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Antimicrobial Susceptibility Pattern of Commonest Gram-Negative Uropathogen among Cancer Patients at a Tertiary Care Hospital in Bangladesh

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Abstract

Background: Urinary tract infections (UTIs) is one of the leading causes of morbidity and mortality in cancer patients. The increasing prevalence of multidrug-resistant (MDR) gram-negative bacterial strains as causative agents of urinary tract infection has emerged as a critical challenge in oncological care. Bangladesh is experiencing a rapidly escalating antimicrobial resistance (AMR) burden, yet organism-specific susceptibility data from oncology settings remain critically scarce. Objective: This study aimed to describe the antimicrobial susceptibility profile of gram-negative uropathogens in cancer patients at Ahsania Mission Cancer and General Hospital (AMCGH), Dhaka, Bangladesh. Methodology: This was a retrospective cross-sectional study of urine culture and sensitivity data from UTI cancer patients aged ≥3 years attending AMCGH between July 2024 and June 2025. Commonest gram negative uropathogen E. coli, Klebsiella spp. and Pseudomonas spp. positive urine samples were taken as study sample. Antibiotic susceptibility testing (AST) was performed by Kirby-Bauer disc diffusion, interpreted per CLSI 2024 M100 breakpoints. MDR was defined as resistance to ≥3 antimicrobial classes. Ethical approval was taken from the ethical review committee of AMCGH. Results: Out of 189 culture-positive isolates, E. coli predominated (47.6%), followed by Klebsiella species (40.2%) and Pseudomonas spp. (12.2%). MDR was identified in 94.4% of Escherichia coli, 100% of Klebsiella species, and 56.5% of Pseudomonas spp. isolates. Meropenem retained the best activity against E. coli (81.1% susceptible), but carbapenem susceptibility was low in Klebsiella spp. (44.7%) and Pseudomonas species (43.5%). Ceftazidime–avibactam was found susceptible in 74.3%, 32.1%, and 25% of Escherichia coli, Klebsiella species and Pseudomonas spp., respectively. Conclusion: Escherichia coli showed high susceptibility to carbapenem but Klebsiella spp. and Pseudomonas species showed very low susceptibility to carbapenem along with ceftazidime -avibactam.

Keywords: Urinary tract infection; antimicrobial resistance; cancer patients; Gram-negative bacteria; Kirby-Bauer disc diffusion; CLSI 2024; AWaRe; multidrug resistance; Bangladesh; oncology

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Introduction

Urinary tract infections (UTIs) are among the most common infections in immunocompromised patients globally. Cancer patients are particularly at risk owing to immunosuppression induced by malignancy, chemotherapy, radiation therapy, and major surgical procedures, which significantly impairs host defense mechanisms and increases susceptibility to opportunistic infections including UTIs[1-2].

The frequent use of urinary catheters, prolonged hospitalization, recurrent antibiotic exposure, and chemotherapy-related neutropenia further compound this risk, creating an environment highly conducive to the selection and proliferation of MDR organisms[3-4].

Bangladesh is a densely populated lower-middle-income country facing a rapidly escalating AMR burden. Convergent factors driving this crisis include unrestricted over-the-counter antibiotic dispensing, widespread empirical use of broad-spectrum agents

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without microbiological guidance, inadequate infection prevention and control (IPC) infrastructure, and a fragmented regulatory framework[5-6]. National surveys have documented alarmingly high rates of extended-spectrum beta-lactamase (ESBL)-producing Enterobacteriaceae and carbapenem-resistant organisms (CROs) in hospital settings[7-8]. However, data specifically from oncology patients remain extremely limited, leaving clinicians without evidence-based guidance for empirical antibiotic selection in this high-risk group.

The cancer burden in Bangladesh is substantial and growing. An estimated 150,000 new cancer cases are diagnosed annually, with cervical, breast, oral, lung, and colorectal cancers predominating[9]. The few dedicated cancer hospitals including AMCGH, Dhaka bear a disproportionate burden of care for patients with advanced malignancy. These patients frequently develop febrile neutropenia and suspected infections, necessitating prompt empirical antibiotic therapy. Without reliable local antibiogram data, clinicians must rely on outdated or geographically restricted guidelines, risking both therapeutic failure and unnecessary escalation to last-resort antibiotics[10].

The WHO AWaRe (Access, Watch, Reserve) classification system, incorporated into CLSI guidelines, provides a globally applicable framework for antibiotic stewardship[11], Resistance to Reserve-group antibiotics-such as ceftazidime-avibactam and tigecycline in hospital settings represents a particularly alarming signal. Published data from India, Pakistan, Egypt, and Nepal document MDR rates of 80 to 100.0% among Gram-negative uropathogens in cancer patients[12-15] consistent with regional trends. A study from Nepal's national cancer hospital reported 89.0% MDR in UTI isolates[15], but comparable data from Bangladesh are conspicuously absent from the literature.

Therefore, the present study aimed to determine the antimicrobial susceptibility pattern of gram negative uropathogen to urinary tract infections among cancer patients at Ahsania mission cancer and general hospital.

Methodology

Study Design and Setting: This was a retrospective cross-sectional study. Urine culture and antibiotic sensitivity data were retrieved from the microbiology laboratory records of Ahsania Mission Cancer and General Hospital (AMCGH), Uttara, Dhaka, Bangladesh, from the period July 2024 to June 2025.

Study Population and Eligibility Criteria: All UTI cancer patients aged ≥3 years who had at least one urine culture positive during the study period and from whom a significant Gram-negative uropathogen was isolated were eligible for inclusion. Repeated cultures from the same patient within a 30-day period; and contaminated specimens (growth of ≥3 organisms) were excluded. Pyuria (pus cells) was not considered a reliable diagnostic criterion for UTI in cancer patients as patients may be neutropenic[16].

Specimen Collection and Organism Identification: Urine specimens had been collected at the time of clinical presentation following the institution's standardized protocol, utilizing the clean-catch midstream technique into sterile containers. Retrieved laboratory records indicated that all specimens were processed promptly upon receipt, with inoculation performed onto Blood Agar and MacConkey Agar plates in accordance with the standard operating procedures of the Microbiology Laboratory of Ahsania Mission Cancer & General hospital (AMCGH). Incubation was carried out at 35°C, and plates were examined for bacterial growth after 24 hours. Identification of bacterial isolates had been established on the basis of colony morphology, Gram staining reaction, and biochemical characteristics. A colony count exceeding 10^5 colony-forming units per milliliter (CFU/mL) of urine was regarded as clinically significant bacteriuria, in accordance with established microbiological criteria[17].

Antibiotic Susceptibility Testing: Antibiotic susceptibility testing (AST) data were retrieved from existing laboratory records, where testing had been performed by the Kirby-Bauer disc diffusion method on Mueller-Hinton Agar (MHA; HiMedia Laboratories, Mumbai, India), as per the Clinical and Laboratory Standards Institute (CLSI) 2024 M100 (34th Edition) guidelines18. The antibiotic disc panel had included: amoxicillin-clavulanic acid (20/10 µg), ampicillin (30 µg), ciprofloxacin (5 µg), nitrofurantoin (300 µg), ceftazidime (10 µg), gentamicin (10 µg), trimethoprim-sulfamethoxazole (1.25/23.75 µg), meropenem (10 µg), cefepime (30 µg), piperacillin-tazobactam (100/10 µg), fosfomycin (200 µg), ceftriaxone (10 µg), aztreonam (30 µg), ceftazidime-avibactam (30/20 µg), and tigecycline (15 µg), all sourced from HiMedia Laboratories (Mumbai, India). Bacterial suspensions had been adjusted to a turbidity equivalent to the 0.5 McFarland standard in 0.9% normal saline, and plates were inoculated by lawn culture technique and incubated at 37°C for 16 to

18 hours. Zone diameters were measured in millimeters and interpreted as Susceptible (S), Intermediate (I), or Resistant (R) using CLSI 2024 breakpoints. For the purpose of the present analysis, Intermediate results were combined with Resistant, in accordance with WHO AWaRe guidance[11].

Quality control: Quality control had been performed using reference strains *Escherichia coli* ATCC 25922, *Klebsiella pneumoniae* ATCC 700603, and *Pseudomonas aeruginosa* ATCC 27853 tested with each batch, ensuring the reliability of the susceptibility data retrieved.

AWaRe classification: For the purposes of this study, antibiotics were classified according to the 2023 WHO AWaRe classification into Access, Watch, and Reserve categories[11]. Fosfomycin susceptibility data are presented for E. coli isolates only, as CLSI 2024 M100 provides validated disc diffusion breakpoints for fosfomycin exclusively for urinary isolates of *Escherichia coli* and *Enterococcus faecalis*. Antimicrobials designated as 'NT' (Not Tested) were excluded from analysis for the respective organism. Multidrug resistance (MDR) was defined as non-susceptibility to at least one agent in three or more antimicrobial categories, as per the criteria established by Magiorakos et al[19].

Statistical Analysis: Data were extracted from laboratory and clinical records using unique patient identifiers. Variables included age, sex, clinical setting, cancer type and AST results. Descriptive statistics were used: frequency and percentage for categorical variables; mean and standard deviation (SD) for continuous variables.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Institutional Ethics Committee of Ahsania Mission Cancer and General Hospital. Patient data were anonymized prior to analysis (AMCGH/ECA-10/26-01). All methods were performed in accordance with the relevant guidelines and regulations.

Results

The mean age of patients was 47.25 ± 30.54 years. Middle-aged adults (45–64 years) constituted the largest group (42.3%, n=80), followed by elderly patients (≥65 years, 33.9%, n=64). Female patients predominated slightly (52.9%, n=100). Solid tumors accounted for 69.8% (n=132) of cases and hematological malignancies accounted for 29.5% (n=56) (Table 1).

Table 1: Demographic and Clinical Characteristics of UTI Cancer Patients (n=189), AMCGH, Dhaka, Bangladesh, July 2024–June 2025

Variable	Frequency	Percent
Age Group		
• Children (≤18 years)	12	6.3
• Young adults (19 to 44 years)	33	17.5
• Middle-aged adults (45 to 64 years)	80	42.3
• Elderly (≥65 years)	64	33.9
Mean ± SD:47.25 ± 30.54 years		
Gender		
• Male	89	47.1
• Female	100	52.9
Type of malignancy		
• Solid tumors	132	69.8
• Hematological malignancy	56	29.5
• Unknown	1	0.5

Among the 189 isolates, Escherichia coli was the most prevalent isolates (90,47.6%), while Klebsiella species and Pseudomonas species was 76 (40.2%) and 23 (12.2%) respectively (Figure-

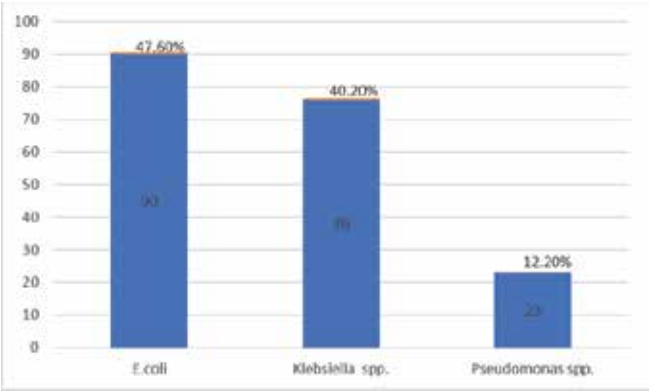

Figure I: Gram-negative uropathogen profile among UTI cancer patients (n=189)

Among the 189 isolates, Escherichia coli was most prevalent in the ICU (17.5%), while *Pseudomonas species* was equally distributed between the ICU and IPD (4.8% each). *Klebsiella species* predominated in the IPD (21.2%) but was also frequently isolated from the ICU (11.6%) (Figure II).

The details on the antibiotic drug susceptibility of bacteria isolated from urine samples were recorded. From the access group, seven antibiotics (nitrofurantoin, ampicillin, amikacin, sulfamethoxazole/trimethoprim, gentamicin, fosfomycin, and tetracycline) were analyzed for *Escherichia coli* and *Klebsiella spp*. and two antibiotics (amikacin and gentamicin) were analyzed

for Pseudomonas species according to CLSI,2024 guideline. Among these, the lowest susceptibility levels were observed for amoxicillin-clavulanate (13.3% and 1.3%) and tetracycline (18.9% and 14.5%) in Escherichia coli and Klebsiella, respectively. In the watch group, meropenem demonstrated the highest susceptibility among the ten drugs analyzed, at 81.1% and 44.7% for Escherichia coli and Klebsiella species, respectively. In the reserve group, among the three drugs analyzed, ceftazidime-avibactam showed the highest susceptibility in Escherichia coli (74.3%), whereas Klebsiella species showed the highest susceptibility to tigecycline (34.0%). In the case of Pseudomonas species, all drugs belonging to the WHO AWaRe classification showed very low susceptibility; only amikacin and gentamicin demonstrated a comparatively higher susceptibility, each at 47.8%.

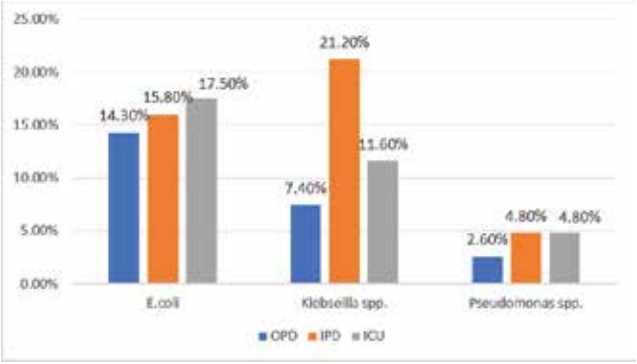

Figure II: Distribution of Gram-negative uropathogen according to patients care settings (n=189)

Table 3: Multidrug Resistance (MDR) Distribution among Gram-Negative Uropathogens (n=189)

Organism	MDR Isolates	MDR Rate
E. Coli (n=90)	85	94.4%
Klebsiella spp.(n=76)	76	100.0%
Pseudomonas spp. (n=23)	13	56.5%
Total (n=189)	**174**	**92.1%**

Table 2: Antimicrobial susceptibility profile of Gram-negative Uropathogens stratified by WHO AWaRe classification (n=189)

Antibiotic	*E. coli* (n=90)	*Klebsiella spp.* (n=76)	*Pseudomonas spp.* (n=23)
WHO AWaRe Group	**Susceptible, n (%)**	**Susceptible, n (%)**	**Susceptible, n (%)**
ACCESS GROUP			
Amikacin	61/90 (67.8%)	41/76 (53.9%)	11/23 (47.8%)
Gentamicin	44/90 (48.9%)	26/76 (34.2%)	11/23 (47.8%)
Amoxicillin–clavulanate	12/90 (13.3%)	1/76 (1.3%)	NT
Nitrofurantoin	29/90 (32.2%)	6/76 (7.9%)	NT
Fosfomycin	54/90 (60.0%)	NT	NT
Cotrimoxazole	19/90 (21.1%)	14/76 (18.4%)	NT
Tetracycline	17/90 (18.9%)	11/76 (14.5%)	NT
WATCH GROUP			
Netilmicin	NT	NT	9/20 (45.0%)
Ceftriaxone	20/90 (22.2%)	12/76 (15.8%)	NT
Ceftazidime	2/90 (2.2%)	4/76 (5.3%)	1/23 (4.3%)
Cefixime	1/89 (1.1%)	0/76 (0.0%)	NT
Cefuroxime	2/87 (2.3%)	3/76 (3.9%)	NT
Cefepime	11/90 (12.2%)	6/76 (7.9%)	8/22 (36.4%)
Piperacillin–tazobactam	18/90 (20.0%)	3/76 (3.9%)	3/23 (13.0%)
Ciprofloxacin	10/89 (11.2%)	8/75 (10.7%)	9/22 (40.9%)
Levofloxacin	12/89 (13.5%)	9/72 (12.5%)	4/23 (17.4%)
Meropenem	73/90 (81.1%)	34/76 (44.7%)	10/23 (43.5%)
RESERVE GROUP			
Aztreonam	21/90 (23.6%)	17/73 (23.3%)	5/22 (22.7%)
Ceftazidime–avibactam	26/35 (74.3%)	9/28 (32.1%)	2/8 (25.0%)
Tigecycline	23/61 (37.7%)	16/47 (34.0%)	NT

Denominators differ per antimicrobial as not all isolates were tested for every agent. Results expressed as n/N (%); NT = Not Tested (antimicrobial agent not included in the susceptibility testing panel for this organism).

Discussion

Antimicrobial resistance (AMR) poses a serious global health crisis by reducing the effectiveness of treatments for infections, making it especially dangerous for cancer patients who face a higher vulnerability to antibiotic-resistant infections[20]. The majority of patients in this cohort were middle-aged (45–64 years, 42.3%), with a mean age of 47.25 years, consistent with the known peak incidence of cancer in older age groups. Females predominated slightly (52.9%), and solid tumors accounted for the majority (69.8%). These findings align closely with studies 21,22 of cancer patients with UTI that reported a mean age of 46.55 ± 13.21 years, 62.2% female predominance, and a higher proportion of solid compared with hematological malignancies.

Of the 189 urine samples tested, *Escherichia coli* (47.6%) was the most frequently isolated gram-negative uropathogen. This finding is similar with study[21] conducted in Ethiopia (44.4%) and India (40%). The second most frequently isolated gram-negative bacterium was *Klebsiella species* (40.2%), which is higher than the study documented by Ashour and El-Sharif[23], who reported isolation of Klebsiella species in lower rate (31.2%). *Pseudomonas species* (12.2%) was the least frequently isolated gram-negative pathogen in the present study, which is consistent with the 11.0% prevalence rate of Pseudomonas species reported by Parikh et al[24].

The distribution of Gram-negative uropathogen differed considerably across patient care settings in the present study. The notable predominance of *Klebsiella species* among inpatients (21.2%) is consistent with the well-documented role of *Klebsiella pneumoniae* as a principal causative agent of healthcare-associated urinary tract infections, especially in patients with indwelling urinary catheters[25]. *Pseudomonas species* in both IPD and ICU (4.8%) reflect its hospital environmental persistence, consistent with evidence that drug resistance develops faster in ICU-associated organisms than in those from other hospital wards or outpatient settings[26]. The proportion of *Escherichia coli* isolated from positive urine cultures among cancer patients in the ICU setting was 17.5%, which is consistent with the findings of Cornejo-Juárez et al[27], who reported a comparable isolation rate of 20.0% in a similar patient population. This finding may be attributed to several converging factors such as ICU patients are frequently subjected to invasive urinary catheterization, prolonged broad-spectrum antibiotic exposure, and severe immunosuppression, all of which disrupt the normal urogenital flora and select for resistant *Escherichia coli* strains[28].

In the present study, the isolates exhibited poor susceptibility to several antibiotics within the WHO "Access" group, particularly amoxicillin-clavulanate, sulfamethoxazole/trimethoprim, & tetracycline. Of greater clinical concern, susceptibility was also markedly reduced against fluoroquinolones and third-generation cephalosporins belonging to the "Watch" group, with isolates showing low susceptibility even to antibiotics classified under the "Reserve" group. These findings are consistent with those reported in similar studies conducted among cancer patient populations[12,27,29].

Among the *Escherichia coli* isolates, Meropenem retained susceptibility in 81.1%, which is the highest of any single agent tested. This finding is consistent with prior studies[23,30] in cancer patients with UTI, where carbapenems demonstrated 72.0% susceptibility in an Indian tertiary oncology center and up to 97.0% in a Jordanian cancer center, reinforcing the role of meropenem as the drug of choice for severe UTI caused by *Escherichia coli* in this immunocompromised population. The fosfomycin susceptibility rate of 60.0% recorded in our study is in close agreement with the 58.0% reported by Toufiq et al[31].

Among the *Klebsiella* isolates in the present study, amikacin and meropenem demonstrated susceptibility rates of 53.9% and 44.7%, respectively, indicating considerably reduced activity of these agents in this patient population. An Indian study[32] on urinary *Klebsiella* isolates reported amikacin and meropenem susceptibility of 74.0% and 78.0%, respectively, which is notably higher than the susceptibility rates observed in our study, suggesting that most of the cancer patients have some form of immune disturbances.

Klebsiella spp. in the present study demonstrated notably low susceptibility to aztreonam (23.3%), indicating extensive resistance to this monobactam agent. This is consistent with patterns reported across Asian healthcare settings[33] where aztreonam susceptibility rate of only 26.7%. In the present study, ceftazidime-avibactam (CAZ-AVI) susceptibility was notably low among *Klebsiella species* (32.1%) compared to Escherichia coli (74.3%). These findings contrast with previously reported data from cancer patient populations. A Singapore study[34] reported CAZ-AVI susceptibility of 64.6 to 72.1% for

Klebsiella spp. and 88.9% for *Escherichia coli.* Still notably higher than the susceptibility rates of 32.1% and 74.3% observed for *Klebsiella species* and *Escherichia coli*, respectively, in the present study. The comparatively higher CAZ-AVI susceptibility of *Escherichia coli* (74.3%) versus *Klebsiella species* (32.1%) in our study is consistent with the known differential resistance patterns between these two organisms. Surveillance data from England[35] also demonstrated high susceptibility rates in Escherichia coli (98.2%) compared to *Klebsiella pneumoniae* (92.5%) for ceftazidime-avibactam among clinical isolates.

Pseudomonas species isolates in this study showed low susceptibility to several antibiotics, including netilmicin (45.0%), meropenem (43.5%), amikacin (47.8%), and gentamicin (47.8%), suggesting a broad multidrug resistance pattern among cancer patients. But in another study[36] a lower trend of susceptibility was reported focused on *Pseudomonas spp.* from cancer patients, where susceptibility to amikacin, gentamicin and meropenem were 38.5%., 32.7% and 34.6% respectively. The CAZ-AVI susceptibility rate (25.0%) of *Pseudomonas spp.* observed in the current study was markedly lower than previously published data. Valzano et al[37] reported CAZ-AVI susceptibility rate of 81.7% among MDR P. aeruginosa isolates in a multicenter Italian surveillance study. Several factors may account for this disparity, including the immunocompromised status of cancer patients, prolonged prior antibiotic exposure, the predominance of carbapenem-resistant strains, and a higher local prevalence of Metallo-β-lactamase (MBL)-producing isolates, against which avibactam has no inhibitory activity[38-39].

The overall MDR rate of 92.1% and 100.0% for Klebsiella species is among the highest reported from comparable settings in South and Southeast Asia. This substantially exceeds the 80–89% MDR rates documented in Nepal and India in comparable oncology populations[12,15] and likely reflects the convergence of high community-level baseline resistance and the immunosuppressed, antibiotic-exposed oncology population.

This study has several limitations. The small number of *Pseudomonas spp.* isolates, and Reserve-group antibiotic testing was restricted to small subsets, limiting the precision of those resistance estimates.

Conclusion

This study documents a profound MDR crisis among Gram-negative uropathogens in cancer patients at AMCGH, Dhaka. Critically low carbapenem susceptibility in *Klebsiella spp.* and *Pseudomonas spp.*, combined with reduced ceftazidime-avibactam susceptibility, suggests critically limited therapeutic options. Meropenem remains the most active agent against *E. coli*, while amikacin and fosfomycin retain partial activity warranting consideration in combination regimens under microbiological guidance.

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Conflict of Interest
The authors declare no conflict of interest.

Financial Disclosure
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Authors' contributions
Sheikh Joly Ferdous Ara: designed the study, analyzed and interpreted the data, wrote up the draft manuscript; Ishad Mazhar: contributed to the manuscript writing; Farhana Ferdausi: involved in data collection; Sheikh Jabin Jakia Sultana: critically reviewing the manuscript. All authors read and approved the final manuscript.

Data Availability
Any inquiries regarding supporting data availability of this study should be directed to the corresponding author and are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate
Ethical approval for the study was obtained from the Institutional Review Board. All methods were performed in accordance with the relevant guidelines and regulations.

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References

1. Rolston KV. Infections in cancer patients with solid tumors: a review. Infectious diseases and therapy 2017;6 (1):69-83
2. Freifeld AG, Bow EJ, Sepkowitz KA, Boeckh MJ, Ito JI, Mullen CA, Raad II, Rolston KV, Young JA, Wingard JR. Clinical practice guideline for the use of antimicrobial agents in neutropenic patients with cancer: 2010 update by the Infectious Diseases Society of America. Clinical Infectious Diseases. 2011;52(4): e56-93
3. Tverdek FP, Rolston KV, Chemaly RF. Antimicrobial stewardship in patients with cancer. Pharmacotherapy: The Journal of Human Pharmacology and Drug Therapy. 2012;32(8):722-34
4. Perez F, Adachi J, Bonomo RA. Antibiotic-resistant gram-negative bacterial infections in patients with cancer. Clinical Infectious Diseases. 2014;59(suppl_5):S335-9
5. Bonna AS, Pavel SR, Ferdous J, Khan SA, Ali M. Antibiotic resistance: An increasingly threatening but neglected public health challenge in Bangladesh. International Journal of Surgery Open. 2022;49:100581
6. Sujan MJ, Habib ZH, Rahman A, Rizvi SS, Barua HT, Aboushady AT, Hasnat MA, Rasul SB, Joh HS, Prifti K, Chi KY. Antimicrobial resistance surveillance methods in Bangladesh: present and way forward. Clinical Infectious Diseases. 2023;77(-Supplement_7):S549-59
7. Haque R, Salam MA. Detection of ESBL-producing nosocomial Gram-negative bacteria from a tertiary care hospital in Bangladesh. Pak J Med Sci. 2010;26(4):887-91
8. Begum N, Shamsuzzaman SM. Emergence of carbapenemase-producing urinary isolates at a tertiary care hospital in Dhaka, Bangladesh. Tzu Chi Medical Journal. 2016;28(3):94-8
9. International Agency for Research on Cancer, WHO. Global Cancer Observatory (GLOBOCAN) 2022: Bangladesh Cancer Factsheet [Internet]. Lyon: IARC; 2022 [cited 2025 Jan 1]. Available from: https://gco.iarc.fr
10. Fazeli H, Moghim S, Zare D. Antimicrobial resistance pattern and spectrum of multiple-drug-resistant enterobacteriaceae in Iranian hospitalized patients with cancer. Advanced Biomedical Research. 2018;7(1):69
11. Zanichelli V, Sharland M, Cappello B, Moja L, Getahun H, Pessoa-Silva C, Sati H, van Weezenbeek C, Balkhy H, Simão M, Gandra S. The WHO AWaRe (Access, Watch, Reserve) antibiotic book and prevention of antimicrobial resistance. Bulletin of the World Health Organization. 2023;101(4):290
12. Murugesan S, Samuel S, Rudrapathy P. Microbiological profile and antibiotic susceptibility pattern of uropathogens isolated among cancer patients at a tertiary care cancer centre, South India. Int J Pharm Sci 2020;11: b56-63
13. Saleem Z, Hassali MA, Hashmi FK, Godman B, Bhutta OA. A repeated point prevalence survey of antimicrobial use in specialized cancer care hospital of Pakistan: findings and implications.Hospital practice. 2019;47(3):149-54
14. Mahmoud AT, Salim MT, Ibrahem RA, Gabr A, Halby HM. Multiple drug resistance patterns in various phylogenetic groups of hospital-acquired uropathogenic E. coli isolated from cancer patients. Antibiotics. 2020;9(3):108
15. Shrestha G, Wei X, Hann K, Soe KT, Satyanarayana S, Siwakoti B, Bastakoti S, Mulmi R, Rana K, Lamichhane N. Bacterial profile and antibiotic resistance among cancer patients with urinary tract infection in a national tertiary cancer hospital of Nepal. Tropical medicine and infectious disease. 2021;6(2):49
16. Klaassen IL, de Haas V, van Wijk JA, Kaspers GJ, Bijlsma M, Bökenkamp A. Pyuria is absent during urinary tract infections in neutropenic patients. Pediatric blood & cancer. 2011;56(5):868-70
17. Chowdhury SS, Tahsin P, Xu Y, Mosaddek AS, Muhamadali H, Goodacre R. Trends in antimicrobial resistance of uropathogens isolated from urinary tract infections in a tertiary care hospital in Dhaka, Bangladesh. Antibiotics. 2024;13(10):925
18. Clinical and Laboratory Standards Institute (CLSI). Performance Standards for Antimicrobial Susceptibility Testing. 34th ed. CLSI Supplement M100. Wayne, PA: CLSI; 2024.
19. AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, Harbarth S, Hindler JF, Kahlmeter G, Olsson-Liljequist BJ, Paterson DL. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. Clinical microbiology and infection. 2012 Mar 1;18(3):268-81.
20. Ntim OK, Awere-Duodu A, Osman AH, Donkor ES. Antimicrobial resistance of bacterial pathogens isolated from cancer patients: a systematic review and meta-analysis. BMC Infectious Diseases. 2025;25(1):296
21. Sime WT, Biazin H, Zeleke TA, Desalegn Z. Urinary tract infection in cancer patients and antimicrobial susceptibility of isolates in Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia.PLoSOne. 2020;15(12): e0243474
22. Mishra R, Patel A, Agarwal A, Thaiyam D, Thaiyam S. Infections and their outcomes in cancer patients with and without neutropenia: a single-center experience. Cureus. 2024;16(1)
23. Ashour HM, El-Sharif A. Species distribution and antimicrobial susceptibility of gram-negative aerobic bacteria in hospitalized cancer patients. Journal of translational medicine. 2009;7(1):14
24. Parikh P, Bhat V. Urinary tract infection in cancer patients in a tertiary cancer setting in India: microbial spectrum and antibiotic susceptibility pattern. Antimicrobial Resistance and Infection Control. 2015;4(Suppl 1): P221
25. Clegg S, Murphy CN. Epidemiology and virulence of Klebsiella pneumoniae. Urinary tract infections: Molecular pathogenesis and clinical management. 2017:435-57
26. Bizuayehu H, Bitew A, Abdeta A, Ebrahim S. Catheter-associated urinary tract infections in adult intensive care units at a selected tertiary hospital, Addis Ababa, Ethiopia. PLOS ONE. 2022;17(3): e0265102
27. Cornejo-Juárez P, Vilar-Compte D, Pérez-Jiménez C, Ñamendys-Silva SA, Sandoval-Hernández S, Volkow-Fernández P. The impact of hospital-acquired infections with multidrug-resistant bacteria in an oncology intensive care unit. International Journal of Infectious Diseases. 2015;31:31-4
28. Hooton TM, Bradley SF, Cardenas DD, Colgan R, Geerlings SE, Rice JC, Saint S, Schaeffer AJ, Tambayh PA, Tenke P, Nicolle LE. Diagnosis, prevention, and treatment of catheter-associated urinary tract infection in adults: 2009 International Clinical Practice Guidelines from the Infectious Diseases Society of America. Clinical Infectious Diseases. 2010;50(5):625-63
29. Mukta Khaparkuntikar NA. Urinary tract infection in cancer patients at government cancer hospital Aurangabad, India. Int. J. Curr. Microbiol. App. Sci. 2017;6:2259-63
30. AbuSara A, Tayyeb N, Matalka L, Almomani B, Abaza H, Nazer L. Prevalence and predictors of multi-drug-resistant organisms among ambulatory cancer patients with urinary tract infections. Infection and Drug Resistance. 2023:747-53
31. Toufiq Ahmed DS, Hasan GS, Karim MM, Ahmad MR, Hossin MI, Islam J. Antibiotic Susceptibility and Resistance Trends in

Uropathogenic Bacteria: a Regional Perspective. J Neonatal Surg. 2025;14(27):189-95
32. Lakshmipriya IS, Yoganand R, Rudresh SM. A study on siderophore production and biofilm formation of Klebsiella isolated from urine samples and detection of antibiotic resistance mechanisms.
33. Effah CY, Sun T, Liu S, Wu Y. Klebsiella pneumoniae: an increasing threat to public health. Annals of clinical microbiology and antimicrobials. 2020;19(1):1
34. Lim TP, Ho JY, Teo JQ, Sim JH, Tan SH, Tan TT, Kwa AL. In vitro susceptibility to ceftazidime-avibactam and comparator antimicrobial agents of carbapenem-resistant Enterobacterales isolates. Microorganisms. 2023;11(9):2158.
35. Guy RL, Hopkins KL, Budd EL, Wilson K, Fountain H, Meunier D, Pike R, Gerver SM, Gnanadurai R, Brown CS, Hopkins S. The importance of monitoring a new antibiotic: ceftazidime/avibactam usage and resistance experience from England, 2016 to 2020. Eurosurveillance.2025;30(14):2400399
36. Abdulhak A, Zedan HH, El-Mahallawy HA, Sayed AA, Mohamed HO, Zafer MM. Multidrug-resistant Pseudomonas aeruginosa in immunocompromised cancer patients: epidemiology, antimicrobial resistance, and virulence factors. BMC Infectious Diseases. 2025;25(1):804
37. Valzano F, La Bella G, Lopizzo T, Curci A, Lupo L, Morelli E, Mosca A, Marangi M, Melfitano R, Rollo T, De Nittis R, Arena F.2024.Resistance to ceftazidime–avibactam and other new β-lactams in Pseudomonas aeruginosa clinical isolates: a multi-center surveillance study. Microbiol Spectr 12: e04266-23
38. Hernando-Amado S, Gomis-Font MA, Valverde JR, Oliver A, Martínez JL. Ceftazidime-avibactam use selects multidrug-resistance and prevents designing collateral sensitivity-based therapies against Pseudomonas aeruginosa. Nature Communications. 2025;16(1):3323
39. Nichols WW, Stone GG, Newell P, Broadhurst H, Wardman A, MacPherson M, Yates K, Riccobene T, Critchley IA, Das S. Ceftazidime-avibactam susceptibility breakpoints against Enterobacteriaceae and Pseudomonas aeruginosa. Antimicrobial Agents and Chemotherapy. 2018;62(11):10-128