Toward a Cross-Pathway Susceptibility Profile for Urinary Tract Infection After Pelvic Floor Reconstruction

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Diana Pop-Lodromanean[1,2], Nicolae Grigore[1], Adrian Hașegan[1], Cristian Ichim[1], Radu Chicea[1], Paula Anderco[1,3], Samuel-Bogdan Todor[1,2], Ionela Mihai[1], Livia-Mirela Popa[1]

[1]Faculty of Medicine, Lucian Blaga University of Sibiu, 550169 Sibiu, Romania
[2]County Clinical Emergency Hospital of Sibiu, 550169 Sibiu, Romania
[3]Faculty of Medicine, Transilvania University of Brasov, 500036 Brasov, Romania

AIM: Urinary tract infection (UTI) is a frequent early complication after pelvic floor reconstruction. This study examined whether perioperative UTI is associated primarily with the surgical approach or with recurring patient-, disease-, and care-related factors.
METHODS: Medical records were retrospectively reviewed for 376 women treated with pelvic floor reconstructive surgery from 2020 through 2025. According to the principal reconstructive procedure, the cohort was divided into three surgical strata: mesh-based sacrospinous fixation accompanied by transobturator tape (TOT) or tension-free vaginal tape (TVT) insertion; combined anterior and posterior colporrhaphy with a midurethral sling; and anterior and posterior colporrhaphy performed without an associated sling procedure. The study endpoint was a symptomatic urinary tract infection confirmed by urine culture during the initial hospital admission. Associations between candidate predictors and infection were estimated separately within each surgical stratum. Stratum-level effect estimates were then integrated using a DerSimonian–Laird random-effects model to obtain pooled odds ratios and 95% confidence intervals. Cross-stratum variability was quantified through Cochran's Q test and the I^2 statistic.
RESULTS: Of the 376 women included, 71 experienced a symptomatic, culture-confirmed infection during the perioperative period, producing an overall event rate of 18.9%. The proportion of affected patients varied numerically among the three reconstructive pathways, although no statistically significant difference was observed in the unadjusted comparison. When risk estimates were synthesized across surgical strata, higher odds of infection were observed in postmenopausal women, patients older than 63 years, those with grade III–IV pelvic organ prolapse, women with morbid obesity, patients requiring bladder catheterization for more than 3 days, and those undergoing hysterectomy during the same operation. The principal significant associations showed little or no between-stratum heterogeneity, suggesting a consistent direction of association across surgical approaches, although the limited number of subgroups (k = 3) and instances of non-estimable models restrict definitive conclusions regarding reproducibility; further validation in larger cohorts is warranted.
CONCLUSIONS: Perioperative urinary tract infection after pelvic floor reconstructive surgery appears to reflect a multifactorial susceptibility profile, influenced mainly by patient characteristics, prolapse severity, and prolonged catheterization rather than procedure type alone. These findings support individualized risk assessment and reduced unnecessary catheter use. However, differences in baseline characteristics between surgical groups preclude concluding that the procedures carry equivalent infectious risk.

Keywords: pelvic organ prolapse; urinary tract infection; urinary catheterization; stress urinary incontinence; postoperative complications; pelvic floor surgery

Introduction

With the progressive aging of the female population, the clinical burden of pelvic organ prolapse (POP) and stress urinary incontinence (SUI)—two leading indications for reconstructive urogynecologic intervention—is expected to drive a substantial increase in surgical demand [1,2]. The choice of reconstructive strategy is tailored to the individual clinical profile and may involve native-tissue repair, apical support procedures, mesh-reinforced reconstruction, or midurethral sling placement, either alone or in combination. Surgical planning is guided by the extent of anatomical defects, the presence and type of urinary incontinence, prior pelvic interventions and the patient's overall risk profile, consistent with current guideline recommendations emphasizing individualized assessment and counselling when POP and SUI procedures are combined [3,4].

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Correspondence to: Paula Anderco, Faculty of Medicine, Lucian Blaga University of Sibiu, 550169 Sibiu, Romania; Faculty of Medicine, Transilvania University of Brasov, 500036 Brasov, Romania (e-mail: paula.anderco@ulbsibiu.ro); Samuel-Bogdan Todor, Faculty of Medicine, Lucian Blaga University of Sibiu, 550169 Sibiu, Romania; County Clinical Emergency Hospital of Sibiu, 550169 Sibiu, Romania (e-mail: samuelbogdant@gamil.com).
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Urinary tract infection (UTI) is one of the most frequent short-term complications after pelvic floor reconstructive surgery [5]. Reported incidence varies because of differences in diagnostic criteria, indications for urine culture, antimicrobial prophylaxis, and catheter-management protocols [6]. It remains uncertain whether perioperative UTI is primarily associated with the reconstructive procedure itself or with patient-, disease-, and care-related factors.

Potential perioperative contributors include concomitant total hysterectomy and postoperative bladder drainage [7]. Current CAUTI-prevention recommendations emphasize restricting catheter use to appropriate indications and prompt removal when continued drainage is no longer necessary, as prolonged catheterization is associated with bacteriuria, biofilm formation, and catheter-associated UTI [8,9]. Advanced pelvic organ prolapse may also contribute through voiding dysfunction, urinary retention, and increased postvoid residual volume [10].

Patient susceptibility may also be influenced by advancing age, postmenopausal status, diabetes mellitus, and obesity through hormonal, mucosal, immune, and metabolic mechanisms relevant to urinary infection [11,12,13].

Most existing studies report postoperative infection rates according to surgical approach, but crude comparisons may obscure clinically important confounding [14,15]. In routine practice, operative categories are not interchangeable exposures. Patients undergoing sacrospinous fixation, mesh-supported repair, sling-associated colporrhaphy, or native-tissue repair alone often differ substantially in prolapse severity, urinary symptoms, previous pelvic surgery, baseline voiding dysfunction, and need for concomitant total hysterectomy [16,17]. Therefore, attributing infection risk to the nominal procedure alone may be misleading if the underlying clinical phenotype is not considered.

The present investigation sought to determine whether infectious morbidity following pelvic floor reconstructive surgery is attributable chiefly to the operative approach or, rather, to a set of recurring clinical determinants shared across different surgical settings. Symptomatic urinary tract infection confirmed by culture during the perioperative period was defined as the principal outcome. Within three routinely used reconstructive pathways, we examined host-related characteristics, disease severity, and perioperative exposures, and then evaluated the robustness of the observed associations by integrating stratum-specific estimates and formally quantifying between-stratum heterogeneity.

Methods

We conducted a retrospective observational cohort study including consecutive adult women who underwent surgery for pelvic organ prolapse (POP) and/or stress urinary incontinence (SUI) between January 2020 and December 2025. Eligible procedures included surgery for primary or recurrent POP, SUI associated with concomitant prolapse, and isolated SUI without clinically significant prolapse.

Patients were included if they met all of the following criteria:

(1) age ≥18 years;

(2) surgery for POP and/or SUI performed during the predefined study period; and

(3) availability of preoperative, operative, and postoperative clinical records sufficient to ascertain the variables included in the study and the primary outcome.

Patients were excluded if any of the following criteria were present:

(1) incomplete baseline or perioperative documentation precluding reliable data extraction;
(2) inability to determine postoperative UTI status during the index admission;
(3) unavailable relevant perioperative laboratory data required for the analysis;
(4) major concomitant pelvic surgery unrelated to POP or SUI treatment;
(5) acute pelvic infection present at admission;
(6) documented immunosuppressive condition; or
(7) active malignant disease requiring oncologic surgical treatment.

After application of these eligibility criteria, 376 patients constituted the final study cohort.

The operative cohort was divided into three clinically defined surgical pathways. Mesh-assisted sacrospinous fixation combined with a midurethral sling, performed using either a transobturator tape (TOT) or tension-free vaginal tape (TVT) approach, was undertaken in 83 women (SFM + TOT/TVT). A further 180 patients underwent combined anterior and posterior colporrhaphy with concomitant TOT or TVT placement (A&P repair + TOT/TVT), whereas 113 patients underwent anterior and posterior colporrhaphy without an associated anti-incontinence procedure (A&P repair alone). Midurethral sling placement was therefore performed during the same operative session as the reconstructive procedure in the two sling-containing groups. Hysterectomy was added selectively according to individual clinical indication and was not a mandatory component of any surgical pathway. All procedures were performed by surgeons experienced in urogynecologic reconstruction and followed the institutional perioperative protocol.

Perioperative care was delivered in accordance with the departmental protocol for urogynecologic surgery, including antimicrobial prophylaxis, bladder drainage and postoperative microbiological investigation. Antimicrobial prophylaxis consisted of ceftriaxone 2 g administered intravenously within 60 minutes prior to skin incision. Metronidazole 500 mg, single dose before incision was added in cases involving rectal/bowel manipulation. In patients with a documented penicillin or cephalosporin allergy, prophylaxis consisted of vancomycin 2 g infused over 60 minutes,

started within 2 h before incision combined with gentamicin 5 mg/kg within 60 minutes before incision.

Procedures were performed under spinal (hyperbaric bupivacaine, L3–L4/L4–L5) or general anesthesia according to patient and anesthesiologist preference, with intraoperative Foley catheterization in all cases.

In the sacrospinous fixation stratum, transvaginal dissection exposed the sacrospinous ligament, which was fixed 2 cm medial to the ischial spine using a synthetic mesh kit; a midurethral sling (TOT or TVT) was then placed, with cystoscopy performed after retropubic passage to confirm bladder/ureteral integrity. Route (TOT vs. TVT) was chosen by surgeon judgment. TVT was favored absent prior retropubic surgery, while TOT was preferred when trocar-related bladder/bowel injury risk was higher.

In the colporrhaphy strata, anterior repair involved vesicovaginal dissection and pubocervical fascial plication, and posterior repair involved rectovaginal dissection and fascial plication with perineorrhaphy as needed. A concomitant midurethral sling was added only in patients with SUI. However, not all patients with SUI received a sling: the decision was made individually by the operating surgeon, and the specific criteria were not standardised or recorded in the study database. The A&P repair-alone group therefore included both patients without SUI and patients with SUI who did not receive a sling.

A transurethral catheter connected to a closed drainage system was inserted intraoperatively under sterile conditions in all patients. Catheter removal was guided by routine postoperative assessment rather than by a fixed study schedule. Continued drainage was permitted when clinically indicated, particularly in the presence of impaired voiding or urinary retention. For each patient, the total duration of indwelling catheterization was retrieved from the medical record and treated as a discrete perioperative exposure.

Postoperative urine cultures were obtained when clinically indicated and were not used as a universal screening measure. Microbiological assessment was initiated when symptoms or examination findings raised suspicion of urinary tract infection, including dysuria, increased urinary frequency, urgency, suprapubic pain or discomfort, fever, clinically significant urinary retention or an abnormal macroscopic appearance of the urine. Culture findings were evaluated alongside the documented clinical presentation and antimicrobial prescribing records. This integrated assessment was used to separate clinically manifest infection from asymptomatic bacterial colonization.

Study data were abstracted from the institutional electronic medical record and encompassed demographic, obstetric, clinical, laboratory, operative and postoperative characteristics. Age at admission, number of births and duration of bladder catheterization were analyzed as continuous variables. Menopausal status, chronic constipation, smoking, diabetes mellitus, chronic pulmonary disease or persistent cough, previous gynaecological surgery, prior hysterectomy, concomitant total hysterectomy, body mass index (BMI) category, pelvic organ prolapse severity and urinary incontinence phenotype were recorded as categorical variables. Menopause was defined as at least 12 consecutive months of amenorrhea. BMI was calculated as weight in kilograms divided by height in meters squared. Patients were classified as non-obese (BMI <30 kg/m^2), obesity class I (BMI 30.0–34.9 kg/m^2), obesity class II (BMI 35.0–39.9 kg/m^2) or obesity class III (BMI $\geq$40.0 kg/m^2). Proteinuria was defined as a urine dipstick protein result of $\geq$1+. Elevated preoperative creatinine was defined as a serum creatinine above the laboratory reference range for the patient's age and sex. Normal urinalysis was defined as the absence of leukocytes, nitrites, blood and protein on dipstick, with no bacteria on microscopy. Prolapse severity was graded from the preoperative pelvic examination according to the Pelvic Organ Prolapse Quantification (POP-Q) system, using the most distal point of prolapse relative to the hymen: stage 0, no prolapse; stage I, leading edge more than 1 cm above the hymen; stage II, leading edge between 1 cm above and 1 cm below the hymen; stage III, leading edge more than 1 cm below the hymen but protruding no further than 2 cm less than the total vaginal length; stage IV, complete eversion (protrusion of at least total vaginal length minus 2 cm). Urinary incontinence phenotype was classified from the documented clinical presentation as no SUI, mixed urinary incontinence, or pure SUI. Pure SUI was defined by involuntary urinary leakage associated with effort, physical exertion, coughing or sneezing without concomitant urgency urinary incontinence, whereas mixed urinary incontinence was defined by the presence of both stress-related and urgency-associated urinary leakage. SUI history was defined as a previous diagnosis of stress urinary incontinence based on a urologist's clinical examination before referral to our department, rather than on patient-reported history alone. The preoperative SUI phenotype was determined based on the findings of the preoperative clinical evaluation and was recorded separately from the history of SUI.

The prespecified primary outcome was symptomatic, culture-confirmed urinary tract infection arising during the index admission. An outcome event required isolation of a single microorganism at a concentration of at least 10^5 colony-forming units per millilitre, together with a documented clinically compatible presentation (e.g., dysuria, urinary frequency, urgency, suprapubic pain, fever, or clinically significant retention). Initiation of organism-directed antimicrobial treatment was used as corroborating evidence of clinical significance but was not, by itself, sufficient to meet the outcome definition in the absence of a compatible clinical presentation. Positive cultures obtained in the absence of a compatible clinical presentation were classified as asymptomatic bacteriuria and were excluded from the primary outcome, regardless of whether antimicrobial treatment was administered.

Duration of bladder catheterization was defined as the interval, in days, from catheter insertion at the time of surgery to catheter removal. Catheter removal timing was individualized per patient based on a standard postoperative voiding trial protocol. Urine cultures for the diagnosis of UTI were collected after catheter removal; catheterization duration therefore reflects the exposure period preceding the diagnostic assessment for UTI. Catheter removal followed a standardized retrograde (backfill) voiding trial. The bladder was backfilled with 300 mL of sterile water, the transurethral catheter was then removed, and the patient was asked to void spontaneously. A trial was considered a pass if the patient voided at least 150 mL (≥50% of the instilled volume).

Continuous data are presented as means with standard deviations, whereas categorical data are summarized as counts and proportions. Normality of continuous variables (age at admission, duration of bladder catheterization, and number of births) was assessed using the Shapiro-Wilk test prior to analysis ($p = 0.122$, $p = 0.246$, and $p = 0.454$, respectively), confirming no significant deviation from a normal distribution. Homogeneity of variances was assessed using Levene's test, which showed no significant differences in variance across groups ($p = 0.213$, $p = 0.409$, and $p = 0.788$, respectively). As both assumptions were met, one-way ANOVA was used for these variables. Categorical and ordinal variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. Differences among the three operative strata were examined using one-way ANOVA for continuous measures and either Pearson's chi-square test or Fisher's exact test for categorical measures, according to the distribution of expected cell counts.

The analytic aim of this study was explanatory rather than predictive: we sought to quantify the strength and direction of association between each candidate risk factor and symptomatic, microbiologically confirmed perioperative UTI, not to build or validate a prognostic score for individual risk prediction.

Associations with symptomatic, culture-confirmed perioperative urinary tract infection were estimated using two complementary approaches, each addressing a different question. First, univariable odds ratios were calculated separately within each of the three surgical strata (SFM + TOT/TVT, A&P repair + TOT/TVT, A&P repair alone) rather than pooling patients across techniques, since the strata differ in operative approach, tissue handling, and baseline exposure distributions, and pooling risked masking true effect heterogeneity. Stratum-level estimates were then synthesized using a DerSimonian–Laird random-effects model to obtain a pooled odds ratio and 95% confidence interval for each risk factor, with cross-stratum heterogeneity quantified by Cochran's Q statistic and the I^2 metric. Continuous perioperative exposures entered into this pooled analysis were dichotomized using the cohort-wide median as the prespecified threshold. Continuous perioperative exposures were therefore analyzed in two distinct ways depending on the analytic step: as continuous measures (means, standard deviations) when comparing baseline characteristics across the three surgical strata, and as binary variables, dichotomized at the cohort-wide median, when entered into the stratum-level and pooled odds ratio analyses. Duration of bladder catheterization was handled according to this same convention.

Second, multivariable logistic regression models were fitted independently within each surgical stratum to adjust for potential confounders. Candidate covariates for each multivariable model were selected using a univariable screening approach, whereby only variables associated with the outcome at $p \leq 0.2$ in the univariable analysis within that specific stratum were entered into the corresponding multivariable model. Because this selection was performed independently within each stratum, the specific covariates adjusted for differed across the three subgroup models. Given the limited number of outcome events within each stratum, the multivariable analyses should be interpreted cautiously because of the potential risk of model overfitting. Because these models were run separately per stratum, variables with few events in one category within a given stratum (e.g., menopause) could produce quasi-complete separation and a singular information matrix, preventing stable coefficient estimation; such cases are reported as "not estimable" in the corresponding table.

The pooled univariable estimates and the stratum-specific multivariable estimates address different statistical questions — the former quantifies the average association across surgical contexts, the latter the confounder-adjusted association within a specific context — and are not directly comparable. The overall analytic aim was explanatory rather than predictive: to quantify the strength and direction of association between each candidate risk factor and infection, not to build or validate a prognostic score.

All inferential tests were two-sided, and statistical significance was defined as $p < 0.05$. Analyses were conducted in Python version 3.12 (Python Software Foundation) within the PyCharm 2025.3.2.1 (JetBrains s.r.o.) development environment.

All procedures governing data collection, analysis and reporting complied with the ethical principles set out in the Declaration of Helsinki. Owing to the retrospective nature of the investigation and the exclusive use of de-identified clinical data, the committee waived the requirement for individual informed consent. All clinical and intraoperative photographs were independently reviewed before inclusion to confirm the absence of directly or indirectly identifiable patient information.

Table 1. Perioperative data by surgical procedure groups.

Variable	SFM + TVT/TOT (n = 83)	A&P repair + TOT/TVT (n = 180)	A&P repair alone (n = 113)	*p*-value
Perioperative Data — Categorical N (%)				
Concomitant total hysterectomy	9 (10.8%)	36 (20.0%)	56 (49.6%)	<0.001
Postoperative complications	8 (9.6%)	16 (8.9%)	8 (7.1%)	0.792
Perioperative urine culture				
Symptomatic microbiologically confirmed perioperative UTI	21 (25.3%)	28 (15.6%)	22 (19.5%)	0.169
E. coli	12 (14.5%)	16 (8.9%)	16 (14.2%)	0.266
Klebsiella spp.	5 (6.0%)	7 (3.9%)	2 (1.8%)	0.295
Enterobacter spp.	1 (1.2%)	1 (0.6%)	3 (2.7%)	0.310
Staphylococcus spp.	1 (1.2%)	0 (0.0%)	0 (0.0%)	0.170
Streptococcus spp.	2 (2.4%)	2 (1.1%)	1 (0.9%)	0.615
Proteus spp.	0 (0.0%)	2 (1.1%)	0 (0.0%)	0.335
Urinalysis and Renal Function				
Normal urinalysis	42 (50.6%)	98 (54.4%)	50 (44.2%)	0.236
Leukocytes	35 (42.2%)	63 (35.0%)	48 (42.5%)	0.344
Nitrites	14 (16.9%)	19 (10.6%)	20 (17.7%)	0.165
Proteinuria	15 (18.1%)	16 (8.9%)	8 (7.1%)	0.030*
Hematuria	28 (33.7%)	50 (27.8%)	45 (39.8%)	0.099
Ketone bodies	2 (2.4%)	9 (5.0%)	9 (8.0%)	0.223
Crystals	1 (1.2%)	1 (0.6%)	0 (0.0%)	0.518
Elevated preoperative creatinine	10 (12.0%)	5 (2.8%)	4 (3.5%)	0.004*
Duration of bladder catheterization	2.9 (±0.9)	2.9 (±0.8)	3.0 (±0.7)	0.753
Total N	83	180	113	—

Continuous variables are presented as mean ± standard deviation (SD). Categorical variables are presented as number (N) and percentage (%). Statistical analysis: One-way ANOVA was used for continuous variables; the Chi-square test or Fisher's exact test was applied for categorical variables. Statistical significance was defined as follows: * $p < 0.05$; Proteinuria: urine dipstick protein ≥1+. Elevated creatinine: above the laboratory reference range for age and sex. Normal urinalysis: no leukocytes, nitrites, blood or protein on dipstick and no bacteria on microscopy.

Results

Perioperative Urinary Tract Infection Across Operative Strata

The analytical population consisted of 376 women undergoing pelvic floor reconstructive surgery, distributed across three operative pathways: 83 received SFM with concomitant TOT/TVT, 180 underwent A&P repair combined with TOT/TVT, and 113 were treated by A&P repair without sling placement. During the index admission, 71 women developed a symptomatic urinary tract infection confirmed by culture, yielding a cohort-wide event frequency of 18.9%.

Infection burden varied across the surgical strata, although the unadjusted comparison provided no evidence of a statistically significant between-group difference. The proportion of affected patients was greatest following SFM + TOT/TVT, at 25.3%, compared with 19.5% after A&P repair alone and 15.6% after A&P repair + TOT/TVT ($p = 0.169$; Table 1). The aggregate occurrence of postoperative complications was likewise similar across the three pathways ($p = 0.792$). Escherichia coli predominated among culture-positive cases in each group, with no significant variation in the spectrum of recovered microorganisms according to operative stratum.

The apparent similarity in crude infectious outcomes occurred against a background of marked differences in operative exposure and selected preoperative characteristics. Concomitant total hysterectomy accompanied 49.6% of A&P repair-alone procedures, compared with 20.0% of A&P repair + TOT/TVT procedures and 10.8% of SFM + TOT/TVT procedures ($p < 0.001$). The SFM + TOT/TVT subgroup also showed a higher prevalence of proteinuria and elevated preoperative serum creatinine, with corresponding p values of 0.030 and 0.004. By contrast, the remaining urinalysis findings were broadly comparable among the three operative categories.

Baseline Heterogeneity Between Surgical Groups

The absence of a statistically detectable difference in unadjusted perioperative UTI rates should be interpreted in the context of substantial clinical variation among the three surgical cohorts (Tables 2,3,4). Patient age was not evenly distributed across operative pathways ($p < 0.001$): women undergoing A&P repair with concomitant TOT/TVT were, on average, younger than those treated with SFM + TOT/TVT or A&P repair alone.

A distinctly more complex preoperative phenotype was observed among patients selected for SFM + TOT/TVT. This

Table 2. Baseline characteristics of patients according to surgical procedure group.

Variable	SFM + TVT/TOT n = 83	A&P repair + TVT/ TOT n = 180	A&P repair n = 113	*p*-value
Demographic features				
Age at admission (years), mean ± SD	64.16 ± 11.98	59.34 ± 9.54	63.19 ± 10.26	$p < 0.001$*
Urban residence	62 (74.7%)	123 (68.3%)	76 (67.3%)	0.487
Vaginal vault prolapse	9 (10.8%)	2 (1.1%)	0 (0.0%)	$p < 0.001$*
Vaginal stump prolapse	1 (1.2%)	1 (0.6%)	0 (0.0%)	0.517
Acute Urinary Retention	5 (6.0%)	0 (0.0%)	0 (0.0%)	$p < 0.001$*
Urinary Tract Infection	2 (2.4%)	0 (0.0%)	0 (0.0%)	0.029*
Ureterohydronephrosis	4 (4.8%)	0 (0.0%)	0 (0.0%)	$p < 0.001$*
Pollakiuria	10 (12.0%)	12 (6.7%)	15 (13.3%)	0.135
History of Stress urinary incontinence	52 (62.7%)	147 (81.7%)	71 (62.8%)	$p < 0.001$*
Urinary leakage while walking	12 (14.5%)	17 (9.4%)	24 (21.2%)	0.018*
Dysuria	7 (8.4%)	1 (0.6%)	2 (1.8%)	$p < 0.001$*
Nocturia	1 (1.2%)	2 (1.1%)	1 (0.9%)	0.973
N (total)	83	180	113	—

Statistical tests: Continuous variables were analyzed using one-way ANOVA; categorical variables were analyzed using the Pearson chi-square test or an appropriate exact test, as applicable. Statistical significance: * $p < 0.05$.

Table 3. Patients' comorbidities according to surgical procedure group.

Variable	SFM + TVT/TOT n = 83	A&P repair + TOT/TVT n = 180	A&P repair n = 113	*p*-value
Comorbidities				
Previous total hysterectomy with bilateral adnexectomy (THBA)	10 (12.0%)	9 (5.0%)	2 (1.8%)	0.008*
Subtotal hysterectomy	1 (1.2%)	1 (0.6%)	0 (0.0%)	0.5178
Neurogenic bladder	0 (0.0%)	1 (0.6%)	0 (0.0%)	0.5793
Cervical cancer (operated)	0 (0.0%)	1 (0.6%)	0 (0.0%)	0.5793
Essential arterial hypertension	41 (49.4%)	104 (57.8%)	64 (56.6%)	0.4299
Chronic ischemic heart disease	22 (26.5%)	33 (18.3%)	32 (28.3%)	0.1017
Atrial fibrillation	4 (4.8%)	1 (0.6%)	2 (1.8%)	0.0590
Hypothyroidism	6 (7.2%)	14 (7.8%)	5 (4.4%)	0.5181
Stroke	2 (2.4%)	2 (1.1%)	1 (0.9%)	0.6146
Varicose veins of the lower limbs	5 (6.0%)	38 (21.1%)	29 (25.7%)	0.002*
Operated vulvar neoplasm	0 (0.0%)	1 (0.6%)	0 (0.0%)	0.5793
Uterine fibroma	2 (2.4%)	1 (0.6%)	0 (0.0%)	0.1521
Osteoarthritis	3 (3.6%)	4 (2.2%)	7 (6.2%)	0.2166
Thyroiditis	0 (0.0%)	1 (0.6%)	1 (0.9%)	0.7005
Operated breast cancer	0 (0.0%)	3 (1.7%)	0 (0.0%)	0.1927
Operated colon cancer	0 (0.0%)	1 (0.6%)	0 (0.0%)	0.5793
N (total)	83	180	113	—

Statistical tests: Categorical variables were analyzed using the Pearson chi-square test or an appropriate exact test, as applicable. Statistical significance: * $p < 0.05$.

group was enriched for advanced and recurrent pelvic floor pathology, including grade IV genital prolapse, vaginal vault prolapse, acute urinary retention, preoperative UTI, ureterohydronephrosis, and a history of previous gynecologic surgery.

The clinical profile of the A&P repair + TOT/TVT cohort was different. Mixed SUI was the most common preoperative urinary incontinence phenotype in all groups. Women undergoing A&P repair without sling placement more commonly presented with chronic constipation and were substantially more likely to undergo total hysterectomy during the index operation.

Outside these procedure-linked differences, the distribution of major comorbid conditions was largely similar across the three groups. Menopausal status, smoking, diabetes mellitus, chronic pulmonary disease or chronic cough, occupational or habitual heavy lifting, and overall body mass index categories showed no significant between-group variation. Notable exceptions were the greater frequency of previous total hysterectomy with bilateral adnexectomy in

Table 4. Surgical history, comorbidities and risk factors according to surgical procedure group.

Variable	SFM + TVT/TOT (n = 83)	A&P repair + TOT/TVT (n = 180)	A&P repair alone (n = 113)	*p*-value
Surgical history				
Previous gynecological surgery	22 (26.5%)	27 (15.0%)	3 (2.7%)	<0.001*
Obstetric history				
Number of births, mean ± SD	2.81 ± 1.34	2.61 ± 1.18	3.03 ± 1.29	0.020*
Fetuses >4 kg	21 (25.3%)	18 (10.0%)	23 (20.4%)	0.003*
Multiple pregnancies	0 (0.0%)	2 (1.1%)	4 (3.5%)	0.133
Difficult labor – overall $p = 0.074$; χ^2 (4) = 8.529				
No	53 (63.9%)	103 (57.2%)	60 (53.1%)	
Forceps delivery	5 (6.0%)	5 (2.8%)	11 (9.7%)	
Yes	25 (30.1%)	72 (40.0%)	42 (37.2%)	
Comorbidities and risk factors				
Chronic constipation	44 (53.0%)	96 (53.3%)	83 (73.5%)	0.001*
Menopause	73 (88.0%)	144 (80.0%)	98 (86.7%)	0.159
Smoking	26 (31.3%)	55 (30.6%)	31 (27.4%)	0.801
COPD / Chronic cough	18 (21.7%)	36 (20.0%)	15 (13.3%)	0.236
Heavy lifting	50 (60.2%)	123 (68.3%)	68 (60.2%)	0.260
Diabetes mellitus	11 (13.3%)	16 (8.9%)	13 (11.5%)	0.531
Preoperative urinary incontinence phenotype- overall $p < 0.001$; χ^2 (4) = 28.472				
No SUI	0 (0.0%)	0 (0.0%)	6 (5.3%)	
Mixed SUI	75 (90.4%)	162 (90.0%)	80 (70.8%)	
Pure stress SUI	8 (9.6%)	18 (10.0%)	27 (23.9%)	
Associated pelvic organ prolapse- overall $p < 0.001$; χ^2 (8) = 40.688				
No prolapse (grade 0)	20 (24.1%)	109 (60.6%)	47 (41.6%)	
Prolapse grade I	15 (18.1%)	19 (10.6%)	9 (8.0%)	
Prolapse grade II	27 (32.5%)	27 (15.0%)	28 (24.8%)	
Prolapse grade III	12 (14.5%)	21 (11.7%)	18 (15.9%)	
Prolapse grade IV	9 (10.8%)	4 (2.2%)	11 (9.7%)	
Obesity (BMI categories)-overall $p = 0.090$; χ^2 (6) = 10.938				
Normal BMI (no obesity)	12 (14.5%)	42 (23.3%)	31 (27.4%)	
Obesity grade 1	33 (39.8%)	76 (42.2%)	40 (35.4%)	
Obesity grade 2	34 (41.0%)	45 (25.0%)	34 (30.1%)	
Obesity grade 3 (morbid)	4 (4.8%)	17 (9.4%)	8 (7.1%)	

Data are n (%) or mean ± SD. SFM, mesh-based sacrospinous fixation; A&P, anterior and posterior colporrhaphy; TVT, tension-free vaginal tape; TOT, transobturator tape; SUI, stress urinary incontinence; BMI, body mass index. Overall comparisons of multicategory variables are given as χ^2(df) with *p*-value. Subgroup *p*-values compare each category against all others combined across the three groups. Continuous variables were compared by one-way ANOVA; categorical variables by Pearson χ^2 test or Fisher's exact test (expected counts <5). * $p < 0.05$.

the SFM + TOT/TVT cohort and the higher prevalence of lower-extremity varicose disease among patients managed through the two colporrhaphy-based pathways.

Stratified Pooled Analysis of Risk Factors for Perioperative UTI

Given the marked differences in baseline case mix across the three operative pathways, determinants of symptomatic, culture-confirmed perioperative UTI were examined through stratum-specific effect estimates, subsequently integrated using random-effects modelling (Table 5; Fig. 1). This approach identified several host-, disease-, and care-related factors associated with early infectious morbidity across the surgical strata.

The strongest patient-level signals were linked to biological ageing and metabolic vulnerability. Postmenopausal women had more than threefold higher odds of perioperative UTI than their premenopausal counterparts (pooled OR 3.36, 95% CI 1.15–9.78). A similar, although less pronounced, association was observed for age above the cohort median of 63 years (OR 2.51, 95% CI 1.43–4.41). Excess body weight did not show a uniform dose-dependent relationship with infection; neither grade I nor grade II obesity was associated with the outcome, whereas morbid obesity was accompanied by a substantial increase in the odds of UTI (OR 3.45, 95% CI 1.21–9.83).

Anatomical disease severity emerged as a second major dimension of susceptibility. Compared with women without the corresponding prolapse stage, those with grade III POP

Table 5. Stratified effect size analysis with heterogeneity testing — symptomatic microbiologically confirmed perioperative UTI.

Variable	Comparison	OR	95% CI	I^2%	Q	p_het	k	*p*-value
Surgical history								
Concomitant total hysterectomy	Yes vs No	1.84	[1.00[@]–3.39]	0.0%	0.61	0.736	3	0.048**
Previous hysterectomy (medical history)	Yes vs No	1.17	[0.45–3.04]	0.0%	1.95	0.378	3	0.747
Previous gynecological surgery	Yes vs No	1.00	[0.46–2.16]	0.0%	0.22	0.897	3	1.000
Obstetric history								
Fetuses >4 kg	Yes vs No	0.83	[0.40–1.71]	0.0%	0.53	0.766	3	0.615
Multiple pregnancies	Yes vs No	1.26	[0.20–7.99]	0.0%	0.02	0.887	2†	0.806
Difficult deliveries	Forceps vs No	0.63	[0.18–2.29]	0.0%	1.00	0.606	3	0.476
	Yes vs No	0.79	[0.45–1.38]	0.0%	1.76	0.415	3	0.410
Number of births	Above median (3.0) vs Below median	1.58	[0.88–2.86]	0.0%	1.54	0.463	3	0.139
Comorbidities and risk factors								
Chronic constipation	Yes vs No	1.06	[0.61–1.82]	0.0%	0.17	0.920	3	0.842
Menopause	Yes vs No	3.36	[1.15–9.78]	0.0%	1.22	0.544	3	0.028*
Smoking	Yes vs No	0.78	[0.40–1.50]	15.3%	2.36	0.307	3	0.256
COPD / Chronic cough	Yes vs No	1.56	[0.83–2.93]	0.0%	0.95	0.620	3	0.366
Heavy lifting	Yes vs No	1.07	[0.62–1.86]	0.0%	1.01	0.603	3	0.809
Diabetes mellitus	Yes vs No	1.51	[0.65–3.48]	12.6%	2.29	0.319	3	0.344
Stress urinary incontinence (SUI) on preoperative evaluation	Mixed SUI vs No SUI	0.72	[0.14–3.68]	0.0%	0.02	0.989	3	0.469
	Pure stress SUI vs No SUI	1.79	[0.29–11.0]	0.0%	1.82	0.403	3	0.851
Associated prolapse	Prolapse Grade I vs No prolapse	1.29	[0.51–3.30]	2.2%	2.05	0.360	3	0.369
	Prolapse Grade II vs No prolapse	1.33	[0.61–2.89]	12.9%	2.30	0.317	3	0.332
	Grade III pelvic organ prolapse vs No prolapse	2.42	[1.14–5.16]	0.0%	0.24	0.888	3	0.032*
	Prolapse Grade IV vs No prolapse	3.00	[1.10–8.19]	0.0%	0.22	0.898	3	0.036*
Obesity	Obesity Grade I vs No obesity	1.66	[0.75–3.67]	0.0%	1.05	0.591	3	0.399
	Obesity Grade II vs No obesity	1.84	[0.80–4.23]	0.0%	0.56	0.757	3	0.406
	Obesity Grade III vs No obesity	3.45	[1.21–9.83]	0.0%	0.99	0.611	3	0.023*
Continuous variables								
Age at admission	Above median (63.0) vs Below median	2.51	[1.43–4.41]	0.0%	0.75	0.689	3	0.001*
Duration of bladder catheterization	Above median (3.0) vs Below median	2.75	[1.45–5.21]	0.0%	0.58	0.749	3	0.002*

OR, odds ratio (random-effects model, DerSimonian-Laird); CI, confidence interval; I^2, percentage of variability due to heterogeneity (>50% moderate, >75% high); Q, Cochran's Q statistic; p_het, *p*-value of Cochran's Q test for heterogeneity; k, number of strata pooled; *p*-value, two-sided Wald test of the pooled odds ratio; SUI, stress urinary incontinence; COPD, chronic obstructive pulmonary disease; UTI, urinary tract infection. * $p < 0.05$. † k = 2 for "Multiple pregnancies" because one stratum had zero events and could not contribute to pooling. [@]The lower confidence limit was 1.002 before rounding to two decimal places. *p* values and confidence intervals were calculated using unrounded estimates.

had higher odds of infection (OR 2.42, 95% CI 1.14–5.16), with the association becoming more pronounced in grade IV disease (OR 3.00, 95% CI 1.10–8.19). By contrast, no statistically supported relationship was detected for grade I or grade II prolapse.

Among modifiable perioperative exposures, prolonged bladder drainage showed the clearest association with the primary outcome. Catheterization extending beyond 3 days was associated with an approximately 2.8-fold increase in the odds of symptomatic, culture-confirmed UTI (OR 2.75, 95% CI 1.45–5.21). Total hysterectomy performed during the index reconstruction was likewise associated with higher infection odds (OR 1.84, 95% CI 1.00–3.39), although the lower confidence limit lay at the threshold of statistical significance.

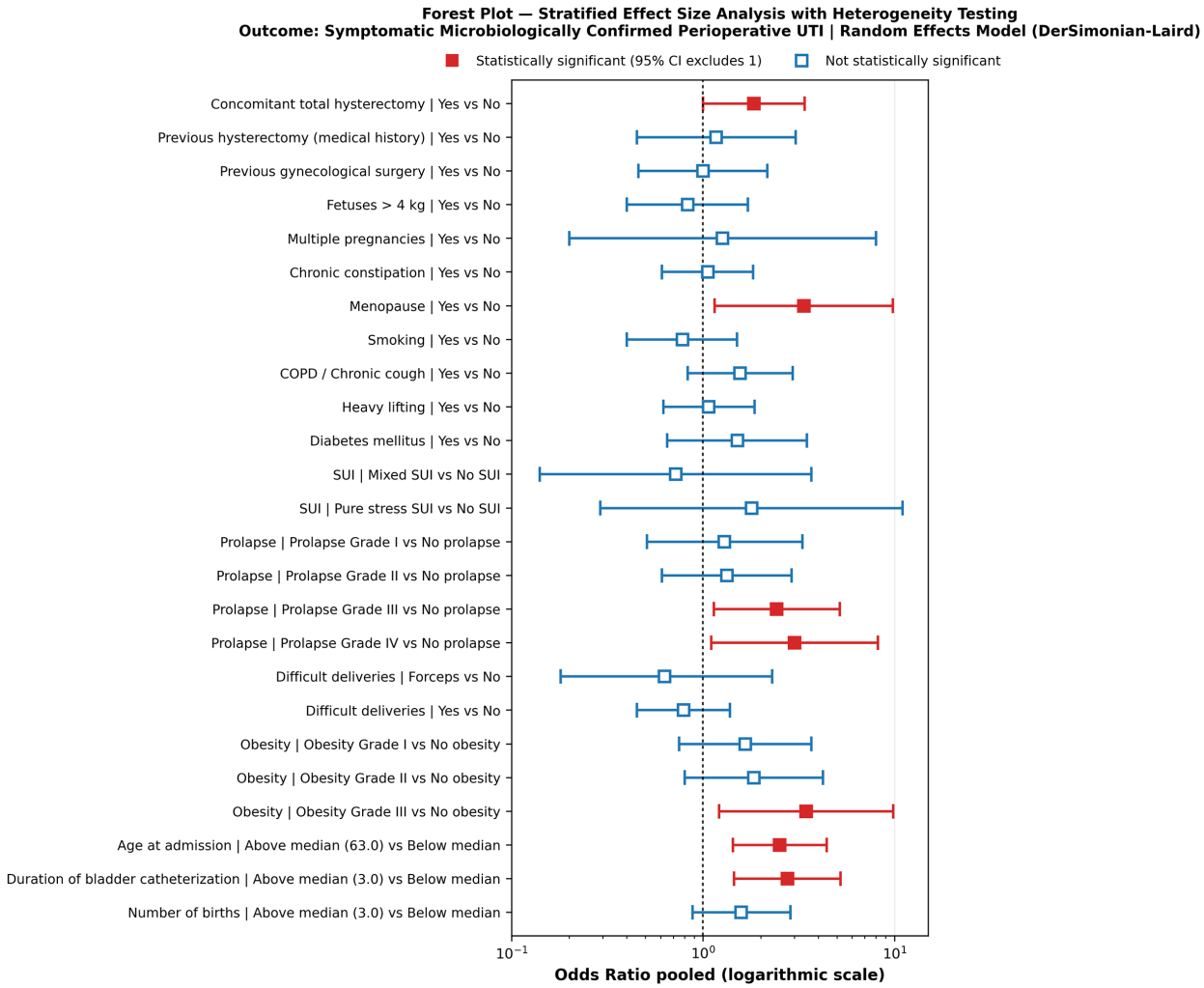


Fig. 1. Stratified analysis of risk factors for symptomatic microbiologically confirmed perioperative UTI. OR, odds ratio; CI, confidence interval.

No evidence of association was found for prior hysterectomy, previous gynaecological surgery, fetal macrosomia, multiple gestation, difficult or forceps-assisted delivery, number of births above the cohort median, chronic constipation, smoking, diabetes mellitus, chronic pulmonary disease or persistent cough, heavy physical lifting, or stress urinary incontinence phenotype.

Importantly, the principal associations were not confined to any single operative pathway. For every factor reaching statistical significance, the corresponding stratum-specific estimates showed no measurable between-group inconsistency, with I^2 values of 0% and non-significant Cochran Q statistics. The absence of detectable heterogeneity indicates that the direction of the main risk signals was preserved across all three reconstructive settings, despite their markedly different baseline clinical profiles.

Subgroup Analyses

In the SFM+TVT/TOT subgroup (n = 83), univariable analysis showed that age at admission, catheterization duration, concomitant total hysterectomy, grade III–IV prolapse, class III obesity, and diabetes mellitus were significantly associated with the outcome ($p < 0.05$). The estimate for menopause was non-interpretable because of quasi-complete separation, and multiple pregnancies could not be evaluated because of zero variance in this subgroup (Table 6).

In the A&P + TVT/TOT subgroup (n = 180), univariable analysis showed that age, catheterization duration, concomitant total hysterectomy, grade IV prolapse, class III obesity, and diabetes mellitus were significantly associated with the outcome ($p < 0.05$). Multiple pregnancies were not included in the multivariable model because the univariable p-value exceeded the prespecified inclusion threshold (Table 7).

In A&P alone subgroup (n = 113), univariable regression showed that age at admission, catheterization duration, concomitant total hysterectomy, grade III–IV pelvic organ prolapse ($p < 0.05$), showing a broadly similar pattern of associations to that observed in the other surgical groups. However, diabetes mellitus was not significant in this group.

Table 6. Logistic regression in mesh-based sacrospinous fixation (SFM)+ TVT-TOT group (n = 83).

	Univariable regression			Multivariable regression		
Variable	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Demographic & obstetric history						
Age at admission	1.07	1.01–1.14	0.021*	1.08	1.02–1.15	0.009*
Number of births	1.24	0.87–1.77	0.236	—	—	—
Difficult deliveries (Forceps vs No)	0.71	0.08–6.76	0.768	—	—	—
Difficult deliveries (Yes vs No)	0.69	0.22–2.16	0.525	—	—	—
Fetuses >4 kg	0.88	0.28–2.79	0.837	—	—	—
Multiple pregnancies	NE	NE	NE	—	—	—
Menopause	NE	NE	NE	—	—	—
Comorbidities & lifestyle						
Obesity – class I	1.61	0.59–4.39	0.351	—	—	—
Obesity – class II	0.83	0.30–2.29	0.717	—	—	—
Obesity – class III	3.20	1.10–9.31	0.032*	3.05	0.94–9.88	0.063
Smoking	1.47	0.52–4.15	0.467	—	—	—
COPD / chronic cough	1.63	0.52–5.10	0.398	—	—	—
Diabetes mellitus	2.35	1.05–5.26	0.038*	2.96	0.68–12.93	0.149
Chronic constipation	0.93	0.35–2.52	0.892	—	—	—
Heavy lifting	1.05	0.38–2.92	0.919	—	—	—
Pelvic floor & surgical history						
Associated prolapse – grade 1	0.68	0.17–2.69	0.583	—	—	—
Associated prolapse – grade 2	0.42	0.12–1.40	0.156	2.43	0.25–18.6	0.455
Associated prolapse – grade III	2.95	1.15–7.58	0.024*	6.01	1.14–31.6	0.034*
Associated prolapse – grade IV	3.40	1.25–9.25	0.017*	3.31	0.75–14.5	0.112
Concomitant total hysterectomy	3.05	1.20–7.75	0.019*	2.19	0.93–5.11	0.101
Previous gynecological surgery	1.12	0.37–3.40	0.835	—	—	—
Postoperative course						
Duration of bladder catheterization (days)	1.83	1.15–2.89	0.010*	1.53	0.95–2.46	0.079

OR, odds ratio; CI, confidence interval; SFM, mesh-based sacrospinous fixation; TVT, tension-free vaginal tape; TOT, transobturator tape; COPD, chronic obstructive pulmonary disease. * $p < 0.05$. NE, not estimable (the model could not compute an OR). —, not entered in the multivariable model (univariable $p > 0.2$). The multivariable model included only variables with univariable $p \leq 0.2$.

Prior gynecologic surgery was non-interpretable because of separation. However, multivariable analisys showed that only number of deliveries and grade 3 prolapse were significant (Table 8).

Discussion

The principal finding of this study is that early urinary infection after pelvic floor reconstruction appears to be more strongly associated with a multidimensional susceptibility profile than with the reconstructive technique considered in isolation. Symptomatic, microbiologically confirmed UTI affected almost 19% of the cohort, yet the variation observed among the three surgical pathways remained statistically inconclusive in crude comparisons. Thus, procedural classification alone offered limited explanatory value for the observed infectious burden. A more coherent pattern emerged when risk was examined within operative strata. The factors associated with infection converged around three domains: intrinsic patient vulnerability, advanced pelvic floor pathology, and cumulative perioperative exposure. Such an interpretation accords with the broader urogynecologic literature, in which reported postoperative UTI frequencies are shaped not only by case mix, but also by substantial variation in diagnostic thresholds, indications for microbiological testing, catheter-removal protocols, antimicrobial practices, and other elements of perioperative care [18,19,20].

Crude comparisons across operative pathways provide only a limited account of infectious risk in pelvic floor reconstruction. Surgical allocation in routine practice is inherently selective rather than interchangeable. Women undergoing mesh-assisted sacrospinous fixation, colporrhaphy with a concomitant sling, or isolated native-tissue repair frequently present with distinct anatomical and functional profiles. Differences in prolapse stage, lower urinary tract symptoms, prior pelvic interventions, baseline voiding impairment and the requirement for additional procedures may all influence both treatment selection and postoperative susceptibility to infection. Against this background, the failure to detect a statistically significant difference in unadjusted

Table 7. Logistic regression in A&P repair + TOT/TVT group (n = 180).

	Univariable regression			Multivariable regression		
Variable	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Demographic & obstetric history						
Age at admission	1.05	1.01–1.09	0.012*	1.08	1.03–1.13	0.001*
Number of births	1.20	0.86–1.67	0.278	—	—	—
Difficult deliveries – Forceps vs. No	1.31	0.14–12.1	0.815	—	—	—
Difficult deliveries – Yes vs. No	1.12	0.50–2.55	0.778	—	—	—
Fetuses >4 kg	1.04	0.28–3.86	0.953	—	—	—
Multiple pregnancies	1.33	0.45–3.78	0.601	—	—	—
Menopause	2.36	0.67–8.32	0.183	2.42	0.75–6.23	0.154
Comorbidities & lifestyle						
Obesity – class I	1.06	0.47–2.41	0.885	—	—	—
Obesity – class II	1.01	0.40–2.57	0.985	—	—	—
Obesity – class III	2.75	1.08–7.00	0.034*	2.23	0.69–7.24	0.182
Smoking	0.55	0.21–1.45	0.227	—	—	—
COPD / chronic cough	1.09	0.41–2.94	0.863	—	—	—
Diabetes mellitus	2.95	1.22–7.13	0.016*	3.55	1.09–11.50	0.035*
Chronic constipation	0.94	0.42–2.11	0.876	—	—	—
Heavy lifting	1.44	0.57–3.62	0.440	—	—	—
Pelvic floor & surgical history						
Associated prolapse – grade 1	0.58	0.13–2.66	0.483	—	—	—
Associated prolapse – grade 2	1.70	0.62–4.72	0.305	—	—	—
Associated prolapse – grade III	2.42	0.98–6.53	0.068	1.44	0.24–12.1	0.715
Associated prolapse – grade IV	3.10	1.18–8.15	0.022*	2.90	0.94–8.97	0.064
Concomitant total hysterectomy	2.90	1.35–6.23	0.007*	6.02	2.70–13.41	<0.001*
Previous gynecological surgery	0.93	0.29–2.95	0.904	—	—	—
Postoperative course						
Duration of bladder catheterization (days)	1.51	1.15–1.98	0.003*	1.43	1.04–1.97	0.029*

OR, odds ratio; CI, confidence interval; A&P, anterior and posterior colporrhaphy; TVT, tension-free vaginal tape; TOT, transobturator tape; COPD, chronic obstructive pulmonary disease. * $p < 0.05$. —, not entered in the multivariable model (univariable $p > 0.2$). The multivariable model included only variables with univariable $p \leq 0.2$.

UTI rates cannot be taken to imply that the procedures carry equivalent infectious consequences. More plausibly, it indicates that the effect attributed to a named operation is inseparable from the clinical phenotype for which that operation was chosen. This distinction is essential when interpreting observational comparisons, because procedure type may function partly as a surrogate for disease complexity, previous surgical exposure and perioperative burden. Consistent with this interpretation, comparative evidence for mesh-augmented versus native-tissue reconstruction has not established a uniform increase in short-term infectious morbidity once differences in case mix and perioperative management are taken into account [21,22,23,24].

Ageing-related vulnerability emerged as a prominent determinant of perioperative infection. Women older than 63 years and those who were postmenopausal had significantly greater odds of symptomatic, culture-confirmed UTI, supporting the view that host biology contributes materially to postoperative infectious risk. The association is mechanistically credible. Declining oestrogen exposure, age-dependent mucosal remodelling, metabolic dysregulation and altered local immune defence may weaken lower urinary tract protection and facilitate bacterial persistence and clinically overt infection. Seen in this light, reconstructive surgery may act less as the primary origin of infection than as a physiological stressor that unmasks or intensifies an existing predisposition. Instrumentation, transient voiding impairment and postoperative bladder drainage may therefore have a disproportionate effect in women whose urinary tract defences are already compromised. These findings argue for a more discriminating preoperative evaluation in older and postmenopausal patients, particularly when the clinical history raises concern for genitourinary syndrome of menopause, recurrent UTI, impaired bladder emptying or pre-existing voiding dysfunction [25,26].

A clear relationship was also observed between the extent of anatomical disruption and perioperative infectious susceptibility. The excess risk was confined to women with stage III or IV pelvic organ prolapse, whereas less advanced disease showed no statistically supported associa-

Table 8. Logistic regression in A&P repair alone group (n = 113).

	Univariable regression			Multivariable regression		
Variable	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Demographic & obstetric history						
Age at admission	1.06	1.01–1.12	0.018*	1.05	0.99–1.12	0.123
Number of births	1.35	0.96–1.91	0.089	2.54	1.50–4.29	<0.001*
Difficult deliveries – Forceps vs. No	0.39	0.05–3.18	0.376	—	—	—
Difficult deliveries – Yes vs No	0.57	0.20–1.60	0.288	—	—	—
Fetuses >4 kg	0.56	0.15–2.09	0.388	—	—	—
Multiple pregnancies	1.40	0.14–14.11	0.777	—	—	—
Menopause	1.9	0.42–8.55	0.403	—	—	—
Comorbidities & lifestyle						
Obesity – class I	0.83	0.30–2.22	0.696	—	—	—
Obesity – class II	1.43	0.54–3.81	0.476	—	—	—
Obesity – class III	3.05	1.09–8.53	0.033*	3.20	0.76–13.52	0.114
Smoking	0.53	0.16–1.70	0.284	—	—	—
COPD / chronic cough	2.38	0.72–7.86	0.154	1.89	0.78–4.02	0.128
Diabetes mellitus	1.71	0.75–3.90	0.202	—	—	—
Chronic constipation	1.29	0.43–3.86	0.652	—	—	—
Heavy lifting	0.75	0.29–1.92	0.548	—	—	—
Pelvic floor & surgical history						
Associated prolapse – grade 1	2.24	0.51–9.75	0.284	—	—	—
Associated prolapse – grade 2	0.87	0.29–2.62	0.804	—	—	—
Associated prolapse – grade III	2.60	1.06–6.38	0.037*	4.56	1.3–16.1	0.018*
Associated prolapse – grade IV	3.25	1.20–8.80	0.020*	1.58	0.56–4.88	0.408
Concomitant total hysterectomy	2.70	1.12–6.51	0.027*	2.01	0.83–4.86	0.124
Previous gynecological surgery	NE	NE	NE	—	—	—
Postoperative course						
Duration of bladder catheterization (days)	1.68	1.09–2.59	0.019*	1.49	0.99–2.24	0.055

OR, odds ratio; CI, confidence interval; A&P, anterior and posterior colporrhaphy; COPD, chronic obstructive pulmonary disease. * $p < 0.05$. NE, not estimable (the model could not compute an OR because of separation or a singular matrix). —, not entered in the multivariable model (univariable $p > 0.2$). The multivariable model included only variables with univariable $p \leq 0.2$.

tion with UTI. This pattern suggests the presence of a clinically relevant severity threshold, beyond which prolapse may substantially alter lower urinary tract function. Such an interpretation is consistent with the pathophysiology of advanced POP. Advanced prolapse may distort the bladder outlet, impair detrusor efficiency and hinder complete bladder emptying, thereby promoting urinary stasis and increased postvoid residual volume. Under these conditions, the perioperative period may further destabilize an already compromised voiding system, thereby facilitating bacterial persistence and progression to symptomatic infection [10]. Severe prolapse may therefore act as a marker of baseline urinary stasis and increased likelihood of postoperative instrumentation, both of which may favor bacterial persistence [27,28]. The higher burden of urinary retention, dysuria, ureterohydronephrosis, and previous pelvic surgery in the sacrospinous fixation group further supports the presence of clinically relevant baseline imbalance between operative strata.

Among perioperative exposures, prolonged bladder catheterization was one of the most clinically actionable factors associated with infection. This finding aligns with current infection-prevention recommendations emphasizing minimization of unnecessary indwelling catheter exposure and prompt catheter removal when clinically appropriate [8,9,29]. In urogynecologic surgery, standardized voiding trials and protocolized catheter management have been proposed to reduce postoperative urinary morbidity [18,29]. More recent randomized evidence following vaginal POP surgery showed that shortening postoperative catheterization from four days to 24 hours did not increase urinary retention or culture-confirmed UTI and was associated with a shorter hospital stay [30].

The observed association between hysterectomy performed during pelvic floor reconstruction and perioperative UTI is more plausibly interpreted as a marker of cumulative procedural burden than as evidence of an independent infectious effect. The addition of hysterectomy typically denotes a broader operative field, more extensive dissection, greater

tissue manipulation and potentially prolonged instrumentation. It may also be accompanied by postoperative voiding impairment and continued bladder drainage. Accordingly, the excess risk may arise from the cluster of exposures accompanying a more complex intervention rather than from hysterectomy itself [7].

Morbid obesity was also associated with higher odds of perioperative UTI, whereas lower obesity categories were not significantly associated with the outcome. This apparent threshold effect is biologically plausible, given the relationship between severe obesity, systemic inflammation, impaired host defense, and less favorable postoperative recovery profiles [31,32]. The lack of a clear linear association across all body mass index categories should be acknowledged. Nevertheless, the present findings suggest that class III obesity may identify a subgroup of patients with increased infectious vulnerability after pelvic floor reconstructive surgery.

The subgroup analyses showed broadly similar patterns of association across the three surgical pathways, although this observation should be interpreted cautiously given the limited number of subgroups (k = 3) and the non-estimability of some variables within individual strata. Increasing age, longer catheterization, concomitant total hysterectomy and class III obesity were associated with UTI in all three operative strata, while advanced POP showed a broadly concordant severity-related pattern. This consistency agrees with previous reports identifying older age, prolonged voiding dysfunction or catheter exposure, and a greater number of concomitant pelvic procedures as determinants of postoperative UTI after urogynecologic surgery [33,34]. Diabetes mellitus was associated with infection in the two sling-containing strata but not in the A&P repair-alone group, while the pooled estimate remained non-significant. Although biologically plausible, this finding should be regarded as exploratory rather than as evidence of a procedure-specific effect [12].

The methodological value of the present analysis rests, first, on the clinical specificity of its primary endpoint. Infection was not inferred from microbiological positivity alone; instead, outcome classification required concordance between urine culture findings and the documented clinical context. This approach is especially important in the postoperative setting, where catheter exposure, transient bacteriuria and non-uniform thresholds for requesting microbiological testing can inflate apparent infection rates and blur the distinction between colonization and clinically meaningful disease. By excluding culture-positive episodes lacking compatible symptoms, the study reduced the likelihood that asymptomatic bacteriuria was misclassified as perioperative UTI. A further strength lies in the analytical strategy used to separate procedure-specific effects from risk patterns shared across heterogeneous operative settings. Estimating associations within each reconstructive stratum before synthesizing them under a random-effects framework made it possible to test whether the identified signals persisted despite differences in surgical indication, anatomical complexity and baseline case mix. The absence of statistically significant between-stratum heterogeneity for the principal associations is compatible with a consistent effect across operative pathways; however, with only three strata and limited statistical power to detect heterogeneity, this finding should be regarded as supportive rather than confirmatory, and does not by itself establish that these associations are independent of operative pathway. Taken together, these findings support early recognition of vulnerable patients and reduction of modifiable perioperative exposures, particularly prolonged bladder drainage [18,29,35,36].

The findings should be interpreted in light of several methodological constraints. Most importantly, the observational and retrospective nature of the study precludes causal attribution and cannot eliminate the possibility of residual or unmeasured confounding. Interpretation of direct comparisons among surgical pathways is further complicated by substantial differences in baseline case mix, because operative selection reflected clinical indication rather than randomized treatment assignment. Consequently, the observed associations may partly capture the underlying severity and complexity of the patients assigned to each reconstructive strategy. Outcome ascertainment was restricted to the index admission, and infections becoming clinically apparent after discharge were therefore outside the study window. The analytical decision to dichotomize continuous measures at cohort-derived medians facilitated harmonized effect estimation across relatively small operative strata, but inevitably reduced the clinical resolution of these variables and may have obscured nonlinear or threshold-dependent relationships. The subgroup regressions were additionally limited by the small number of events within each operative stratum and by separation or non-estimability for several variables; these estimates should therefore be interpreted as supportive of the pooled analysis rather than as independent confirmatory models. In addition, the limited number of UTI events within each surgical stratum relative to the number of covariates included in the multivariable models may have increased the risk of overfitting and reduced the stability of the adjusted estimates. Although univariable odds ratios for concomitant total hysterectomy were consistent across surgical subgroups (2.70–3.05), the multivariable estimates varied more widely (2.01–6.02). This is most likely explained by differences in sample size and event counts across subgroups, which affect the precision and stability of adjusted estimates, as well as differences in covariate distributions across surgical groups. These findings should be interpreted with caution given the relatively small subgroup sizes, and larger multicenter studies are needed to confirm the independent effect of concomitant total hysterectomy across surgical approaches.

An additional methodological consideration relates to our use of the DerSimonian–Laird random-effects model to pool effect estimates across the three surgical subgroups. While this method is conventionally applied to meta-analyses combining independent studies, we used it here to combine estimates from procedurally distinct surgical subgroups within a shared retrospective cohort, in order to formally assess between-subgroup heterogeneity and obtain a precision-weighted pooled estimate. Because these subgroups were not derived from independent populations, they may share underlying institutional practices, perioperative protocols, and baseline patient characteristics, which could introduce a degree of non-independence not accounted for by this method. This differs from the assumptions underlying a traditional meta-analysis and should be considered when interpreting the pooled effect estimates. Future studies employing prospective, multicenter designs with fully independent surgical cohorts would help validate and extend these findings.

In addition, although the primary endpoint incorporated both microbiological confirmation and clinical context, urine cultures were obtained only when infection was suspected. This symptom-triggered approach reflects routine clinical practice but may have introduced differential ascertainment, particularly in patients with atypical, subtle or poorly documented postoperative manifestations. Prospective investigation should address these limitations through predefined, symptom-based diagnostic criteria, standardized indications and timing for urine culture, and harmonized perioperative bladder-management pathways. Incorporating objective measures of baseline and postoperative voiding function—including postvoid residual volume, urinary retention and structured voiding-trial outcomes—would permit a more precise characterization of the mechanisms linking advanced prolapse and catheter exposure to infection. Larger cohorts would also support adequately adjusted multivariable modelling, evaluation of nonlinear associations and formal assessment of interactions between host susceptibility, anatomical severity and perioperative care. Such studies could move perioperative infection prevention beyond procedure-based assumptions towards clinically actionable risk phenotypes. In particular, they may identify which patients derive the greatest benefit from accelerated catheter removal, protocolized voiding assessment, closer post-discharge surveillance and individualized preoperative evaluation of lower urinary tract function [29,31,32,37].

Conclusions

Symptomatic, culture-confirmed urinary tract infection emerged as a substantial component of early morbidity after pelvic floor reconstructive surgery, affecting 18.9% of the cohort. Although infection frequencies varied across the three operative pathways, the absence of statistically significant crude differences indicates that procedural classification alone does not adequately account for postoperative infectious risk. Instead, the observed pattern of susceptibility was characterized by advanced age, postmenopausal status, severe POP, morbid obesity, prolonged bladder catheterization and concomitant total hysterectomy. The broadly similar direction of these associations across the reconstructive strata suggests a shared susceptibility pattern, although this observation requires confirmation in larger and independent cohorts. Patients with advanced prolapse, impaired voiding or marked biological vulnerability may benefit from more rigorous preoperative urinary assessment, structured postoperative voiding evaluation and protocol-driven limitation of catheter duration. In particular, avoiding unnecessary prolongation of bladder drainage represents an immediately actionable target for reducing early infectious morbidity. Because treatment allocation reflected clinical indication and the operative groups differed substantially at baseline, the lack of significant unadjusted differences cannot be interpreted as evidence of equivalent infectious risk across procedures. Prospective studies incorporating standardized diagnostic criteria, objective measures of bladder emptying, harmonized catheter protocols and adequately adjusted multivariable analyses are required to validate this risk framework and translate it into targeted perioperative prevention.

Availability of Data and Materials

The data presented in this study are available on request from the corresponding authors. The data are not publicly available due to privacy and ethical restrictions.

Author Contributions

Validation: CI, IM and LMP; supervision: NG; software and data analysis: SBT and PA; resources: CI, IM, RC and DPL; investigation: AH, PA and SBT; formal analysis: DPL, RC and SBT; methodology: SBT and NG; conceptualization and study design: AH, PA, DPL and LMP. Writing—original draft preparation: AH, DPL, CI and PA. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The Ethics Committee of the County Clinical Emergency Hospital of Sibiu, Romania, confirmed that formal ethical approval was not required for this retrospective study, which used anonymised data and involved no experimental interventions. The requirement for informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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