0.5%)	3 (1.4%)	38 (1.7%)	0.232*
Intestinal	6 (0.7%)	7 (1.1%)	2 (0.6%)	0	2 (0.9%)	17 (0.8%)	0.706*
Hemorrhage	20 (2.3%)	8 (1.2%)	5 (1.6%)	1 (0.5%)	2 (0.9%)	36 (1.6%)	0.329*
Infection	12 (1.4%)	10 (1.5%)	1 (0.3%)	2 (1.0%)	4 (1.8%)	29 (1.3%)	0.451*
Unplanned conversion	4 (0.5%)	1 (0.2%)	5 (1.6%)	0	4 (1.8%)	16 (0.7%)	0.011*
Reoperation	34 (3.9%)	18 (2.8%)	5 (1.6%)	1 (0.5%)	4 (1.8%)	62 (2.7%)	0.035*

Overweight patients had lower odds of staying >1 day compared to patients of normal weight (OR = 0.65, $p = .015$).

Overall, complications occurred in 6.8% of patients. The odds of any surgical complication for obese class II patients were lower compared to normal weight patients (OR = 0.27, $p = .010$), but patients from the other high BMI categories did not sustain more complications compared with patients with normal BMI. Urologic complications were not statistically more common in any category, occurring in 1.7% of patients. Intestinal injuries occurred in 0.8% without impact by BMI. Hemorrhagic and infectious complications each occurred in 1.6 and 1.3%, respectively, in all BMI categories.

The rate of unplanned laparotomy was statistically, but not clinically, significantly higher in obese class III patients (1.8% v. 0.7%, $p = .011$), most often due to large fibroids. There were 10 conversions to laparotomy due to fibroids causing surgical difficulty, with uterine weights between 216 and 2072 grams, and blood losses between 250 and 2,000 cc, all during the first 13 years. Four patients had venous injuries (vena cava, common iliac, 2 infundibulopelvic), 2 during node dissections, requiring open address, with 2 patients having ideal BMI, 1 overweight and 1 obese class III, with blood losses between 100 and 1800 cc. One patient with an ideal BMI was converted due to partial avulsion of the inferior mesenteric artery with a 700 cc blood loss. One patient was converted due to hypercapnea who had a BMI 48 and cardiomyopathy, in 2008, prior to development of the current protocol for following the pCO_2.

Sixty-two patients, 2.7%, required reoperation, with fewest in obese class II at 0.5% and most in ideal BMI patients at 3.9% ($p = .035$). Obese class III patients sustained 1.8% reoperations.

Tests for skewness and kurtosis of surgical duration and volume of blood loss indicated that the assumption of normality was violated. Thus, both of these continuous outcome measures were log-transformed and linear regression models were run on the log-transformed

Table 5.
Linear or Logistic Regression Models with Year as Independent Variable Predicting BMI and the Surgical Outcomes

Dependent Variable	Independent variable: year of surgery experience — ADJUSTED MODEL* B (SE)	p value
Linear regression models		
BMI, mean	0.15 (0.03)	<.001
Duration of surgery	−3.21 (0.20)	<.001
Volume of blood loss	−1.64 (0.72)	.024

	OR (SE)	p value
Logistic regression model:		
Length of inpatient stay for more than 1 day, odds ratio	0.68 (0.02)	<.001
Any complication, odds ratio	0.92 (0.02)	<.001

*Covariates controlled in the linear or logistic regression models include patients' age, parity, procedure categories, postoperative diagnosis, enlarged adnexal size, uterine weight, presence of any complex procedure, cystoscopy performed, lymph node dissection performed, and presence of endometriosis.

versions of these variables. Multicollinearity was tested and none of the covariates were collinear.

Table 5 shows that the results of linear regression models indicated that after controlling for patients' postoperative pathological diagnoses and other characteristics, the surgeries for obese class III individuals ($\beta = 0.10$, p = .003) took, on average, 11% (i.e., exp (0.10) = 1.11) longer than did normal weight individuals'. No other BMI group had significantly longer surgery durations compared to the normal weight group. After covariate adjustment, obese class II ($\beta = 0.23$, p = .009) and class III ($\beta = 0.21$, p = .011) patients had 26% (exp(.23) = 1.26) and 23% (exp(.21) = 1.23) higher amounts of blood loss, compared to normal weight patients, respectively.

Figure 5 presents the results of linear or logistic regression models that examine the effect of year of surgery experience on surgery outcomes. The year of surgery was strongly predictive of both increasing average BMI ($\beta = 0.15$, $p < .001$) and more favorable outcomes. Specifically, with each year, on average, the mean of BMI increased by nearly 00.2 ($\beta = 0.15$, $p < .001$), whereas duration of surgery decreased by 3 minutes ($\beta = -3.21$, $p < .001$), and volume of blood loss decreased by 1.64 cc ($\beta = -1.64$, P = .024). Odds of hospital stay for more than 1 day (OR = 0.68, $p < .001$) and any complication (OR = 0.92, $p < .001$) were also reduced over time.

DISCUSSION

In the last decade, the number of women with BMI over 40 has increased to nearly 7.5% in the United States.[11] The incidence of such severe obesity has caused a subsequent increase in endometrial cancer,[12] in both postmenopausal and premenopausal women, with a nearly 20-fold increase in uterine cancer risk for women whose BMI is over 40.[13] High-BMI patients with either uterine cancer or benign disease alike are less likely to be offered a minimally invasive approach for their hysterectomy than lower-BMI patients.[4,5] Surgeons operating on high-BMI patients are more likely to convert to open laparotomy, with the attendant increased risk of complications from the large abdominal incision.[2] Wound complications in high-BMI patients are more frequent and severe after open surgeries than after minimally invasive approaches.[5] Additionally, high-BMI patients are more likely to have multiple medical comorbidities predisposing them to more multisystem intra-operative and postoperative complications.[2,14]

Many surgeons hesitate to operate on patients with BMI >40 potentially due to unfamiliarity of initial trocar entry, port placement, or management of hypercarbia. Such

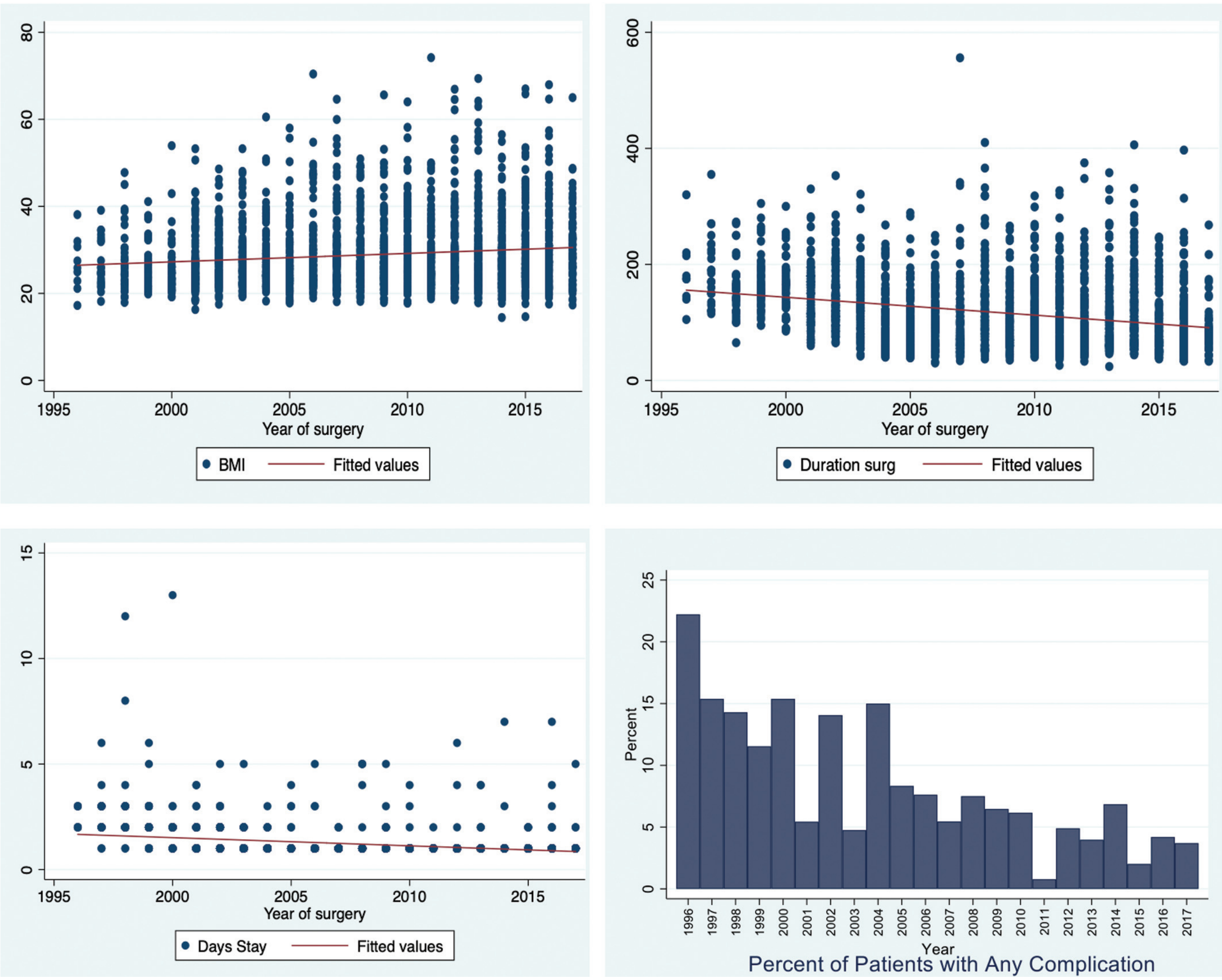

Figure 5. Reflects the results of linear regression models from the primary surgeon's data showing the increase in BMI of patients receiving surgery, the decreasing duration of surgeries and length of hospital stays, and the decrease in complications per year over time.

perceived hurdles for gynecologic surgeons who operate on only a few morbidly obese patients annually should not preclude them from approaching these surgeries laparoscopically. Such hurdles can be easily overcome, especially with the advent of balloon fixation trocars, and reliable vessel sealers. Some surgeons have advocated using far more expensive laparoscopic devices, but there has been no evidence that patients benefit from these robotic assists.[15]

Laparoscopic approaches should be considered for all patients requiring gynecologic surgery who cannot or should not be cared for by vaginal approach (eg. nulliparous patient with long, narrow vagina with BMI >40, or a diagnosis of pelvic mass or endometrial cancer). Although laparoscopic surgery in the obese gynecologic patient is technically challenging, careful preparation and collaboration with anesthesia offers the best outcomes.[16]

During the operation, the thickness of the high-BMI patients' abdominal wall and the preperitoneal and mesenteric fat bear down on the diaphragm and lungs pose significant challenge to ventilation. These features compound to decrease respiratory compliance, increasing airway pressure, and impairing cardiac function.[17] Many ventilatory adjustments are needed to avoid hypercapnia, hypoxemia, and acidosis: addition of positive end expiratory pressure (PEEP), increasing the frequency of ventilation, and increasing the oxygen concentration.[18] The triple challenge of pneumoperitoneum at 8-15 mmHg, morbid obesity, and Trendelenburg to 40°, can blend to make conversion to open laparotomy a default option.

In their 2015 review of 23 published reports on 2232 patients, Blikkendaal and colleagues[3] observed that 12.5% of patients with BMI between 39 and 50 were converted to laparotomy. Uccella and colleagues[2] converted 8% of their 64 patients with BMI over 40 to open laparotomy in 2016. Guraslan and colleagues[19] reported conversion to open surgery in 9% of patients with BMI over 40 in 2015. Obermair and colleagues[20] converted 7% of their 27 patients with BMI over 35 in their 2016 review. In this study, 4 out of 223 patients with BMI over 40, 1.8%, required unplanned conversion to open laparotomy. There was no conversion due to obesity or obesity-related challenges. This lower rate can be attributed, in part, to improved surgical instrumentation such as manipulators, vessel sealing devices, hemostatic agents, but also to the model collaborative anesthetic monitoring. There was one conversion to open laparotomy due to anesthetic challenges in a patient with BMI of 48 and cardiomyopathy, prior to instituting any collaborative hypercarbia standards with anesthesia.

A protocol for monitoring and managing the partial pressure of oxygen (pO_2) and carbon dioxide (pCO_2) was agreed to by surgeon and anesthesiologist to address the challenges of high BMI compounded by pneumoperitoneum of 8-15 mmHg, and steep 40° Trendelenburg. The pCO_2 was kept well under 60 mmHg using positive end-expiratory pressure (PEEP), increased concentration of oxygen, and increased respiratory rate, but no increase in volume, to achieve the best compliance so as to avoid barotrauma. Four patients had one to three episodes of pCO_2 elevation, which was promptly addressed by flattening the table, and desufflating the pneumoperitoneum to allow the ventilation to reduce the pCO_2 to <40 mmHg. Each of these episodes lasted for about 2–4 minutes; and in all cases the surgery was resumed and progressed to completion laparoscopically.

Guraslan[19] observed that their overall complication rate of 6% in their high-BMI cohort, similar to that of their lower BMI patients. Blikkendaal and colleagues[3] reported an overall complication rate of 14.5% in their cohort of laparoscopically treated patients with BMI over 35. Obermaier and colleagues[20] observed that 41% of their multiply-morbid and complex patients had grade 2+ adverse events. Siedhoff and colleagues[21] observed a greater severity of complications in their obese patients, as well as longer operating times and greater blood loss with increasing BMI. In the present cohort of 223 patients with BMI over 40, there was a 6.7% complication rate, and no clinically important difference between the normal and any other class of obese patients' outcomes.

The "obesity paradox," the finding of fewer complications among the highest BMI patients undergoing bariatric surgeries, may also be a factor in our hysterectomy results.[22] The highest-BMI patients received fewer concomitant procedures. This may in part, explain why the normal weight patients received more cystoscopies. Additional hypotheses explaining the obesity paradox include potentially protective features of increased muscle body mass and peripheral body fat, reduced inflammatory response, genetics, and a decline in cardiovascular disease risk factors, but many unknown factors must also play a role.

There are several limitations to this single-surgeon, retrospective chart review. Follow-up data for patients was limited in some cases to only phone conversations, since many patients were referred from locations up to nine hours away. This study took place over 20 years, during which time many new developments were introduced, such as uterine manipulators, safer bowel retractors, improved hemostatic agents, effective shoulder bolsters, and laparoscopic vessel sealing devices, diverse suture options, and Enhanced Recovery After Surgery (ERAS) programs, all of which have improved outcomes from gynecologic surgery.[23] Despite patient size gradually increasing over 20 years (**Figure 5, upper left**), their surgical durations (**Figure 5, upper right**) and length of stay (**Figure 5, lower left**), and complications (**Figure 5, lower right**) decreased.

This report is thus limited in terms of generalizability, because other gynecologic surgeons may not have the caseload of obese patients to enable them to develop their expertise in laparoscopic hysterectomy for high-BMI patients. There are also many unrecorded variables impacting outcome besides cancer status, such as nutritional status and the numerous uncounted medical comorbidities, not taken into account in this observational comparison. Additionally, there were nearly 2,000 additional procedures performed at the time of hysterectomy that prolong the durations and can add complications. Any future randomized clinical study would need to control for patients' baseline comorbidities and for additional operative procedures.

In the United States, where obesity is on the rise and where laparoscopy has become the standard of care, it becomes important to demonstrate the safety of performing laparoscopic approaches on larger women. This manuscript confirms that the 223 patients undergoing hysterectomy having BMI from 40 to 74 had clinically similar surgical outcomes to those with lower BMI, in terms of duration of surgery, estimated blood loss, length of stay, conversions to open laparotomy, and complications.

The success and safety of the hysterectomies on the highest BMI patients can be attributed to careful patient positioning, preoperative optimization, a collaborative team approach with anesthesia to include the preoperative tilt to 40°, and most importantly the mutual agreement to flatten the table, deflate the abdomen, and allow the elevated pCO_2 to be blown off, when and if it ever elevated. It was never necessary to reduce the degree of Trendelenburg, which would have compromised the surgical efficacy.

On the basis of this cohort of cases, gynecological surgeons are encouraged to learn to perform indicated hysterectomies laparoscopically for their high BMI patients, and as skills improve, they will be able to provide this minimally invasive surgery for even the highest BMI patients. Randomized prospective studies comparing outcomes should be performed to confirm the safety and feasibility of minimally invasive procedures in this high-risk population.

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