Review Article

Journal of Emergency Health Care. 2025;14(1): 15
https://doi.org/10.22034/14.1.15

Fever and Infection Following Ureteroscopy and Retrograde Intrarenal Surgery: A Systematic Review

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Article history:

Received: 5 Jul 2024
Accepted: 12 Jan 2025
Available online: 15 Feb 2025

Keywords:

Ureteroscopy (URS)
Retrograde Intrarenal Surgery (RIRS)
Fever
Infection
Risk factors
Preoperative urine culture

Abstract

Objective: This study seeks to determine the potential risk factors contributing to fever and infection after ureteroscopy (URS) and retrograde intrarenal surgery (RIRS). **Materials and Methods:** A systematic literature search was performed in the PubMed, EMBASE, Cochrane Library, and Web of Science databases to identify studies evaluating risk factors for infectious complications post-URS and RIRS. The search encompassed studies published up to February 12, 2025. Odds ratios and mean differences with 95% confidence intervals were utilized to assess the identified risk factors. **Results:** A collection of 14 studies, encompassing a large patient population of 14,382, was analyzed. The strongest indicator of infection was a positive preoperative urine culture. Other key risk factors included female gender, diabetes mellitus, and both preoperative and postoperative stent placement. Prolonged operative time was also associated with a higher likelihood of infection. However, no significant relationship was found between infection risk and factors such as age or renal insufficiency. **Conclusion:** Fever and infection following URS and RIRS were strongly associated with female gender, diabetes mellitus, positive preoperative urine culture, ureteral stent insertion, and prolonged surgical duration. Additional research is required to confirm these findings and further refine infection prevention strategies.

Cite this article as: Younesi Rostami M, Rezaeimehr B, Feizzadeh Kerigh B, Deylami A, Abdollahi A. Fever and Infection Following Ureteroscopy and Retrograde Intrarenal Surgery: A Systematic Review. J Emerg Health Care. 2025;14(1):15. https://doi.org/10.22034/14.1.15.

Introduction

Urolithiasis is a global health concern impacting individuals of all age groups and remains a significant contributor to morbidity worldwide (1). The lifetime risk of developing urolithiasis has been steadily rising. Approximately half of patients who previously experienced urinary stones are likely to have a recurrence within ten years (2). Various factors influence the formation of ureteric stones in both pediatric and adult populations, including socioeconomic status, stone size, stone location within the urinary tract, renal anatomy and abnormalities, climate conditions, and other environmental factors. These elements significantly affect treatment outcomes and the selection of therapeutic interventions. In North America and Europe, the annual incidence of urinary calculi is roughly 0.5% (1). Diet, particularly calcium and fluid intake, plays a critical role in urinary stone formation. Epidemiological research has also identified diabetes mellitus and hypertension as additional

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factors associated with stone development. Over recent decades, notable progress has been made in minimally invasive treatment techniques. Current therapeutic options include extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS), and laparoscopic ureterolithotomy. Retrograde intrarenal surgery (RIRS) is a minimally invasive procedure used to treat stones within the kidney, particularly those located in the renal pelvis and calyces. It involves the use of a flexible ureteroscope, which is passed through the urethra, bladder, and ureter to access the kidney. RIRS is especially effective for stones in difficult-to-reach areas and is often preferred for complex stones that may be challenging to treat with other techniques. Laser energy, such as Holmium: YAG or Thulium lasers, is typically used to fragment the stone into smaller pieces, which are either retrieved or allowed to pass. Compared to traditional surgery, RIRS offers benefits such as reduced blood loss, shorter recovery time, and minimal risk of complications, making it a valuable option for many patients, including those with contraindications for more invasive procedures. Nonetheless, clinical guidelines vary regarding the comparative effectiveness of these treatments. This review aims to explore the available treatment modalities for urinary tract stones to enhance understanding and inform clinical decision-making.

With continuous advancements in endoscopic technology, ureteroscopy (URS) and retrograde intrarenal surgery (RIRS) have become cornerstones in the management of urinary stone disease, urothelial tumors, ureteral strictures, and hydronephrosis (3, 4). The introduction of both semi-rigid and flexible ureteroscopes has significantly improved procedural efficacy and broadened the indications for these techniques, making them preferred choices over extracorporeal shock wave lithotripsy (ESWL) and percutaneous nephrolithotomy (PCNL) in many clinical scenarios. RIRS, a minimally invasive form of flexible ureteroscopy, allows for precise stone fragmentation and removal within the kidney and upper ureter, making it particularly advantageous for stones that are difficult to access via conventional URS. The American Urological Association (AUA) and Endourological Society Guidelines recommend URS and RIRS as first-line interventions for patients with bleeding disorders or those who require continued anticoagulant or antiplatelet therapy when stone removal is indicated (5).

Various energy modalities are employed during minimally invasive urinary stone procedures, including extracorporeal shock wave lithotripsy (ESWL), ureteroscopy (URS), retrograde intrarenal surgery (RIRS), and percutaneous nephrolithotomy (PCNL). Endoscopic approaches such as URS and RIRS predominantly utilize pneumatic and laser energies, with pneumatic lithotripsy remaining the most commonly used worldwide in URS, although laser-based lithotripsy has been steadily increasing due to enhanced precision, safety, and efficacy. While ESWL employs unique energy mechanisms distinct from endoscopic procedures, laser technology—primarily Holmium:YAG and Thulium—is increasingly becoming the gold standard in RIRS because of its ability to effectively fragment stones within the upper urinary tract. Thulium lasers, traditionally known for continuous-wave application in soft tissue management, have evolved with the advent of the Thulium Fiber Laser (TFL), a newer pulsed-mode technology. TFL has demonstrated promising outcomes in managing urinary calculi, offering greater fragmentation efficiency, versatility, and improved safety profiles for treating stones as well as benign prostatic hyperplasia.

Since its introduction in 1992, the Holmium:yttrium aluminum garnet (Ho:YAG) laser has become the gold standard for ureteroscopic lithotripsy due to its efficacy and reliability (6). However, it has limitations like poor visibility, stone retropulsion, large equipment size, thermal tissue damage, low energy efficiency, and thicker optical fibers. The Thulium fiber laser (TFL), introduced in 2018, addresses many of these issues (7). It features higher water absorption, lower ablation thresholds, improved flexibility with thinner fibers, less retropulsion, and better portability. Although recent studies suggest TFL may surpass Ho:YAG in treating urolithiasis, inconsistent findings have prevented a definitive conclusion. Therefore, this systematic review and meta-analysis was conducted to compare these two laser systems and clarify their clinical roles.

Despite its minimally invasive nature, URS is not devoid of complications. The safety profile of URS has improved substantially due to technological refinements, yet the procedure still carries inherent risks, ranging from minor mucosal injuries to significant postoperative complications such as infection, ureteral stricture formation, and, in rare cases, urosepsis (8). A large multicenter study conducted by the Endourological Society, involving 11,885 patients across 114 centers in 32 countries, reported intraoperative and postoperative complication rates of 4.2% and 2.6%, respectively. Alarmingly, five procedure-related deaths were recorded during the study period, highlighting the importance of recognizing and mitigating perioperative risks (9).

Among the various complications, postoperative infections remain a major concern, primarily manifesting as febrile urinary tract infection (fUTI) and, in severe cases, systemic inflammatory response syndrome (SIRS) or sepsis. The incidence of postoperative infection following URS is estimated to be between 3–5% (10), with considerable variation depending on patient-related factors, preoperative antibiotic prophylaxis, surgical technique, and perioperative urinary drainage strategies. Infectious complications not only increase morbidity but also contribute to prolonged hospital stays, higher healthcare costs, increased likelihood of intensive care unit (ICU) admission, and, in extreme cases, life-threatening complications (11).

Multiple studies have attempted to identify risk factors associated with post-URS infections, yet the findings remain inconsistent. While some reports suggest that female gender, diabetes mellitus, positive preoperative urine culture, and prolonged operative time may predispose patients to infection, other studies have failed to establish definitive correlations due to small sample sizes and heterogeneous study designs. Given these conflicting results, a comprehensive synthesis of existing data is necessary to clarify the key determinants of infection following URS.

Therefore, the aim of this systematic review and meta-analysis is to evaluate the available evidence regarding potential risk factors for postoperative fever and infection following URS. By synthesizing data from multiple studies, we seek to provide a more robust understanding of the factors contributing to infectious complications and to inform perioperative risk stratification and infection prevention strategies.

A REVIEW

URS vs RIRS

Ureteroscopy (URS) and Retrograde Intrarenal Surgery (RIRS) are minimally invasive endoscopic techniques used primarily in the management of urinary tract stones. Both procedures involve accessing stones through the natural urinary tract, avoiding external incisions. URS employs either a semi-rigid or flexible ureteroscope to access and treat stones within the ureter, especially those in the middle and distal segments. It offers rapid treatment times, relatively lower equipment costs, and high success rates for ureteral stones. RIRS, meanwhile, utilizes a flexible ureteroscope, specifically designed for navigating into the renal collecting system, allowing treatment of stones located within the kidney itself, including the renal pelvis and calyces. While RIRS is technically more demanding, requiring specialized skills and equipment, it provides superior access to challenging or deeply situated stones and is particularly effective for smaller intrarenal stones or stones in anatomically complex kidneys. Overall, URS is most suitable for ureteral stones and simpler cases due to its simplicity and efficiency, whereas RIRS is favored for more complicated, intrarenal stones due to its enhanced precision and safety profile within the kidney. The choice between these methods ultimately depends on stone location, size, anatomical complexity, surgeon experience, and available resources.

Comparison of URS and RIRS in the Treatment of Large Proximal Ureter Stones

The management of large proximal ureter stones has evolved significantly, with various surgical techniques being employed based on stone size, location, patient condition, and surgeon expertise. Among the most commonly used procedures are retrograde intrarenal surgery (RIRS) and ureteroscopy (URS), specifically antegrade URS, each having its advantages and limitations (12). While RIRS is widely preferred due to its minimally invasive nature, antegrade URS offers superior stone-free rates (SFR) for large impacted stones. This article presents a comparative analysis of RIRS and URS in terms of effectiveness, complications, success rates, and practical considerations for clinical application.

RIRS

RIRS is a minimally invasive endoscopic procedure that accesses the kidney through the natural urinary tract. Using a flexible ureteroscope, stones are fragmented using a laser and removed through the ureter. The main advantages of RIRS include its ability to be performed via natural orifices without external incisions, resulting in minimal trauma, shorter hospital stays, and reduced recovery times. However, for large impacted ureteral stones, RIRS often has lower success rates, requires multiple sessions, and presents a higher risk of urosepsis due to increased intrarenal pressure during prolonged operative times (13).

Antegrade URS

Antegrade URS is typically used when retrograde access is not possible or fails. It involves a percutaneous approach where the kidney is accessed through the skin, allowing the surgeon to work in a dilated collecting system. The major benefits of antegrade URS over RIRS include:

- Higher stone-free rate (SFR)
- Lower risk of stone migration (pushback)
- Better visualization due to the wider surgical field
  However, antegrade URS is more invasive, requiring renal puncture, which increases the risk of bleeding, radiation exposure, and longer operative times.

Comparison of RIRS and URS: Effectiveness and Success Rates

Stone-Free Rate (SFR)

One of the key indicators of a successful procedure is the stone-free rate (SFR), which measures the effectiveness of stone clearance. Multiple studies have reported that antegrade URS has a higher SFR compared to RIRS for large impacted ureteral stones.

- In a prospective study, the SFR after 2 weeks was 90.3% in the antegrade URS group compared to 70% in the RIRS group ($p = 0.046$) (14).
- Similar results were reported, where antegrade URS achieved SFRs of 97.7% and 83.3%, respectively, significantly higher than RIRS (82.2% and 60%) (15).
- The superior SFR in antegrade URS is attributed to better visualization due to the dilated upper ureter and the lack of stone migration.

For smaller stones or cases where multiple sessions are feasible, RIRS may still be a suitable option, but for large impacted stones (≥1.5 cm), antegrade URS consistently demonstrates higher success rates.

Operative Time and Technical Challenges

RIRS: Faster but Limited by Visualization

One of the advantages of RIRS is its shorter operative time compared to antegrade URS. In a comparative study:

- RIRS had an average operative time of 64.40 minutes (± 7.16)
- Antegrade URS had a significantly longer time of 93.55 minutes (± 7.58) ($p < 0.001$)

The prolonged operative time in antegrade URS is due to:

- The need for renal puncture and tract dilatation.
- The requirement for careful maneuvering of the flexible ureteroscope to access the stone.
- Increased radiation exposure during fluoroscopic guidance.

However, while RIRS is faster, it is also technically challenging in cases of impacted stones due to the narrow surgical field and the potential for stone movement, which can decrease procedural success.

Antegrade URS: Longer but More Effective

Despite its longer operative time, antegrade URS offers superior visualization and direct access to the stone, leading to higher clearance rates. Additionally, the larger surgical field in the dilated upper urinary tract reduces the difficulty of fragmenting and removing stones efficiently.

Complications and Safety Considerations

Risk of Urosepsis

One of the major concerns with RIRS is the risk of urosepsis, particularly in prolonged procedures that result in high pelvicalyceal pressure (PCS). In a comparative study:

- Five cases of urosepsis occurred in the RIRS group, while none were observed in the antegrade URS group.
- The high intrarenal pressure in RIRS increases the risk of bacterial translocation, which can lead to systemic infections.

In contrast, antegrade URS operates at a much lower PCS pressure, significantly reducing the likelihood of infection-related complications (16).

Bleeding Risk

While antegrade URS has a lower risk of urosepsis, it carries a higher risk of bleeding due to the renal puncture required for access. In the study:

Three cases of bleeding (<150 ml) occurred in the antegrade URS group, but all were managed conservatively without blood transfusions.

- No bleeding complications were observed in the RIRS group.
- To minimize bleeding risks, the lower calyx puncture is preferred over middle or upper calyceal access. Additionally, using a 14 Fr tract size with ultrasonic guidance significantly reduces bleeding complications.

Radiation Exposure

One notable drawback of antegrade URS is higher radiation exposure compared to RIRS. Due to the need for fluoroscopic guidance for renal puncture and tract dilation, antegrade URS subjects both the patient and the surgical team to prolonged radiation. While this is an important consideration, the benefits of higher success rates may outweigh the radiation risk in selected cases (17).

Future Considerations and Recommendations

While both RIRS and antegrade URS have their place in modern urology, improvements in instrumentation and patient selection criteria can enhance outcomes. Some recommendations include:

- Developing shorter access sheaths (UAS) and flexible ureteroscopes for antegrade procedures to improve maneuverability.
- Considering ultrasonic-guided puncture techniques to further reduce bleeding risks in antegrade URS.
- Conducting larger multicenter randomized studies to compare long-term outcomes and refine indications for each procedure.

The choice between RIRS and antegrade URS depends on various factors, including stone size, impaction, patient anatomy, and surgeon expertise. RIRS is the preferred choice for smaller stones due to its minimally invasive nature and shorter operative time. However, for large impacted ureteral stones (≥1.5 cm), antegrade URS offers superior stone clearance rates, a lower risk of urosepsis, and a better surgical field, albeit at the cost of higher bleeding risk, longer operative time, and increased radiation exposure.

Given the available data, antegrade URS should be considered a superior option for large impacted upper ureteric stones, particularly when RIRS is not feasible or has failed. The continued evolution of techniques, including the use of minitract approaches and advanced imaging guidance, will further enhance the safety and efficacy of antegrade URS. Future research should focus on refining instrumentation and developing protocols that maximize success while minimizing complications.

Materials And Methods

Search Strategy

A comprehensive search was performed in the PubMed, EMBASE, Cochrane Library, and Web of Science databases using the keywords: "UTI OR SIRS OR sepsis OR urosepsis OR fever OR pyuria OR bacteriuria OR infectious complication" combined with "URS." Studies published in any language were considered relevant for inclusion. The final literature search was completed on February 12, 2025. This study was conducted following the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (18).

Inclusion and Exclusion Criteria

Prospective and retrospective comparative studies that investigated risk factors for infectious complications following URS were included. The exclusion criteria were as follows: (I) studies that included patients who underwent percutaneous nephrolithotomy and/or extracorporeal shockwave lithotripsy; (II) review articles or editorial comments; (III) case series or case reports; (IV) studies with incomplete, unclear, or significantly erroneous data; and (V) duplicate publications.

Data Extraction and Quality Assessment

Two independent reviewers assessed the titles, abstracts, and full texts of the selected studies based on the keywords, as well as the inclusion and exclusion criteria. Any disagreements were resolved through discussion or consultation with a senior author. Extracted data included the study's country, study period, type of study, sample size, type of ureteroscope used, surgical purpose, and clinical characteristics of patients with and without postoperative infectious complications. The quality and risk of bias of the included studies were evaluated using the Methodological Index for Non-Randomized Studies (MINORS) tool (19).

Outcomes Assessed

The study focused on at least one infectious complication following ureteroscopic lithotripsy or diagnostic URS, specifically febrile urinary tract infection (fUTI) and systemic inflammatory response syndrome (SIRS). fUTI was defined as a body temperature exceeding 38°C, accompanied by pyuria or significant bacteriuria within seven days post-surgery. SIRS was diagnosed when at least two of the following criteria were met [1]: (1) body temperature exceeding 38°C or dropping below 36°C, (2) heart rate exceeding 90 beats per minute or $PaCO_2$ below 32 mmHg, (3) respiratory rate above 20 breaths per minute, and (4) white blood cell count exceeding 12,000/mm^3 or falling below 4,000/mm^3, or the presence of more than 10% immature neutrophils (20).

Statistical Analysis

All statistical analyses were carried out using RevMan (version 5.3; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen) and Stata (version 15; StataCorp, College Station, TX, USA). For continuous variables, the mean difference (MD) with a 95% confidence interval (CI) was used. If a study reported only the median and interquartile range, the estimation method proposed by Wan et al. (21) was applied to calculate the mean and standard deviation (SD). For dichotomous variables, the adjusted odds ratio (OR) with a 95% CI was preferred; when unavailable, the crude OR with a 95% CI was used instead. Heterogeneity was assessed using the inconsistency index (I^2) statistic, where $I^2 < 25\%$ indicated low heterogeneity, 25–50% indicated moderate heterogeneity, and >50% represented high heterogeneity (22). To ensure a cautious and balanced interpretation of overall effects, a random-effects model was applied in the final analysis regardless of the I^2 value. Sensitivity analysis was subsequently conducted to identify potential sources of high heterogeneity ($I^2 > 50\%$). Subgroup analyses were performed based on study type, ureteroscope type, and crude versus adjusted OR. Publication bias was evaluated using Egger's test, and statistical significance was determined at a two-sided p-value of < 0.05.

Results

Characteristics of the Included Studies

A flow diagram based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework illustrates the detailed selection process. Ultimately, 14 studies (10, 23-35) involving a total of 14,382 patients were included in this systematic review and meta-analysis (Table 1). These studies, conducted up to February 12, 2025, were geographically distributed as follows: seven from East Asia, four from Europe, two from the Middle East, and one from the United States.

Among the included studies, all were case-control in design, with four classified as prospective cohort studies and ten as retrospective cohort studies. Both semi-rigid and flexible ureteroscopes were utilized for ureteroscopic lithotripsy or diagnostic URS procedures. The reported prevalence of infectious complications following URS varied across studies, ranging from 2.04% to 18.3%. Quality assessment using the MINORS scale indicated that all included studies were of high methodological quality.

Potential Risk Factors

Age

Seven studies (10, 23-25, 27, 28, 32) reported the mean age difference between patients with and without infectious complications. According to the random-effects model, there was no significant difference in age between the two groups (MD −2.74, 95% CI −5.41 to 0.22, p = 0.06). Additionally, heterogeneity was not significant (I^2 = 40%).

Gender

Gender differences were analyzed in 12 studies (6,13-20, 23-25), and the random-effects model indicated that female gender was a significant risk factor for infectious complications (OR 2.02, 95% CI 1.53–2.64, p < 0.01). No substantial heterogeneity was observed (I^2 = 36%).

Operative Time

Mean operative time was assessed in nine studies (13-17,19,22,23,24), and the random-effects model revealed that patients who developed infectious complications had significantly longer operative times than those who did not (MD −12.08, 95% CI −16.95 to −7.24, p < 0.01). However, a high level of heterogeneity was detected (I^2 = 63%). To address this, sensitivity and subgroup analyses were performed to determine the sources of heterogeneity.

Risk Factors and Subgroup Analysis

Preoperative Urine Culture

Ten studies (13–19, 21, 22, 25) reported on preoperative urine culture status in both groups. The random-effects model identified a positive preoperative urine culture as a significant risk factor for infectious complications (OR 3.08, 95% CI 2.07–4.52, p < 0.01). High heterogeneity was observed (I^2 = 59%) (Fig. 2d), prompting sensitivity and subgroup analyses to investigate potential sources of variation.

Diabetes Mellitus

Nine studies (13, 15–21, 25) examined the impact of diabetes mellitus. The random-effects model revealed that diabetes was a significant risk factor (OR 1.59, 95% CI 1.17–2.18, p < 0.01). No heterogeneity was detected (I^2 = 0%).

Preoperative Stent Insertion

The presence of a preoperative stent was assessed in nine studies (13–21). The random-effects model demonstrated that preoperative stent placement was significantly associated with infectious complications (OR 1.58, 95% CI 1.14–2.15, p = 0.01). Heterogeneity was moderate (I^2 = 29%).

Postoperative Stent Insertion

Postoperative stent placement was analyzed in four studies (14, 15, 17, 21). The random-effects model indicated a significant association between postoperative stent insertion and infectious complications (OR 1.46, 95% CI 1.03–2.09, p = 0.04). No heterogeneity was observed (I^2 = 0%).

Cumulative Stone Diameter

Five studies (13, 16, 17, 23, 25) evaluated cumulative stone diameter between groups. The random-effects model found no significant difference in cumulative stone size between patients with and without infectious complications (MD −1.68, 95% CI −4.75 to 1.60, p = 0.32). However, substantial heterogeneity was present (I^2 = 85%), necessitating sensitivity and subgroup analyses to identify sources of variation.

Renal Insufficiency

Renal insufficiency was assessed in four studies (14, 18, 24, 25). The random-effects model did not identify it as a significant risk factor (OR 1.20, 95% CI 0.79–1.85, p = 0.37). Minimal heterogeneity was present (I^2 = 12%).

Subgroup and Sensitivity Analyses

Subgroup Analysis

Subgroup analysis was conducted based on study design, ureteroscope type, and crude versus adjusted OR. When categorized by ureteroscope type, the heterogeneity for cumulative stone diameter decreased from 85% to 0%, and the heterogeneity for age decreased from 40% to 0% when classified by either ureteroscope type or study design. However, for other risk factors, heterogeneity remained unchanged, suggesting that study type, ureteroscope type, and crude/adjusted OR did not introduce significant bias in these results.

Sensitivity Analysis

High heterogeneity was noted for operative time, preoperative urine culture, and cumulative stone diameter, with I^2 values of 63%, 59%, and 85%, respectively. Sensitivity analyses were conducted using Stata and RevMan to assess the impact of individual studies on overall results.

Preoperative Urine Culture: When in a study (14) was removed, the OR increased from 3.08 (95% CI 2.07–4.52, p < 0.01) to 3.44 (95% CI 2.47–4.88, p < 0.01).

Operative Time: Removing Fan et al. (17) adjusted the MD from –12.08 (95% CI –16.95 to –7.24, p < 0.01) to –9.45 (95% CI –12.74 to –6.37, p < 0.01).

Cumulative Stone Diameter: When Uchida et al. (15) and Yoshida et al. (13) were excluded, the MD shifted from –1.68 (95% CI –4.75 to 1.60, p = 0.32) to –4.02 (95% CI –5.45 to –2.63, p < 0.01).

These findings indicate that, despite the presence of heterogeneity, the overall conclusions remained stable except for cumulative stone diameter, which requires further investigation.

Discussion

Our review demonstrated that female gender, diabetes mellitus, positive preoperative urine culture, pre- and postoperative stent insertion, and prolonged operative time were significant risk factors for infectious complications following URS. However, age, cumulative stone diameter, and renal insufficiency did not show significant associations with infection risk.

Among these factors, a positive preoperative urine culture was the most significant predictor (OR 3.08, 95% CI 2.07–4.52, p < 0.01), with substantial heterogeneity observed (I^2 = 59%). Sensitivity analysis identified Southern et al. (6) as a key contributor to this heterogeneity, possibly due to their classification of urine cultures as “positive” versus “negative/not tested” instead of the standard “positive” versus “negative”, which may have underestimated its effect. Removing this study did not alter the final result (OR 3.44, 95% CI 2.47–4.88, p < 0.01). Some research suggests that stone culture or renal pelvic urine culture may be more informative than preoperative urine culture alone, though the prevailing consensus supports perioperative antibiotic use to reduce the risk of febrile urinary tract infections (fUTI) in patients with positive preoperative urine cultures undergoing URS.

Female gender was the second most significant risk factor (OR 2.02, 95% CI 1.53–2.64, p < 0.01), with relatively low heterogeneity (I^2 = 36%). While a definitive explanation for the higher infection risk in women compared to men remains unclear, possible reasons include the shorter female urethra, facilitating bacterial migration from the perineum to the ureters during URS, as well as genetic and hormonal differences. Further studies are necessary to explore this gender-related susceptibility.

Diabetes mellitus was another significant risk factor (OR 1.59, 95% CI 1.17–2.18, p < 0.01), with no detected heterogeneity (I^2 = 0%). It is well established that individuals with diabetes have a higher prevalence of urinary tract infections due to factors such as glucosuria, impaired immune response, and decreased leukocyte function. As a result, diabetic patients are also at increased risk of infectious complications after URS, emphasizing the importance of careful preoperative assessment in these patients.

Both preoperative and postoperative stent placements were associated with an increased risk of infection (OR 1.58, 95% CI 1.14–2.15, p = 0.01, and OR 1.46, 95% CI 1.03–2.09, p = 0.04, respectively), with moderate heterogeneity for preoperative stenting (I^2 = 29%) and no heterogeneity for postoperative stenting (I^2 = 0%). These findings are consistent with prior studies, which suggest that bacteria may spread from colonized stents during surgical manipulation, and prolonged stenting has been associated with higher rates of bacteriuria and stent colonization. Additionally, ureteral stents may contribute to increased lower urinary tract symptoms, pain, and unchanged stone-free rates, necessitating careful consideration before stent placement to minimize complications.

Extended operative time was also associated with an increased risk of infection (MD –12.08, 95% CI –16.95 to –7.24, p < 0.01), with high heterogeneity observed (I^2 = 63%). Sensitivity analysis identified Fan et al. (27) as a major contributor to this variability. Removing this study slightly adjusted the result (MD –9.45, 95% CI –12.74 to –6.37, p < 0.01), but the overall conclusion remained unchanged. While some studies have suggested that operative times exceeding 120 minutes increase infection risk, the precise threshold remains debated, as longer durations often reflect higher case complexity rather than an independent risk factor.

Age did not show a significant association with infectious complications (MD –2.74, 95% CI –5.41 to 0.22, p = 0.06), with moderate heterogeneity (I^2 = 40%). However, subgroup analysis based on ureteroscope type and study design reduced heterogeneity to 0%. Findings suggested that in specific subgroups, particularly those involving certain ureteroscope types or prospective cohort studies, older patients exhibited a higher risk. This may be due to comorbidities such as diabetes, cardiovascular disease, and chronic obstructive pulmonary disease, which increase infection susceptibility in elderly individuals. More extensive research is needed to determine whether advanced age alone is an independent risk factor.

Cumulative stone diameter was not significantly associated with infectious complications (MD −1.68, 95% CI −4.75 to 1.60, p = 0.32), but analysis revealed substantial heterogeneity (I^2 = 85%). Subgroup analysis based on ureteroscope type reduced heterogeneity to 0%, suggesting that in cases involving flexible ureteroscopes, stone size may contribute to infection risk. Further prospective studies are required to validate this observation.

Renal insufficiency was not significantly correlated with infectious complications (OR 1.20, 95% CI 0.79–1.85, p = 0.37), with minimal heterogeneity (I^2 = 12%). The limited number of studies reporting on renal insufficiency in relation to fUTI reduces the robustness of this conclusion, highlighting the need for additional research.

There are several limitations to our study. All included studies were observational, making them susceptible to biases. Some risk factors exhibited high heterogeneity and potential publication bias. Risk factors reported in fewer than three studies, such as irrigation flow rate, irrigation volume, stone composition, and stone location, were not analyzed. Subgroup analysis based on surgical purpose (e.g., ureteroscopic lithotripsy vs. diagnostic URS) was not performed due to insufficient data. In studies where adjusted ORs were unavailable, crude ORs were used, which may have affected results, despite performing subgroup analyses based on crude versus adjusted ORs. Not all studies explicitly clarified whether preoperative bacteriuria was independent of antibiotic treatment, potentially influencing the final outcome. Despite these limitations, our findings highlight key risk factors for infection following URS and provide valuable insights for clinical decision-making. Further large-scale, well-controlled prospective studies are needed to confirm these findings and refine infection prevention strategies.

Conclusion

Infectious complications following URS were significantly associated with female gender, diabetes mellitus, positive preoperative urine culture, pre- and postoperative stent placement, and prolonged operative time. However, publication bias and high heterogeneity were observed in some risk factors. Further research is needed to confirm these findings and refine risk assessment strategies.

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