Risk factors of lower urinary tract injury with laparoscopic sacrocolpopexy

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BACKGROUND: Lower urinary tract injuries can occur during pelvic reconstructive surgery, including sacrocolpopexy. The reported injury rates range from 0.4% to 10.6% with laparoscopic sacrocolpopexy, 1.1% to 3.3% with abdominal sacrocolpopexy, and 2.3% to 10% with robotic sacrocolpopexy. Specific literature identifying the risk factors for lower urinary tract injury during pelvic reconstructive surgery is lacking; therefore, we aim to identify the patient characteristics predisposing a patient to lower urinary tract injury during laparoscopic sacrocolpopexy.

OBJECTIVE: The primary objective of this study was to identify the patient-specific risk factors for lower urinary tract injury with laparoscopic sacrocolpopexy.

STUDY DESIGN: This was an age-matched, case-control study including patients who underwent laparoscopic sacrocolpopexy from July 2014 to December 2017 in a high-volume female pelvic medicine and reconstructive surgery practice. The patients were excluded if they underwent laparoscopic uterosacral ligament suspension, had abnormal uterine tract anatomy, or if incorrect, incomplete, or duplicated data. Risk factors such as race, body mass index, pelvic organ prolapse quantification stage, previous abdominal and/or vaginal surgeries, and concurrent procedures (lysis of adhesions, adnexal surgery, midurethral sling placement, and anterior or posterior colporrhaphy) were analyzed. Groups were compared using the Student t-test for independent samples and chi-square tests. Conditional logistic regression was used to estimate the crude and adjusted odds ratios.

RESULTS: A total of 930 patients were identified during electronic medical record chart review using the current procedural terminology code 57425 (laparoscopic colpopexy). A total of 167 patients met the exclusion criteria, resulting in a total of 763 patients for primary analysis. The prevalence of lower urinary tract injury was 2.4% (17 bladder injuries and 1 ureteral injury out of 763 laparoscopic sacrocolpopexy procedures). These 18 cases were age-matched to 72 controls. The mean age and body mass index of all patients was 64.8 years (±9.32) and 26.5 kg/m² (±3.99), respectively. Most of the patients were Caucasian, had previously undergone abdominal and/or vaginal surgery, had pelvic organ prolapse stage 3 or greater, and underwent concurrent surgeries, including adnexal surgery and midurethral sling placement at the time of laparoscopic sacrocolpopexy. A history of previous hysterectomy (odds ratio, 19.94; 95% confidence interval, 2.48−160.38; P= .005) and lysis of adhesions at the time of laparoscopic sacrocolpopexy (odds ratio, 4.94; 95% confidence interval, 1.05−23.19; P=.043) were associated with an increased odds of lower urinary tract injury in unadjusted models. In a multivariable logistic regression model controlling for the previously listed variables, a history of previous hysterectomy remained significantly associated with lower urinary tract injury (adjusted odds ratio, 162.41; 95% confidence interval, 3.21−8227; P=.011). Race, body mass index, pelvic organ prolapse quantification system stage, previous abdominal and/or vaginal surgery, and concurrent procedures were not associated with an increased risk of lower urinary tract injury.

CONCLUSION: Although lower urinary tract injury with laparoscopic sacrocolpopexy only occurred in 2.4% of patients, previous hysterectomy increased this risk substantially. As sacrocolpopexy is the common treatment for prolapse after hysterectomy or recurrent prolapse, this increased risk of lower urinary tract injuries can guide surgical counseling on the basis of patient-specific risk factors and aid in setting appropriate postoperative patient expectations.

Key words: cystotomy, laparoscopy, pelvic organ prolapse, reconstructive surgery, sacrocolpopexy, surgical complications, ureteral injury

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Introduction
Approximately 300,000 surgical procedures are performed every year for the treatment of symptomatic pelvic organ prolapse. Abdominal sacrocolpopexy (ASCP) is a mesh-based approach, which demonstrates superior anatomic outcomes than native tissue vaginal apical suspension procedures. Minimally invasive options such as laparoscopic sacrocolpopexy (LSCP) or robotic-assisted laparoscopic sacrocolpopexy (RSCP) have become more common and preferable to the open method because of decreased surgical morbidity, faster recovery time, and similar surgical success rates.

Lower urinary tract (LUT) injuries can occur with any route of sacrocolpopexy (SCP), with variable rates on the basis of the surgical approach. The reported LUT injury rates range from 1.1% to 3.3% with ASCP, 0.4% to 10.6% with LSCP, and 2.3% to 10% with RSCP. Although uncommon, LUT injuries, particularly when unrecognized, can cause significant morbidity, including ureteral obstruction, stricture, urinary tract fistulas, need for nephrostomy tube placement, acute renal insufficiency, and sepsis. Sound anatomic knowledge and meticulous surgical technique remain essential to minimize the risk of LUT injury.

The reported patient-specific risk factors that increase the risk of LUT injury during hysterectomy are because of distortion of the anatomy and natural tissue planes. These include obesity, urinary tract abnormalities, previous abdominal and/or vaginal surgery, endometriosis, and a history of pelvic irradiation. These factors likely increase the risk of LUT injury during other pelvic surgeries, but specific literature identifying these characteristics during pelvic reconstructive surgery is lacking. The objective of this retrospective case-control study is to identify the patient-specific risk factors for LUT injury, specifically during LSCP.

Materials and Methods
This was an age-matched case-control study including patients who underwent LSCP in a high-volume female pelvic medicine and reconstructive surgery (FPMRS) practice. This analysis was reviewed by the Inova Institutional Review Board and was designated as exempt (protocol ID U19-02-3434). All the patients who were assigned a surgical current procedural terminology (CPT) code 57425 (laparoscopic colpopexy) from July 2014 to December 2017 were initially included, and then charts were individually reviewed by the investigators to confirm that a conventional laparoscopic mesh sacrocolpopexy was performed. There were no RSCPs performed during the studied time frame.

The patients who were assigned a surgery with delayed LUT injury were included whereas the controls did not; patients with delayed LUT injury were included in the cases. The cases and controls were matched on the basis of age using the MatchIt procedure nearest neighbor method, and all the cases were matched without replacement to exactly 4 controls with age within 1 year of the cases’ age. The records were then reviewed retrospectively for demographic information, race, body mass index (BMI), pelvic organ prolapse quantification (POP-Q) stage, post-hysterectomy state, previous abdominal and/or vaginal surgery, and concurrent procedures (lysis of adhesions, adnexal surgery, midurethral sling placement, and anterior or posterior colporrhaphy). All the surgeries were performed by 3 FPMRS-trained surgeons, with a similar surgical technique for LSCP. Abdominal access was obtained with 4 abdominal incisions: 3 5-mm ports (umbilicus, superior to the left anterior superior iliac spine (ASIS), and 2 centimeters above and medial to the right ASIS) and a 12-mm port midway between the umbilical and left lower quadrant port site in a semilunar fashion. For the patients undergoing hysterectomy, this was first performed either as a supracervical hysterectomy with imbrication of the cervical stump, or as a total hysterectomy with vaginal or laparoscopic closure of the vaginal cuff. The LSCP started with a sharp dissection of the vesicovaginal and rectovaginal spaces with the distension of the vaginal spaces using a rounded end-to-end anastomosis sizer. Laparoscopic dissection of the vesicovaginal plane was performed using a combination of blunt and sharp dissection with and...
without electrosurgery. This dissection was typically carried caudally to approximately 1 to 1.5 cm cephalad of the intertrigonal ridge. The rectovaginal space was similarly dissected caudally as close to the perineal body as possible, taking care to avoid rectal injury. The surgeons used 2 separate leaflets of a type 1 polypropylene mesh, which were attached to the anterior and posterior vagina using interrupted permanent or absorbable monofilament sutures. The peritoneum overlying the sacral promontory was then incised and the presacral space developed to visualize the anterior longitudinal ligament to the level of S1 to S2. The anterior and posterior mesh leaflets were then separately tensioned and secured to the anterior longitudinal ligament using a permanent suture. The mesh was then reperitonealized using an absorbable monofilament suture. Concurrent vaginal procedures such as anterior colporrhaphy, posterior colporrhaphy, and sling procedures were performed after the sacrocolpopexy.

The primary outcome was identification of the patient-specific risk factors for LUT injury in LSCP. The characteristics of the cases and controls were described using the mean and standard deviation for continuous variables and frequency or percent for categorical variables. Chi-square tests were used to compare the proportions between the groups, and the Students t-test was used for continuous data. Conditional logistic regression was used to estimate the crude and adjusted odds ratios. All the regression models were conditioned on the matching variable. The model for adjusted odds ratios included all the variables listed in Table 1. Analyses were performed using SPSS version 25 for Windows (IBM Corp, Armonk, NY) and STATA 15.1 (StataCorp, College Station, TX). The P values of <.05 were considered statistically significant.

Results
A total of 930 patients were identified using the CPT code 57425 (laparoscopic colpopexy) between July 2014 and December 2017 (Figure). Of the 167 patients who met the exclusion criteria, resulting in a total of 763 patients for primary analysis. There were 18 LUT injuries out of a total of 763 LSCP procedures, establishing a prevalence of 2.4%. Out of these injuries, there were 17 bladder injuries and 1 ureteral injury. These 18 cases were age-matched to 72 controls. Table 2 displays the patient characteristics. The mean age and the BMI of all patients was 64.8 years (±9.32) and 26.5 kg/m² (±3.99), respectively. Most of the patients were Caucasian, had previously undergone abdominal and/or vaginal surgery, had POP-Q stage 3 or greater, and underwent concurrent adnexal surgery and midurethral sling placement at the time of LSCP (Table 2). Of note, with further classification of “previous surgery” into “upper abdominal” (eg, cholecystectomy, Nissen fundoplication) vs “pelvic” surgery (eg, hysterectomy, myomectomy, cesarean delivery, appendectomy), only 1 of the 18 cases and 1 of the 72 controls who were included in the “previous surgery” category underwent upper abdominal surgery without pelvic surgery; therefore, the categorization of “previous surgery” in this study can be viewed as previous pelvic surgery. In addition, of the 8 patients who underwent adhesiolysis (4 cases and 4 controls), all had dense adhesions of the bladder to the uterus or the vaginal cuff, with only 1 case with additional intestinal involvement.

A greater proportion of cases had previously undergone hysterectomy (66.7% cases vs 25.0% controls) and had lysis of adhesions at the time of LSCP (22.2% cases vs 5.6% controls). A greater percentage of controls had concurrent posterior colporrhaphy (44.4% cases vs 73.2% controls).

All but 1 LUT injury was identified intraoperatively, with 16 patients sustaining a cystotomy at the time of vesicovaginal dissection. In all but 1 of the 16 patients with cystotomy, the injury occurred at the dome of the bladder. A similar approach to the cystotomy repair was performed for these patients.
using multiple layers of an absorbable braided suture in either interrupted or running fashion. The integrity of the repair was tested with intraoperative distension to ensure a water-tight closure, and the transurethral catheter was left in place between 1 and 7 days. There was a single cystotomy that was because of the placement of a retropubic midurethral sling after LSCP, with the deferral of the repeat trocar passage and sling placement; this did not require repair as it was hemostatic in nature.

For inclusiveness, all LUT injuries that occurred in conjunction with the LSCP procedures were included. In our practice, all vaginal procedures such as anterior and posterior colporrhaphy and sling placement are performed after the completion of SCP. It is possible that the SCP portion of the procedure can impact the vaginal dissection for the antiincontinence sling and ease of placement and increase the risk of LUT injury. Six out of 17 patients with cystotomy had imaging (that is, cystography or fluoroscopy) before catheter removal. No long-term sequelae were noted in these patients. The sole ureteral injury was delayed in diagnosis. After minimal ureteral spill with cystoscopy, a retrograde pyelogram demonstrated an angulated ureter; therefore, a stent was placed intraoperatively. The stent was removed 2 weeks postoperatively, and the patient developed continuous urinary leakage 3 weeks afterwards, with subsequent radiographic diagnosis of a ureterovaginal fistula. The involved ureter was stented and the fistula healed after 6 weeks. No long-term sequelae were noted in this patient after stent removal with follow-up.

Given the potential for a missed LUT injury if any patients were converted from LSCP to native tissue uterosacral ligament suspension with concern for mesh placement after cystotomy repair, a secondary analysis of these charts was performed. Of the 155 patients who underwent laparoscopic uterosacral ligament suspension, 2 had their surgical plan intraoperatively converted from sacrocolpopexy because of extensive sigmoid or rectal adhesions with an inaccessible sacrum; none were converted because of an LUT injury.

Logistic regression was performed for the following variables: BMI, race, history of previous abdominal and/or vaginal surgery, previous hysterectomy, POP-Q stage, and concurrent procedures (lysis of adhesions, adnexal surgery, midurethral sling placement, and anterior or posterior colporrhaphy) (Table 1). A history of previous hysterectomy (unadjusted odds ratio [OR], 19.94; confidence interval [CI], 2.48 –160.38; P=.005) and lysis of adhesions

![Flowchart for patient selection](image-url)
at the time of LSCP (unadjusted OR, 4.94; 95% CI, 1.05–23.19; \( P = .043 \)) were associated with an increased odds of LUT injury. The patients who underwent concurrent posterior colporrhaphy appeared to have decreased odds of LUT injury (unadjusted OR, 0.32; 95% CI, 0.11–0.88; \( P = 0.028 \)). In a multivariable logistic regression model controlling for the previously listed variables, a history of previous hysterectomy remained significantly associated with LUT injury (adjusted OR, 162.41; 95% CI, 3.21–8227; \( P =.011 \)).

### Discussion

#### Principal findings

This is one of the largest studies to date evaluating LSCP and LUT injury. The prevalence of LUT injury within our study was low: 2.23% for bladder injury and 0.13% for ureteral injury, which reflect similar rates reported in the literature.\(^1\)–\(^6\) A history of hysterectomy and lysis of adhesions at the time of LSCP were associated with increased LUT injury risk, whereas concurrent posterior colporrhaphy was associated with decreased LUT injury risk. Multivariate analysis strengthened the association between LUT injury and the post-hysterectomy state. Conversely, this analysis failed to maintain significant associations between LUT injury and adhesiolysis and posterior colporrhaphy. Race, BMI, POP-Q stage, previous abdominal and/or vaginal surgery, and other concurrent procedures (adnexal surgery, midurethral sling placement, anterior colporrhaphy) were not associated with an increased risk of LUT injury.

### Results

Similar to existing literature, we found that cystotomy occurred more commonly than ureteral injury during LSCP.\(^1\)–\(^6\) Although the rates of LUT injury during pelvic reconstructive surgery are reportedly higher with laparoscopic vs open approaches,\(^1\)–\(^6\) this study verifies the safety of a minimally invasive route for SCP with its low rate of LUT complications.

The risk factors for LUT injury during hysterectomy have been investigated; however, the specific characteristics predisposing a patient to injury during SCP are limited. In a retrospective cohort study, Saguan et al\(^{21}\) did not find an association between LUT injury during reconstructive surgery and patients with a previous pelvic surgery; however, they did report an increased risk of injury with a higher degree of prolapse. Of note, approximately 95% of the analyzed cases were performed vaginally, which has been associated with an increased risk of LUT injury when prolapse is present; this is because of the anatomic distortion of the bladder and the ureter, and particularly with uterosacral ligament suspension, as the uterosacral ligament can be as close as 1 centimeter to the ureter.\(^{18,22–24}\) In a smaller study, Dubinskaya et al\(^{25}\) found that women undergoing minimally invasive sacrocolpopexy who previously had a hysterectomy were 2.3 times more likely than women with concurrent hysterectomy to have a perioperative complication, particularly bladder injury. We report significantly higher odds of LUT injury in patients with a previous hysterectomy, with an almost 20-fold increase.

### Clinical implications

Although LUT injury during pelvic reconstructive surgery is rare, it is imperative to know the risk factors that predispose patients to these injuries to recognize and prevent LUT injury. It is crucial for the surgeon to recognize...
these injuries intraoperatively, as the complications are greater when the injury is unrecognized. Although bladder injuries are generally detected intraoperatively, 62%–87% of ureteral injuries are unrecognized. \(^1,26^-28\) In patients with unrecognized injuries compared with recognized ureteral injuries, the odds of 90-day readmission and acute renal failure are increased 24-fold, with the odds of fistula and sepsis increased 6-fold and 2-fold, respectively. \(^7,26\) These injuries are also more difficult to manage when detected postoperatively. Urine causes inflammation and compromised tissue integrity, leading to a more challenging and potentially less optimal repair. Because a synthetic mesh is used in SCP, there is concern that tissue disruption, such as with cystotomy and repair, can increase the mesh and/or suture erosion risk. Therefore, prevention of LUT injury is key by having comprehensive knowledge of the anatomy, optimizing surgical views, and employing meticulous surgical technique.

The most common locations of ureteral injury are at the pelvic brim with ligation of the infundibulo-pelvic ligament, as it courses below the uterine vessels anterolateral to the cervix, and near the ureterovesical junction with vesicovaginal dissection. The sacral promontory is a key landmark that assists in ureter identification. The right internal iliac artery averages 2.5 cm from the sacral promontory, and the sacral promontory will be an approximate 45° from the bifurcation of the right common iliac artery. The ureter, as it passes over the bifurcation of the common iliac vessels at the pelvic brim, averages 2.7 cm from the sacral promontory. \(^29\) Understanding these anatomic relationships enables the surgeon to decrease the risk of ureteral injury.

The surgeon can use several advanced surgical techniques to further reduce the risk of LUT injury. The bladder can be backfilled with various media such as sterile milk, dyed or undyed normal saline or water, and carbon dioxide. Cystoscopy with concurrent laparoscopy can be performed. Compared with the aforementioned techniques, the bladder demarcator—a rigid urethral catheter guide inside a more flexible, partially inflated Foley catheter—is utilized without bladder distension, thus not compromising the surgeon’s ability to delineate bladder planes while proceeding with laparoscopic dissection. \(^30\) In patients with anatomic distortion and difficult visualization of the ureter, ureteral stents can be inserted with or without the use of an indocyanine green dye. \(^31\) The surgeon should selectively perform ureterolysis to reduce the risk of devascularization and resultant necrosis, with the consideration of postoperative stent placement if aggressive ureterolysis is performed. \(^32,33\)

The increased LUT injury risk in patients who previously underwent hysterectomy and indicated lysis of adhesions during LSCP in our study is unsurprising. The bladder is in close proximity to the uterus and the vagina, and in cases of a previous hysterectomy, the normal anatomic landmarks and structures are absent, along with less pronounced uterosacral ligaments. The need for adhesiolysis indicates scarring, which can also distort the anatomy, leading to a more challenging dissection in close proximity to the adjacent viscera, nerves, and vasculature.

The decreased odds of LUT injury with concurrent posterior colporrhaphy was unexpected, as the need for rectovaginal dissection should not anatomically improve or worsen the risks of LUT injury. Rather, LUT injury risk would have been expected to be greater with procedures involving anterior colporrhaphy and vesicovaginal dissection, but this association was not identified. More likely, this association was because of selection bias, as more controls underwent posterior colporrhaphy than cases. It is possible that the patients who previously had a hysterectomy had undergone previous pelvic reconstructive surgery, including posterior colporrhaphy, thus obviating the need for posterior compartment repair. In addition, if LUT injury had occurred, this could have deterred the surgeon from proceeding with all planned procedures, including posterior colporrhaphy, to prevent further prolongation of the operating time. Conversely, more cases underwent concurrent lysis of adhesions than controls, which could have been another area of selection bias. This could explain why the associations between posterior colporrhaphy and adhesiolysis with LUT injury risk were no longer significant when controlling for other risk factors.

**Research implications**

Our study enables the clinician to individualize surgical counseling on the basis of patient-specific risk factors. Further research is needed to gauge patient satisfaction and the subjective short-term outcomes as a result of patient-centered counseling for pelvic reconstructive surgery. In addition, further categorization of the patient’s previous abdominal and/or vaginal surgery should be performed and correlated with LUT injury, as not all surgeries impart the same risk.

Although our study specifically investigated LUT injuries with LSCP, the robotic platform continues to gain traction in the field of FPMRS. With the expansion in technology, surgeon experience, and surgical technique, further investigation into patient outcomes and complications for this platform compared with the conventional laparoscopic approach should be pursued. This would not only provide feedback and direction for the continued advancement of surgical technique within reconstructive surgery but would also allow for improved patient counseling regarding the available minimally invasive approaches.

**Strengths and limitations**

The strengths of this study include the sizable initial cohort investigated and the age-matched case-control design. Furthermore, clearly outlined objective measures that were applicable to the clinical setting were chosen, with data spanning several years within a high-volume practice of multiple FPMRS-board certified surgeons. In addition, the electronic medical record was reviewed, and data extracted and double
checked by physician researchers to ensure accuracy for the investigated outcomes. There are several limitations to this study. This study is retrospective in nature, with a potential for information bias. Despite our cases being selected from the same cohort of patients who underwent LSCP in the same FPMRS practice with age-matching, there were baseline differences between the groups (that is, concurrent anterior or posterior colporrhaphy and a post-hysterectomy state), which could have affected our results. Moreover, because of the low prevalence of LUT injury with LSCP in our study, there may be inflation of the specific odds ratios. Despite this, the association between a post-hysterectomy state and LUT injury remained statistically significant even after multivariate analysis; therefore, it should be recognized as a clinically important risk factor. In addition, our study included a primarily Caucasian population; therefore, our findings may not be fully generalizable to a more diverse patient population. Further study in a more racially and ethnically diverse patient population is needed. Moreover, as patients with abnormal urinary tract anatomy were excluded from this study, the population studied represents a lower risk patient population. We did not specifically account for endometriosis or history of pelvic irradiation, which are established risk factors for LUT injury. However, there were no concurrent gynecologic cancers and low rates of adhesiolysis in our study population. Lastly, although our LSCP technique is generally well-established, our findings may not be applicable to differing LSCP techniques.

**Conclusions**

Although the prevalence of LUT injury with LSCP is rare, a history of hysterectomy significantly elevates this risk. As SCP is the common treatment in patients with recurrent prolapse after hysterectomy and/or failed native tissue repair, these patients are at the highest risk for LUT injury. On the basis of our findings, the clinician can individualize surgical counseling considering patient-specific risk factors. This also aids in setting appropriate postoperative patient expectations, including discussion as necessary, regarding the potential for prolonged catheterization and postoperative imaging or additional procedures in the case of LUT injury.

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