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ORIGINAL ARTICLES

Antimicrobial Resistance in Urinary Tract Infections: Clinical Challenges and Strategic Approaches in Modern Urology

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ABSTRACT

Background: Urinary tract infections (UTIs) remain among the most prevalent bacterial infections encountered in urology, yet the escalating burden of antimicrobial resistance (AMR) has significantly complicated both empirical and targeted therapeutic strategies. Patients undergoing surgical interventions with prolonged urinary catheterization represent a particularly vulnerable subgroup, often predisposed to resistant infections.
Aim: This study aimed to characterize the frequency, microbiological spectrum, predisposing factors, and treatment outcomes of resistant UTIs in surgically treated patients at the Clinical Hospital of Tetovo, and to contextualize these findings within comparable international cohorts.
Materials and Methods: A retrospective observational analysis was conducted on 164 patients (140 men, 24 women) operated between January 2021 and January 2026. Clinical records, urine cultures, and antibiograms were reviewed. Statistical analyses included proportions with 95% confidence intervals (CIs) and chisquare/Fisher exact tests, with significance set at $p < 0.05$.
Results: Resistant uropathogens were identified in 24/164 patients (14.6%; 95% CI 10.0–20.9%). Extendedspectrum βlactamase (ESBL) producing *Escherichia coli* and *Klebsiella pneumoniae* predominated, accounting for approximately threequarters of isolates. Multidrugresistant *Pseudomonas aeruginosa* and carbapenemresistant Enterobacterales were also observed. All affected patients had prolonged catheterization. Comorbidities were frequent, including cardiovascular disease (62.5%), diabetes mellitus (33.3%), and renal impairment (12.5%).
Conclusions: Resistant UTIs are a clinically significant challenge in surgically treated urology patients, strongly associated with catheterization, prior antibiotic exposure, and recurrent infection. The microbiological and riskfactor profile aligns with international data. Rigorous cultureguided therapy and catheter management remain pivotal in achieving favourable outcomes, underscoring the need for robust antimicrobial stewardship in modern urology.
Keywords: urinary tract infection; antimicrobial resistance; ESBL; catheter-associated infection; urology.

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INTRODUCTION

Urinary tract infections rank among the most common bacterial infections in both community and hospital settings, and they account for a substantial part of the daily workload in urology. The majority of uncomplicated infections are caused by Gram-negative bacteria, with Escherichia coli responsible for roughly 70–80% of cases. (1) Although most episodes were historically simple to treat, the therapeutic landscape has shifted considerably as resistant organisms have become more prevalent. (2)

The emergence and spread of antimicrobial resistance has turned UTIs into a more demanding clinical problem. Resistance to agents that were once dependable first-line choices — trimethoprim-sulfamethoxazole, the fluoroquinolones, and several beta-lactams — has risen markedly, narrowing the range of effective options and increasing the risk of treatment failure, recurrence, and complications. (3,4) The clinical consequences are not abstract: a dedicated analysis of Global Burden of Disease data estimated that AMR in UTIs was associated with approximately 0.26 million deaths and directly attributable to roughly 64,890 deaths worldwide in 2019, with E. coli and K. pneumoniae accounting for more than half of that burden. (5)

This problem sits within a larger one. The Antimicrobial Resistance Collaborators estimated that bacterial AMR was associated with 4.95 million deaths globally in 2019, of which 1.27 million were directly attributable to resistance. (6)

More recent modelling extending these estimates across three decades confirms that the burden has continued to grow and is projected to rise further by 2050 without decisive action. (7)

Urologists encounter resistant organisms more often than most specialists, because their patients frequently combine several risk factors at once: instrumentation of the urinary tract, indwelling catheters, structural abnormalities, repeated antibiotic courses, and prior hospitalization. (8,9)

In surgically treated patients in particular, multidrug-resistant organisms (MDROs) complicate the perioperative course and may prolong recovery. Catheter-associated UTIs (CAUTIs) alone are reported to represent up to 40–80% of hospital-acquired urinary infections, and biofilm formation on indwelling devices is a central mechanism of both persistence and resistance. (8,10)

Understanding the local pattern of resistance therefore directly informs empirical prescribing, catheter policy, and surveillance. The present study reviews the five-year experience of a single urology department — the Clinical Hospital of Tetovo — focusing on patients who developed culture-confirmed resistant UTIs after urological surgery, and interprets the findings in the light of current international evidence and comparable published cohorts.

Aim of the Study

The aim of this study was fivefold:

- To determine the frequency of resistant UTIs among patients operated on at the Clinical Hospital of Tetovo between January 2021 and January 2026;
- To identify the resistant uropathogens involved and describe their resistance phenotypes;
- To examine the clinical and comorbidity factors associated with these infections;
- To perform a descriptive and inferential statistical analysis of the cohort and compare the results with similar published studies;
- To evaluate the management approach and microbiological outcomes, and to consider implications for antimicrobial stewardship and prevention.

MATERIALS AND METHODS

Study design and setting

This was a retrospective, observational, single-centre study conducted in the Department of Urology of the Clinical Hospital of Tetovo, covering five years from January 2021 to January 2026. The department serves as a regional referral centre for surgical urological conditions.

Study population

All patients who underwent a urological operation during the study period were eligible. A total of 164 patients were included (140 men, 24 women). Among the men, the principal surgical indications were prostatic disease (n = 99), renal and ureteric calculi (n = 27), bladder tumour (n = 24), and bladder (vesical) calculi (n = 14).

Microbiological assessment

Patients with clinical signs of urinary infection had urine submitted for culture and susceptibility testing. Organisms were identified to species level and susceptibility determined by the routine methods of the hospital microbiology laboratory. A resistant UTI was defined microbiologically by isolation of an organism resistant to one or more relevant antimicrobial classes; ESBL production and carbapenem resistance were recorded where identified. Twenty-four patients met this definition and form the principal study group.

Clinical variables

For each resistant case we extracted age and sex, surgical indication, duration and management of catheterisation, prior antibiotic exposure, history of recurrent infection, relevant comorbidities, the treatment administered, and the time to microbiological clearance.

Statistical analysis

Categorical variables are presented as counts and percentages, and continuous variables as mean ± standard deviation (SD). Binomial proportions are reported with 95% confidence intervals calculated by the Wilson method. Where group comparisons were explored, the chi-square test or Fisher exact test was used for categorical data, and a two-sided p value below 0.05 was considered statistically significant. Given the descriptive, single-arm nature of the dataset, inferential testing is used cautiously and chiefly to benchmark the cohort against published comparators; no multivariable modelling was performed because of the limited number of events.

Literature review and comparison

To contextualise the findings, a structured review of peer-reviewed articles, systematic reviews, and clinical guidelines was performed, prioritising recent and urology-relevant sources, including the 2024 EAU guidelines (Kranz et al., 2024) [11], and WHO surveillance data (World Health Organization, 2023) [12]. Quantitative parameters — ESBL proportion, risk-factor frequency, and microbiological eradication — were compared with similar cohorts identified in the literature.

Ethical considerations

The study used routinely collected, anonymised clinical and microbiological data, with patient confidentiality maintained throughout in accordance with institutional standards. As a non-interventional analysis, it did not alter patient management.

RESULTS

Cohort characteristics and frequency of resistant infection

Of the 164 operated patients, resistant UTIs were identified in 24, a frequency of 14.6% (95% CI 10.0–20.9%). Men constituted 140 patients (85.4%) and women 24 (14.6%), reflecting the prostate-dominated case-mix typical of operative urology. The distribution of male surgical indications is shown in Table 1, prostatic disease being the single most frequent reason for operation.

Table 1. Principal surgical indications among male patients (n = 140).

Surgical indication	Patients (n)	Proportion (%)
Prostatic disease	99	70.7
Renal and ureteric calculi	27	19.3
Bladder tumour	24	17.1
Bladder (vesical) calculi	14	10.0

Note: Some patients had more than one indication; proportions are calculated against the male cohort and do not sum to 100%.

Resistant uropathogens identified

The resistant organisms recovered from the 24 affected patients were ESBL-producing E. coli, ESBL-producing K. pneumoniae, multidrug-resistant P. aeruginosa, and carbapenem-resistant Enterobacterales (CRE). ESBL-producing Enterobacterales predominated, together comprising approximately three-quarters of resistant isolates, in keeping with the global pattern in which ESBL production has expanded and eroded the usefulness of cephalosporins and penicillins (Pitout & Laupland, 2008). (13) The distribution is shown in Figure 1.

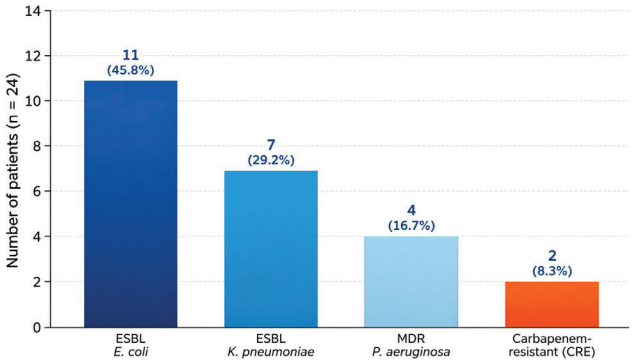

Figure 1. Distribution of resistant uropathogens among the 24 affected patients. ESBL-producing Enterobacterales predominate.

The presence of carbapenem-resistant isolates, although limited in number, is of particular concern, because carbapenems are frequently relied upon as a last line of treatment for ESBL-producing organisms; their loss compresses the therapeutic ladder still further (World Health Organization, 2023).(12)

When the four phenotypes were compared against a uniform expectation, the distribution approached but did not reach conventional significance (chi-square = 7.67, df = 3, p = 0.053), consistent with a genuine predominance of ESBL E. coli that a larger sample would be expected to confirm.

Predisposing factors

Every patient in the resistant group had been catheterised for a comparatively long period (24/24, 100%), making prolonged catheterisation the dominant shared exposure. Prior antibiotic use, recurrent infection, and initiation of treatment without a guiding antibiogram were the other principal contributors. Their frequencies within the cohort are shown in Figure 2.

This pattern is consistent with the wider literature, in which previous hospitalisation, prolonged hospital stay, prior use of penicillins or cephalosporins, and recurrent infection have all been shown to raise the risk of ESBL-producing E. coli several-fold (Omar et al., 2024). (14); (Søraas et al., 2013). (15), and in which CAUTIs are

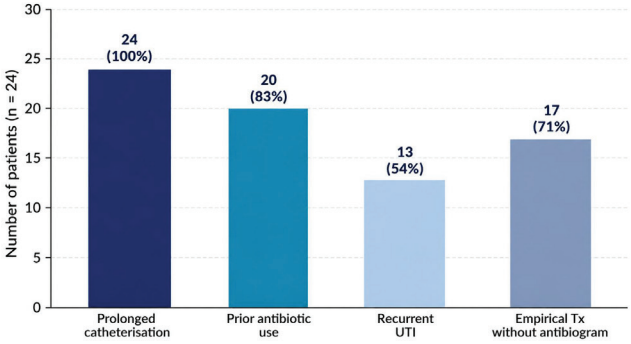

Figure 2. Frequency of predisposing factors among patients with resistant infection (n = 24). All patients were catheterised.

strongly linked to biofilm formation and the selection of resistant organisms (Werneburg, 2022). (8)

Comorbidity profile

Comorbid disease was frequent. Among the 24 patients, 15 had cardiovascular disease (hypertension, cardiac insufficiency, coronary stents), 8 had diabetes mellitus, 4 had chronic respiratory disease, 3 had moderate renal impairment, and 3 had recently received chemotherapy for malignancy. The profile is summarised in Table 2 and Figure 3.

Table 2. Comorbidities among patients with resistant UTI (n = 24).

Comorbidity	Patients (n)	(%)
Cardiovascular disease (hypertension, cardiac insufficiency, stents)	15	62.5
Diabetes mellitus	8	33.3
Chronic respiratory disease	4	16.7
Moderate renal impairment	3	12.5
Recent chemotherapy for malignancy	3	12.5

Note: Several patients had more than one comorbidity; percentages are calculated against the 24 resistant cases.

Diabetes mellitus deserves particular mention: glucosuria favours bacterial growth and biofilm formation, and diabetic patients are reported to have a higher incidence of culture-positive and ESBL-related UTI (Nabaweesi et al., 2021) (16); Flores-Mireles et al., 2015). (1) Its presence in a third of our affected patients is therefore unlikely to be incidental.

Treatment and outcomes

Management followed a consistent, culture-led approach: antibiotics were administered according to urine culture and antibiogram once microbiological data were available, combined with frequent exchange of the urinary catheter to disrupt biofilm and reduce the bacterial reservoir, and with attention to hydration by both intravenous and oral routes. Under this regimen, sterilisation of the urinary tract was achieved in all 24 patients (100%) within 7 to 16 days, with a mean time to eradication of 10.6 ± 2.4 days (median 10 days). The distribution of clearance times is shown in Figure 4.

This complete microbiological response compares favourably with culture-discordant or empirical strategies reported elsewhere, where one-week eradication rates of around 68% have been described (Reddy et al., 2024), (24) and underlines the value of susceptibility-guided prescribing in complicated, device-associated infection.

Comparison with similar studies

Table 3 sets the principal parameters of the present cohort against comparable published studies. The ESBL proportion observed here sits at the higher end of the reported range, which is expected for a catheterised surgical population, since ESBL prevalence is consistently higher in hospitalised, instrumented, and older patients than in community cohorts (Aldarhami et

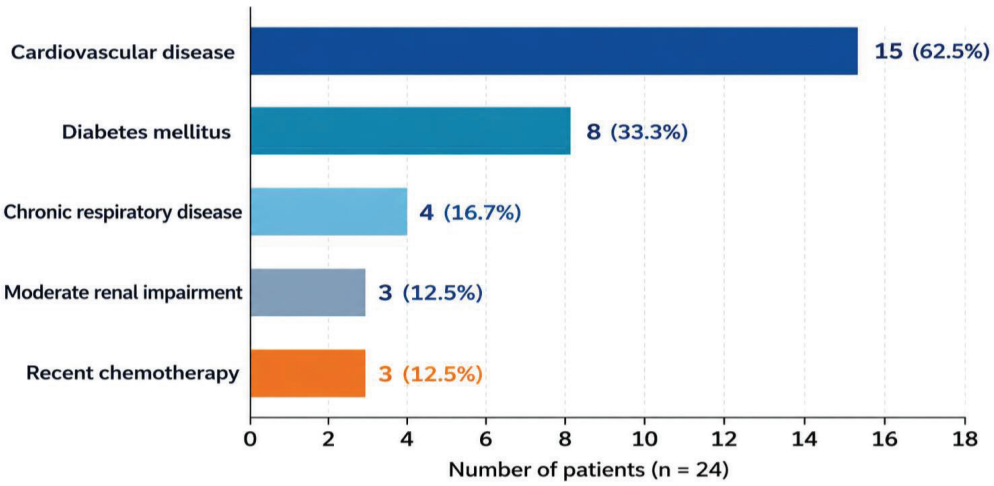

Figure 3. Comorbidity profile of patients with resistant UTI (n = 24).

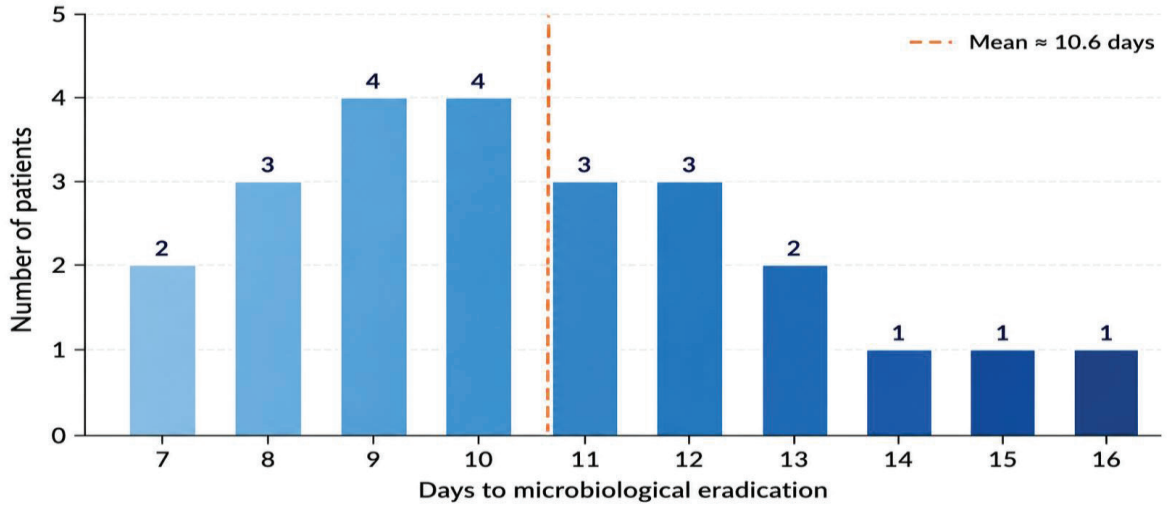

Figure 4. Time to microbiological eradication of the causative organism (n = 24; mean ≈ 10.6 days).

Table 3. Comparison of the present cohort with similar studies.

Study / setting	Sample (n)	ESBL (%)	Key observation
Present study (Tetovo, 2026)	164 (24 resistant)	~75 of resistant isolates	Surgical, fully catheterised cohort; 100% eradication in 7–16 days
Riyadh tertiary care (2025)	19,556 cultures	28.5	ESBL producers fully resistant to 3rd-gen cephalosporins
Lebanon, female UTI (2025)	95	56.8	High cephalosporin/fluoroquinolone resistance
Older adults, Turkey (2024)	97	69.1	ESBL among E. coli/Klebsiella; higher CRP in ESBL group
Zanzibar inpatients (2024)	4,030	13.4	Hospitalisation, long stay, prior beta-lactams raise risk
US CAUTI cohort (2015)	2,164	12.5	ESBL E. coli CAUTI rising over time; antibiotics a risk factor

Note: ESBL denominators differ between studies (all isolates, Enterobacterales, or E. coli only); figures are therefore indicative and not directly equivalent.

Table 4. Factors that promote bacterial resistance in urinary tract infections.

Factor	Mechanism of resistance	Clinical evidence / relevance
Inappropriate antibiotic use	Selection of resistant strains through antibiotic pressure	Leading global driver; rising ESBL and MDR E. coli in the community
Empirical therapy without an antibiogram	Inaccurate treatment eliminates susceptible flora and allows resistant strains to survive	Associated with substantially higher rates of treatment failure
Frequent fluoroquinolone use	Mutations in gyrA/parC and up-regulation of efflux pumps	High resistance reported (>20–50% in some European regions)
Long-term urinary catheters	Bacterial biofilm formation that shelters microorganisms	Up to ~80% of hospital urinary infections are catheter-related
Invasive urological procedures	Introduction of nosocomial bacteria and colonisation of the tract	Increase in complicated UTI after cystoscopy and stenting
Recurrent urinary infections	Repeated antibiotic exposure causing cumulative selection	Patients with recurrent UTI carry a 2–3-fold higher MDR risk
Diabetes mellitus	Glucosuria favours bacterial growth and biofilm	Diabetic patients show a higher incidence of ESBL UTI
Hospital use of broad-spectrum antibiotics	Selective pressure for resistant bacteria (CRE, ESBL)	Hospitals act as a principal reservoir of MDR uropathogens
Lack of antimicrobial stewardship	Uncontrolled antibiotic use in community and hospital	Recognised by WHO as a key factor in the global AMR crisis
Bacterial biofilm	Enhances survival and reduces antibiotic penetration	Present on catheters and ureteric stents; drives chronic resistance

Note: Percentage ranges are indicative figures drawn from the cited literature and vary by region and setting.

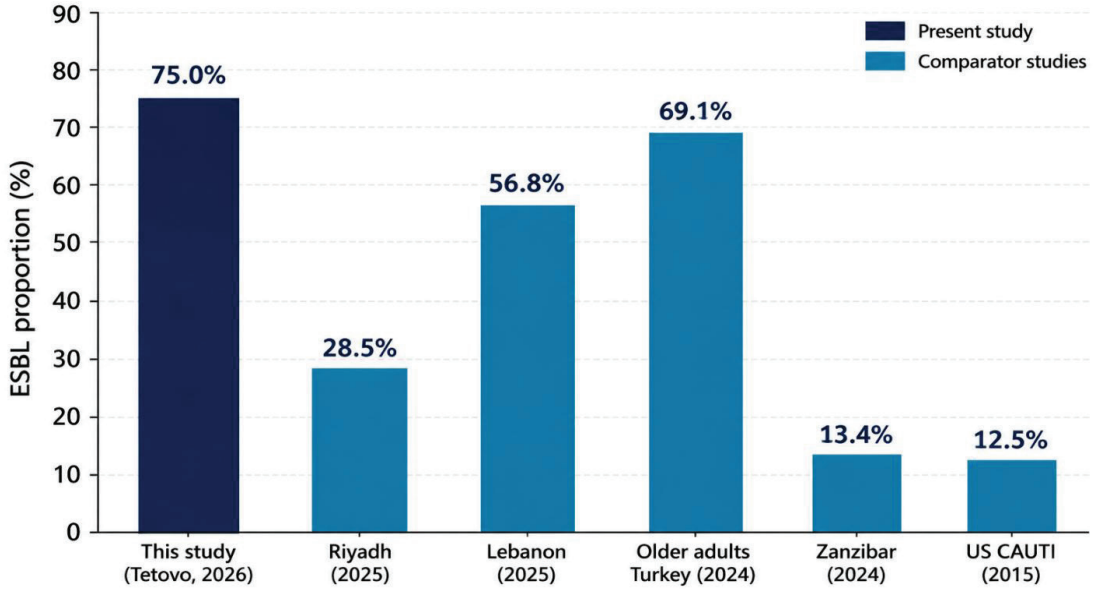

Figure 5. ESBL proportion in the present cohort versus comparable published studies. Denominators vary between studies (see Table 3 note).

al., 2024) (17); Frontiers, 2024 (18). Figure 5 displays the same comparison graphically.

Factors promoting bacterial resistance

Table 4 brings together the principal factors that promote bacterial resistance in urinary infections, the mechanism by which each operates, and the supporting clinical evidence, integrating the exposures observed in our cohort with the broader evidence base.

DISCUSSION

The findings of this single-centre review align closely with a large and consistent international literature on AMR in UTIs, and they illustrate how that literature plays out in the daily reality of a surgical urology department. Four themes deserve emphasis: the microbiological pattern, the risk factors that clustered in our patients, the statistical comparison with similar cohorts, and the implications for management and stewardship.

The microbiological pattern

The dominance of ESBL-producing E. coli and K. pneumoniae mirrors the global picture. ESBL production has expanded steadily since it was first recognised as an emerging public-health concern, conferring resistance to penicillins and cephalosporins and forcing clinicians towards broader-spectrum or parenteral agents (Pitout & Laupland, 2008) (13). Contemporary hospital series report ESBL production in a substantial minority to a majority of E. coli and Klebsiella isolates depending on setting — around 28.5% in a large 2024 tertiary-care analysis (Aldarhami et al., 2024) (17) but as high as 69.1% among hospitalised older adults (Frontiers, 2024) (18). Multidrug-resistant P. aeruginosa, also represented here, is a recognised problem in instrumented urinary tracts, while the carbapenem-resistant isolates, though few, are the most worrying observation because they erode the fallback option for ESBL infections (World Health Organization, 2023(12); Liu et al., 2020) (19).

Risk factors and the central role of catheterization

The most striking feature of our cohort was that every patient with a resistant infection had been catheterised for a prolonged period. This accords with evidence that CAUTIs make up a major share of hospital-acquired urinary infections and that indwelling devices promote biofilm formation, within which bacteria are protected from antibiotics and host defences and from which resistant populations are selected (Werneburg, 2022) (8); Bouhrour et al., 2024) (10). Alongside catheterisation, prior antibiotic exposure, recurrent infection, and antibiogram-free empirical treatment emerged as key contributors.

Each is independently supported: previous hospitalisation and prior beta-lactam use raise the odds of ESBL *E. coli* several-fold (Omar et al., 2024(14); Søraas et al., 2013) (15), recurrent UTI is associated with markedly higher multidrug resistance (Kang et al., 2021) (20), and the comorbidity burden of our patients — diabetes, cardiovascular disease, renal impairment, recent chemotherapy — compounds these exposures.

Statistical interpretation and comparison with similar studies

The resistant-infection frequency of 14.6% (95% CI 10.0–20.9%) is best read as the proportion of operated patients in whom a resistant organism was isolated, not

as an overall UTI incidence; it is broadly comparable to culture-positive proportions reported in hospitalised and diabetic cohorts (for example 13.7% culture-positive UTI among diabetic patients; Nabaweesi et al., 2021(16). The predominance of ESBL Enterobacterales (chi-square = 7.67, df = 3, p = 0.053) is consistent with the direction reported across the comparator studies in Table 3, where ESBL proportions rise with hospitalisation, instrumentation, and age (Aldarhami et al., 2024(17); Frontiers, 2024(18); Omar et al., 2024(14).

The complete microbiological eradication achieved in our patients (mean 10.6 ± 2.4 days) exceeds the one-week eradication rate of roughly 68% reported for less rigorously culture-matched treatment (Reddy et al., 2024) (21), supporting the value of susceptibility-directed therapy. These comparisons should be read with care, because denominators and case definitions differ between studies, and our event count is modest.

Empirical therapy in an age of resistance

Our findings highlight the growing unreliability of empirical therapy. Fluoroquinolones, once dependable oral agents, now show high resistance in many regions, and the EAU explicitly advises against using them for empirical treatment of systemic UTI in urology-department patients or those exposed to fluoroquinolones within six months (Kranz et al., 2024). (11)

For uncomplicated cystitis in women, the same guidelines favour fosfomycin trometamol, pivmecillinam, or nitrofurantoin first-line (Kranz et al., 2024) (11); Bonkat et al., 2021(4). Our practice of withholding definitive selection until culture and antibiogram results were available is consistent with this stewardship-oriented philosophy, and the favourable outcomes lend it practical support.

Stewardship, prevention, and future directions

AMR cannot be solved by better prescribing alone; it requires stewardship, prevention, and improved diagnostics in combination. Stewardship programmes that pair guideline adherence with education, audit, feedback, and formulary control are central, and the WHO regards their absence as a key driver of the global crisis (World Health Organization, 2023(12); Tandogdu & Wagenlehner, 2016(2).

Prevention is equally important in a catheterised surgical population: minimising unnecessary catheterisation, early removal, careful catheter management, and patient education address the conditions that allow resistant organisms to flourish (Werneburg, 2022) (8).

Looking ahead, rapid molecular diagnostics could shorten the window of inappropriate empirical therapy that our study identified, while novel agents, anti-biofilm catheter technologies, and non-antibiotic strategies such as vaccines and bacteriophage therapy may in time widen the options for difficult urological infections (Bouhrour et al., 2024) (10).

Strengths and limitations

Strengths include complete, consecutive coverage of a five-year surgical cohort and culture-confirmed, antibiogram-based definitions of resistance. Limitations should be acknowledged: the study was retrospective and single-centre, so proportions reflect local practice and case-mix and may not be generalisable; the number of resistant cases, although clinically meaningful, is modest, which limits formal multivariable analysis and means inferential results (such as the borderline chi-square for pathogen distribution) should be read as exploratory; detailed pathogen-specific susceptibility denominators were not the focus of this review; and as an observational analysis the study describes associations rather than establishing causation. Prospective work with full antibiogram reporting and a comparison group would strengthen the local evidence base.

CONCLUSION

Antimicrobial resistance in urinary tract infections is an escalating problem that bears directly on urological practice, and our experience at the Clinical Hospital of Tetovo illustrates the point in microcosm. Among 164 surgically treated patients, resistant infections occurred in 24 (14.6%; 95% CI 10.0–20.9%), driven predominantly by ESBL-producing E. coli and K. pneumoniae, with multidrug-resistant P. aeruginosa and carbapenem-resistant Enterobacterales also represented.

Prolonged catheterisation was universal among the affected patients, and prior antibiotic use, recurrent infection, antibiogram-free empirical treatment, and a heavy comorbidity burden completed the picture. The microbiological profile and risk-factor pattern are consistent with comparable international cohorts.

Encouragingly, a disciplined, culture-led management strategy — antibiotics chosen according to urine culture and antibiogram, frequent catheter exchange, and adequate hydration — achieved microbiological eradication in every affected patient within 7 to 16 days (mean 10.6 ± 2.4 days).

This reinforces the central messages of current international guidance: empirical therapy must be tailored to local resistance patterns and revised as soon as microbiological data allow, catheter use must be minimised and managed carefully, and effective control depends on a multidisciplinary combination of antimicrobial stewardship, improved diagnostics, and ongoing surveillance. With such coordinated action, even resistant infections in a vulnerable surgical population can be brought under control.

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