Section: Miscellaneous

Original Research Article

ANTIBIOTIC SUSCEPTIBILITY PATTERN OF NOSOCOMIAL PATHOGENS ISOLATED FROM ICU PATIENTS

Neha Garg[1], Mahak Jain[2], Vineet Agrawal[3]

[1]*Assistant Professor, Department of Microbiology, Narayan Medical College & Hospital, Jamuhar, Sasaram, Bihar, India.*
[2]*Associate Professor, Department of Microbiology, Heritage Institute of Medical Sciences, Varanasi, India.*
[3]*Assistant Professor, Department of Anaesthesia, Narayan Medical College & Hospital, Jamuhar, Sasaram, Bihar, India.*

Received *: 12/02/2026*
Received in revised form *: 19/03/2026*
Accepted *: 05/04/2026*

Corresponding Author:
Dr. Neha Garg,
Assistant Professor, Department of Microbiology, Narayan Medical College & Hospital, Jamuhar, Sasaram, Bihar, India.
Email: neha986garg@gmail.com

DOI: 10.70034/ijmedph.2026.2.726

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (2); 4433-4439

ABSTRACT

Background: Nosocomial infections are a major cause of morbidity and mortality among critically ill patients admitted to intensive care units (ICUs). The increasing prevalence of multidrug-resistant (MDR) bacteria has further complicated the management of these infections, emphasizing the importance of continuous surveillance of bacterial pathogens and their antimicrobial susceptibility patterns. **Objective:** To determine the bacterial profile and antibiotic susceptibility pattern of bacterial isolates causing nosocomial infections among patients admitted to the intensive care unit of a tertiary care teaching hospital.

Materials and Methods: A hospital-based cross-sectional observational study was conducted over one year among 100 culture-positive ICU patients who developed nosocomial infections 48 hours or more after admission. Clinical specimens, including endotracheal aspirates, urine, blood, pus/wound swabs, bronchoalveolar lavage, and catheter tips, were processed using standard microbiological methods. Bacterial isolates were identified by conventional microbiological techniques, and antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion method according to Clinical and Laboratory Standards Institute (CLSI) 2025 guidelines. Data were analyzed using SPSS.

Results: Of the 100 culture-positive cases, 62.0% were males and 38.0% were females. Endotracheal aspirates (34.0%) were the most common clinical specimens, followed by urine (25.0%) and blood (18.0%). Gram-negative bacteria accounted for 83.0% of all isolates, while Gram-positive bacteria constituted 17.0%. *Acinetobacter baumannii* (28.0%) was the predominant isolate, followed by *Klebsiella pneumoniae* (22.0%), *Pseudomonas aeruginosa* (18.0%), *Escherichia coli* (15.0%), *Staphylococcus aureus* (10.0%), and *Enterococcus faecalis* (7.0%). Among Gram-negative isolates, colistin (98.8%) and tigecycline (90.4%) demonstrated the highest susceptibility, whereas resistance was highest to ampicillin (92.8%), ceftriaxone (85.5%), and ciprofloxacin (73.5%). Linezolid and vancomycin showed 100% susceptibility against Gram-positive isolates. Overall, 58.0% of isolates were multidrug-resistant (MDR), 18.0% were extensively drug-resistant (XDR), and no pan-drug-resistant (PDR) isolate was identified.

Conclusion: Gram-negative bacteria, particularly *Acinetobacter baumannii*, were the predominant pathogens responsible for nosocomial infections in ICU patients. The high prevalence of multidrug-resistant organisms and increasing resistance to commonly used antibiotics underscore the need for continuous antimicrobial resistance surveillance, hospital-specific antibiograms, antimicrobial stewardship programmes, and stringent infection prevention and

control measures to improve patient outcomes and limit the spread of antimicrobial resistance.
Keywords: Nosocomial infection; Healthcare-associated infection; Intensive care unit; Antimicrobial susceptibility; Multidrug-resistant bacteria; *Acinetobacter baumannii*; Antibiotic resistance.

INTRODUCTION

Healthcare-associated infections (HAIs), also known as nosocomial infections, are infections that develop 48 hours or more after hospital admission and were neither present nor incubating at the time of admission.[1] HAIs are among the most frequent adverse events affecting hospitalized patients and are associated with increased morbidity, mortality, prolonged hospital stay, healthcare costs, and the emergence of antimicrobial resistance.[1,2] ICU patients are particularly susceptible to HAIs because of critical illness, invasive procedures, mechanical ventilation, urinary catheterization, central venous catheterization, prolonged hospitalization, and frequent exposure to broad-spectrum antibiotics.[1,3] These factors increase the risk of ventilator-associated pneumonia (VAP), catheter-associated urinary tract infection (CAUTI), central line-associated bloodstream infection (CLABSI), and surgical site infections, which remain the most common healthcare-associated infections in critically ill patients.[1,4] Gram-negative bacteria, particularly Acinetobacter baumannii, Klebsiella pneumoniae, and Pseudomonas aeruginosa, have emerged as the predominant pathogens in ICUs because of their remarkable ability to survive in the hospital environment, form biofilms, and acquire antimicrobial resistance mechanisms.[3,5] The increasing prevalence of multidrug-resistant (MDR) organisms has considerably limited therapeutic options and has become a major challenge for clinicians worldwide.[2,5] Continuous surveillance of local bacterial epidemiology and antimicrobial susceptibility patterns is therefore essential for guiding empirical therapy, developing institutional antibiograms, and strengthening antimicrobial stewardship programmes.[2,6] The present study was undertaken to determine the bacterial profile and antibiotic susceptibility pattern of bacterial isolates causing nosocomial infections among ICU patients admitted to a tertiary care teaching hospital.

MATERIALS AND METHODS

Study Design

A hospital-based, cross-sectional observational study was conducted to determine the bacterial profile and antibiotic susceptibility pattern of nosocomial infections among patients admitted to the intensive care unit (ICU).

Study Setting

The study was carried out in the Department of Microbiology in collaboration with the Intensive Care Units of a tertiary care teaching hospital. Clinical specimens received from patients admitted to the Medical ICU, Surgical ICU, Cardiac ICU, Neurosurgical ICU, and Burn ICU were processed according to standard microbiological procedures.

Study Duration

The study was conducted over a period of one year, from **January 2025 to December 2025**.

Study Population

The study included **100 culture-positive ICU patients** diagnosed with nosocomial infections. Patients who developed signs and symptoms of infection **48 hours or more after ICU admission** and yielded significant bacterial growth on culture were included in the study.

Inclusion Criteria

- Patients admitted to any ICU for ≥48 hours.
- Patients with clinical suspicion of nosocomial infection.
- Culture-positive bacterial isolates from appropriate clinical specimens.
- Patients of all age groups and both sexes.

Exclusion Criteria

- Patients with community-acquired infections present at the time of admission.
- Patients admitted to the ICU for less than 48 hours.
- Duplicate bacterial isolates obtained from the same patient during the same infectious episode.
- Specimens showing contamination or mixed growth not considered clinically significant.

Sample Collection

Clinical specimens including endotracheal aspirates, urine, blood, pus or wound swabs, bronchoalveolar lavage (BAL), and catheter tips were collected aseptically by trained healthcare personnel following standard infection prevention and control practices. Samples were transported immediately to the microbiology laboratory and processed without delay.

Isolation and Identification of Bacterial Isolates

All specimens were cultured using standard microbiological techniques. Blood samples were processed using an automated blood culture system, where available, and positive bottles were subcultured onto Blood agar and MacConkey agar. Urine specimens were inoculated using a calibrated loop onto Cysteine Lactose Electrolyte Deficient (CLED) agar and Blood agar. Respiratory specimens, pus, wound swabs, BAL, and catheter tips were inoculated onto Blood agar and MacConkey agar and incubated aerobically at 35–37°C for 18–24 hours.

Bacterial isolates were identified based on colony morphology, Gram staining, motility, and standard biochemical tests. Where available, identification

was confirmed using an automated identification system.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing (AST) was performed by the Kirby–Bauer disc diffusion method on Mueller–Hinton agar according to the recommendations of the Clinical and Laboratory Standards Institute (CLSI). The inhibition zone diameters were interpreted as susceptible, intermediate, or resistant according to CLSI breakpoints. Isolates showing intermediate susceptibility were excluded from the final susceptibility analysis.

The antibiotics tested for Gram-negative isolates included ampicillin, amoxicillin-clavulanate, piperacillin-tazobactam, ceftriaxone, cefepime, ceftazidime, cefoperazone-sulbactam, amikacin, gentamicin, ciprofloxacin, imipenem, meropenem, tigecycline, and colistin. Gram-positive isolates were tested against penicillin, cefoxitin, erythromycin, clindamycin, gentamicin, doxycycline, trimethoprim-sulfamethoxazole, teicoplanin, linezolid, and vancomycin.

Data Collection

Demographic details, clinical information, ICU admission data, specimen type, bacterial isolates, and antimicrobial susceptibility results were recorded in a structured data collection form. Duplicate isolates from the same patient were excluded to avoid overestimation of resistance patterns.

RESULTS

A total of 100 culture-positive nosocomial infection cases admitted to various intensive care units (ICUs) were included in the study. The demographic characteristics of the study participants are presented in Table 1. Of the 100 patients, 62 (62.0%) were male and 38 (38.0%) were female, resulting in a male-to-female ratio of approximately 1.6:1. The age of the patients ranged from 18 to over 70 years. The highest proportion of patients belonged to the 51–60 years age group (25.0%), followed by 61–70 years (22.0%), 41–50 years (18.0%), >70 years (13.0%), 31–40 years (12.0%), and 18–30 years (10.0%).

The distribution of patients according to the type of ICU is shown in Table 2. The majority of patients were admitted to the Medical ICU (35.0%), followed by the Surgical ICU (25.0%). The Neurosurgical ICU and Cardiac ICU each accounted for 15.0% of cases, while the Burn ICU contributed 10.0% of the total study population.

The distribution of clinical specimens is summarized in Table 3. Endotracheal aspirates were the most frequently collected specimens, accounting for 34.0% of all samples, followed by urine (25.0%) and blood (18.0%) specimens. Pus/wound swabs constituted 12.0% of the samples, while catheter tips and bronchoalveolar lavage (BAL) specimens represented 6.0% and 5.0%, respectively. These findings indicate that respiratory tract infections were the most common nosocomial infections among ICU patients.

The bacteriological profile of the isolates is presented in Table 4. Acinetobacter baumannii was the most frequently isolated organism, accounting for 28.0% of all isolates, followed by Klebsiella pneumoniae (22.0%), Pseudomonas aeruginosa (18.0%), and Escherichia coli (15.0%). Among the Gram-positive bacteria, Staphylococcus aureus constituted 10.0% of isolates, whereas Enterococcus faecalis accounted for 7.0%. Overall, Gram-negative bacilli predominated among ICU-acquired infections.

As shown in Table 5, Gram-negative bacteria comprised 83.0% of the total bacterial isolates, whereas Gram-positive bacteria accounted for only 17.0%, demonstrating the predominance of Gram-negative pathogens in nosocomial infections occurring in the ICU setting.

The antimicrobial susceptibility pattern of Gram-negative isolates is presented in Table 6. Among these isolates, colistin exhibited the highest antimicrobial activity, with a susceptibility rate of 98.8%, followed by tigecycline (90.4%), amikacin (72.3%), and cefoperazone-sulbactam (65.1%). Moderate susceptibility was observed for piperacillin-tazobactam (60.2%), imipenem (57.8%), and meropenem (55.4%). In contrast, high resistance rates were observed against ampicillin (92.8%), ceftriaxone (85.5%), amoxicillin-clavulanate (78.3%), cefepime (75.9%), ciprofloxacin (73.5%), and ceftazidime (71.1%), indicating widespread resistance to commonly prescribed β-lactam antibiotics and fluoroquinolones.

The antibiotic susceptibility profile of Gram-positive isolates is shown in Table 7. All Gram-positive isolates were 100% susceptible to linezolid and vancomycin, while teicoplanin demonstrated 94.1% susceptibility. Good susceptibility was also observed with gentamicin (76.5%), cefoxitin (70.6%), doxycycline (70.6%), and clindamycin (64.7%). However, a high level of resistance was observed against penicillin (82.4%), followed by erythromycin (47.1%) and trimethoprim-sulfamethoxazole (41.2%).

The distribution of multidrug resistance is summarized in Table 8. Of the 100 bacterial isolates, 58.0% were identified as multidrug-resistant (MDR), while 18.0% were classified as extensively drug-resistant (XDR). Twenty-four percent of isolates were non-MDR, and no pan-drug-resistant (PDR) isolate was detected. The high prevalence of MDR and XDR organisms emphasizes the increasing burden of antimicrobial resistance in ICU-acquired infections and highlights the need for continuous surveillance, stringent infection control measures, and effective antimicrobial stewardship programs.

Table 1: Demographic characteristics of study participants (n = 100)

Variable	Frequency (n)	Percentage (%)
Gender		
Male	62	62.0
Female	38	38.0
Age group (years)		
18–30	10	10.0
31–40	12	12.0
41–50	18	18.0
51–60	25	25.0
61–70	22	22.0
>70	13	13.0

Table 2: Distribution of patients according to ICU (n = 100)

ICU	Frequency	Percentage (%)
Medical ICU	35	35.0
Surgical ICU	25	25.0
Neurosurgical ICU	15	15.0
Cardiac ICU	15	15.0
Burn ICU	10	10.0

Table 3: Distribution of clinical specimens (n = 100)

Specimen	Frequency	Percentage (%)
Endotracheal aspirate	34	34.0
Urine	25	25.0
Blood	18	18.0
Pus/Wound swab	12	12.0
Catheter tip	6	6.0
BAL	5	5.0

Table 4: Distribution of bacterial isolates (n = 100)

Organism	Frequency	Percentage (%)
Acinetobacter baumannii	28	28.0
Klebsiella pneumoniae	22	22.0
Pseudomonas aeruginosa	18	18.0
Escherichia coli	15	15.0
Staphylococcus aureus	10	10.0
Enterococcus faecalis	7	7.0

Table 5: Distribution of Gram-positive and Gram-negative isolates

Group	Frequency	Percentage (%)
Gram-negative bacteria	83	83.0
Gram-positive bacteria	17	17.0

Table 6: Antibiotic susceptibility pattern of Gram-negative isolates (n = 83)

Antibiotic	Sensitive n (%)	Resistant n (%)
Ampicillin	6 (7.2)	77 (92.8)
Amoxicillin–clavulanate	18 (21.7)	65 (78.3)
Piperacillin–tazobactam	50 (60.2)	33 (39.8)
Ceftriaxone	12 (14.5)	71 (85.5)
Cefepime	20 (24.1)	63 (75.9)
Ceftazidime	24 (28.9)	59 (71.1)
Cefoperazone–sulbactam	54 (65.1)	29 (34.9)
Amikacin	60 (72.3)	23 (27.7)
Gentamicin	42 (50.6)	41 (49.4)
Ciprofloxacin	22 (26.5)	61 (73.5)
Imipenem	48 (57.8)	35 (42.2)
Meropenem	46 (55.4)	37 (44.6)
Tigecycline	75 (90.4)	8 (9.6)
Colistin	82 (98.8)	1 (1.2)

Table 7: Antibiotic susceptibility pattern of Gram-positive isolates (n = 17)

Antibiotic	Sensitive n (%)	Resistant n (%)
Penicillin	3 (17.6)	14 (82.4)
Cefoxitin	12 (70.6)	5 (29.4)
Erythromycin	9 (52.9)	8 (47.1)
Clindamycin	11 (64.7)	6 (35.3)
Gentamicin	13 (76.5)	4 (23.5)
Linezolid	17 (100.0)	0 (0.0)
Vancomycin	17 (100.0)	0 (0.0)

Teicoplanin	16 (94.1)	1 (5.9)
Doxycycline	12 (70.6)	5 (29.4)
Trimethoprim–sulfamethoxazole	10 (58.8)	7 (41.2)

Table 8: Distribution of antimicrobial resistance patterns

Resistance category	Frequency	Percentage (%)
Non-MDR	24	24.0
MDR	58	58.0
XDR	18	18.0
PDR	0	0.0

DISCUSSION

The present study evaluated the bacteriological profile and antibiotic susceptibility pattern of bacterial isolates causing nosocomial infections among patients admitted to the intensive care unit (ICU). The findings demonstrated a predominance of Gram-negative bacteria, with Acinetobacter baumannii being the most frequently isolated pathogen, followed by Klebsiella pneumoniae, Pseudomonas aeruginosa, and Escherichia coli. Furthermore, a high prevalence of multidrug-resistant (MDR) organisms and reduced susceptibility to commonly prescribed antibiotics were observed, highlighting the increasing challenge of antimicrobial resistance in critically ill patients. Similar observations have been reported in recent surveillance studies conducted in ICUs worldwide, where Gram-negative pathogens have become the predominant cause of healthcare-associated infections (HAIs) owing to prolonged hospitalization, invasive procedures, and extensive exposure to broad-spectrum antibiotics.[7,8]

In the present study, males constituted 62.0% of the study population, while females accounted for 38.0%. A similar male predominance has been reported in several Indian and international studies investigating ICU-acquired infections.[8,9] This finding may be attributed to the higher rate of ICU admission among males because of trauma, chronic illnesses, cardiovascular diseases, and other comorbid conditions requiring intensive care. Additionally, the majority of patients belonged to the 51–60 years age group, indicating that increasing age is an important risk factor for nosocomial infections. Elderly patients often have impaired immune responses, multiple comorbidities, prolonged hospital stays, and increased exposure to invasive devices, all of which contribute to an increased risk of infection.[9,10]

Respiratory tract specimens, particularly endotracheal aspirates, represented the most frequently collected clinical samples (34.0%) in the present study. This observation reflects the high incidence of ventilator-associated pneumonia (VAP), which remains one of the most common healthcare-associated infections among mechanically ventilated patients. Urine and blood samples were the second and third most common specimen types, corresponding to catheter-associated urinary tract infections (CAUTIs) and central line-associated bloodstream infections (CLABSIs), respectively. These findings are consistent with reports from the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), which identify respiratory tract infections as the leading ICU-acquired infections worldwide.[1,11]

Among all bacterial isolates, Acinetobacter baumannii accounted for 28.0%, making it the predominant pathogen in the present study. This finding agrees with several recent studies reporting A. baumannii as one of the leading causes of ICU-acquired infections because of its ability to survive for prolonged periods on hospital surfaces, produce biofilms, and acquire multiple antimicrobial resistance genes.[7,12] Klebsiella pneumoniae (22.0%) and Pseudomonas aeruginosa (18.0%) were the second and third most common isolates, respectively. These opportunistic pathogens are well recognized for causing ventilator-associated pneumonia, bloodstream infections, urinary tract infections, and surgical site infections among critically ill patients. Their increasing prevalence in ICUs has been associated with extensive antimicrobial use and prolonged hospitalization.[8,13]

The present study demonstrated that Gram-negative bacteria accounted for 83.0% of all isolates, whereas Gram-positive organisms represented only 17.0%. This predominance of Gram-negative pathogens is consistent with recent antimicrobial resistance surveillance reports from India and other developing countries.[8,12] The increasing predominance of Gram-negative organisms may be explained by their remarkable ability to acquire plasmid-mediated resistance genes, produce extended-spectrum β-lactamases (ESBLs), AmpC β-lactamases, and carbapenemases, and persist in the hospital environment through biofilm formation and environmental contamination.[2,7]

Antimicrobial susceptibility testing demonstrated alarmingly high resistance to ampicillin (92.8%), ceftriaxone (85.5%), amoxicillin-clavulanate (78.3%), cefepime (75.9%), ceftazidime (71.1%), and ciprofloxacin (73.5%) among Gram-negative isolates. Similar resistance patterns have been reported by the Indian Council of Medical Research (ICMR) Antimicrobial Resistance Surveillance Network, which documented increasing resistance to third-generation cephalosporins and fluoroquinolones among Enterobacterales and non-fermenting Gram-negative bacilli.[14] The widespread resistance to β-lactam antibiotics observed in the present study is likely due to excessive empirical

antibiotic use, prolonged ICU stay, and the dissemination of ESBL- and carbapenemase-producing organisms.[15]

Among the antimicrobial agents tested, colistin exhibited the highest susceptibility (98.8%), followed by tigecycline (90.4%) and amikacin (72.3%). Similar findings have been reported by several investigators, who identified colistin and tigecycline as the most effective therapeutic agents against carbapenem-resistant Acinetobacter baumannii and Klebsiella pneumonia.[12,16] Although these agents remain highly effective, increasing reliance on reserve antibiotics may accelerate the emergence of colistin-resistant and tigecycline-resistant strains, emphasizing the importance of antimicrobial stewardship and rational antibiotic prescribing.[2,16]

Among Gram-positive isolates, linezolid and vancomycin demonstrated 100% susceptibility, while teicoplanin retained excellent activity (94.1%). High resistance was observed against penicillin (82.4%) and erythromycin (47.1%). These findings are comparable with previous reports indicating that glycopeptides and oxazolidinones remain highly effective against methicillin-resistant Staphylococcus aureus (MRSA) and Enterococcus species despite increasing resistance to β-lactam antibiotics and macrolides.[17,18] Preservation of these last-line agents through appropriate antimicrobial stewardship is essential to prevent further resistance development.

A major finding of the present study was the high prevalence of multidrug-resistant organisms. Overall, 58.0% of isolates were classified as MDR and 18.0% as extensively drug-resistant (XDR), while no pan-drug-resistant isolate was detected. The increasing prevalence of MDR organisms has become a major concern because these pathogens are associated with prolonged hospitalization, increased healthcare costs, limited therapeutic options, and higher mortality rates.[2,14] Similar MDR prevalence has been reported in recent ICU-based studies from India and other low- and middle-income countries, where inappropriate antibiotic use, inadequate infection control practices, and prolonged ICU stay have contributed significantly to the spread of resistant pathogens.[8,15]

The findings of the present study emphasize the importance of continuous microbiological surveillance and periodic preparation of hospital-specific antibiograms to guide empirical antibiotic therapy. Institution-specific antimicrobial susceptibility data allow clinicians to select appropriate empirical treatment while reducing unnecessary use of broad-spectrum antibiotics. Furthermore, implementation of comprehensive antimicrobial stewardship programmes, strict hand hygiene, environmental cleaning, device-care bundles, and adherence to standard infection prevention protocols are essential to reduce the burden of healthcare-associated infections and limit the emergence of antimicrobial resistance.[2,19]

The present study has certain limitations. It was conducted at a single tertiary care centre and included only 100 culture-positive cases, which may limit the generalizability of the findings. Molecular characterization of antimicrobial resistance mechanisms, including detection of ESBL, carbapenemase, methicillin resistance, and colistin resistance genes, was not performed. Future multicentre studies with larger sample sizes and molecular diagnostic techniques are recommended to better understand the epidemiology and resistance mechanisms of ICU pathogens.[20]

Overall, the present study demonstrates that Gram-negative bacteria, particularly Acinetobacter baumannii, remain the predominant cause of nosocomial infections in ICU patients. The high prevalence of multidrug-resistant organisms and increasing resistance to commonly used antibiotics underscore the urgent need for continuous antimicrobial resistance surveillance, evidence-based empirical antibiotic policies, effective antimicrobial stewardship programmes, and rigorous infection prevention and control measures to improve patient outcomes and reduce the burden of healthcare-associated infections.

CONCLUSION

The present study demonstrated that Gram-negative bacteria were the predominant pathogens causing nosocomial infections among ICU patients, with Acinetobacter baumannii, Klebsiella pneumoniae, and Pseudomonas aeruginosa being the most frequently isolated organisms. A high prevalence of multidrug-resistant (MDR) isolates was observed, with marked resistance to commonly used antibiotics such as ampicillin, third-generation cephalosporins, and fluoroquinolones. In contrast, colistin and tigecycline retained excellent activity against most Gram-negative isolates, while linezolid and vancomycin remained highly effective against Gram-positive organisms.

These findings highlight the growing burden of antimicrobial resistance in intensive care settings and emphasize the need for continuous microbiological surveillance, periodic preparation of hospital-specific antibiograms, and evidence-based empirical antibiotic therapy. Strengthening antimicrobial stewardship programmes, implementing strict infection prevention and control measures, promoting hand hygiene, and ensuring the judicious use of antibiotics are essential to limit the emergence and spread of resistant pathogens. Regular monitoring of antimicrobial susceptibility patterns will support clinicians in selecting appropriate treatment, improve patient outcomes, reduce healthcare costs, and contribute to the containment of antimicrobial resistance in tertiary care hospitals.

REFERENCES

1. Tobin EH, Zahra F. Nosocomial Infections. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025. Available from: National Center for Biotechnology Information Bookshelf.
2. Haque M, McKimm J, Sartelli M, Dhingra S, Labricciosa FM, Islam S, Jahan D, Nusrat T, Chowdhury TS, Coccolini F, Catena F. Strategies to Prevent Healthcare-Associated Infections: A Narrative Overview. Risk Manag Healthc Policy. 2020;13:1765-1780.
3. Sartelli M, Catena F, et al. Preventing and Controlling Healthcare-Associated Infections. Antibiotics (Basel). 2024;13(9):896.
4. Rimaz S, Tajzadeh P, Bahrami M, Nooghabi MJ, Eshrati B, Effati S, et al. Study of epidemiological features, antimicrobial resistance profile and clinical outcomes of healthcare-associated infections in intensive care units by Iranian Nosocomial Infection Surveillance System. East Mediterr Health J. 2023;29(5).
5. European Centre for Disease Prevention and Control. Healthcare-associated infections acquired in intensive care units – Annual Epidemiological Report 2020. Stockholm: ECDC; 2023.
6. Haque M, Sartelli M, McKimm J, Bakar MA. Health care-associated infections – an overview. Infect Drug Resist. 2018;11:2321-2333.
7. Karukappadath RMR, Sirbu DS, Zaky AZ. Drug-resistant bacteria in the critically ill: patterns and mechanisms of resistance and potential remedies. Front Antibiot. 2023;2:1145190.
8. Chakraborty M, et al. Current trends in antimicrobial resistance patterns in ICU patients. Cureus. 2023;15:e36768.
9. Dadi NCT, Radochová B, Vargová J, Bujdáková H. Impact of Healthcare-Associated Infections Connected to Medical Devices—An Update. Microorganisms. 2021;9(11):2332. doi:10.3390/microorganisms9112332.
10. Di Domenico EG, Oliva A, Guembe M. The Current Knowledge on the Pathogenesis of Tissue and Medical Device-Related Biofilm Infections. Microorganisms. 2022;10(7):1259.
11. World Health Organization: Infection prevention and control. Geneva: World Health Organization; 2023.
12. Jedud L, Cicvarić A, Bogdan M, et al. A change in nosocomial infections among surgical ICU patients in the COVID-19 era and MALDI-TOF mass spectrometry—A cross-sectional study. Microorganisms. 2024;12:1510.
13. Varshini MK, Ganesan V, Sundaramurthy R, Rajendran T. Risk Factors and Clinical Outcomes of Infections: Scenario in a Tertiary Care Center from South India. Indian J Crit Care Med. 2022;26(8):935-937.
14. Indian Council of Medical Research. Antimicrobial Resistance Surveillance & Research Network (AMRSN): Annual Report 2023. New Delhi: ICMR.
15. World Health Organization. Global Antimicrobial Resistance and Use Surveillance System (GLASS) Report 2024. Geneva: WHO.
16. Clinical and Laboratory Standards Institute. Performance Standards for Antimicrobial Susceptibility Testing. 35th ed. Wayne, PA: CLSI; 2025.
17. Puro V, Coppola N, Frasca A, Gentile I, Luzzaro F, Peghetti A, Sganga G. Pillars for prevention and control of healthcare-associated infections: an Italian expert opinion statement. Antimicrob Resist Infect Control. 2022;11:87.
18. Tartari E, Bellissimo-Rodrigues F, Pires D, et al. Updates and future directions regarding hand hygiene in the healthcare setting. Antimicrob Resist Infect Control. 2024;13:26.
19. Centers for Disease Control and Prevention. Antibiotic Use in the United States, 2024 Update: Progress and Opportunities. Atlanta: CDC; 2024.
20. Sandu AM, et al. Healthcare-Associated Infections: The Role of Microbial and Environmental Factors, Current Diagnosis, and Future Prevention Strategies. Infect Dis Ther. 2025.