J Current Biomed Report
ISSN: 2717-1906

2026, Volume 7, Number 1

Research Paper

Prevalence of bacterial infections among hospitalized patients with malignancies

Maryam Barati[1], Mohamad Hossein Khoshhal[2], Soheil Hassanipour[3], Tofigh Yaghubi Kalurazi2[*]

1. *Department of Medical Laboratory Sciences, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran*
2. *Razi Clinical Research Development Unit, Razi Hospital, Guilan University of Medical Sciences, Rasht, Iran*
3. *Gastrointestinal and Liver Diseases Research Center, Guilan University of Medical Sciences, Rasht, Iran*

ABSTRACT

Article info:
Received: 17 Dec 2025
Accepted: 22 Feb 2026

Keywords:
Malignancy
Nosocomial infection
Bacterial infection
Escherichia coli
Hospital mortality

Hospital-acquired bacterial infections are a major cause of morbidity and mortality among patients with malignancies due to underlying immunosuppression and frequent exposure to invasive procedures. This study aimed to evaluate the types of infection and clinical outcomes of hospitalized cancer patients with nosocomial infections. This cross-sectional study was conducted on 19 hospitalized patients with malignancies at Razi Educational and Medical Center, Rasht, Iran, between 2021 and 2023. Demographic, clinical data, and patients' outcomes were recorded. The mean age was 48.31 ± 18.14 years. Urinary tract infection (UTI) was the most common infection (57.9%), followed by bloodstream infection (26.3%). *Escherichia coli* was the predominant pathogen (52.6%). The mean time to infection onset was 8.21 ± 11.17 days, and the mean length of hospitalization was 16.84 ± 12.61 days. Overall, in-hospital mortality was 42.1%. Among deceased patients, UTI (62.5%) and *E. coli* (62.5%) were most frequent. Nosocomial bacterial infections, particularly UTIs caused by *E. coli*, are common among hospitalized cancer patients and are associated with considerable mortality. Continuous surveillance and targeted infection control strategies are essential in oncology settings.

***Corresponding Author(s):**
Tofigh Yaghubi Kalurazi, MD
Address: *Razi Clinical Research Development Unit, Razi Hospital, Guilan University of Medical Sciences, Rasht, Iran*
Tel: +98 13 33550028
E-mail: tofigh_yaghubi@yahoo.com

Copyright © 2026: Author(s)
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license(https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

https://jcbior.com https://doi.org/10.66224/jcbior.7.1.351

1. Introduction

Cancer remains one of the leading causes of morbidity and mortality worldwide, with a steadily increasing global burden attributable to population aging, environmental exposures, and improved diagnostic capabilities [1,2]. Despite advances in early detection and multimodal treatment strategies, including surgery, chemotherapy, radiotherapy, targeted therapy, and immunotherapy, infectious complications continue to represent a major challenge in the management of patients with malignancies [3–7]. Among these complications, bacterial infections are particularly significant, contributing substantially to prolonged hospitalization, treatment delays, increased healthcare costs, and mortality [8,9].

Patients with malignancies are uniquely predisposed to infections due to both disease-related and treatment-related immunosuppression. Hematologic malignancies, in particular, are frequently associated with profound neutropenia, impaired cellular immunity, and mucosal barrier disruption [10,11]. Similarly, cytotoxic chemotherapy and radiotherapy compromise bone marrow function and damage epithelial surfaces, facilitating microbial invasion.

The use of invasive devices such as central venous catheters, urinary catheters, and mechanical ventilation further increases susceptibility to hospital-acquired infections. In addition, repeated hospitalizations and exposure to broad-spectrum antibiotics promote colonization and infection with multidrug-resistant organisms [12,13].

Nosocomial infections in cancer patients commonly manifest as urinary tract infections (UTIs), bloodstream infections (BSIs), pneumonia, including ventilator-associated pneumonia (VAP), and surgical site infections (SSIs) or skin and soft tissue infections (SSTIs) [14,15]. The microbiological profile of these infections has evolved over time, with Gram-negative bacteria such as *Escherichia coli*, *Klebsiella* species, *Acinetobacter* species, and *Pseudomonas* species frequently reported as predominant pathogens in many centers [16–18]. However, the distribution of bacterial etiologies varies according to geographic region, hospital setting, patient population, and local antimicrobial stewardship practices [19,20].

In hospitalized cancer patients, bacterial infections are not only common but also associated with significant clinical consequences. They may result in sepsis, septic shock, organ dysfunction, and increased in-hospital mortality. Furthermore, infectious complications often necessitate interruption or modification of anticancer therapy, potentially compromising oncologic outcomes [8,21].

Given the vulnerability of cancer patients and the growing concern regarding antimicrobial resistance, the present study investigated the demographic characteristics and clinical outcomes of hospitalized patients with malignancies in a referral hospital in Guilan province, the North of Iran.

2. Materials and Methods

2.1 Study design and setting

This retrospective cross-sectional study was conducted to evaluate the epidemiological characteristics and bacterial etiologies of nosocomial infections among hospitalized patients with malignancies at Razi Educational and Medical Center, Rasht, the North of Iran, over a three-year period from 2021 to 2023. The participants were selected through census sampling method. Patients with incomplete or missing medical records were excluded from the study. The study was confirmed by the ethical committee of the Guilan University of Medical Sciences, Rasht, Iran (approval number: IR.GUMS.REC.1403.159). Because this study was retrospective and involved the analysis of existing anonymized medical records without direct patient contact or intervention, the requirement for written informed consent was waived by the regional ethics committee.

2.2 Study variables

Demographical and clinical data of participants included patients' age (years, continuous variable), gender (male/female, categorical variable), hospital ward of admission (hematology, pulmonology, intensive care unit (ICU), endocrinology, or vascular surgery), type of infection (SSIs, BSI, UTI, or VAP), time from hospital admission to onset of infection (days), bacterial pathogen identified based on positive microbiological culture results (including genus and species), total length of hospital stay (days), and clinical outcome (recovery or death). Hospital-acquired infection was defined according to Centers for Disease Control and Prevention (CDC) criteria as an infection occurring 48 hours or more after hospital admission and was confirmed by the standard microbial tests [22].

2.3 Statistical Analysis

Descriptive statistics were used to calculate, describe, and summarize collected research data. Data were presented as mean ± standard deviation (SD), median (IQR), frequency (n), and percentage (%). Data were analyzed using SPSS software version 26 (IBM Corp., Armonk, NY, USA).

3. Results

The mean age of the patients was 48.31 ± 18.14 years (15 - 80 years), with the median of 50 years (31–60 years). The mean duration from hospital admission to the onset of infection was 8.21 ± 11.17 days (2 to 47 days), with the median time of 3 days (2 - 13 days). The mean total length of hospital stay was 16.84 ± 12.61

days (3 - 52 days), with the median length of 14 days (7–22 days). Eight patients (42.1%) were male and 11 patients (57.9%) were female. The majority of patients were admitted to the hematology ward (8 patients, 42.1%), followed by the pulmonology ward (6 patients, 31.6%), and the ICU (3 patients, 15.7%). Regarding clinical outcomes, 11 patients (57.9%) were discharged following clinical improvement, whereas 8 patients (42.1%) died during hospitalization (Table 1).

UTI was the most common, observed in 11 patients (57.9%). This was followed by BSI infection in 5 patients (26.3%), VAP in 2 patients (10.5%), and SST infection in 1 patient (5.3%). Of which, *E. coli* was the most frequently isolated pathogen, identified in 10 patients (52.6%). Other isolates included *Klebsiella* species in 3 patients (15.8%), *Citrobacter* species in 2 patients (10.5%), *Acinetobacter* species in 2 patients (10.5%), *Enterobacter* species in 1 patient (5.3%), and *Pseudomonas* species in 1 patient (5.3%) (Table 1).

Among the patients with fatal outcomes, UTI was the most frequent type of infection, observed in 5 cases (62.5%), followed by VAP in 2 cases (25.0%) (Table 2).

4. Discussion

Patients with malignancies represent a uniquely vulnerable population due to disease-related immune dysfunction, cytotoxic chemotherapy, corticosteroid exposure, invasive procedures, prolonged hospitalization, and frequent device utilization [23]. Within this context, our findings demonstrate a substantial in-hospital mortality rate (42.1%), a predominance of UTIs, and a microbiological spectrum dominated by Gram-negative bacilli, particularly *E. coli*. The mean age of 48 years in our study is relatively younger compared with previous reported data [24]. Evidence have shown that cancer-associated healthcare infections in the United States are often concentrated among older adults, reflecting demographic patterns of malignancy in high-income countries. As of 2026, 59% of all cancer diagnoses in the US occur in people aged 65 or older [24–26].

In the current study, the mean time from hospital admission to onset of infection suggests that a substantial proportion of infections were either early healthcare-associated or possibly incubating at admission. Early-onset infections in cancer patients are often linked to pre-existing colonization, mucosal barrier injury from chemotherapy, or prior antibiotic exposure. Evidence have demonstrated that mucosal barrier injury–associated bloodstream infections are common in hematologic malignancies, particularly during neutropenic phases [27,28]. The relatively short median time to infection in this study underscores the importance of early risk stratification, prompt microbiological sampling, and empirical antimicrobial optimization at admission [29].

Prolonged length of stay is both a consequence and a risk factor for infection. It increases exposure to multidrug-resistant (MDR) organisms through cumulative antibiotic pressure and environmental colonization [30].

Table 1. Frequency of demographics and clinical data of 19 hospitalized patients with malignancies.

Variables		Frequency n (%)
Gender	Male	8 (42.12)
	Female	11 (57.9)
Hospital ward	Hematology	8 (42.1)
	Pulmonology	6 (31.6)
	Intensive Care Unit	3 (15.7)
	Endocrinology	1 (5.3)
	Vascular Surgery	1 (5.3)
Type of infection	Urinary tract infection	11 (57.9)
	Bloodstream infection	5 (26.3)
	Ventilator-associated pneumonia	2 (10.5)
	Skin and soft tissue/surgical site infection	1 (5.3)
Bacterial isolates	*Escherichia coli*	10 (52.6)
	Klebsiella species	3 (15.8)
	Citrobacter species	2 (10.5)
	Acinetobacter species	2 (10.5)
	Enterobacter species	1 (5.3)
	Pseudomonas species	1 (5.3)
Patients outcome	Discharged	11 (57.9)
	Death	8 (42.1)

Table 2. Frequency of bacterial infection among eight cancer patients with death outcomes.

Variables		Frequency n (%)
Type of infection	Urinary tract infection	5 (62.5)
	Ventilator-associated pneumonia	2 (25.0)
	Bloodstream infection	1 (12.5)
Bacterial isolates	*Escherichia coli*	5 (62.5)
	Citrobacter species	1 (12.5)
	Acinetobacter species	1 (12.5)
	Enterobacter species	1 (12.5)

A study by Zafra Poves et al. demonstrated that hospital-acquired infections in cancer patients significantly extended hospital stays and independently increased mortality [31]. In our study, the extended hospitalization likely contributed to the observed infection spectrum dominated by nosocomial Gram-negative organisms. The distribution of ward admissions, particularly the predominance of hematology and pulmonology, is clinically meaningful. Hematologic malignancies are well established as high-risk conditions for severe infection due to profound and prolonged neutropenia, impaired cellular immunity, and frequent central venous catheter use. Multiple studies have shown that patients with leukemia or lymphoma experience higher rates of bacteremia and sepsis compared with those with many solid tumors. The Gram-negative bacteremia remains a leading cause of death in neutropenic patients [32–34]. Furthermore, UTI was the most common infection type, while bloodstream infections and ventilator-associated pneumonia were less frequent. UTIs are common in hospitalized cancer patients due to urinary catheterization, immunosuppression, and mucosal damage. Studies have shown that catheter-associated UTIs are frequent in hospitalized oncology populations, particularly among patients with prolonged stays or critical illness [35,36].

Although, in the current study, VAP was observed in only two cases, both cases associated with a poor outcome. VAP in immunocompromised patients is associated with particularly high mortality due to impaired pulmonary immune clearance, frequent MDR pathogens, and delayed clinical response. Studies reported VAP mortality rates exceeding 40%. The pathophysiology involves compromised alveolar macrophage function, impaired neutrophil recruitment, and colonization of ventilator circuits [37,38].

We found *E. coli* was the predominant pathogen, followed by *Klebsiella*, *Citrobacter*, and *Acinetobacter*. This Gram-negative predominance aligns with global shifts observed over the past two decades, where Gram-negative bacilli have re-emerged as leading pathogens in oncology settings [16–18]. From a mechanistic standpoint, *E. coli* possesses virulence factors such as adhesins, siderophores, and toxins that facilitate urinary tract colonization and systemic invasion, particularly in immunocompromised hosts [39].

However, the presence of non-fermenting Gram-negative organisms such as *Acinetobacter* and *Pseudomonas* is also clinically concerning. These pathogens are frequently associated with hospital environments, biofilm formation, and intrinsic resistance mechanisms [40].

Our findings demonstrated the urgent need for robust infection control programs. However, there are some limitations that should be considered. The small sample size, single-center design, and the cross-sectional nature of the study limit the generalizability of the findings. Additionally, data regarding antimicrobial resistance patterns, comorbidities, cancer type, treatment regimens, and severity of illness were not analyzed, which may influence infection outcomes. Future multicenter studies with resistance profiling and larger sample sizes are warranted to further elucidate antimicrobial susceptibility patterns and optimize therapeutic algorithms in oncology settings.

This study demonstrated that hospital-acquired bacterial infections remain a significant clinical concern among hospitalized patients with malignancies. UTI were the most prevalent type of infection, and *E. coli* was the predominant causative organism. A substantial in-hospital mortality rate, particularly among patients with UTIs and Gram-negative infections, highlights the vulnerability of these patients to nosocomial infections and emphasize the importance of strict infection control measures, and early microbial diagnosis.

Acknowledgment

This study was extracted from MD thesis by Mohamad Hossein Khoshhal at Guilan University of Medical Sciences, Rasht, Iran.

Declaration of artificial intelligence (AI) in the writing process

The authors declare whether AI or AI-assisted technologies were used during the preparation of this manuscript. If used, AI tools were employed solely to improve language quality, grammar, readability, and organizational structure. The authors carefully reviewed and edited all AI-generated content and take full responsibility for the accuracy, integrity, and originality of the final manuscript. No AI tool was used to generate, analyze, or interpret scientific data or images, or to draw scientific conclusions. The use of AI-assisted technologies complies with current publication ethics recommendations and journal policies.

Authors' contributions

All authors contributed to the study's conception and design, and revisions. Material preparation and data collection were performed by MHK and TYK. Data analysis was performed by MB and SH. The first draft of the manuscript was written by MB, MHK, SH, and TYK. All authors read and approved the final version of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Ethical declarations

This study was approved by the ethics committees of the Guilan University of Medical Sciences [IR.GUMS.REC.1403.159]. The methods were carried out in agreement with the principles and propositions

established in the Declaration of Helsinki for human subjects.

Financial support

Self-funded.

References

1. Burzyńska M, Pikala M. Cancer Mortality in an Ageing Population: Evidence of Sex-Specific Divergence from a National Study in Poland. Cancers (Basel). 2026;18(3):447. DOI: 10.3390/cancers18030447 PMID: 41681919
2. Tu Z, Yu Y, Li C, Hu Q, Cai C, Luo J, et al. Global epidemiological trend of cancer incidence and death in adults aged 60 years and older: a systematic analysis of data from GLOBOCAN 2022 and GBD2021. BMC Geriatr. 2025;26(1):22. DOI: 10.1186/s12877-025-06632-y PMID: 41339810
3. Zafar A, Khatoon S, Khan MJ, Abu J, Naeem A. Advancements and limitations in traditional anti-cancer therapies: a comprehensive review of surgery, chemotherapy, radiation therapy, and hormonal therapy. Discov Oncol. 2025;16(1):607. DOI: 10.1007/s12672-025-02198-8 PMID: 40272602
4. Faraji N, Vahidnezhad H, Eslami N, Zeinali T, Shenagari M, Shanehbandi D, et al. Role of non-coding RNAs in human-papillomavirus-associated cutaneous neoplasms. Arch Virol. 2025;170(8):170. DOI: 10.1007/s00705-025-06335-0 PMID: 40581896
5. Faraji N, Almasi M, Mirmazloumi M, Padasht N, Mansouri SS, Ghaderibarmi F, et al. Altered expression patterns of lncRNA MEG3 and LINC01611 in patients with colorectal cancer. Hum Gene. 2025:201470. DOI: 10.1016/j.humgen.2025.201470
6. Faraji N, Mashkoor NR, Emamifar A, Ghamarsoorat F, Ghalehjoughi ZP, Bajgiran FA, et al. The cytotoxic effect of cobalt oxide nanoparticle conjugated by menthol on colorectal cancer cell line and evaluation of the expression of CASP8 and FEZF1-AS1. J Clust Sci. 2025;36(2):39. DOI: 10.1007/s10876-024-02757-z
7. Faraji N, Farokhi S, Fakouri A, Aali S, Motiei M, Gharaei Nejad K. Human papillomavirus-associated skin cancers among organ transplant recipients: A systematic review and meta-analysis. Caspian J Intern Med. 2025;16(4):641-650. DOI: 10.22088/cjim.16.4.641 PMID: 41383790
8. Seo SK, Liu C, Dadwal SS. Infectious Disease Complications in Patients with Cancer. Crit Care Clin. 2021;37(1):69-84. DOI: 10.1016/j.ccc.2020.09.001 PMID: 33190776
9. Yan S, Li Z, Zhang S, Wu Z. Postoperative infectious complications in gastric and colorectal cancer patients: A multicenter prospective cohort study from China. Surgery. 2026;189:109780. DOI: 10.1016/j.surg.2025.109780 PMID: 41087228
10. Blijlevens NMA, de Mooij CEM. Mucositis and Infection in Hematology Patients. Int J Mol Sci. 2023;24(11):9592. DOI: 10.3390/ijms24119592 PMID: 37298545
11. Aliyath A, Eni-Olotu A, Donaldson N, Trivedi P. Malignancy-associated immune responses: Lessons from human inborn errors of immunity. Immunology. 2023;170(3):319-333. DOI: 10.1111/imm.13675 PMID: 37335539
12. Kafazi A, Apostolopoulou E, Andreou E, Gavala A, Stefanidis E, Antwniadou F, et al. Device-associated infections in adult intensive care units: A prospective surveillance study. Acta Microbiol Hellenica. 2025;70(2):15. DOI: 10.3390/amh70020015
13. Alinasab Z, Jahani MA, Mahmoudi G, Charati JY. Factors affecting hospital-acquired infections in hospitalized patients in iran: a qualitative study. BMC Res Notes. 2025;19(1):22. DOI: 10.1186/s13104-025-07611-7 PMID: 41388463
14. Hosseini M, Hasannejad Bibalan M, Yaghoubi T, Mobayen M, Khoshdoz P, Khoshdoz S, et al. Prevalence And Antibiotic Resistance Pattern Of Gram-Positive Isolates From Burn Patients In Velayat Burn Center In Rasht, North Of Iran. Med Lab J. 2021;15(6):52-57. URL: https://sid.ir/paper/1015036/en
15. Faraji N, Malekzadegan Y, Khashei R, Haghighi MA, Alam AN, Fathi J, et al. The prevalence and characterization of the epidemic ST239-MRSA clone. Rev Res Med Microbiol. 2024;35(1):1-7. DOI: 10.1097/MRM.0000000000000317
16. Sharma SK, Bhadra S, Sarwat T, Kakru DK. Antibiotic Resistance Rate among Bacterial Pathogens Isolated from Bronchoalveolar Lavage Fluid at a Tertiary Care Center in Western Uttar Pradesh, India. JoMMID. 2023;11(2):110-116. URL: http://jommid.pasteur.ac.ir/article-1-525-en.html
17. Ibrahim R, Duwiejuah AB, Osei KM. Prevalence and antimicrobial susceptibility of gram-negative bacteria in the urine of females in their reproductive ages in the Tamale Teaching Hospital. J Health Popul Nutr. 2025;44(1):276. DOI: 10.1186/s41043-025-00853-y PMID: 40759982
18. Abban MK, Ayerakwa EA, Mosi L, Isawumi A. The burden of hospital acquired infections and antimicrobial resistance. Heliyon. 2023;9(10):e20561. DOI: 10.1016/j.heliyon.2023.e20561 PMID: 37818001
19. Tanni NN, Nesa M, Kabir RB, Habib FB, Asaduzzaman M, Sarker A, et al. Distribution, epidemiology, and antimicrobial resistance pattern of gram-negative bacteria isolated from blood: A retrospective study in a tertiary care hospital, Dhaka, Bangladesh. PLOS Glob Public Health. 2025;5(10):e0004915. DOI: 10.1371/journal.pgph.0004915 PMID: 41171775
20. Deress T, Belay G, Ayenew G, Ferede W, Worku M, Feleke T, et al. Bacterial etiology and antimicrobial resistance in bloodstream infections at the University of Gondar Comprehensive Specialized Hospital: a cross-sectional study. Front Microbiol. 2025;16:1518051. DOI: 10.3389/fmicb.2025.1518051
21. Bhat S, Muthunatarajan S, Mulki SS, Archana Bhat K, Kotian KH. Bacterial Infection among Cancer Patients: Analysis of Isolates and Antibiotic Sensitivity Pattern. Int J Microbiol. 2021;2021:8883700. DOI: 10.1155/2021/8883700 PMID: 33510793
22. Kouchak F, Askarian M. Nosocomial infections: the definition criteria. Iran J Med Sci. 2012;37(2):72-3. PMID: 23115435
23. Kreitmann L, Gaudet A, Nseir S. Ventilator-Associated Pneumonia in Immunosuppressed Patients. Antibiotics (Basel). 2023;12(2):413. DOI: 10.3390/antibiotics12020413 PMID: 36830323
24. Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: a narrative review. Intensive Care Med. 2020;46(5):888-906. DOI: 10.1007/s00134-020-05980-0 PMID: 32157357
25. Siegel RL, Kratzer TB, Wagle NS, Sung H, Jemal A. Cancer statistics, 2026. CA Cancer J Clin. 2026;76(1):e70043. DOI: 10.3322/caac.70043 PMID: 41528114
26. Weir HK, Sherman R, Yu M, Gershman S, Hofer BM, Wu M, et al. Cancer Incidence in Older Adults in the United States: Characteristics, Specificity, and Completeness of the Data. J Registry Manag. 2020;47(3):150-160. PMID: 33584972
27. Ryerson AB, Massetti GM. CDC's Public Health Surveillance of Cancer. Prev Chronic Dis. 2017;14:E39. DOI: 10.5888/pcd14.160480 PMID: 28520553
28. Liu M, Jiang X, Pi Y, Chen M, Ren X, Dai X, et al. Mucosal barrier injury as an independent risk factor for laboratory-confirmed bloodstream infection in patients with hematological malignancies: a real-world study. Eur J Med Res. 2025;30(1):649. DOI: 10.1186/s40001-025-02913-9 PMID: 40685351
29. Gustinetti G, Mikulska M. Bloodstream infections in neutropenic cancer patients: A practical update. Virulence. 2016;7(3):280-97. DOI: 10.1080/21505594.2016.1156821 PMID: 27002635

30. Sandu AM, Chifiriuc MC, Vrancianu CO, Cristian RE, Alistar CF, Constantin M, et al. Healthcare-Associated Infections: The Role of Microbial and Environmental Factors in Infection Control-A Narrative Review. Infect Dis Ther. 2025;14(5):933-971. DOI: 10.1007/s40121-025-01143-0 PMID: 40208412
31. Zafra Poves M, Vicente Conesa MA, Guirao García ME, Sanchez Cánovas M, Alonso Fernandez N, Ayala de la Peña F, et al. Is mortality truly higher for oncology patients admitted to intensive care units? A matched cohort observational study. Clin Transl Oncol. 2026. DOI: 10.1007/s12094-026-04224-9 PMID: 41627640
32. Hansen BA, Wendelbo Ø, Bruserud Ø, Hemsing AL, Mosevoll KA, Reikvam H. Febrile Neutropenia in Acute Leukemia. Epidemiology, Etiology, Pathophysiology and Treatment. Mediterr J Hematol Infect Dis. 2020;12(1):e2020009. DOI: 10.4084/MJHID.2020.009 PMID: 31934319
33. Gudiol C, Albasanz-Puig A, Cuervo G, Carratalà J. Understanding and Managing Sepsis in Patients With Cancer in the Era of Antimicrobial Resistance. Front Med (Lausanne). 2021;8:636547. DOI: 10.3389/fmed.2021.636547 PMID: 33869250
34. Ayaz CM, Hazırolan G, Sancak B, Hascelik G, Akova M. Factors Associated with Gram-Negative Bacteremia and Mortality in Neutropenic Patients with Hematologic Malignancies in a High-Resistance Setting. Infect Dis Clin Microbiol. 2022;4(2):87-98. DOI: 10.36519/idcm.2022.141 PMID: 38633337
35. 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. PLoS One. 2020;15(12):e0243474. DOI: 10.1371/journal.pone.0243474 PMID: 33301465
36. Al-Amri HA, Almalhan LA, Alghamdi MA, Ibrahim ME. Catheter-associated urinary tract infection and associated factors among patients admitted to intensive care unit at King Abdullah Hospital, Bisha, Saudi Arabia. BMC Infect Dis. 2025;25(1):1640. DOI: 10.1186/s12879-025-12061-4 PMID: 41286652
37. Kreitmann L, Gaudet A, Nseir S. Ventilator-Associated Pneumonia in Immunosuppressed Patients. Antibiotics (Basel). 2023;12(2):413. DOI: 10.3390/antibiotics12020413 PMID: 36830323
38. Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: a narrative review. Intensive Care Med. 2020;46(5):888-906. DOI: 10.1007/s00134-020-05980-0 PMID: 32157357
39. Gebremedhin KB, Amogne W, Alemayehu H, Bopegamage S, Eguale T. The role of uropathogenic Escherichia coli virulence factors in the development of urinary tract infection. J Med Life. 2025;18(8):701-709. DOI: 10.25122/jml-2024-0396 PMID: 41020073
40. Di Pilato V, Willison E, Marchese A. The microbiology and pathogenesis of nonfermenting Gram-negative infections. Curr Opin Infect Dis. 2023;36(6):537-544. DOI: 10.1097/QCO.0000000000000969 PMID: 37732777