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Original Article

Laparoscopic-Assisted Myomectomy with Bilateral Uterine Artery Occlusion/Ligation

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ABSTRACT **Study Objective:** Conventional laparoscopic myomectomy (CLM) and robotic-assisted myomectomy (RAM) are limited in the number and size of myomas that can be removed, whereas abdominal myomectomy (AM) is associated with increased complications and morbidity. Here we evaluated the surgical outcomes of these myomectomy techniques compared with those of laparoscopic-assisted myomectomy (LAM), a hybrid approach that combines laparoscopy and minilaparotomy with bilateral uterine artery occlusion or ligation to control blood loss.

Design: Retrospective chart review (Canadian Task Force classification II-1).

Setting: Suburban community hospital.

Patients: Women age ≥ 18 years with nonmalignant indications.

Intervention: A total of 1313 consecutive CLMs, RAMs, AMs, and LAMs performed between January 2011 and December 2013.

Measurements and Main Results: Our review included 163 CLMs (12%), 156 RAMs (12%), 686 AMs (52%), and 308 LAMs (23%). Although the average number, size, and total weight of leiomyomas removed were comparable in the LAM and AM groups (9.1, 8.13 cm, and 391 g, respectively, vs 9.0, 7.5 cm, and 424 g; $p < .0001$), the number and weight of myomas were significantly greater in those 2 groups compared with the CLM and RAM groups (2.9 and 217 g, respectively, and 2.9 and 269 g; $p < .0001$). The intraoperative complication rate was highest in the RAM group, and the postoperative complication rate was highest in the AM group, both of which were approximately 3 times greater than the rates in the LAM group. There was no statistically significant difference in postoperative complication rates between the CLM and LAM groups.

Conclusion: LAM with uterine artery occlusion/ligation is a viable approach for removing large tumor loads while minimizing blood loss and precluding the need for power morcellation. Journal of Minimally Invasive Gynecology (2019) 26, 856−864. © 2018 AAGL. This is an open access article under the CC BY-NC-ND license. (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Keywords: Hybrid; Leiomyoma; Logistic; Minilaparotomy; Regression

Uterine myomas are the most common gynecologic tumors in the United States, occurring in 20%−50% of women of reproductive age [1,2]. Symptomatic submucosal myomas are often treated by hysteroscopic resection [3,4], whereas hysterectomy and myomectomy have been the traditional therapies for women with symptomatic leiomyomas with intramural or subserosal components. The 3 most common surgical approaches to myomectomy are conventional laparoscopic myomectomy (CLM), robotic-assisted laparoscopic myomectomy (RAM), and abdominal myomectomy (AM). Compared with AM, CLM has been associated with less blood loss, fewer complications, shorter length of stay (LOS), and improved cosmesis, but longer operating times [5]. RAM parallels the advantages of CLM but is associated with increased operating time and higher costs [6,7].

An abdominal myomectomy via minilaparotomy (3- to 5-cm incision) has reported advantages over laparoscopic surgery, including the ability to palpate the uterine body, remove larger myomas, and facilitate suturing of the uterine

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incision [8]. Nezhat et al [9] described the laparoscopic-assisted myomectomy (LAM) technique, a hybrid approach that combines laparoscopy with a minilaparotomy and is associated with less blood loss, shorter operating time, and shorter length of stay than AM and with a shorter uterine incision, shorter operating time, but significantly greater blood loss compared with CLM [10,11].

The aim of this study was to compare the surgical outcomes of LAM combined with a blood loss control technique of uterine artery occlusion or ligation with those of the 3 most commonly performed myomectomy approaches: CLM, RAM, and AM.

Materials and Methods

We conducted a retrospective chart review of all patients who underwent a myomectomy procedure for a benign indication between January 1, 2011, and December 31, 2013, at Holy Cross Hospital, a not-for-profit, high-volume hospital in suburban Maryland serving the greater metropolitan Washington, DC area. The surgeons included obstetrics and gynecology generalists, fellowship-trained laparoscopic surgeons, and gynecologic oncologists. Table 1 shows the distribution of generalists and specialists by myomectomy procedure. This investigation was approved by the hospital's Institutional Review Board (approval no. 2017-01; January 9, 2015).

The cases reviewed in this study were grouped into 4 categories: CLM, robotic-assisted laparoscopic myomectomy (RAM), abdominal myomectomy (AM), and laparoscopic-assisted myomectomy (LAM).

LAM Surgical Technique

Abdominal entry is obtained with a 5-mm direct entry trocar via the umbilicus and a 5-mm suprapubic port. A ZUMI uterine manipulator is used in all cases. Retroperitoneal dissection is performed. Blood loss control measures, consisting of either uterine artery occlusion or ligation, are applied based on the patient's desire for fertility preservation, uterine size, number of myomas, and complexity of the case. Uterine artery occlusion is performed by applying a laparoscopic latex (or nonlatex in patients with latex allergy) tourniquet around the isthmus of the uterus, causing temporary occlusion of the utero-ovarian pedicle and thereby limiting the blood flow and decreasing the pulse pressure to the uterus. Uterine artery ligation is performed with a harmonic scalpel at its origin at the anterior branch of the internal iliac artery. The suprapubic incision is then extended in either a transverse or vertical direction (depending on the exposure needed) to 3 to 4 cm, followed by placement of a small or medium Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA). This allows the wound diameter to stretch to 6 to 8 cm, similar to a smaller open incision.

A uterine incision is made once the leiomyomas are localized both visually and via palpation. The leiomyomas are then removed either intact or by manual segmentation above the fascia at the level of the skin, minimizing the risk of scattering leiomyomatous fragments below the fascia and into the abdominopelvic cavity. The uterus can be externalized if needed, and uterine defects, including posterior ones, are hand-sewn and closed in layers using a standard abdominal myomectomy closure technique. The tourniquet is released on closure of the uterine defect, and hemostasis is confirmed by a laparoscopic survey at the end of the procedure. Skin incisions are closed using absorbable sutures.

The major indications for myomectomy included symptomatic leiomyomas causing pelvic pain, abnormal uterine bleeding with symptomatic anemia, and infertility. Our cohort included patients who underwent a concomitant procedure routinely performed during myomectomy, such as adnexal surgery, adhesiolysis, cystoscopy, or resection of endometriosis. Patients who underwent concomitant pelvic or abdominal surgery unrelated to the myomectomy, such as appendectomy, hernia repair, and pelvic organ prolapse procedures, were excluded from the analysis because of the added operating time and increased risk of complications. Patients with presumed malignancies based on the preoperative diagnosis were excluded as well.

Data were retrieved from electronic medical records and included age, race, weight, body mass index (BMI), leiomyoma weight, and pathology. The Elixhauser Comorbidity Index was used to identify and record comorbid conditions that have been shown to potentially affect operative outcomes. Operative outcomes included length of stay (LOS; 0 if the patient was discharged before 12 midnight on the same day as surgery); number of laparoscopic ports used; estimated blood loss (EBL); operating time; number, size, type, and aggregate weight of leiomyomas; rate of conversion from laparoscopy to standard laparotomy; and intraoperative and postoperative complications. Tissue extraction was identified as power morcellation (i.e., endoscopic morcellation) or manual debulking, either vaginally or abdominally, and/or minilaparotomy (<5 cm incision).

Table 1

Distribution of generalists and specialists for myomectomy procedures

	LAM (N = 308)	CLM (N = 163)	RAM (N = 156)	AM (N = 686)
Generalists, n	1	25	4	127
Specialists, n	2	10	3	4
Total, n	3	35	7	131

AM = abdominal myomectomy; CLM = conventional laparoscopic myomectomy; LAM = laparoscopic-assisted myomectomy; RAM = robotic-assisted myomectomy.

We identified intraoperative complications and conversions from the surgeon's operative note. Complications were categorized as intraoperative when recognized at the time of the procedure. Complications presenting within 30 days after the myomectomy procedure were categorized as postoperative and collected from the inpatient hospital record, and when the patient was readmitted or seen in the emergency department or hospital's Ob-Gyn clinic.

Statistical Analysis

Before inferential analyses, data were checked for potential outlier and aberrant measurements. Patients' demographic and clinical characteristics measured on a nominal or ordinal scale were summarized as count and percentage and compared across myomectomy surgical techniques using Fisher's exact test. Variables measured in the interval scale were summarized as mean and standard deviation and compared across myomectomy surgical techniques using the nonparametric Kruskal−Wallis rank sum test.

The nonparametric Kruskal−Wallis test was also used to compare continuous surgical outcomes across myomectomy surgical techniques. Post hoc comparisons between LAM and each of the other myomectomy surgical techniques were performed using the Bonferroni-adjusted Wilcoxon rank sum test. Dichotomous operative outcomes (intraoperative complications, postoperative complications, conversions to laparotomy) were compared using Fisher's exact test. A post hoc Bonferroni-adjusted Fisher's exact test was used to compare probabilities between LAM and each of the other myomectomy surgical techniques. LOS and number of ports were compared individually across myomectomy surgical technique by using negative binomial regression. Bonferroni-adjusted Wald tests were used to compare predicted (marginal) counts between LAM and each of the other myomectomy surgical techniques. A similar approach was used within each stratum of total leiomyoma weight.

A second analysis was performed to control for age, race, number of previous abdominal surgeries, leiomyoma number, total leiomyoma weight, BMI, and number of comorbidities. Surgeon's experience was also controlled for by including the actual number of myomectomies performed during the 3-year study period as a continuous covariate in the model ("surgeon volume"). Because of concerns about non-normality of the dependent variable, we used median regression to model EBL and surgery time. Logistic regression was used to model the occurrence of intraoperative and postoperative complications, as well as conversions to laparotomy. Negative binomial regression was used to model LOS and number of ports. We computed adjusted (marginal) means, proportions, or counts, as well as corresponding delta-method standard errors. Bonferroni-adjusted Wald tests on linear combinations of the marginal predictions were used for post hoc comparisons of the LAM method with each of the other myomectomy surgical techniques.

All tests maintained a familywise error rate at 5%. Statistical analyses were performed by using Stata version 14.0 (StataCorp, College Station, TX).

Results

We reviewed the medical charts of 1380 patients who underwent myomectomy. After exclusion of patients who underwent hysteroscopic or vaginal myomectomy and those with major concomitant procedures or malignant indications, our sample size was 1313, with the following distribution: 308 in the LAM group (24%), 163 in the CLM group (12%), 156 in the RAM group (12%), and 686 in the AM group (52%). In 2 patients, leiomyosarcoma was diagnosed on postoperative pathology. One of these was a patient with CLM in whom power morcellation was performed for specimen extraction, and the other was a patient with LAM, in whom the specimen was extracted via minilaparotomy without morcellation.

Patient age, weight, BMI, and previous abdominopelvic surgery were equally distributed among the surgical groups (Table 2). Although the average number, size, and total weight of leiomyomas removed via LAM and AM were comparable, the average number and total weight of leiomyomas were significantly larger in the LAM and AM groups compared with the CLM and RAM groups (Table 3 and Fig. 1). Only 1 leiomyoma was removed in 58% of CLM cases and 45% of RAM cases. The LAM and AM groups showed the widest range of number of leiomyomas removed, as well as the highest number of cases with leiomyomas weighing >750 g (Table 2).

Approximately one-half of all myomas removed in all myomectomy procedures were subserosal. The percentage of intramural myoma removed was lowest in the CLM group. The LAM approach removed almost 4 times as many leiomyomas with a submucosal component compared with CLM and RAM, and 1.5 times more than AM (Table 2). However, when examining cases by high-volume surgeons (i.e., performing >30 myomectomies per year) only, the LAM and AM approaches removed comparable percentages of myomas with a submucosal component (32.2% and 33.2%, respectively).

Uterine artery occlusion was performed in 56.8% of LAM cases, 3.1% of CLM cases, and 3.6% of AM cases, but not in any RAM cases. Uterine artery ligation was performed in 43.2% of LAM cases, 0.6% of RAM cases, 6.1% of CLM cases, and 0.9% of AM cases.

Surgical outcomes were compared across myomectomy procedures with and without controlling for demographics, surgeon volume, and case complexity factors, such as BMI, previous abdominal surgeries, number of comorbidities, and tumor load. The unadjusted results are summarized in Table 4. The adjusted results are summarized in Table 5 and are reported below unless otherwise noted.

Table 2

Patient demographic and clinical characteristics

Variable	LAM (N = 308)	CLM (N = 163)	RAM (N = 156)	AM (N = 686)	p value
Age group, n (%)					.4138*
<40 yr	207 (67.2)	103 (63.2)	110 (70.5)	434 (63.3)	
40−50 yr	99 (32.1)	56 (34.4)	44 (28.2)	240 (35.0)	
>50 yr	2 (0.6)	4 (2.5)	2 (1.3)	12 (1.7)	
Race, n (%)					<.0001*
Black	47 (15.3)	48 (29.4)	41 (26.3)	80 (11.7)	
White	235 (76.3)	90 (55.2)	91 (58.3)	535 (78.0)	
Other	25 (8.1)	21 (12.9)	21 (13.5)	71 (10.3)	
Leiomyoma weight, n (%)					<.0001*
≤100 g	81 (26.3)	68 (41.7)	33 (21.2)	139 (20.3)	
101−500 g	132 (42.9)	67 (41.1)	96 (61.5)	349 (50.9)	
501−750 g	37 (12.0)	10 (6.1)	14 (9.0)	89 (13.0)	
>750 g	48 (15.6)	7 (4.3)	7 (4.5)	96 (14.0)	
Previous abdominal surgeries, n (%)					.3045*
None	172 (55.8)	92 (56.4)	102 (65.4)	412 (60.1)	
1	95 (30.8)	49 (30.1)	38 (24.4)	192 (28.0)	
2	27 (8.8)	17 (10.4)	10 (6.4)	68 (9.9)	
>2	14 (4.5)	5 (3.1)	6 (3.8)	14 (2.0)	
Comorbidities, n (%)					<.0001*
None	185 (60.1)	100 (61.3)	99 (63.5)	369 (53.8)	
1	93 (30.2)	44 (27.0)	42 (26.9)	166 (24.2)	
2	22 (7.1)	11 (6.7)	11 (7.1)	88 (12.8)	
>2	8 (2.6)	8 (4.9)	4 (2.6)	63 (9.2)	
Age, yr, mean (SD)	37.3 (5.7)	37.1 (7.3)	36.5 (5.7)	37.4 (5.6)	.2892†
Weight, kg, mean (SD)	76.9 (18.1)	74 (18.1)	77.7 (19.1)	78.4 (18.9)	.0341†
Body mass index, kg/m^2, mean (SD)	28 (6.5)	27.7 (6.5)	28.6 (7.7)	29.1 (6.7)	.011†

AM = abdominal myomectomy; CLM = conventional laparoscopic myomectomy; LAM = laparoscopic-assisted myomectomy; RAM = robotic-assisted myomectomy.
* Fisher's exact test.
† Kruskal−Wallis rank sum test.

Fig. 1

Average weight and number of leiomyomas removed. AM = abdominal myomectomy; CLM = conventional laparoscopic myomectomy; LAM = laparoscopic-assisted myomectomy; RAM = robotic-assisted myomectomy.

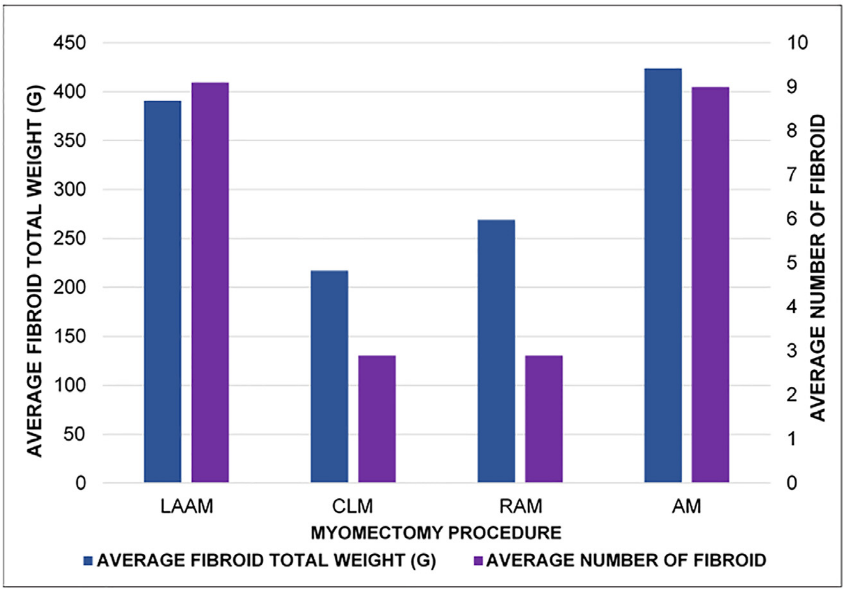

Table 3

Leiomyoma number, weight, length, and type by myomectomy procedure

Variable	LAM	CLM	RAM	AM	p value
	N = 152	N = 139	N = 142	N = 581	
Mean number of leiomyomas (SD)	9.1 (17.9)	2.9 (8.5)*	2.9 (2.7)*	9.0 (8.8)	<.0001
Maximum number of leiomyomas	103	18	13	65	
	N = 297	N = 153	N = 150	N = 673	
Average leiomyoma total weight, g (SD)	391 (435.3)	217 (263.5)*	269 (249.7)*	424 (523.5)	<.0001
Maximum leiomyoma total weight, g	3046	1363	1901	5668	
	N = 129	N = 117	N = 122	N = 602	
Average length of largest leiomyoma, cm (SD)	8.13 (4.3)	7.17 (3.3)	8.34 (3.5)	7.5 (4.8)	<.0001
Length of largest leiomyoma, cm	20	16	22	80*	
	N = 307	N = 163	N = 142	N = 679	
Subserosal myoma, n (%)	147 (47.9)	92 (56.4)	78 (55.0)	359 (52.9)	<.0001
Intramural myoma, n (%)	148 (48.2)	41 (25.2)*	84 (59.2)	287 (42.3)	
Submucosal myoma, n (%)	99 (32.2)	16 (9.8)*	13 (9.2)*	145 (21.4)*	

AM = abdominal myomectomy; CLM = conventional laparoscopic myomectomy; LAM = laparoscopic-assisted myomectomy; RAM = robotic-assisted myomectomy.

* Kruskal-Wallis rank test; statistically significant compared with LAM.

Table 4

Operative outcomes (unadjusted analysis)

Outcome	LAM (N = 308)	CLM (N = 163)	RAM (N = 156)	AM (N = 686)	p value
Estimated blood loss, mL, mean (SD)	245.0 (337.8)	172.6 (223.7)	160.3 (165.7)	404.7 (441.6)*	<.0001
Length of stay, d, mean (SD)	0.5 (1.0)	0.9 (1.0)*	0.8 (0.9)*	2.5 (1.2)*	<.0001
Total surgery time, min, mean (SD)	76.2 (28.8)	103.8 (60.6)*	154.7 (67.8)*	105.8 (44.8)*	<.0001
Number of ports, mean (SD)	2.4 (0.8)	3.2 (1.3)*	4.4 (1.0)*	N/A	<.0001
Retroperitoneal dissection (SD)	100 (0.0)	9.2 (29.0)*	5.1 (22.1)*	2.8 (16.4)*	<.0001
Uterine artery ligation, mean (SD)	43.2 (49.6)	6.1 (24.1)*	.6 (8.0)*	.9 (9.3)*	<.0001
Uterine artery occlusion (SD)	56.8 (49.6)	3.1 (17.3)*	0.0 (0.0)*	3.6 (18.8)*	<.0001
Intraoperative complications, n (%)	12 (3.9)	8 (4.9)	10 (6.4)	64 (9.3)*	.0112
Postoperative complications, n (%)†	34 (11.0)	21 (12.9)	14 (9.0)	181 (26.4)*	<.0001
Postoperative blood transfusion, n (%)	19 (6.2)	7 (4.3)	6 (3.8)	130 (19.0)*	<.0001
Conversion to minilaparotomy, n (%)	N/A	31 (19.0)	27 (17.3)	N/A	N/A
Conversion to open surgery, n (%)	2 (0.7)	27 (16.6)*	10 (6.4)*	N/A	<.0001

AM = abdominal myomectomy; CLM = conventional laparoscopic myomectomy; LAM = laparoscopic-assisted myomectomy; N/A = not applicable; RAM = robotic-assisted myomectomy.

* Bonferroni-adjusted $p < .05$ comparing each procedure to LAM.

† Includes blood transfusions.

Table 5

Operative outcomes (adjusted analysis)

Outcome	LAM (N = 308)	CLM (N = 163)	RAM (N = 156)	AM (N = 686)	*p*-value
Estimated blood loss, mL, median (95% CI)	182.7 (137.5– 228.0)	224.0 (176.5–271.4)	205.9 (159.3– 252.4)	252.1 (229.3–274.9)*	.0449
LOS, d, median (95% CI)	0.4 (0.3–0.5)	1.1 (0.9–1.3)*	0.9 (0.7–1.0)*	2.5 (2.3– 2.6)*	<.0001
Total surgery time, min, median (95% CI)	82.0 (74.1–90.0)	115.2 (106.9–123.5)*	156.8 (148.7–165.0)*	93.0 (89.0–97.0)*	<.0001
Number of ports, median (95% CI)	2.3 (2.0–2.5)	3.3 (2.9–3.6)*	4.4 (4.1–4.8)*	N/A	<.0001
Probability of intraoperative complications, % (95% CI)	2.8 (0.1–5.5)	8.8 (3.2–14.5)	10.7 (4.9–16.5)*	7.5 (5.5–9.5)*	.0156
Probability of postoperative complications, % (95% CI)†	8.0 (3.7–12.4)	15.6 (8.7–22.5)	12.3 (6.2–18.3)	23.6 (20.2–27.0)*	.0001
Probability of postoperative blood transfusion, % (95% CI)	3.9 (0.9–6.9)	4.6 (0.5–8.8)	5.9 (1.4–10.4)	16.6 (13.7–19.5)*	<.0001
Probability of conversion to minilaparotomy, % (95% CI)	N/A	27.5 (19.7–35.3)	18.8 (12.6–25.0)	N/A	N/A
Probability of conversion to open surgery, % (95% CI)	0.7 (0.0–1.6)	22.9 (14.7–31.1)*	8.2 (3.3–13.2)*	N/A	<.0001

The analysis was adjusted for age, race, total leiomyoma weight, number of leiomyomas, number of previous abdominal surgeries, body mass index, number of comorbidities, weight, and surgeon volume.

AM = abdominal myomectomy; CI = confidence interval; CLM = conventional laparoscopic myomectomy; LAM = laparoscopic-assisted myomectomy; LOS = length of stay; N/A = not applicable; RAM = robotic-assisted myomectomy.

* Post hoc analysis comparing each surgical procedure to LAM. Significance probability corrected to maintain the familywise error rate at $\alpha = 0.05$.

† Includes blood transfusions.

Analysis of the surgical outcomes showed statistically significant differences in the number of ports, LOS, operating times, complication and conversion rates. The LAM group had the shortest LOS, at 0.4 days, and the AM group had the longest, at 2.5 days (Table 5). Same-day discharge was seen in 70% of LAM cases, 40% of CLM cases, 37% of RAM cases, and 0% of AM cases. However, it should be noted that LOS is often a protocol-driven outcome that can be influenced as much by surgeon preference and the time of day of the procedure as by the condition of the patient.

Controlling for case complexity and surgeon volume, the mean operating time was nearly twice as long for RAM as for LAM, which had the shortest mean operating time (Table 5). When operative outcomes were stratified by total leiomyoma weight, the most significant difference was found in cases with a leiomyoma weighing >750 g, in which the total operating time for RAM was 3 times longer than that for LAM, the procedure with the shortest operating time (292 minutes vs 98 minutes; $p < .0001$).

RAM had the highest intraoperative complication rate and AM had the highest postoperative complication rate, both at approximately 3 times greater than the rates for LAM (Table 5). The most frequent complications overall were hemorrhage and the need for blood transfusion. Significantly, the rate of intraoperative hemorrhage (defined here as EBL >1000 mL), and the rate of intraoperative and postoperative blood transfusion, as well as the rate of postoperative ileus, were more than 3 times higher in the AM group compared with the other groups (Table 6).

The rate of conversion to standard laparotomy was highest in the CLM group, almost 3 times greater than that seen in the RAM group. Conversion occurred in <1% of cases in the LAM group. Although minilaparotomy is an intrinsic component of the LAM procedure, it was performed in almost 20% of RAM cases and >25% of CLM cases (Table 5). Power morcellation was performed in 2% of AM cases, 41% of CLM cases, and 62% of RAM cases, and was not performed in any LAM cases.

Discussion

Our results demonstrate that LAM enables surgeons to remove large tumor loads while effectively controlling blood loss and minimizing complications. Previous reports on the LAM approach have described advantages over laparotomy and laparoscopy. Kalogiannidis et al [11] reported shorter operation time, faster patient recovery, reduced blood loss, shorter skin and uterine incisions, and decreased risk of postoperative adhesions compared with an AM approach. Comparing LAM with laparoscopy, Prapas et al [10] reported shorter operation time, as well as easier and faster uterine repair with a shorter incision and a minimal requirement for electrocautery, an important factor in avoiding thermal tissue damage and maintaining uterine integrity for future pregnancy. This study also highlighted the ability to palpate the uterus during LAM to detect and

Table 6

Most common complications

Complications*	LAM (N = 308)	CLM (N = 163)	RAM (N = 156)	AM (N = 686)	Total
Intraoperative					
Intraoperative hemorrhage (EBL >1000 mL)	8 (2.6)	1 (0.6)	2 (1.3)	48 (7.0)	59
Blood transfusion	5 (1.6)	1 (0.6)	0	21 (3.1)	27
Bowel injury	3 (1.0)	1 (0.6)	1 (0.6)	9 (1.3)	14
Endometrial defect	0	2 (1.2)	3 (1.9)	2 (0.3)	7
Uterine serosal injury†	0	2 (1.2)	2 (1.3)	1 (0.1)	5
Postoperative					
Transfusion	18 (5.8)	8 (4.9)	6 (3.8)	137 (20)	169
Ileus	2 (0.7)	2 (1.2)	2 (1.3)	29 (4.2)	35
Fever	2 (0.7)	3 (1.8)	0	8 (1.2)	13
Emergency department for abdominal pain	4 (1.3)	3 (1.8)	1 (0.6)	2 (0.3)	10
Shortness of breath, chest pain	2 (0.7)	2 (1.2)	0	4 (0.6)	8
Hemorrhage requiring reoperation	1 (0.3)	0	1 (0.6)	6 (0.9)	8
Incisional bleeding	1 (0.3)	0	1 (0.6)	2 (0.3)	4
Incisional hematoma	2 (0.7)	0	0	2 (0.3)	4
Hypoxia	1 (0.3)	1 (0.6)	1 (0.6)	1 (0.1)	4
Infection	0	0	0	3 (0.4)	3
Postoperative complications requiring readmittance or reoperation	10 (3.2)	5 (3.1)	3 (1.9)	22 (3.2)	40

AM = abdominal myomectomy; CI = confidence interval; CLM = conventional laparoscopic myomectomy; EBL − estimated blood loss; LAM = laparoscopic-assisted myomectomy; RAM = robotic-assisted myomectomy.

* Includes multiple intraoperative complications as recorded in the operative notes but counted as 1 event for statistical analysis.

† Recorded in the operative notes but not clearly defined

excise smaller or deep intramural myomas that may be inadvertently left behind during laparoscopy, which may decrease the risk of recurrence. Studies comparing laparoscopy and abdominal myomectomy have shown higher rates of leiomyoma recurrence following laparoscopy, supporting the idea that the more complete the myoma removal, the lower the risk of recurrence [12].

LAM also eliminates the need for power morcellation, which is significant given the 2014 Food and Drug Administration (FDA) safety warning about power morcellation. Studies examining the practice patterns of gynecologic surgeons since the issuance of the FDA warning have shown an increase in laparotomies and a decrease in minimally invasive myomectomies [13−16]. However, an investigation by Pereira et al [17] at a single reproductive medicine center in the 2 years before and after the FDA recommendation found no change in the ratio of AM to minimally invasive myomectomy. Interestingly, however, the authors reported significant decreases in CLM and RAM and a corresponding increase in LAM, which was performed without electric morcellation.

The LAM technique also allows for excision of a significantly higher percentage of submucosal myomas compared with the laparoscopic approaches. This is significant because the presence of submucosal myomas has been associated with reduced fertility rates, and studies have demonstrated that removing such myomas results in improvements in both conception and live birth rates [18].

Hemorrhage remains a major risk of myomectomy, and previous studies have found significantly higher blood loss with LAM compared with laparoscopy [10]. Seidman et al [19] used the pharmacologic agent vasopressin to control blood loss in a study comparing LAM with CLM and AM and found similar myoma weight and blood loss between the LAM and AM groups, but both these measurements were significantly lower with laparoscopy. Although vasopressin is often used to prevent blood loss, it has some limitations, including a short half-life of 10 to 20 minutes and rare but serious side effects, such as bradycardia, cardiovascular collapse, and even death [20−23].

The surgeons who performed LAM in this study provided uterine artery occlusion with a pericervical tourniquet or uterine artery ligation to control blood loss, both of which have been shown to decrease EBL and transfusion rates [24−29]. Our results found comparable myoma removal with LAM and AM, but significantly lower rates of hemorrhage and blood transfusion with LAM. This hemostatic control allowed for the removal of significantly more myomas than with laparoscopic approaches with similar or less blood loss.

We acknowledge several limitations of the present study. The retrospective design is limited by inherent selection bias. We selected all myomectomy cases performed at a single institution between 2011 and 2013, but excluded cases with major concomitant procedures or malignant indications, as well as vaginal and hysteroscopic myomectomies, because there were too few cases to enable a meaningful analyses. In addition, because the data on postoperative complications were limited to that reported in the hospital medical record, patients who may have been seen in their physician's office or at a different hospital for postoperative complications are not reflected in our data.

Furthermore, although tests were conducted to ensure interrater and intrarater reliability among data abstractors, the accuracy and transcription of medical records data remains an intrinsic limitation.

Another limitation is that the different myomectomy approaches were not performed by the same surgeons. The 3 surgeons who performed all the LAM procedures and the 3 surgeons who performed 89% of RAM procedures are all skilled and experienced laparoscopists who perform a high volume of cases. The 3 high-volume robotics surgeons have each been performing robotics for more than 10 years. Thus, there are limitations in making direct comparisons with other types of procedures performed by different surgeons of varying experience, skill levels, and practice patterns. Because high-volume surgeons are associated with better surgical outcomes [30], we attempted to enable meaningful comparisons by controlling for surgeon volume in our regression models.

Conclusion

LAM is an effective and safe approach to managing the inherent technical challenges and limitations associated with laparoscopic myomectomy. This approach, in combination with uterine artery occlusion or ligation, enables the removal of numerous large myomas while minimizing blood loss and eliminating the need for power morcellation. These blood loss control techniques should be further evaluated in randomized prospective studies.

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