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Original Article

Perioperative Outcomes of Myomectomy for Extreme Myoma Burden: Comparison of Surgical Approaches

L. Joya Jansen, MD, Nisse V. Clark, MD, Monalisa Dmello, MD, Xiangmei Gu, MS, Jon I. Einarsson, MD, MPH, PhD, and Sarah L. Cohen, MD, MPH

From the Division of Minimally Invasive Gynecologic Surgery, Brigham and Women's Hospital, Boston, Massachusetts (all authors)

ABSTRACT **Study Objective:** To describe the perioperative outcomes of various modes of myomectomy (abdominal [AM], laparoscopic [LM], or robotic [RM]) in cases of extreme myoma burden.

Design: Retrospective cohort study (Canadian Task Force classification II-2).

Setting: A tertiary academic center in Boston, Massachusetts.

Patients: All women who underwent an AM, LM, or RM for extreme myoma burden, defined as representing the upper quartile for specimen weight (≥434.6 g) or myoma count (≥7 myomas), between 2009 and 2016.

Interventions: Baseline demographics and perioperative outcomes were collected from review of medical records, including estimated blood loss, operative time, length of stay, and complications. Univariate linear and logistic regression analyses were conducted.

Measurements and Main Results: During the study period 659 women underwent myomectomy for extreme myoma burden; 47.2% of cases were AM, 28.1% LM, and 24.7% RM. Overall myoma burden differed across the 3 routes and was greatest in the AM group (mean weight: 696.2 ± 784.5 g for AM vs 586.6 ± 426.1 g for LM and 586.6 ± 426.1 g for RM; mean number: 16.8 ± 15.0 for AM vs 7.2 ± 7.0 for LM and 6.7 ± 4.7 for RM; p <.001 for both). The 3 routes differed in operative time and length of stay, with RM having the longest operative time (mean, 239.7 minutes; p <.001) and AM the longest length of stay (mean, 2.2 ± .9 days; p <.001). Other perioperative outcomes were similar across the surgical approaches. Increasing myoma burden was associated with an increased risk of perioperative complications for all surgical approaches, with a threshold of 13 myomas associated with an almost 2-fold higher risk of perioperative complications (odds ratio, 1.77; 95% confidence interval, 1.17−2.70; p = .009). Cumulative incidence of perioperative complications with increasing specimen weight was greater in the RM cases as compared with AM (p = .002) or LM (p = .020), whereas the cumulative incidence of perioperative complications with increasing myoma count was lowest with AM compared with LM (p <.001) or RM (p <.001).

Conclusion: Myomectomy for extreme myomas is feasible using an abdominal, laparoscopic, or robotic approach. Increased myoma burden is associated with an increased risk of perioperative complications. A threshold of 13 myomas was associated with an almost 2-fold higher risk of perioperative complications for all modes. Perioperative complication outcomes were more favorable in AM or LM over RM with increased myoma weight and AM over LM or RM with increased myoma number. Journal of Minimally Invasive Gynecology (2019) 26, 1095−1103 © 2018 AAGL. All rights reserved.

Keywords: Complications; Laparoscopy; Laparotomy; Myoma burden; Myomectomy; Minimally invasive surgery; Robotic surgery

Myomas affect approximately 225 million women worldwide and can significantly impair quality of life and productivity [1,2]. A myomectomy is a surgical option for women with symptomatic myomas who want to preserve their uterus. Compared with an open approach, laparoscopic and robotic approaches are associated with decreased postoperative morbidity and a shorter hospital stay [3,4]. Despite these benefits many myomectomies are performed abdominally, especially in the setting of large or numerous myomas that require extensive dissection and suturing [5]. Although several reports of laparoscopic myomectomy (LM) for very large myomas have been published [6−9], choosing the optimal surgical approach for large or numerous myomas remains a matter of debate. Prior studies have suggested that the feasibility of an LM is impaired when a myoma exceeds 12 cm in maximum dimension [10] or if the

The authors declare that they have no conflict of interest.
Corresponding author: Sarah L. Cohen, MD, MPH, Brigham and Women's Hospital, 75 Francis Street, ASB 1-3, Boston, MA 02115.
E-mail: scohen20@bwh.harvard.edu

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cumulative specimen weight is >500 g [11]. A recent study found that a combination of dominant myoma diameter ≥ 10 cm and uterine volume ≥ 600 cm^3 was predictive of complications for minimally invasive myomectomy [12], whereas other reports have concluded that the laparoscopic approach is safe irrespective of size, number, and location when performed by experienced surgeons [13].

Because of controversies surrounding the preferred surgical approach for women undergoing a myomectomy for particularly large or numerous myomas, we sought to compare perioperative outcomes for extreme cases, defined as high specimen weight or myoma count, from within a large cohort of myomectomy cases. The primary aim of this study was to describe the perioperative outcomes in cases of extreme myoma burden by comparing abdominal myomectomy (AM), LM, and robotic myomectomy (RM) approaches. The secondary aim was to define a threshold of myoma weight and count at which certain modes of myomectomy are associated with an increased risk of perioperative complications.

Methods

This retrospective cohort study was approved by the Partners Institutional Review Board. Participants were selected by querying the institutional Research Patient Data Registry system by surgical procedure, using codes for “myomectomy.” All AMs, LMs, and RMs performed between 2009 and 2016 at Brigham and Women’s Hospital, an academic tertiary care center in the northeastern United States, were identified. Patients with a preoperative diagnosis of malignancy or those who were pregnant at the time of myomectomy were excluded. The total specimen weight and myoma count removed (per operative and/or pathology report) were collected for all procedures, and the upper quartile for both myoma weight and number was determined. This upper quartile of cases became the cohort of extreme myomas for this study.

Medical records were reviewed and data abstracted for patient characteristics, including age, race, body mass index (BMI), prior laparoscopic surgery or laparotomy, indication for surgery (pressure or pain symptoms, menorrhagia, urologic or bowel symptoms, infertility, pelvic mass, or other), and the largest myoma diameter on preoperative imaging (ultrasound or magnetic resonance imaging). Data about type and location of the myomas (submucous, intramural, and subserous) were collected as well. Additionally, procedure characteristics were abstracted including year of surgery, surgical mode (AM, LM, or RM), intraoperative findings (specimen weight and number of resected myomas), operative time (defined as time from first incision until procedure end), length of hospital stay (same-day discharges coded as 0 days), estimated blood loss (EBL; minimal blood loss was defined as 10 mL), need for blood transfusion, type of surgeon (classified according to subspecialization), and perioperative complications. Intraoperative complications were defined as organ injury (bowel, bladder, ureter, or vascular injury), EBL > 1000 mL, and conversion to hysterectomy. Postoperative complications were classified according to the Clavien-Dindo classification system [14], with grade 1 including any deviation from the normal postoperative course, grade 2 reflecting the need for pharmacologic treatment, grade 3 requiring an intervention (grade 3a, not under general anesthesia; grade 3b, under general anesthesia), and grade 4 including a life-threatening complication (grade 4a, multiorgan failure; grade 4b, death of a patient). Major postoperative complications were defined as Clavien-Dindo rating ≥ 3. Immediate and delayed postoperative complications that occurred up to 60 days postoperatively were included for both inpatient and outpatient encounters.

Myomectomy cases were performed by both general gynecologists and fellowship-trained gynecologists; the latter group was comprised of subspecialists in minimally invasive gynecologic surgery, reproductive endocrinology and infertility, gynecologic oncology, and urogynecology. The surgical approach was chosen by individual surgeons according to surgeon and patient preference. LM was performed using a multiport approach; hand-assisted laparoscopic procedures (n = 3) were categorized into this group [15]. RM was performed with a da Vinci Robot (Intuitive Surgical, Sunnyvale, CA) and in some cases used a hybrid approach whereby myoma enucleation was performed with conventional laparoscopy and uterine closure was performed with robotic assistance. For minimally invasive procedures tissue extraction was performed using either power morcellation or hand morcellation with a scalpel, dependent mainly on practice trends by year of procedure.

Statistical analyses were performed using SAS, version 9.4 (SAS Institute, Cary, NC). Patient characteristics and perioperative outcomes were compared across the 3 modes of surgery (AM, LM, RM) using χ^2 tests for categorical variables, Student’s *t* tests for normally distributed continuous variables, and Wilcoxon rank-sum tests for non-normally distributed variables. Data were adjusted to compensate for possible confounders using the following variables: year of surgery, age, race, BMI, prior surgeries, and specimen weight. Linear regression was used to calculate multivariable adjusted means with 95% confidence intervals for the continuous variables EBL, operative time, and length of stay. Logistic regression models were used to estimate associations between mode of surgery and the dichotomous (yes or no) outcome variables: intraoperative complication, major postoperative complication, any perioperative complication, and transfusion.

A 2-sided $p = .05$ was considered significant for all variables. To evaluate the association between myoma weight or number and probability of any perioperative complication among each mode of surgery, estimated cumulative

Table 1

Demographics and patient characteristics by mode of surgery

	AM (n = 311)	LM (n = 185)	RM (n = 163)	p*
Year of surgery				
2009	45 (14.5)	27 (14.6)	13 (8.0)	.047
2010	34 (10.9)	33 (17.8)	29 (17.8)	
2011	44 (14.2)	27 (14.6)	23 (14.1)	
2012	42 (13.5)	34 (18.4)	26 (16.0)	
2013	32 (10.3)	16 (8.7)	25 (15.3)	
2014	44 (14.2)	19 (10.3)	11 (6.8)	
2015	32 (10.3)	12 (6.5)	14 (8.6)	
2016	38 (12.2)	17 (9.2)	22 (13.5)	
Age, yr	38.1 ± 5.9	39.1 ± 7.3	38.4 ± 6.8	.251
Type of surgeon				
MIGS	5 (1.6)	171 (92.4)	5 (3.1)	.000
REI	278 (89.4)	12 (6.5)	157 (96.3)	
Oncology	5 (1.6)	0 (0)	0 (0)	
Urogynecology	3 (1.0)	0 (0)	0 (0)	
Gynecology	20 (6.4)	2 (1.1)	1 (.6)	
Race				
White	126 (40.5)	78 (42.2)	89 (54.6)	.004
Black	139 (44.7)	70 (37.8)	44 (27.0)	
Hispanic	5 (1.6)	11 (6.0)	8 (4.9)	
Asian	23 (7.4)	12 (6.5)	14 (8.6)	
Other/unknown	18 (5.8)	14 (7.6)	8 (4.9)	
BMI, kg/m^2	27.8 ± 6.0	27.2 ± 5.7	27.2 ± 5.8	.515
Previous laparoscopy	39 (12.5)	30 (16.2)	24 (14.7)	.548
Previous laparotomy	77 (24.8)	37 (20.0)	33 (20.3)	.409
Indication for surgery†				
Pressure/pain	187 (60.1)	148 (80.0)	97 (59.5)	<.001
Menorrhagia	182 (58.5)	106 (57.3)	71 (43.6)	.002
Urologic/bowel	89 (28.6)	70 (37.8)	54 (33.1)	.014
Infertility	88 (28.3)	15 (8.1)	42 (25.8)	<.001
Pelvic mass	4 (1.3)	0 (0)	0 (0)	.014
Other	20 (6.4)	3 (1.6)	10 (6.1)	.045
Dominant myoma diameter from preoperative imaging, cm	9.5 ± 4.1	10.2 ± 3.7	9.0 ± 3.4	.013

Values are n (%) or mean ± standard deviation. MIGS = minimally invasive gynecologic surgery; REI = reproductive endocrinology and infertility.
* p <.05 is considered significant. p Values were calculated from χ^2 tests, Student's *t* tests, and Wilcoxon rank-sum tests.
† Not mutually exclusive.

incidence rates were calculated. Unadjusted cumulative incidence function curves were plotted, stratified by mode of surgery. Logistic regression analysis was used to determine the threshold in weight or number of myomas at which differential complication rates were maximal [16].

Results

A total of 1675 myomectomy cases were performed at our institution between 2009 and 2016. The upper quartile of uterine weight and myoma count were determined as any cases exceeding a total specimen weight ≥ 434.6 g or count ≥ 7 myomas. Of all cases, 659 women met this definition of extreme myoma burden in the upper quartile: 360 women had an extreme specimen weight, 432 women had extreme myoma number, and 163 had both extreme characteristics. The cases in this cohort predominantly involved multiple myomas in multiple layers of the uterus; in cases of a single dominant myoma, this myoma most commonly traversed several layers of the uterus. Of the cases with only a single dominant myoma (n = 109, 16.5% of cases) as opposed to multiple myomas in a combination of locations, the following distribution of myoma type was observed: 37.6% were intramural, 13.8% were subserosal, 9.2% were pedunculated, and 1.8% were submucosal. The remaining cases were listed as either being in multiple layers of the uterus (such as submucosal and intramural); were transmural, cervical, or retroperitoneal in location; or were unable to be defined based on available surgical or imaging reports.

Most cases in the extreme myoma cohort (n = 311) were performed through an abdominal incision (47.2%); 185 cases (28.1%) were completed via a laparoscopic approach and 163 cases (24.7%) via a robot-assisted laparoscopy. The patient characteristics of the AM, LM, and RM groups are summarized in Table 1. The mode of

Table 2

Perioperative outcomes by mode of surgery

	AM (n = 311)	LM (n = 185)	RM (n = 163)	p*
Surgical findings				
Specimen weight, g	696.2 ± 784.5	586.6 ± 426.1	399.6 ± 250.1	<.001
No. of myomas	16.8 ± 15.0	7.2 ± 7.0	6.7 ± 4.7	<.001
EBL, mL	304.1 ± 383.9	345.7 ± 479.6	262.2 ± 205.6	.127
Operative time, min	147.4 ± 51.9	153.7 ± 62.6	239.7 ± 55.8	<.001
Length of stay, days	2.2 ± .9	.6 ± 1.3	.7 ± .9	<.001
Conversion to open surgery	N/A	6 (3.2)	1 (.6)	.002
Transfusions	23 (7.4)	11 (6.0)	8 (4.9)	.552
Any intraoperative complications	14 (4.5)	9 (4.9)	2 (1.2)	.139
Any postoperative complications	53 (17.0)	28 (15.1)	27 (16.6)	.790
Postoperative complications†				
0	256 (82.3)	154 (83.2)	135 (82.8)	.790
1	16 (5.1)	8 (4.3)	8 (4.9)	.918
2	36 (11.6)	15 (8.1)	16 (9.8)	.459
3a	1 (.3)	1 (.5)	2 (1.2)	.375
3b	0 (0)	2 (1.1)	0 (0)	.139
4a	0 (0)	1 (.5)	1 (.6)	.278
4b	0 (0)	1 (.5)	0 (0)	.528

Values are n (%) or mean ± standard deviation.

* p <.05 is considered significant. p Values were calculated from χ^2 tests, Student's *t* tests, and Wilcoxon rank-sum tests.

† According to the Clavien-Dindo scale.

surgery differed across years (p = .047), reflecting variations in local practice patterns over time. Throughout the study period AM was performed more often than LM or RM, with a peak in 2014 (59.5% of all surgeries); however, during the year 2010 all routes were used in a relatively equal distribution (35.4% AM vs 34.4% LM vs 30.2% RM). A total of 30 surgeons contributed cases to the extreme myoma cohort, 20 of whom completed subspecialty fellowship training. Minimally invasive gynecologic surgery subspecialists performed most LMs (92.4%), and reproductive endocrinology and infertility surgeons performed most of both AMs (89.4%) and RMs (96.3%). Gynecologic oncologists, urogynecologists, and gynecologists performed a minority of cases, predominantly via the abdominal approach. Patient characteristics including age, BMI, and prior surgical history were similar across the 3 surgical approaches. Upon univariate analysis, differences were found with regard to race; LM (42.2%) and RM (54.6%) were performed more frequently in white patients and AM more in frequently black patients (40.5%, p = .004). The largest myoma diameter, as assessed by preoperative imaging (9 cases of missing information were reported), was also different among surgical routes (p = .013) with the greatest myoma diameter for LM (mean, 10.2 ± 3.7 cm) followed by AM (mean, 9.5 ± 4.1 cm) and RM (mean, 9.0 ± 3.4 cm).

Perioperative outcomes are described in Table 2. Myoma burden was different across the groups, with AM cases comprising the highest specimen weight (mean weight: 696.2 ± 784.5 g for AM vs 586.6 ± 426.1 g for LM vs 399.6 ± 250.1 g for RM; p <.001) and number of resected myomas (mean number: 16.8 ± 15.0 for AM vs 7.2 ± 7.0 for LM vs 6.7 ± 4.7 for RM; p <.001). The presence of endometriosis noted at time of surgery was low, with 8% of patients having concomitant endometriosis overall and a similar representation among modes (10% of AM cases, 5.4% of LM cases, and 8.6% of RM cases). Operative time and patient length of stay were also found to be different across surgical approaches, with RM having the longest mean operative time at 239.7 minutes (p <.001) and AM having the longest mean length of stay at 2.2 days (p <.001). Perioperative outcomes including EBL, blood transfusion, and perioperative complications were similar across all modalities of myomectomy. Of note, vasopressin was administered in most (81%) myomectomy cases. One case of conversion to hysterectomy was encountered within the AM group. Other intraoperative complications included 5 cases of organ injury (1.0% of AMs and 1.2% of RMs) and 20 cases with EBL > 1000 mL (3.5% of AMs and 4.9% of LMs). Conversion from laparoscopic or robotic to open surgery was higher for LM (3.2%) compared with RM (.6%, p = .002); these cases were analyzed in an intention-to-treat fashion and not recategorized to the abdominal approach. In total, 7 minimally invasive cases were converted to AM due to either massive blood loss (n = 2), myoma size (n = 4) or unintended vascular injury (n = 1).

Table 3 shows the outcomes of the logistic and linear regression analyses. To compensate for the low absolute number of complications, a composite outcome variable for any perioperative complication (including organ injury, EBL > 1000 mL, conversion to hysterectomy, and postoperative complication Clavien-Dindo grades > 0) was also

Table 3

Regression analysis: surgical outcomes by mode of surgery

	AM (n = 311)	LM (n = 185)	RM (n = 163)
EBL, mL			
Mean (95% CI)*	188.5 (0−404.6)	206.1 (0−424.7)	192.9 (0−408.2)
p	Ref	.593	.899
Operative time, min			
Mean (95% CI)*	114.5 (79.2−150.0)	121.1 (85.4−156.9)	213.7 (178.5−248.8)
p	Ref	.222	<.001
Length of stay, days			
Mean (95% CI)*	1.71 (1.11−2.31)	.10 (0−.70)	0.43 (0−1.03)
p	Ref	<.001	<.001
Intraoperative complication†			
OR (95% CI)*	1.00	1.51 (.85−2.7)	.6 (.27−1.34)
p	Ref	.162	.209
Major postoperative complication‡			
OR (95% CI)*	1.00	1.831 (.877−3.822)	2.211 (.945−5.177)
p	Ref	.107	.067
Any perioperative complication§			
OR (95% CI)*	1.00	.898 (.639−1.262)	1.147 (.808−1.629)
p	Ref	.534	.443
Transfusion			
OR (95% CI)*	1.00	.95 (.6−1.52)	.99 (.59−1.66)
p	Ref	.836	.969

CI = confidence interval; OR = odds ratio.

* Adjusted for year of surgery (2009−2016), age (continuous), race (white, black, Hispanic, Asian, or other/unknown), BMI (continuous), prior surgeries (laparoscopy or laparotomy), and specimen weight (continuous).

† Intraoperative complication (organ injury, EBL > 1000 mL, or conversion to hysterectomy).

‡ Major postoperative complication (Clavien-Dindo rating ≥ 3).

§ Any perioperative complication (intraoperative complication or postoperative complication Clavien-Dindo rating > 0).

assessed. Factors included in the regression model were year of surgery, age, race, BMI, prior surgeries, and specimen weight; all prior findings were maintained after adjusting for these possible confounders. When adjusting for myoma number rather than weight in the regression analysis, outcomes were similar except for operative time, which was found to be prolonged for both LM (p = .002) and RM (p <.001).

Unadjusted cumulative incidence function graphs were plotted with predicted cumulative incidence of any perioperative complication for all modes of myomectomy, in relation to either specimen weight (Fig. 1) or number of resected myomas (Fig. 2). Within the cohort of extreme myoma cases there was an overall difference across surgical approaches (p <.008) when specimen weight increased, with a greater chance of any perioperative complication for RM compared with AM (p = .002) or LM (p = .020); however, no difference was seen for AM compared with LM (p = .566). With increasing myoma count an overall difference between modes was also seen across modes (p <.001); however, the chance of any perioperative complication was less for AM compared with LM (p <.001) or RM (p <.001), but no difference was found for LM compared with RM (p = .343). Unadjusted cumulative incidence function graphs with predicted cumulative incidence of perioperative transfusion for increased weight and myoma count have similar outcomes to Figs. 1 and 2, whereas graphs on any major postoperative complication (Clavien-Dindo rating ≥ 3) did not demonstrate any statistically significant differences, possibly reflecting a Type II statistical error (data not shown).

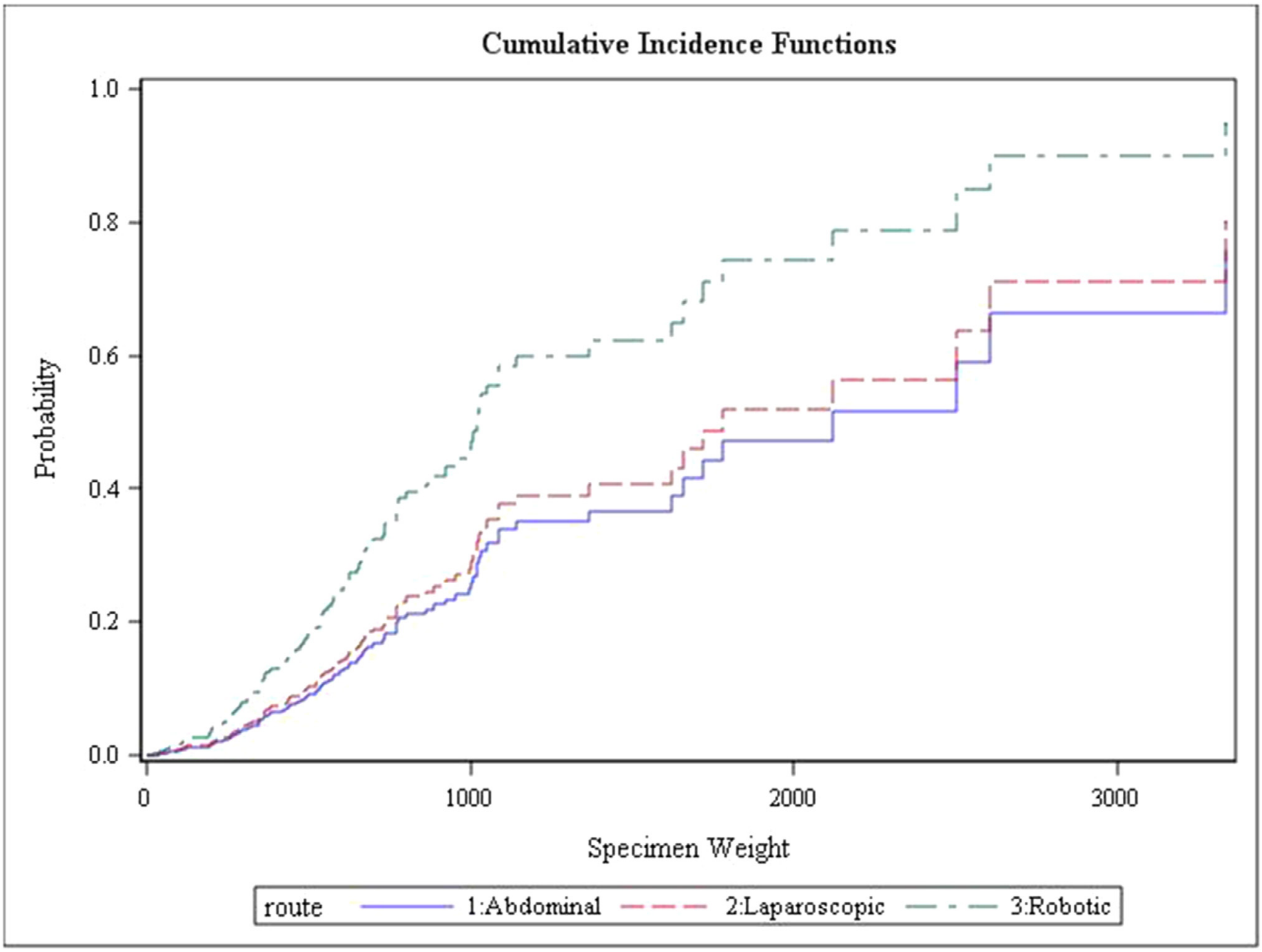
Logistic regression analysis demonstrated a significant association between myoma count and probability of any complication for all routes of myomectomy, achieving maximal statistical significance at a threshold of 13 myomas, whereby patients undergoing myomectomy had an almost 2-fold higher risk of any perioperative complication (odds ratio; 1.77; 95% confidence interval, 1.17−2.70; p = .009) than did patients below this threshold, with a variation between surgical modes. No cut-off point in myoma weight was found to be significantly associated with adverse outcomes.

Discussion

In this study we compared perioperative outcomes of 3 modes of myomectomy (AM, LM, and RM) within a cohort of women with extreme weight or number or myomas. We found that myoma burden was correlated with the mode of myomectomy, with the more extreme cases approached abdominally. Aside from the differences found in length of stay and operative time, the

Fig. 1

Cumulative incidence function curve showing the probability of any perioperative complication with increased myoma specimen weight (in grams). p values: 3 routes, .008; AM versus LM, .566; AM versus RM, .002; LM versus RM, .020.



perioperative outcomes, including EBL, transfusion rates, and perioperative complications, were similar across myomectomy routes. In the setting of extreme myomectomy the likelihood of any perioperative complication increases as myoma weight and number increase. Based on our analyses a laparoscopic or abdominal approach may be preferred for cases with extraordinary myoma weight, whereas an abdominal approach may be preferred for cases of extreme myoma number. Overall, a threshold of 13 myomas was determined to be associated with an almost 2-fold higher risk of complications.

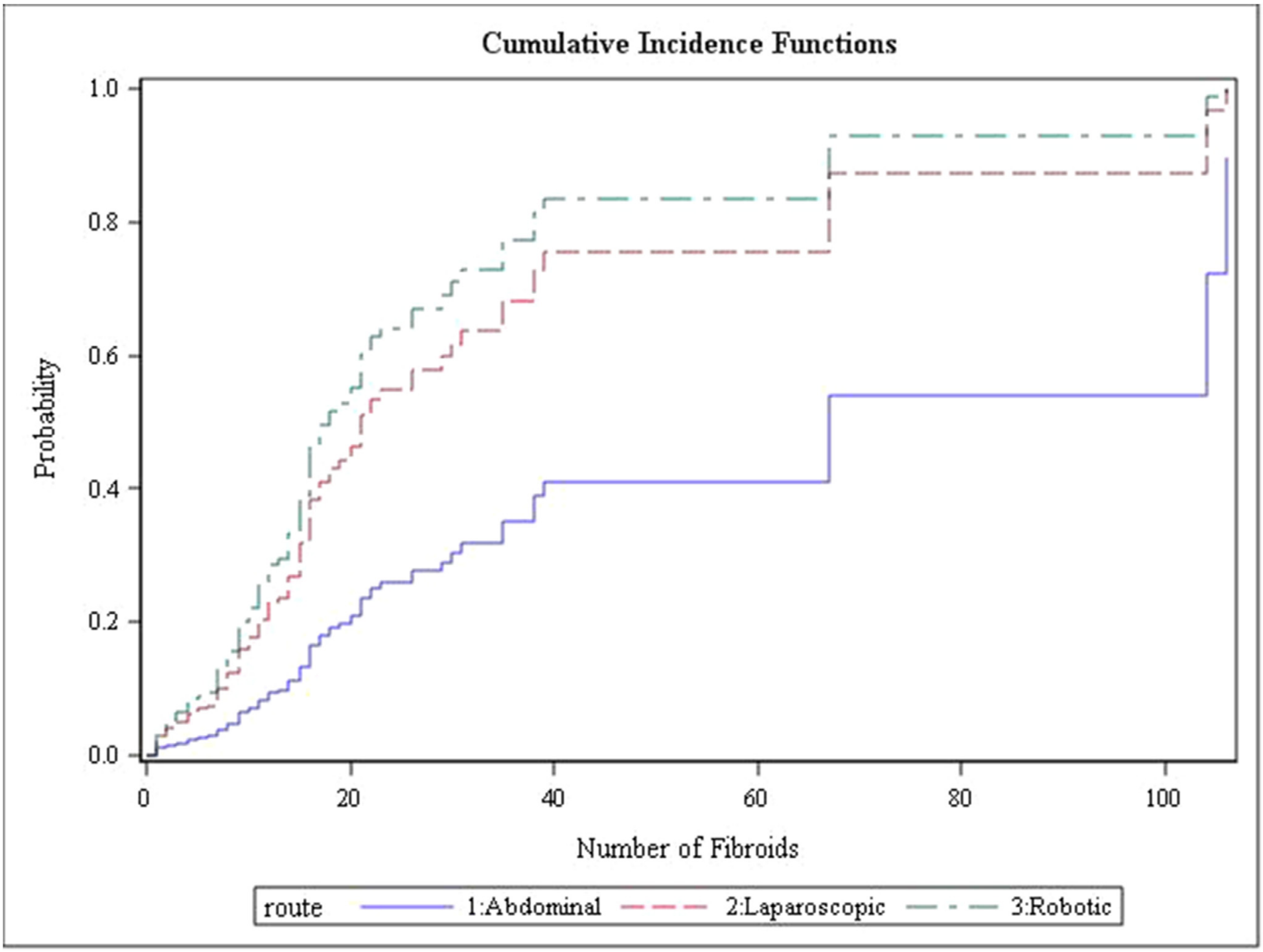
The recognized benefits of minimally invasive myomectomy include shortened hospital stay, decreased postoperative pain, less blood loss, and a lower likelihood of transfusion [3,4]. In this study of extreme myomectomy cases we confirm prior associations between RM and increased operative time [17] while demonstrating reduced length of stay for LM and RM. However, in our cohort blood loss, transfusion rates, and perioperative complications were similar across all groups. This likely reflects the complex nature of these procedures, where the advantages of minimally invasive surgery may be overshowed by the complexity of the procedure, and provides support for the use of a minimally invasive approach in many extreme cases because of the additional benefits with regards to pain and return to normal activities without compromised perioperative outcomes.

The extreme nature of this cohort is demonstrated by the higher rates of conversion and blood transfusions compared with prior studies that evaluate all myoma weights and sizes. Specifically, rates of blood transfusion for AM, LM, and RM (7.4%, 6.0%, and 4.9%, respectively) were relatively high, albeit not out of range with prior reports [5,18], and the conversion rate was higher than previous research on myomectomies performed at our institution (2% vs .1% [11]).

Within our study population the likelihood of any perioperative complication positively correlates with a higher

Fig. 2

Cumulative incidence function curve showing the probability of any perioperative complication with increased number of myomas. p values: 3 routes, <.001; AM versus LM, <.001; AM versus RM, <.001; LM versus RM, .343.



specimen weight or increased number of myomas. Previous studies, although not limited to extreme cases, have also assessed predictors of adverse outcomes for various modes of myomectomy. Vargas et al [12] suggested a combination of dominant myoma diameter ≥ 10 cm and uterine volume ≥ 600 cm^3 were predictive of complications for LM and RM. Saccardi et al [19] identified intramural myomas more than 8 cm and subserosal myomas more than 12 cm as the best predictors of complications and surgical difficulties for LM, including increased operative time and blood loss. For RM Barakat et al [5] demonstrated that the weight of the removed myoma did not appear to be a limitation against performing RM, because it was comparable for robotic and open groups. Sandberg et al [11] found a specimen weight exceeding 500 g to be associated with an increased risk of conversion to laparotomy. Mais et al [20] suggested that patients are better treated by AM if myoma number exceeds 4 or the largest myoma diameter exceeds 6 cm. Such predictors of complications are rarely defined for AM, however.

With technical advances in minimally invasive surgery, increasingly complex cases are being considered for the laparoscopic approach [13]. To illustrate this, the largest mean dominant myoma diameter of our cohort (10.2 ± 3.7 cm) was found within the LM group. Although not clearly demonstrated in the literature, clinical opinion suggests that AM allows for a greater number of myomas to be removed given improved palpation of individual myomas and feasibility of uterine closure of multiple incisions. A preference for AM or LM over RM for increased myoma weight may be because of a possible prolonged procedure time, which has the potential to increase bleeding, infection risk, and other complications, especially in the setting of extreme myomas. Of note, the restrictions in the use of power morcellation during laparoscopic surgeries may also be responsible for the trend toward AM starting in 2013.

Strengths of this study include the large cohort of patients with a high specimen weight (591.3 ± 606.8 g), number of resected myomas (11.6 ± 12.2), and largest myoma diameter (9.6 ± 3.9 cm). The large number of myomectomies included allows the specific focus on only women with the greatest myoma burden. In addition, there was a wide variety of surgeons, long-term follow-up of patients, and great diversity of cases. Although patient cohorts with on average heavy or numerous myomas have been reported [13], many studies identify all consecutive cases without restrictions for inclusion in either myoma weight or count [11,12]. This study is unique in that it focuses exclusively on extreme cases. To our knowledge, defining extreme cases of myomas with an internal threshold has not been previously described in the literature.

Limitations of this study include the retrospective nature with limitations on the granular nature of data available for review. In particular, data on pre- and postoperative hemoglobin/hematocrit levels were not available, and thus the impact of surgical blood loss was only reflected in the use or nonuse of blood transfusion. The surgeon's individual preference for a particular route of myomectomy was not able to be accounted for, and the underlying surgical skill or relative myoma burden remaining at the end of each case was not able to be assessed. Additionally, despite the relatively large cohort size there is the possibility of Type II error with an inability to detect a difference given the overall low incidence of adverse events. The case mix under study may not be universally generalizable because of the complex nature of referral cases at our center. Specifically with regard to the patient cohort, our definition of extreme myomas is an internally generated threshold and may not be applicable to other centers. In addition, myoma characteristics, including type and location, were not considered for analysis, although these factors may play a significant role in making a decision about the most suitable route of myomectomy. The largest myoma diameter was used to determine myoma size, because estimated myoma volume was not consistently available from preoperative imaging studies. For the purpose of this research the assumption was made that postoperative findings (i.e., weight and number of myomas) were a reliable proxy for preoperative myoma burden.

In conclusion, our findings suggest that perioperative complications and blood transfusions are similar for AM, LM, and RM in cases of extreme myoma burden. We found that as myoma burden increases, the chances of any perioperative complication differ across modes, with a preference for AM or LM over RM for increased specimen weight and for AM over LM or RM when considering increased number of myomas. Even in the setting of extreme myoma weight, LM remains a feasible option in the hands of a skilled laparoscopist; however, AM should be considered in cases of extremes of myoma number. In addition, a threshold of 13 myomas is associated with an almost 2-fold higher risk of complications. This cut-off point may be clinically relevant, given that estimated myoma number can be calculated preoperatively based on imaging findings. In an effort to optimize patient outcomes, we suggest that surgeons should consider the individual case carefully and counsel patients about the increased chances of adverse outcomes if extreme myoma burden is present.

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