

COMMUNICATION

Nosocomial infections in intensive care units: Bacterial profiles and microbial resistance patterns

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Abstract

Nosocomial infections (NIs) are a significant global health issue, specifically in intensive care units (ICUs). The study aims to identify the bacterial profiles and antimicrobial resistance patterns of NI pathogens in the ICU of a tertiary care hospital, with the goal of informing effective treatment and infection control approaches. This cross-sectional, descriptive study was conducted between March 2024 and March 2025 in the ICUs of Saidu Teaching Hospital. Clinical samples were collected from patients who had acquired signs of infection after 48 h of admission. Identification and antimicrobial susceptibility of bacteria were conducted using standard microbiological and Kirby–Bauer disc diffusion techniques. Multidrug resistance (MDR) was defined as non-susceptibility to at least one agent in three or more antimicrobial categories. Among 450 admitted patients, 112 (24.9%) had clinical NIs, and 98 (21.8%) were microbiologically verified. Gram-negative bacilli predominated (78.6%), followed by *Acinetobacter baumannii* (27.7%) and *Pseudomonas aeruginosa* (21.4%). Ventilator-associated pneumonia (45.5%) and catheter-associated urinary tract infections (28.6%) were the most common sites of infection. The prevalence of MDR was alarming, 76.8% overall, with 100% of *A. baumannii* and *K. pneumoniae* being MDR. Carbapenem resistance was found to be high (*A. baumannii*: 93.5, *K. pneumoniae*: 72.2). Most Gram-negative isolates were mostly susceptible to colistin. NIs tend to have a high burden in the ICU, as observed in this study, particularly with Gram-negative bacteria that exhibit MDR. The extreme prevalence of carbapenem-resistant *A. baumannii* and *K. pneumoniae* signals an highlights a crisis in antimicrobial resistance. These findings underscore the importance of implementing robust infection prevention and control policies, executing rigorous antibiotic stewardship initiatives, and maintaining ongoing local surveillance to inform empirical treatment and improve patient outcomes.

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1. Introduction

Nosocomial infections (NIs), also known as hospital-acquired infections, refer to infections that a patient contracts during the period of his or her stay in a healthcare facility, most frequently after 48 h of admission.¹ These infections continue to be a major global health issue due to their effects on patient safety, extended hospitalization, unnecessary medical expenses, morbidity, and death. Intensive care units (ICUs), accommodating highly frail patients and requiring specialized attention, are the most susceptible areas to the emergence of NIs.² ICUs are especially prone to outbreaks due to the performance of invasive procedures, the presence of immunocompromised individuals, and increased use of medical equipment.³

Infections in the ICUs include ventilator-associated pneumonia (VAP), bloodstream infections, catheter-associated urinary tract infections (CA-UTIs), and surgical site infections (SSIs).⁴ Such infections are mainly associated with invasive devices such as endotracheal tubes, central venous catheters, and urinary catheters, as these devices serve as entry points for disease-causing microorganisms.⁵ The frequent use of broad-spectrum antibiotics in ICUs interferes with the native microbiota, thereby increasing the colonization process of opportunistic and multidrug-resistant (MDR) pathogens.⁶

Bacterial pathogens are the most common cause of ICU-acquired infections.⁷ Common gram-negative bacilli that are frequently isolated in ICUs include *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, and *Escherichia coli*.⁸ These pathogens have evolved advanced immunological resistance to extended-spectrum β -lactamases (ESBLs) and carbapenemases, rendering most traditional antibiotics inefficient against them.⁹ Gram-positive disease-causing organisms, especially methicillin-resistant *Staphylococcus aureus* (MRSA) and *Enterococcus* species, are significant contributors to the epidemiology of NIs.¹⁰

The emergence and transmission of MDR organisms in an ICU pose a significant treatment challenge. Infections associated with MDR bacteria have been associated with a lack of therapy, poor patient outcomes, and high morbidity.¹¹ The unjustified and overuse of antibiotics within the hospital's premises, the absence of effective infection control measures, and the absence of a monitoring system only exacerbate the issue of antimicrobial resistance.¹² To overcome this problem, more effective infection prevention measures and initiatives to increase the general knowledge of the local bacterial ecology and resistance trends within ICUs are needed.¹³

Observation of bacterial pathogens and their sensitivity to antimicrobials is critical for guiding empirical therapy.¹⁴

Most patients with severe illnesses require empirical treatment, which is initiated before laboratory diagnosis; therefore, identifying the most frequent organisms and their sensitivity patterns is crucial for effective and timely treatment.¹⁵ As a valuable source of information, surveillance data can be used to formulate hospital-specific antibiotic policies and stewardship programs to curb the misuse of antimicrobials and antimicrobial resistance.¹⁶ NIs pose a significant clinical and economic burden; therefore, it is imperative to ensure continuous monitoring of bacterial profiles and resistance patterns in the ICU.¹³ Evidence-based information can help clinicians select effective therapies, increase infection prevention efforts, and ultimately improve patient outcomes.¹⁷

Despite global recognition of NIs as a major ICU threat, data from Pakistan remain sparse, hindering hospital-specific empirical therapy and policy development. Hence, this study addresses this regional gap by profiling the spectrum of bacteria associated with ICU-acquired infections and assessing antimicrobial resistance patterns, which may play a significant role in managing the infection situation and promoting antibiotic stewardship in the ICU setting in Pakistan.

2. Materials and methods

2.1. Study design and setting

This descriptive, cross-sectional study was conducted at the ICUs of the Microbiology Department of Saidu Teaching Hospital, Swat, from March 1, 2024, to March 1, 2025. Patients admitted to the ICUs who developed signs and symptoms of infection after 48 h of hospital stay were selected as the target population, thereby satisfying the requirements for NIs (VAP, CA-UTI, central line-associated bloodstream infections, & SSI).

2.2. Study population and inclusion criteria

The inclusion criteria were all ICU patients, regardless of age or gender, who presented with clinical features suggestive of NIs (fever, elevated inflammatory markers, purulent secretions, or sepsis). Patients who had documented infections at the time of ICU admission or had infections acquired within 48 h of hospitalization were excluded.

2.3. Sample collection

Aseptic clinical specimens were collected according to the location of suspected infection. These included blood samples from suspected bloodstream infections, endotracheal or bronchoalveolar lavage samples from VAP, urine samples from CA-UTIs, and pus/wound swabs from SSIs. All specimens were immediately taken to the microbiology laboratory, where they were processed.

2.4. Microbiological analysis

The specimens were cultured on routine bacteriological media, including blood agar, MacConkey agar, and chocolate agar, and incubation was performed at 35–37°C for 24–48 h. Bacterial isolates were identified by their morphology, Gram staining, and through common biochemical tests (catalase, coagulase, oxidase, indole, citrate utilization, urease, and TSI reactions). Confirmation was done through automated systems such as VITEK 2 (BioMérieux, France) or matrix-assisted laser desorption/ionization time-of-flight (2024 Model, Neoflex, France).¹⁸

2.5. Antimicrobial susceptibility testing

All bacterial isolates were tested for antimicrobial susceptibility using the Kirby–Bauer disc diffusion method, as per the guidelines of the Clinical and Laboratory Standards Institute. Eight types of commonly used antibiotics in ICU settings, including piperacillin-tazobactam, ceftriaxone, cefepime, meropenem, amikacin, gentamicin, ciprofloxacin, colistin, vancomycin, and linezolid, were tested. MDR was defined as non-susceptible to at least one agent in three or more classes of antimicrobials. The combined disc test was used to detect ESBL production, whereas carbapenem resistance was detected through the modified Hodge test or automated susceptibility systems.¹⁹

2.6. Ethical considerations

Ethical approval for this study was obtained from the Institutional Review Board of Saidu Teaching Hospital (Reference no.: 1754).

2.7. Data analysis

Categorical data are presented as frequencies and percentages. The Chi-square test was applied to the distribution of pathogens among sites of infection. The mean number of resistant antibiotic classes in Gram-negative and Gram-positive isolates was compared using an independent sample *t*-test. A *p* < 0.05 was considered significant. The data analyses were conducted using the Statistical Package for the Social Sciences software (version 23.0).

3. Results

3.1. Demographic and clinical characteristics

A total of 450 patients were admitted to the ICUs during the 1-year study period. Among them, 112 patients developed clinical signs and symptoms suggestive of a NI after 48 h of admission, yielding an overall incidence rate of 24.9%. After microbiological confirmation, 98 patients were found to have positive cultures, resulting in a confirmed NI rate of 21.8%.

The demographic and clinical characteristics of the 98 patients with confirmed infections are summarized in Table 1. The mean age of the patients was 58.7 ± 16.2 years, with a male predominance (62.2%, *n* = 61). The most common underlying comorbidities were hypertension (44.9%), diabetes mellitus (38.8%), and chronic kidney disease (18.4%). The majority of patients (85.7%, *n* = 84) had undergone invasive procedures, primarily mechanical ventilation (71.4%, *n* = 70) and central venous catheterization (67.3%, *n* = 66).

3.2. Distribution of infection sites and bacterial isolates

A total of 112 bacterial pathogens were isolated from the 98 patients, as some patients had polymicrobial infections. The most common site of infection was the respiratory tract (VAP; 45.5%, *n* = 51), followed by urinary tract (CA-UTI; 28.6%, *n* = 32), bloodstream (central line-associated bloodstream infection; 16.1%, *n* = 18), and surgical sites (9.8%, *n* = 11).

Gram-negative bacilli were the predominant pathogens, accounting for 78.6% (*n* = 88) of all isolates. The most frequently isolated organisms were *A. baumannii* (27.7%, *n* = 31), followed by *P. aeruginosa* (21.4%, *n* = 24), *K. pneumoniae* (16.1%, *n* = 18), and *E. coli* (13.4%, *n* = 15). Gram-positive cocci constituted 21.4% (*n* = 24) of the isolates, with *S. aureus* (14.3%, *n* = 16) being the most common, of which 81.3% (*n* = 13) were identified as MRSA. The distribution of pathogens is detailed in Table 2.

A Chi-square test of independence was performed to examine the relation between infection site and type

Table 1. Demographic and clinical characteristics of study participants (*n*=98)

Characteristics	Values
Age (years), mean±standard deviation	58.7±16.2
Gender	
Male	61 (62.2%)
Female	37 (37.8%)
Comorbidities	
Hypertension	44 (44.9%)
Diabetes mellitus	38 (38.8%)
Chronic kidney disease	18 (18.4%)
Chronic obstructive pulmonary disease	15 (15.3%)
Invasive procedure	
Mechanical ventilation	70 (71.4%)
Central venous catheter insertion	66 (67.3%)
Urinary catheter insertion	89 (90.8%)
Surgery	32 (32.7%)

Note: Data presented as *n* (%), unless stated otherwise.

of pathogen (Gram-negative vs. Gram-positive). The association between these variables was statistically significant ($\chi^2[3, n = 112]: 11.83; p=0.008$), indicating that Gram-negative bacteria were significantly more likely to be associated with VAP and CA-UTI.

3.3. Antimicrobial resistance patterns

Antimicrobial resistance was highly prevalent among the isolates. The total incidence of MDR organisms was 76.8%. All the isolates of *A. baumannii* and *K. pneumoniae* were MDR. *A. baumannii* (93.5%) and *K. pneumoniae* (72.2%) recorded the highest proportion of resistance to carbapenem. Gram-negative isolates did not exhibit resistance to last-line agents, such as colistin (<7%), and resistance to vancomycin or linezolid was not detected in *S. aureus* isolates. Resistance profiles are detailed in Table 3.

Carbapenem resistance was notably high, particularly in *A. baumannii* (93.5%) and *K. pneumoniae* (72.2%). The modified Hodge test confirmed carbapenemase production in 83.3% of carbapenem-resistant *K. pneumoniae* isolates. ESBL production was detected in 88.9% (16/18) of *K. pneumoniae* and 73.3% of *E. coli* isolates.

An independent samples *t*-test was conducted to compare the mean number of antibiotic classes to which isolates were resistant in Gram-negative versus Gram-positive organisms. Gram-negative isolates (mean = 5.2, standard deviation = 1.4) were resistant to significantly more antibiotic classes than Gram-positive isolates (mean = 3.1, standard deviation = 1.1; $t[110] = 8.17; p<0.001$).

Table 2. Distribution of bacterial isolates by infection site (n=112)

Bacterial isolate	VAP (n=51)	CA-UTI (n=32)	CLABSI (n=18)	SSI (n=11)	Total (%)
<i>Acinetobacter baumannii</i>	20	4	5	2	31 (27.7)
<i>Pseudomonas aeruginosa</i>	15	3	4	2	24 (21.4)
<i>Klebsiella pneumoniae</i>	7	8	2	1	18 (16.1)
<i>Escherichia coli</i>	2	10	2	1	15 (13.4)
Methicillin-resistant <i>Staphylococcus aureus</i>	5	1	3	2	11 (9.8)
Methicillin-susceptible <i>Staphylococcus aureus</i>	1	1	1	2	5 (4.5)
<i>Enterococcus</i> spp.	1	3	1	0	5 (4.5)
Others	0	2	0	1	3 (2.7)
Total	51	32	18	11	112 (100)

Abbreviations: CA-UTI: Catheter-associated urinary tract infection; CLABSI: Central line-associated bloodstream infection; SSI: Surgical site infection; VAP: Ventilator-associated pneumonia.

Table 3. Antimicrobial resistance patterns of predominant bacterial isolates

Antibiotic agent	<i>Acinetobacter baumannii</i> (n=31) (%)	<i>Pseudomonas aeruginosa</i> (n=24) (%)	<i>Klebsiella pneumoniae</i> (n=18) (%)	<i>Escherichia coli</i> (n=15) (%)	<i>Staphylococcus aureus</i> (n=16) (%)
Piperacillin-tazobactam	100	70.8	88.9	66.7	-
Ceftriaxone	100	-	100	73.3	-
Cefepime	100	75.0	94.4	66.7	-
Meropenem	93.5	45.8	72.2	26.7	-
Amikacin	80.6	29.2	55.6	20.0	-
Ciprofloxacin	96.8	62.5	83.3	60.0	-
Gentamicin	90.3	50.0	77.8	53.3	-
Colistin	6.5	4.2	5.6	0	-
Oxacillin	-	-	-	-	81.3 (MRSA)
Clindamycin	-	-	-	-	75.0
Erythromycin	-	-	-	-	81.3
Vancomycin	-	-	-	-	0
Linezolid	-	-	-	-	0

Abbreviation: MRSA: Methicillin-resistant *Staphylococcus aureus*.

4. Discussion

This study presents a critical analysis of bacterial etiology and antimicrobial resistance patterns of NIs in the ICUs of a tertiary care hospital. The findings reveal that the healthcare-associated infection burden is substantial and primarily composed of MDR Gram-negative bacteria, representing a highly challenging and threatening global health trend.

The overall incidence of NIs in our ICU was 24.9%, of which 21.8% were confirmed by microbiological analysis. Such a rate correlates with other low- and middle-income countries, as ICU infection rates are commonly between 15% and 30%. In contrast, in high-income countries with strong infection prevention and control strategies, the infection rates are 5–10%.^{20,21} This gap highlights the influence of resource availability, congestion, and variations in adherence to infection prevention and control practices on the rate of infection.

In line with other studies in many countries, the respiratory tract and the urinary tract were the most frequent sites of infection.^{22,23} This is directly due to the high rate of invasive devices, such as endotracheal tubes and urinary catheters, that disrupt natural host defenses and form pathogen conduction. The high statistical correlation ($p=0.008$) between infection site and Gram-negative pathogens further reinforces the already established relationship between these devices and Gram-negative bacteriology.

Our results show that Gram-negative bacilli were predominant (78.6%), with *A. baumannii* and *P. aeruginosa* as the most common isolates. This is consistent with recent data in the International NI Control Consortium, along with recent studies in South Asia and the Middle East that reported the continual domination of the *Acinetobacter* spp. and *Pseudomonas* spp. as primary contributors of ICU-acquired infection, particularly VAP and bloodstream infections.^{24,25} The high prevalence of *A. baumannii* is alarming, as it has the ability to acquire pan-drug resistance and survive in the hospital setting.

There are serious concerns regarding the antimicrobial resistance patterns observed in this study. The general rate of MDR was 76.8%, which is very high and exceeds most current reports. The high proportion of 100% of MDR isolates of *A. baumannii* and *K. pneumoniae* is indicative of a severe resistance crisis in the ICU setting. Of particular concern is the high rate of resistance to carbapenems, a group of antibiotics typically used as a last-resort agent. The 93.5% carbapenem resistance in *A. baumannii* and 72.2% in *K. pneumoniae* are reflective of the concerning trends in other locations, including Greece, Italy, and

some of Asia, which are commonly linked to the spread of certain carbapenemase-resistant genes (e.g., OXA-48 in *Klebsiella*, OXA-23/OXA-51 in *Acinetobacter*).^{26,27}

The prevalence of ESBL-producing *K. pneumoniae* and *E. coli* is a significant barrier to the use of broad-spectrum cephalosporins in empirical therapy. The significantly greater mean number of antibiotic classes against which Gram-negative isolates were resistant, compared to Gram-positive isolates (5.2 vs. 3.1, $p<0.001$), highlights the difficulty in treating these infections. The susceptibility of most Gram-negative isolates to colistin and Gram-positives to vancomycin and linezolid supports the roles of these agents as essential last-line agents. However, their applications should be carefully controlled to prevent the development of resistance.

Among Gram-positive bacteria, MRSA represented a large fraction (81.3% of *S. aureus* isolates), which is greater than that associated with many Western countries but similar to data in some Asian ICUs.²⁸ This highlights the ongoing burden of MRSA and the continuous need for rigorous screening and contact precautions.

5. Conclusion

This study demonstrated that NIs are high in ICUs due to MDR Gram-negative bacilli, with the most common pathogens being carbapenem-resistant *A. baumannii* and *K. pneumoniae*. The widespread resistance to first-line and last-resort drugs, which are mostly carbapenems, highlights an impending crisis of antimicrobial resistance. These results suggest that a multidimensional intervention approach should be implemented. The intensity of infection control and prevention, particularly of device care and hand hygiene, should be increased to minimize infection. Ongoing local monitoring represents a crucial step in informing empirical treatment guidelines and surveillance of the evolving microbial threat to enhance patient safety and clinical outcomes in the intensive care setting. While this single-center study from Pakistan addresses a critical regional evidence gap, its generalizability is limited. Future studies should include multicenter studies with cohorts nationwide to facilitate national validation and inform policy impact.

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Conflict of interest

The authors declare that they have no competing interests.

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Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Saidu Teaching Hospital (IRB/SGTH/1754). Informed consent was obtained from patients or their guardians before they participated in this study.

Consent for publication

Consent for publication was obtained from the patients.

Availability of data

Data used in this work are available from the corresponding author upon reasonable request.

References

- Liu JY, Dickter JK. Nosocomial infections: A history of hospital-acquired infections. *Gastrointest Endosc Clin N Am*. 2020;30(4):637–652.
doi: 10.1016/j.giec.2020.06.001
- Ndlovu B. *Nosocomial Infections in Neonatal Intensive Care Unit of a Public Healthcare Facility in Saudi Arabia*. University of South Africa (South Africa); 2021. Available from: <https://www.proquest.com/openview/f5ac71c877ede83cd24395277c098697/1?pq-origsite=gscholar&cbl=2026366&diss=y> [Last accessed on 2025 Dec 25].
- Garzotto F, Comoretto RI, Ostermann M, *et al*. Preventing infectious diseases in intensive care unit by medical devices remote control: Lessons from COVID-19. *J Crit Care*. 2021;61:119–124.
doi: 10.1016/j.jcrc.2020.10.014
- Gouel-Cheron A, Swihart BJ, Warner S, *et al*. Epidemiology of ICU-onset bloodstream infection: Prevalence, pathogens, and risk factors among 150,948 ICU patients at 85 US hospitals. *Crit Care Med*. 2022;50(12):1725–1736.
doi: 10.1097/CCM.0000000000005662
- 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
- Zjajo A. *The Influence of Antimicrobial Stewardship Measures on Outcome of Patients with Severe Infections treated in Intensive Care Unit*. University of Zagreb. School of Medicine. Department of Infectious Diseases; 2024. Available from: <https://urn.nsk.hr/urn:nbn:hr:105:735179> [Last accessed on 2025 Dec 25].
- Yetkin F, Yakupogullari Y, Kuzucu C, *et al*. Pathogens of intensive care unit-acquired infections and their antimicrobial resistance: A 9-year analysis of data from a university hospital. *Jundish J Microbiol*. 2018;11(10):1–8.
doi: 10.5812/jjm.67716
- MacVane SH. Antimicrobial resistance in the intensive care unit: A focus on gram-negative bacterial infections. *J Intensive Care Med*. 2017;32(1):25–37.
doi: 10.1177/0885066615619895
- Husna A, Rahman MM, Badruzzaman A, *et al*. Extended-spectrum β -lactamases (ESBL): Challenges and opportunities. *Biomedicine*. 2023;11(11):2937.
doi: 10.3390/biomedicine11112937
- Nimer NA. Nosocomial infection and antibiotic-resistant threat in the Middle East. *Infect Drug Resist*. 2022;15:631–639.
doi: 10.2147/IDR.S351755
- Gajic I, Tomic N, Lukovic B, *et al*. A comprehensive overview of antibacterial agents for combating Multidrug-Resistant bacteria: The current landscape, development, future opportunities, and challenges. *Antibiotics*. 2025;14(3):221.
doi: 10.3390/antibiotics14030221
- Zulfkar Q, Humaira A, Mohd AD, Afshana Q. The growing threat of antibiotic resistance: Mechanisms, causes, consequences, and solutions. *Int J Cognit Neurosci Psychol*. 2025;3(3):28–36.
- Calvo M, Stefani S, Migliorisi G. Bacterial infections in intensive care units: Epidemiological and microbiological aspects. *Antibiotics (Basel)*. 2024;13(3):238.
doi: 10.3390/antibiotics13030238
- Zhu Y, Huang WE, Yang Q. Clinical perspective of antimicrobial resistance in bacteria. *Infect Drug Resist*. 2022;15:735–746.
doi: 10.2147/IDR.S345574
- Ippolito M, Cortegiani A. Empirical decision-making for antimicrobial therapy in critically ill patients. *BJA Educ*. 2023;23(12):480–487.
doi: 10.1016/j.bjae.2023.09.001
- Giamarellou H, Galani L, Karavasilis T, Ioannidis K, Karaikos I. Antimicrobial stewardship in the hospital setting: A narrative review. *Antibiotics (Basel)*. 2023;12(10):1557.
doi: 10.3390/antibiotics12101557

17. Connor L, Dean J, McNett M, *et al.* Evidence-based practice improves patient outcomes and healthcare system return on investment: Findings from a scoping review. *Worldviews Evid Based Nurs.* 2023;20(1):6-15.
doi: 10.1111/wvn.12621
18. Assefa M, Tigabu A, Belachew T, Tessema B. Bacterial profile, antimicrobial susceptibility patterns, and associated factors of community-acquired pneumonia among adult patients in Gondar, Northwest Ethiopia: A cross-sectional study. *PLoS One.* 2022;17(2):e0262956.
doi: 10.1371/journal.pone.0262956
19. Gaur P, Hada V, Rath RS, Mohanty A, Singh P, Rukadikar A. Interpretation of antimicrobial susceptibility testing using European committee on antimicrobial susceptibility testing (EUCAST) and clinical and laboratory standards institute (CLSI) breakpoints: Analysis of agreement. *Cureus.* 2023;15(3):e36977.
doi: 10.7759/cureus.36977
20. Allegranzi B, Nejad SB, Combescure C, *et al.* Burden of endemic health-care-associated infection in developing countries: Systematic review and meta-analysis. *Lancet.* 2011;377(9761):228-241.
doi: 10.1016/S0140-6736(10)61458-4
21. Rosenthal VD, Desse J, Maurizi DM, *et al.* Impact of the international nosocomial infection control consortium's multidimensional approach on rates of ventilator-associated pneumonia in 14 intensive care units in 11 hospitals of 5 cities within Argentina. *Am J Infect Control.* 2018;46(6):674-679.
doi: 10.1016/j.ajic.2017.11.021
22. Mengistu DA, Alemu A, Abdukadir AA, Mohammed Husen A, Ahmed F, Mohammed B. Incidence of urinary tract infection among patients: Systematic review and meta-analysis. *Inquiry.* 2023;60:1-12.
doi: 10.1177/00469580231168746
23. Koulenti D, Lisboa T, Brun-Buisson C, *et al.* Spectrum of practice in the diagnosis of nosocomial pneumonia in patients requiring mechanical ventilation in European intensive care units. *Crit Care Med.* 2009;37(8):2360-2369.
doi: 10.1097/CCM.0b013e3181a037ac
24. Manchanda V, Sanchaita S, Singh N. Multidrug resistant *Acinetobacter*. *J Glob Infect Dis.* 2010;2(3):291-304.
doi: 10.4103/0974-777X.68538
25. Borgio JF, Rasdan AS, Sonbol B, fAlhamid G, Almandil NB, AbdulAzeez S. Emerging status of multidrug-resistant bacteria and fungi in the Arabian Peninsula. *Biology (Basel).* 2021;10(11):1144.
doi: 10.3390/biology10111144
26. Logan LK, Weinstein RA. The epidemiology of carbapenem-resistant Enterobacteriaceae: The impact and evolution of a global menace. *J Infect Dis.* 2017;215(Suppl_1):S28-S36.
doi: 10.1093/infdis/jiw282
27. Lee CR, Lee JH, Park KS, Kim YB, Jeong BC, Lee SH. Global dissemination of carbapenemase-producing *Klebsiella pneumoniae*: Epidemiology, genetic context, treatment options, and detection methods. *Front Microbiol.* 2016;7:895.
doi: 10.3389/fmicb.2016.00895
28. Sakr A, Brégeon F, Rolain JM, Blin O. *Staphylococcus aureus* nasal decolonization strategies: A review. *Expert Rev Anti Infect Ther.* 2019;17(5):327-340.
doi: 10.1080/14787210.2019.1604220