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Perioperative Complications and Cost of Vaginal, Open Abdominal, and Robotic Surgery for Apical Vaginal Vault Prolapse

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Summary

Accounting for selection bias, MMC is associated with decreased operative time, non-UTI morbidity, and hospital costs to patients compared with sacrocolpopexy in treating posthysterectomy prolapse.

Abstract

Objectives—To determine the rate of perioperative complications and cost associated with Mayo-McCall culdoplasty (MMC), open abdominal sacrocolpopexy (ASC), and robotic sacrocolpopexy (RSC) for posthysterectomy vaginal vault prolapse.

Methods—We retrospectively searched for the records of patients undergoing posthysterectomy apical vaginal prolapse surgery (MMC, ASC, or RSC) between January 1, 2000, and June 30, 2012, at our institution. For all patients identified, perioperative complications, length of hospital stay, and inpatient costs to patients were abstracted from the medical records and compared by procedure. Inverse-probability-of-procedure weighting using propensity scores was used to obtain less-biased comparisons of outcomes between procedures.

Results—A total of 512 patients met the inclusion criteria (174 MMC, 237 ASC, and 101 RSC). Using inverse-probability weighting, the MMC group had a significantly lower intraoperative complication rate (3.3% vs 11.6% for ASC; 3.4% vs 24.1% for RSC), median operative time (94 min vs 217 min for ASC; 100 min vs 228 min for RSC), and median cost (\$8,776 vs \$12,695 for ASC and \$8,773 vs \$13,107 for RSC) than the ASC and RSC groups (all $P < .01$). In addition, the MMC group had significantly fewer postoperative grade III+ complications than the RSC group (1.1% vs 9.4%; $P < .01$).

Conclusions—In the treatment of posthysterectomy vaginal vault prolapse, MMC is associated with decreased non-urinary tract infection, less perioperative morbidity, and lower cost to patients compared with sacrocolpopexy.

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Keywords

Mayo-McCall culdoplasty; sacrocolpopexy; uterosacral ligament

Introduction

An estimated 3.2% of women who have undergone hysterectomy subsequently undergo surgery for posthysterectomy vaginal prolapse, regardless of the indication for the prior hysterectomy (1). Prolapse of the vaginal apex, or vaginal vault, after hysterectomy is attributed to loss of DeLancey level I support, predominantly consisting of the cardinal and uterosacral ligaments (2). Treatments for vaginal vault prolapse include observation, vaginal pessary, or surgical correction (3), such as transvaginal approaches (eg, uterosacral ligament suspension, sacrospinous fixation, or colpocleisis), open abdominal surgery (eg, abdominal sacrocolpopexy), and minimally invasive transabdominal surgery (eg, laparoscopic sacrocolpopexy or robotically assisted laparoscopic sacrocolpopexy) (4).

The ideal surgical procedure for vaginal vault prolapse has not been determined (4,5). Complication rates for transabdominal and transvaginal surgical approaches vary widely in the literature, ranging from as high as 24.9% for open abdominal sacrocolpopexy (ASC) to as low as 7% for Mayo-McCall culdoplasty (MMC) in an earlier systematic review (6). In contrast, a more recent systematic review found more comparable overall complication rates for open abdominal (17.1%) vs all transvaginal procedures (15.3%) (4). The newer, minimally invasive, robotically assisted laparoscopic sacrocolpopexy (RSC) has become increasingly adopted with the hope of mitigating some of the morbidity associated with traditional ASC (7). At our institution, the most frequently performed vaginal surgery for apical prolapse is MMC, which is also performed worldwide. The most frequently performed transabdominal surgeries for apical prolapse at our institution are ASC and RSC.

The objective of the current study was to determine perioperative complication rates and associated costs of the 3 vaginal vault prolapse surgeries performed at our institution: MMC, ASC, and RSC. We hypothesized that MMC would have the lowest complication rate and cost among the 3 procedures.

Methods

This study was approved by the Mayo Clinic Institutional Review Board. We retrospectively searched for and reviewed the cases of patients undergoing posthysterectomy vaginal vault prolapse surgery with the MMC, ASC, or RSC method between January 1, 2000, and June 30, 2012, at Mayo Clinic, Rochester, Minnesota.

Patients who did not allow access to their medical records for research purposes were excluded. Patients were also excluded if they had prior or concomitant vaginal mesh excision, upper vaginectomy, nonhealing vaginal wound, radical hysterectomy, oncologic surgery, systemic chemotherapy, pelvic radiation therapy, current malignancy, connective tissue disease, nonpermanent mesh, concomitant trachelectomy or hysterectomy, concomitant major nongynecologic surgery (rectopexy, colectomy), suspension of

neovagina, fistula repair, pouch of Douglas hernia, or no apical prolapse, or if their procedure was performed by a nongynecologic surgeon or otherwise misclassified (8).

All data were abstracted from the electronic health record. Study data were collected and managed using REDCap electronic data capture tools hosted at Mayo Clinic (9). Patient baseline characteristics abstracted included age, ethnicity, body mass index, smoking status, vaginal parity, comorbid conditions, American Society of Anesthesiologists (ASA) physical classification status, number and type of previous pelvic organ prolapse surgeries, number and type of previous urinary incontinence surgeries, pelvic floor symptoms (eg, bladder dysfunction, bowel dysfunction, and dyspareunia), chronic pain of any kind, and preoperative Baden-Walker prolapse grade of each vaginal compartment (10). A Charlson comorbidity index score for longitudinal morbidity was assigned on the basis of comorbid conditions (8,11).

MMC, a type of uterosacral ligament suspension, was performed consistently across the staff surgeons; it consisted of 2 external McCall sutures and 1 internal McCall suture, using VICRYL #1 Suture (Ethicon). ASC was performed via Pfannenstiel or low-midline laparotomy incisions, using absorbable (2-0 VICRYL) or permanent (2-0 PROLENE, Ethicon) suture for attachment of mesh to the vagina, typically at 9 points per compartment, and using permanent suture (2-0 PROLENE) at the sacrum, typically at 3 points. RSC was performed using absorbable suture (2-0 VICRYL) at both the vaginal and sacral attachment sites. Type of permanent mesh selected for ASC or RSC was at the discretion of the surgeon and consisted of polypropylene mesh (PROLENE; Pelvitex, C. R. Bard; IntePro, Endo Pharmaceuticals; or ULTRAPRO, Ethicon), with only occasional use of Gore-Tex and, rarely, MERSILENE mesh (Ethicon) for ASC in the early 2000s.

Intraoperative and postoperative data were abstracted from the electronic medical records. Intraoperative variables included surgeon, anesthesia type, primary and concomitant surgeries performed, operative time, estimated blood loss, intraoperative complications, and preoperative and postoperative laboratory values. Intraoperative complications analyzed included conversion to laparotomy; blood transfusion; vaginotomy; unintentional cystotomy; ureteral, bowel, or vascular injury; direct intensive care unit admission; or death. Postoperative variables consisted of length of hospitalization, follow-up data, and complications.

A postoperative window of 63 days was set arbitrarily to optimize capture of postoperative complications, particularly those reported by telephone after an approximately 6-week postoperative examination, which may have been conducted elsewhere. Data abstracted included more than 40 distinct complications in the following categories: wound, infectious, gastrointestinal, electrolyte, cardiopulmonary, neurologic, psychiatric, and endocrine. Other complications included pelvic floor symptoms including de novo or worsened stress or urge urinary incontinence, irritative voiding symptoms, need for catheterization or urethrolisis, and vaginal pain or dyspareunia. Each complication was assigned a Clavien-Dindo classification grade based on the need for subsequent intervention, as follows: grade I, any deviation from the normal postoperative course with certain acceptable pharmacologic and low-tech interventions; grade II, other pharmacologic interventions; grade IIIa, procedural

intervention not requiring general anesthesia; grade IIIb, procedural intervention requiring general anesthesia; grade IV, life-threatening complication; grade V, death (12).

Cost of hospitalization was determined using the Olmsted County Healthcare Expenditure and Utilization Database (13-15). This claims-based database contains information on medical resource utilization, associated charges, and estimated economic costs for patients receiving care at 2 medical groups in Olmsted County, Minnesota (Mayo Clinic and Olmsted Medical Center). It provides a standardized inflation-adjusted estimate of costs for each service or procedure. Inpatient charges from the hospital stay for the index surgery until date of discharge were determined using this database, multiplied by Medicare cost-to-charge ratios for the year of surgery, and inflated to 2013 dollars. Costs reflected charges to the patient but not the cost of surgical instruments or other durable medical equipment. Costs were only available for procedures that occurred on or after January 1, 2003, and therefore cost analysis was restricted to patients who had surgery on or after that date.

Statistical Analyses

All analyses were performed using SAS version 9.3 software (SAS Institute Inc). Separate analyses were conducted for 3 comparisons: MMC vs ASC, RSC vs ASC, and RSC vs MMC. The latter 2 comparisons were limited to cases after February 1, 2007, when RSC was first performed at our institution. Using the original data, intraoperative and postoperative variables were compared between any 2 procedure groups using the χ^2 test for nominal variables and the Wilcoxon rank sum test for continuous variables.

In a previous analysis of this study population, we reported the existence of selection bias among the 3 procedures for prolapse (8). To obtain less-biased comparisons of outcomes between procedures, propensity score (PS) analysis was used. PS analysis can be used in observational studies to determine the conditional probability of undergoing (in this case, being selected to receive) one type of procedure versus another, conditional of a set of measured baseline covariates. These PSs are then used as balancing scores to obtain comparison groups that are more balanced on the measured covariates as well as to remove potential confounding of baseline covariates, before comparing outcomes between groups. Using PS-based methods is advantageous over simple regression adjustment in the final model, since it allows for separation of the design of the study from the analysis of the study (16).

For each of the 3 aforementioned comparisons, a PS for each patient was defined as the estimated conditional probability of having procedure A (vs procedure B) given a patient's baseline covariates. The PS values were estimated by fitting a multivariable logistic regression model, with procedure type (A vs B) as the dependent variable and the following patient baseline characteristics as the independent covariates: age, Charlson Comorbidity Index score (0, 1, 2+), ASA score (1 or 2 vs 3 or 4), number of prior prolapse surgeries (0, 1, or 2+), chronic pain (yes vs no), apical prolapse grade (1 or 2 vs 3 or 4), anterior prolapse grade (1 or 2 vs 3 or 4), and posterior prolapse grade.

There are 4 common PS methods, which yield different results. One technique, adjustment on the PS, is less preferred, and another technique, stratification on the PS, would have been

cumbersome to apply to our dataset. The other 2 PS methods, inverse-probability-weighted (IPW) analysis and matching, were therefore explored as approaches to use the PS values to balance the baseline covariates between procedure groups. For the IPW approach, intraoperative and postoperative variables were compared between any 2 procedure groups using a weighted χ^2 test for nominal variables and a weighted least-squares regression model for continuous variables, after applying a logarithmic transformation to operative time, estimated blood loss, length of hospitalization, and total cost of hospitalization. All calculated *P* values were 2-sided, and *P* < .05 was considered statistically significant. The weights were derived as 1/PS for patients with procedure A and 1/(1-PS) for patients with procedure B, using each patient's specific PS value. Large weights were trimmed at the 95th percentile, and the weights were then stabilized according to the proportion of patients in the 2 procedure groups. For the matching approach, patients who underwent procedure A were matched 1:1 to patients who underwent procedure B using a greedy matching algorithm (17). Patients were matched on 1) the logit of the PS within 0.2 of the SD of the logit and 2) surgery date within 180 days in the same calendar year. Because the cost outcome measures were based on costs that are set each year using the Medicare cost-to-charge ratio for that calendar year, patients were also matched on calendar year.

Balance in the baseline covariates between the 2 procedure groups was assessed by calculating standardized differences separately for each of the covariates included in the PS model (18). The standardized difference for a continuous covariate is defined as the absolute difference in procedure group means divided by an estimate of the pooled SD. The derivation is similar for nominal covariates. The standardized difference has the advantage of not depending on the unit of measurement and not being influenced by the sample size. It has been suggested that a standardized difference of <0.10 denotes negligible imbalance between groups.

Results

After all exclusions, the final cohort for this study included 512 patients in the 3 groups: 174 who underwent MMC, 237 who underwent ASC, and 101 who underwent RSC. The most common reasons for exclusion were concomitant hysterectomy, use of biologic mesh, excision of previously implanted vaginal mesh, or, for sacrocolpopexy, if the procedure were modified in a significant way (eg, mesh extended laterally to pelvic side walls). The baseline characteristics and selection factors have been extensively described in a previous publication (8).

To summarize, we had found that MMC tended to be selected for advanced anterior vaginal prolapse and for the presence of baseline characteristics, such as older age, that increased surgical risk. ASC was more frequently selected for advanced apical prolapse, and ASC or RSC was more often selected for recurrent prolapse, for suspected abdominal pathologic processes, and for patients with chronic pain or lifestyles including heavy lifting. Key baseline characteristics are shown in Table 1.

In our propensity analysis, for each of the 3 comparisons, the distributions of PS values for the 2 procedure groups are depicted in Figure 1, on the basis of the original cohort.

Covariate imbalance between the 2 procedure groups is apparent when the histograms do not overlap for procedure A and procedure B. Figure 2 shows the standardized difference for each baseline covariate within the original cohort, the IPW cohort, and a 1:1 matched cohort, separately for each of the 3 comparisons. For the MMC vs ASC comparison, nearly all of the standardized differences were below the recommended threshold of 0.10 for the IPW and matched cohorts, with the exception of residual imbalance for age and ASA score. Given the observed overlap in the PS distributions for RSC vs ASC (middle panel, Figure 1), most of the standardized differences were below the 0.10 threshold in the original cohort, with only some residual imbalance for ASA score in the matched cohort (middle panel, Figure 2). For the RSC vs MMC comparison, neither the IPW approach nor the matched approach yielded acceptable covariate balance across all assessed covariates. Although the covariate balance in general was comparable for the 2 statistical approaches using PSs for all 3 comparisons, covariate adjustment was performed using the IPW approach since each of the matched cohorts had nearly one-third of the sample size and therefore less statistical power.

Tables 2, 3, and 4 present the pairwise comparisons of outcomes for the 3 groups in the original and IPW cohorts. All subsequent results presented are based on the IPW cohort. Median operative time was significantly shorter for the MMC group than for either the ASC or RSC group (both $P<.001$). The median estimated blood loss was significantly less in the RSC group than the other 2 groups (100 vs 200 mL; $P<.001$), although the change in hemoglobin value did not significantly differ among any of the groups. The median hospital length of stay was significantly different between each of the 3 groups, from 1 (RSC) to 2 (MMC) to 3 days (ASC) (all $P<.001$). The median cost of hospitalization was nearly \$4,000 less for the MMC group than for either the ASC or RSC group ($P<.001$).

The overall rate of intraoperative complications was significantly different between the 3 groups ($P<.01$) and was highest in the RSC group, followed by ASC and MMC (Tables 2-4). The incidence of cystotomy was greatest in the RSC group, followed by ASC and MMC, but these differences were not statistically significant. The incidence of vaginotomy was higher in the RSC group than the ASC group (IPW, 10% vs 3.9%; $P=.05$). Six of the RSC cases (5.9%) were converted to laparotomy.

Thirty-six patients lacked postoperative follow-up at 9 weeks. The proportion of patients with postoperative Clavien-Dindo grade II+ complications (including urinary tract infection [UTI]) was significantly greater in the MMC group than the RSC group (IPW, 37.0% vs 23.4%; $P=.04$) (Table 4). The overall rate of grade III+ complications (requiring some type of procedural intervention) was, however, increased among the RSC compared with the MMC group (IPW, 9.4% vs 1.1%; $P=.008$). Among the grade II or higher postoperative complications, wound complications occurred more frequently among ASC and RSC patients than MMC patients (ASC vs MMC, $P=.02$; RSC vs MMC, $P=.06$). Granulation tissue, a grade I complication, made up 92% of all wound complications in the MMC group. Grade II UTIs, in contrast, were significantly more common in the MMC group than in the ASC or RSC group (MMC vs ASC, $P=.02$; MMC vs RSC, $P<.001$). Grade II or higher gastrointestinal tract complications, including ileus and small bowel obstruction, were rare, with less than 2% in the ASC group. Hematologic, electrolyte, cardiopulmonary, neurologic,

and endocrine complications were infrequent overall and were not significantly different between groups (data not shown). No deaths occurred within 9 weeks postoperatively.

Reoperation rates involving the urinary tract (eg, sling placement or tightening, sling or Burch lysis, ureteral stent, or ureterolysis) for the 476 patients with postoperative follow-up within 9 weeks after surgery were 1.2% (2/164) for MMC, 3.2% (7/218) for ASC, and 3.2% (3/94) for RSC. Overall reoperations for indications of bleeding, abscess, bowel obstruction, leak, or mesh or wound complications were 1.2% (2/164) for MMC, 2.3% (5/218) for ASC, and 5.3% (5/94) for RSC. One patient in the ASC group and 1 patient in the RSC group required nonapical reoperation for either vaginal tightening or loosening within the 9-week follow-up period.

Discussion

Patients who underwent MMC had the lowest overall rate of intraoperative complications, followed by those with ASC and, finally, RSC, in both the unadjusted and IPW analyses. In addition, we found that operative time, non-UTI perioperative morbidity, and cost of hospitalization to patients were lower in the MMC group than either the ASC or RSC group. However, RSC was associated with shorter hospitalization. These findings were similar to those of a systematic review in which another transvaginal approach, sacrospinous ligament fixation, was associated with shorter operative time, shorter recovery, and lower inpatient cost compared with ASC (19).

Intraoperative complication rates in our MMC cohort were similar to those described in a large case series by Webb et al (20) of patients undergoing MMC for primary posthysterectomy prolapse repair. In that series, the rate of incidental entry into the bladder or rectum was 2.3% (20), the same as the rate of incidental entry into the bladder in our study. The postoperative grade II+ complication rates were significantly higher in the MMC group than in the RSC group, partly resulting from the high rate of UTI among the MMC patients. We also found no significant difference in change in hemoglobin value in this cohort.

To our knowledge, comparisons of hospital costs to patients for MMC vs ASC or RSC have not previously been conducted. However, we found that the MMC transvaginal route is less expensive than ASC, which, in turn, is less expensive than RSC. Similarly, Barber and Maher (21) found that ASC was less costly than RSC.

Strengths and Limitations

Strengths of our study include the large sample size and the attempt to mitigate selection bias by using PSs to lessen the covariate imbalance between the procedure groups. The streamlined cohort of only patients with posthysterectomy prolapse (as opposed to uterovaginal prolapse) augments internal validity. Additionally, the overall large proportion of patients with prior prolapse surgeries increases generalizability to surgeons considering MMC for recurrent prolapse. MMC, like other transvaginal vault prolapse repairs, is frequently performed for primary prolapse, but it is not commonly used for recurrent

prolapse in other centers (22). Finally, many perioperative outcomes were tracked, including de novo or worsened voiding dysfunction.

Limitations of our study are its retrospective design and lack of a conventional laparoscopic comparison cohort. Of a wide variety of transvaginal procedures commonly performed for posthysterectomy apical vaginal prolapse (eg, uterosacral ligament suspension, sacrospinous ligament fixation, colpocleisis), the only transvaginal procedure for this indication routinely performed at our institution, and therefore included, was MMC (a type of high uterosacral ligament suspension); this thereby limits the generalizability of our results. The complications were retrospectively abstracted; it is possible that patients sought care for complications at different facilities, which may not have been captured. In addition, 36 patients did not have postoperative follow-up. We acknowledge that the study may have been underpowered to detect all differences. Complications in the RSC cohort may have been time dependent, because most occurred during the learning curve phase of robotic surgery (23).

Another limitation is that the PS analysis only addresses the imbalance of the measured covariates; for example, more frequent selection of a procedure such as MMC based on patient desire to avoid a transabdominal surgery could not be accounted for, based on PS analysis. Considerable covariate imbalance also was still present for the RSC vs MMC comparison. This implies that the inability to fully account for selection bias in this comparison could yield a type 1 error, or false-positive result. Finally, cost perspectives and methods differ. Our cost analysis was unable to account for hospital medical equipment costs, such as purchase and maintenance of the robotic system. We also could not account for long-term costs to the patient, nor could we account for long-term societal costs.

Conclusion

In the treatment of posthysterectomy vaginal vault prolapse, we found, after accounting for selection bias, that MMC is associated with decreased operative time, non- perioperative morbidity, and cost compared with sacrocolpopexy. Future studies, if unable to be randomized, should aim to account for selection bias and investigate outcomes beyond the perioperative period, such as comparative outcomes regarding quality of life and time to retreatment.

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Abbreviations

ASA	American Society of Anesthesiologists
ASC	open abdominal sacrocolpopexy
IPW	inverse-probability-weighted
MMC	Mayo-McCall culdoplasty
PS	propensity score
RSC	transabdominal robotic sacrocolpopexy
UTI	urinary tract infection

Figure 1.

Distribution of Propensity Score (PS) Values. PS values were derived separately for each of the 3 comparisons: Mayo-McCall culdoplasty (MMC) vs open abdominal sacrocolpopexy (ASC), robotic sacrocolpopexy (RSC) vs ASC, and RSC vs MMC. For each comparison, the PS for each patient is the estimated conditional probability of having procedure A (vs procedure B), given a patient's baseline covariates included in the logistic regression model.

Figure 2.

Summary of the Standardized Difference for Each Covariate in the Original Cohort, the Inverse-Probability-Weighted (IPW) Cohort, and a 1:1 Matched Cohort. Standardized differences were calculated separately for each of the 3 comparisons: Mayo-McCall culdoplasty (MMC) vs open abdominal sacrocolpopexy (ASC), robotic sacrocolpopexy (RSC) vs ASC, and RSC vs MMC. The mean (SD) distribution of the stabilized weights for the 3 comparisons were: 1.00 (0.53) for MMC vs ASC (range, 0.52-2.92), 1.00 (0.23) for RSC vs ASC (range, 0.50-2.03), and 1.00 (0.54) for RSC vs MMC (range, 0.57-2.75). The 1:1 matched cohorts consist of 76 matched pairs for MMC vs ASC, 66 matched pairs for RSC vs ASC, and 34 matched pairs for RSC vs MMC.

Table 1

Summary of Baseline Characteristics

Characteristic	Surgical Group ^a			P Value ^b		
	MMC (n=174)	ASC (n=237)	RSC (n=101)	Overall	MMC vs ASC	MMC vs RSC
Age at surgery, y	68.9 (10.4)	60.4 (10.2)	59.9 (9.3)	<.001	<.001	<.001
Race, white	159 (99.4) (n=160)	221 (98.7) (n=224)	99 (99.0) (n=100)	.79		
BMI, kg/m ²	28.0 (4.8)	27.9 (4.8)	27.4 (4.3)	.55		
Ever smoker	109 (63.0) (n=173)	157 (68.0) (n=231)	69 (68.3)	.52		
Nulliparous	4 (2.3)	9 (3.8) (n=236)	3 (3.0)	.68		
No. of vaginal deliveries	3 (2-4)	3 (2-4)	3 (2-4)	.41		
Charlson Comorbidity Index				.11		
0	96 (55.2)	152 (64.1)	61 (60.4)			
1	53 (30.5)	66 (27.8)	32 (31.7)			
2+	25 (14.4)	19 (8.0)	8 (7.9)			
ASA classification				<.001	.001	<.001
1	5 (2.9)	8 (3.5)	6 (5.9)			
2	123 (71.9)	194 (84.7)	86 (85.1)			
3+	43 (25.1)	27 (11.8)	9 (8.9)			
No. of prior prolapse surgeries				<.001	<.001	<.001
0	101 (58.0)	72 (30.4)	35 (34.7)			
1	62 (35.6)	122 (51.5)	44 (43.6)			
2	8 (4.6)	36 (15.2)	20 (19.8)			
3	1 (0.6)	5 (2.1)	2 (2.0)			
4+	2 (1.1)	2 (0.8)	0 (0.0)			
Prior vaginal surgeries for prolapse	62 (35.6)	149 (62.9)	62 (61.4)	<.001	<.001	<.001
Prior abdominal surgeries for prolapse	10 (5.7)	27 (11.4)	10 (9.9)	.14		
Prior hysterectomy for indication of prolapse	9 (5.2)	23 (9.7)	8 (7.9)	.24		
No. of prior incontinence surgeries				.04	.17	.01
						.13

Characteristic	Surgical Group ^a				P Value ^b		
	MMC (n=174)	ASC (n=237)	RSC (n=101)	Overall	MMC vs ASC	MMC vs RSC	ASC vs RSC
0	138 (79.3)	175 (73.8)	66 (65.3)				
1	32 (18.4)	51 (21.5)	30 (29.7)				
2	4 (2.3)	8 (3.4)	4 (4.0)				
3+	0 (0.0)	3 (1.3)	1 (1.0)				
Prior MMK	6 (3.4)	18 (7.6)	4 (4.0)	.14			
Prior Burch procedure	6 (3.4)	15 (6.3)	6 (5.9)	.41			
Prior sling placement	15 (8.6)	20 (8.4)	25 (24.8)	<.001	.94	<.001	<.001
No. of prior transabdominal surgeries				.67			
0	34 (19.5)	46 (19.4)	19 (18.8)				
1	56 (32.2)	90 (38.0)	38 (37.6)				
2	48 (27.6)	55 (23.2)	30 (29.7)				
3+	36 (20.7)	46 (19.4)	14 (13.9)				
Recurrent UTIs	7 (4.0)	14 (5.9)	3 (3.0)	.44			
Chronic pain	6 (3.4)	36 (15.2)	12 (11.9)	<.001	<.001	.006	.43
Apical grade	(n=168)	(n=224)	(n=98)	<.001	.003	.18	<.001
1	22 (13.1)	29 (12.9)	17 (17.3)				
2	93 (55.4)	80 (35.7)	56 (57.1)				
3	38 (22.6)	90 (40.2)	20 (20.4)				
4	15 (8.9)	25 (11.2)	5 (5.1)				
Apical grade 3 or 4	53 (31.6)	115 (51.3)	25 (25.5)	<.001	<.001	.29	<.001
Anterior prolapse grade	(n=166)	(n=202)	(n=95)	.001	<.001	.007	.78
0	8 (4.8)	28 (13.9)	6 (6.3)				
1	21 (12.7)	22 (10.9)	14 (14.7)				
2	43 (25.9)	73 (36.1)	39 (41.1)				
3	75 (45.2)	66 (32.7)	32 (33.7)				
4	19 (11.5)	13 (6.4)	4 (4.2)				
Anterior prolapse grade 3 or 4	94 (56.6)	79 (39.1)	36 (37.9)	.001	<.001	.004	.84
Posterior prolapse grade	(n=169)	(n=206)	(n=91)	.06			
0	9 (5.3)	30 (14.6)	8 (8.8)				

Characteristic	Surgical Group ^a				P Value ^b		
	MMC (n=174)	ASC (n=237)	RSC (n=101)	Overall	MMC vs ASC	MMC vs RSC	ASC vs RSC
1	29 (17.2)	35 (17.0)	18 (19.8)				
2	73 (43.2)	67 (32.5)	49 (53.8)				
3	44 (26.0)	61 (29.6)	13 (14.3)				
4	14 (8.3)	13 (6.3)	391 (3.3)				

Abbreviations: ±, with or without; ASA, American Society of Anesthesiologists; ASC, open abdominal sacrocolpopexy; BMI, body mass index; MMK, Marshall-Marchetti-Krantz operation; MMC, Mayo-McCall culdoplasty; RSC, transabdominal robotic sacrocolpopexy; UTI, urinary tract infection.

^aValues are mean (SD), No. of patients (%), or median (interquartile range).

^bComparisons among the 3 procedures were evaluated using the χ^2 test for categorical (nonordered) variables, the F-test from a 1-way analysis of variance model for age and BMI, and the Kruskal-Wallis test for all other ordinal variables. If the Pvalue was <.05 for the overall test, then pairwise comparisons were evaluated using the χ^2 test, 2-sample t test, or Wilcoxon rank sum test, as appropriate.

Adapted from Anand et al (8). Used with permission.

Table 2
Comparison of Intraoperative Variables, Length of Hospital Stay, and Cost Among Patients Undergoing MMC vs ASC, January 1, 2000, to June 30, 2012

Variable	Original Cohort ^a			IPW Cohort ^b		
	MMC (n=174)	ASC (n=237)	P ^c	MMC	ASC	P ^c
Operative time, min	98 (76, 121)	215 (167, 252)	<.001	94 (76, 117)	217 (168, 251)	<.001
Estimated blood loss, mL	200 (150, 300)	200 (125, 300)	.17	200 (150, 300)	200 (150, 250)	.64
Change (postop–preop) in hemoglobin, mg/dL	–2.3 (–2.8, –1.7)	–2.3 (–2.9, –1.8)	.84	–2.3 (–2.9, –1.7)	–2.3 (–2.9, –1.8)	.57
Change (postop–preop) in creatinine, mg/dL	–0.1 (–0.2, 0)	–0.1 (–0.1, 0)	.06	–0.1 (–0.2, 0)	–0.1 (–0.1, 0)	.04
Any intraop complication	4.6% (8/174)	11.8% (28/237)	.01	3.3%	11.6%	.002
Vaginotomy	NA	3.8% (9/237)	...	NA	3.7%	...
Unintentional cystotomy	2.3% (4/174)	3.0% (7/237)	.68	1.4%	2.9%	.30
Any postop grade II+ complication ^d	37.8% (62/164)	35.3% (77/218)	.62	34.8%	35.0%	.97
Urinary tract infection	24.4% (40/164)	11.9% (26/218)	.001	22.1%	13.2%	.02
Ileus or small bowel obstruction	0% (0/164)	1.4% (4/218)	.13	0%	1.7%	.10
Any grade wound complication	43.9% (72 ^e /164)	22.0% (48 ^f /218)	<.001	42.6%	20.9%	<.001
Any intraop or postop grade II+ complication	40.8% (67/164)	42.2% (92/218)	.79	36.8%	41.6%	.34
Any intraop or postop grade II+ complication (excluding UTI)	22.6% (37/164)	34.9% (76/218)	.009	20.9%	32.6%	.01
Any postop grade III+ complication ^d	2.4% (4/164)	6.0% (13/218)	.10	3.0%	5.2%	.30
Length of hospitalization, d	2 (2, 3)	3 (3, 3)	<.001	2 (2, 3)	3 (3, 3)	<.001
Total cost of hospitalization (in 2013 dollars) ^g	\$8,985 (\$8,072, \$10,118)	\$12,573 (\$11,247, \$13,933)	<.001	\$8,776 (\$7,928, \$9,834)	\$12,695 (\$11,397, \$14,079)	<.001

Abbreviations: ASC, open abdominal sacrocolpopexy; intraop, intraoperative; IPW, inverse-probability–weighted; MMC, Mayo-McCall culdoplasty; NA, not applicable; postop, postoperative; preop, preoperative; UTI, urinary tract infection.

^aValues are median (25th and 75th percentiles) for continuous variables and percentage (No. with variable/No. available) for categorical variables.

^bValues are weighted median (weighted 25th and 75th percentiles) for continuous variables and weighted percentage for categorical variables.

^cNominal variables were compared between the 2 procedure groups using the χ^2 test. All other variables were compared with the Wilcoxon rank sum test in the original cohort and a weighted least-squares regression in the weighted cohort after applying a logarithmic transformation to operative time, estimated blood loss, length of hospitalization, and total costs.

^dSome patients lacked necessary information on postoperative complications within the first 9 weeks after surgery.

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^eWound complications included granulation tissue (n=66), vaginitis (n=1), secondary intention (n=1), infection (n=3), hematoma (n=1), and hernia (n=1). Some patients had more than 1 wound complication.

^fWound complications included granulation tissue (n=20), vaginitis (n=11), infection (n=5), hematoma (n=1), seroma (n=10), mesh erosion (n=3), hernia (n=1), and fascial dehiscence (n=1). Some patients had more than 1 wound complication.

^gCosts were only available for procedures that occurred after January 1, 2003 (152 MMC and 207 ASC).

Table 3
Comparison of Intraoperative Variables, Length of Hospital Stay, and Cost Among Patients Undergoing RSC vs ASC, February 1, 2007, to June 30, 2012

Variable	Original Cohort ^a			IPW Cohort ^b		
	RSC (n=101)	ASC (n=153)	P ^c	RSC	ASC	P ^c
Operative time, min	228 (185, 285)	222 (189, 253)	.19	233 (185, 285)	221 (179, 252)	.02
Estimated blood loss, mL	100 (88, 200)	200 (150, 300)	<.001	100 (75, 200)	200 (150, 300)	<.001
Change (postop–preop) in hemoglobin, mg/dL	−2.0 (−2.6, −0.15)	−2.2 (−2.7, −1.8)	.09	−2.0 (−2.6, −1.5)	−2.2 (−2.7, −1.7)	.13
Change (postop–preop) in creatinine, mg/dL	−0.1 (−0.2, 0)	−0.1 (−0.1, 0)	.08	−0.1 (−0.2, 0)	−0.1 (−0.1, 0)	.02
Any intraop complication	23.8% (24/101)	12.4% (19/153)	.02	24.4%	11.6%	.007
Vaginotomy	9.9% (10/101)	3.9% (6/153)	.05	10.0%	3.9%	.05
Unintentional cystotomy	6.9% (7/101)	3.9% (6/153)	.29	7.7%	3.6%	.15
Any postop grade II+ complication ^d	26.6% (25/94)	36.7% (54/147)	.10	28.6%	37.7%	.15
Urinary tract infection	7.4% (7/94)	12.2% (18/147)	.23	7.3%	13.3%	.14
Ileus or small bowel obstruction	0% (0/94)	1.4% (2/147)	.26	0%	2.2%	.15
Any grade wound complication	20.2% (19 ^e /94)	23.1% (34 ^f /147)	.59	21.9%	22.4%	.92
Mesh erosion	2.1% (2/94)	1.4% (2/147)	.65	2.1%	1.4%	.66
Any intraop or postop grade II+ complication	42.1% (40/95 ^g)	42.9% (63/147)	.91	44.0%	43.5%	.94
Any intraop or postop grade II+ complication (excluding UTI)	41.1% (39/95 ^g)	34.7% (51/147)	.32	43.0%	34.3%	.17
Any postop grade III+ complication ^d	9.6% (9/94)	7.5% (11/147)	.57	9.8%	6.4%	.34
Length of hospitalization, d	1 (1, 2)	3 (2, 3)	<.001	1 (1, 2)	3 (2, 3)	<.001
Total cost of hospitalization (in 2013 dollars)	\$12,859 (\$11,997, \$14,575)	\$12,680 (\$11,371, \$13,880)	.11	\$13,035 (\$11,997, \$14,663)	\$12,654 (\$11,334, \$13,768)	.13

Abbreviations: ASC, open abdominal sacrocolpopexy; intraop, intraoperative; IPW, inverse-probability–weighted; postop, postoperative; preop, preoperative; RSC, robotic sacrocolpopexy; UTI, urinary tract infection.

^aValues are median (25th and 75th percentiles) for continuous variables and percentage (No. with variable/No. available) for categorical variables.

^bValues are weighted median (weighted 25th and 75th percentiles) for continuous variables and weighted percentage for categorical variables.

^cNominal variables were compared between the 2 procedure groups using the χ^2 test. All other variables were compared with the Wilcoxon rank sum test in the original cohort and a weighted least-squares regression in the weighted cohort after applying a logarithmic transformation to operative time, estimated blood loss, length of hospitalization, and total costs.

^dSome patients lacked necessary information on postoperative complications within the first 9 weeks after surgery.

^eWound complications included granulation tissue (n=5), vaginitis (n=2), secondary intention (n=2), infection (n=2), seroma (n=4), mesh erosion (n=2), and hernia (n=1). Some patients had more than 1 wound complication.

^fWound complications included granulation tissue (n=14), vaginitis (n=7), infection (n=3), hematoma (n=1), seroma (n=7), mesh erosion (n=2), hernia (n=1), and fascial dehiscence (n=1). Some patients had more than 1 wound complication.

^gThe denominator is 95 because 1 of the patients without information on postoperative complications had an intraoperative complication.

Table 4

Comparison of Intraoperative Variables, Length of Hospital Stay, and Cost Among Patients Undergoing RSC vs MMC, February 1, 2007, to June 30, 2012

Variable	Original Cohort ^a			IPW Cohort ^b		
	RSC (n=101)	MMC (n=109)	P ^c	RSC	MMC	P ^c
Operative time, min	228 (185, 285)	101 (82, 123)	<.001	228 (183, 288)	100 (80, 120)	<.001
Estimated blood loss, mL	100 (88, 200)	200 (150, 300)	<.001	100 (100, 200)	200 (150, 300)	<.001
Change (postop–preop) in hemoglobin, mg/dL	–2.0 (–2.6, –0.15)	–2.2 (–2.7, –1.5)	.25	–1.9 (–2.6, –1.5)	–2.0 (–2.7, –1.5)	.49
Change (postop–preop) in creatinine, mg/dL	–0.1 (–0.2, 0)	–0.1 (–0.2, 0)	.83	–0.1 (–0.2, 0)	–0.1 (–0.2, 0)	.68
Any intraop complication	23.8% (24/101)	4.6% (5/109)	<.001	24.1%	3.4%	<.001
Vaginotomy	9.9% (10/101)	NA	...	10.5%	NA	...
Unintentional cystostomy	6.9% (7/101)	2.8% (3/109)	.16	7.4%	1.8%	.05
Any postop grade II+ complication ^d	26.6% (25/94)	38.5% (40/104)	.08	23.4%	37.0%	.04
Urinary tract infection	7.4% (7/94)	26.9% (28/104)	<.001	7.0%	27.9%	<.001
Ileus or small bowel obstruction	0% (0/94)	0% (0/104)	...	0%	0%	...
Any grade wound complication	20.2% (19 ^e /94)	49.0% (51 ^f /104)	<.001	19.1%	51.4%	<.001
Any intraop or postop grade II+ complication	42.1% (40/95 ^g)	42.3% (44/104)	.98	39.2%	40.0%	.90
Any intraop or postop grade II+ complication (excluding UTI)	41.1% (39/95 ^g)	21.2% (22/104)	.002	37.9%	19.0%	.003
Any postop grade III+ complication ^d	9.6% (9/94)	1.0% (1/104)	.006	9.4%	1.1%	.008
Length of hospitalization, d	1 (1, 2)	2 (2, 3)	<.001	1 (1, 2)	2 (1, 3)	.003
Total cost of hospitalization (in 2013 dollars)	\$12,859 (\$11,997, \$14,575)	\$8,879 (\$7,967, \$10,124)	<.001	\$13,107 (\$12,119, \$14,663)	\$8,773 (\$7,967, \$9,719)	<.001

Abbreviations: intraop, intraoperative; IPW, inverse-probability–weighted; MMC, Mayo-McCall culdoplasty; NA, not applicable; postop, postoperative; preop, preoperative; RSC, robotic sacrocolpopexy; UTI, urinary tract infection.

^aValues are median (25th and 75th percentiles) for continuous variables and percentage (No. with variable/No. available) for categorical variables.

^bValues are weighted median (weighted 25th and 75th percentiles) for continuous variables and weighted percentage for categorical variables.

^cNominal variables were compared between the 2 procedure groups using the χ^2 test. All other variables were compared with the Wilcoxon rank sum test in the original cohort and a weighted least-squares regression in the weighted cohort after applying a logarithmic transformation to operative time, estimated blood loss, length of hospitalization, and total costs.

^dSome patients lacked necessary information on postoperative complications within the first 9 weeks after surgery.

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^eWound complications included granulation tissue (n=5), vaginitis (n=2), secondary intention (n=2), mesh erosion (n=2), and hernia (n=1). Some patients had more than 1 wound complication.

^fWound complications included granulation tissue (n=48), vaginitis (n=1), secondary intention (n=1), infection (n=1), and hematoma (n=1). Some patients had more than 1 wound complication.

^gThe denominator is 95 because 1 of the patients without information on postoperative complications had an intraoperative complication.