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A Comparative Review of Hospital-Acquired Infection Rates and Etiologies in Pediatric Intensive Care Units: Iran versus Developed Countries

Maryam Naseri[1], Kobra Sadat Hossaini[2], *Sedigheh Shariatmoghani[3]

[1]Fellowship of Pediatric Intensive Care, Department of Pediatrics, Faculty of Medicine, Mashhad University of Medical sciences, Mashhad, Iran.
[2]MSc in Midwifery, Student Research Committee, School of Midwifery Nursing, Mashhad University of Medical Sciences, Mashhad, Iran.
[3]Faculty Members, Department of Health, Mashhad University of Medical Sciences, Mashhad, Iran.

Abstract

Background: Hospital-acquired infections (HAIs) in pediatric intensive care units (PICUs) pose a major global challenge, significantly increasing morbidity, mortality, and healthcare costs. This review aims to compare the rates, causes, and risk factors of HAIs in PICUs in Iran and developed countries to identify key differences and guide improvements.

Materials and Methods: In this narrative review, a literature search was conducted up to April 2025 in both English and Persian. Two independent reviewers used relevant keywords to search international databases including PubMed, Scopus, Web of Science, and Google Scholar, as well as Persian databases such as SID and CIVILICA. Data extraction focused on infection incidence, causative pathogens, associated risk factors, infection control measures, and patterns of antimicrobial resistance.

Results: This review shows that HAIs in PICUs in Iran reach up to 96.61 per 1,000 patient-days, notably higher than the 5 to 20 per 1,000 patient-days reported in developed countries. Predominant pathogens in Iran include multidrug-resistant Acinetobacter and Klebsiella, while developed countries report a broader range of pathogens. Device-associated infections, especially those linked to central venous catheters and respiratory equipment, are significant in both settings, but stricter preventive protocols reduce risks in developed countries. Antimicrobial resistance remains a key challenge in Iran but is managed more effectively in developed countries through stewardship and prevention programs. Continued improvements in healthcare infrastructure, specialized training, and infection control in Iran are enhancing care quality and reducing HAIs.

Conclusion: This review highlights a higher burden of hospital-acquired infections in Iranian PICUs compared to developed countries, driven by multidrug-resistant pathogens and limited resources. Advancing infection control, education, infrastructure, surveillance, and antibiotic stewardship is crucial to reduce infections and improve outcomes in resource-limited settings.

Key Words: Antimicrobial resistance, Developed countries, Infection control, Iran, Hospital-acquired infection, Pediatric intensive care unit.

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Corresponding Author:

Sedigheh Shariatmoghani, Mashhad University of Medical Sciences, Mashhad, Iran.

Email: s_shariat47@yahoo.com

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1- INTRODUCTION

Hospital-acquired infections (HAIs) in pediatric intensive care units (PICUs) represent one of the most complex and critical healthcare challenges worldwide, significantly impacting mortality, length of hospital stay, and healthcare costs. Children admitted to PICUs are at high risk of developing HAIs due to their critical conditions, use of invasive devices such as catheters and ventilators, and immunodeficiency (1, 2). Antimicrobial resistance, especially in developing countries, has become a serious problem, complicating infection control and treatment (3, 4). Developed countries have successfully reduced infection rates by investing in healthcare infrastructure, strictly enforcing infection control protocols, and effectively managing antibiotic use. However, in developing countries like Iran, resource limitations, inadequate infrastructure, and weaknesses in infection control contribute to higher infection rates (5–7).

A better understanding of the influential factors, prevalence, and differences between developed and developing countries—particularly in pediatric intensive care—is crucial for improving care quality and reducing HAIs globally. This knowledge can facilitate the development of more effective policies and the implementation of targeted preventive and therapeutic strategies (8, 9).

The aim of this review is to examine and compare the incidence, causative agents, and risk factors of hospital-acquired infections in pediatric intensive care units in Iran and developed countries. By identifying specific challenges and gaps in both settings, the review seeks to inform targeted improvements in infection control strategies and enhance clinical management to reduce infection rates and improve patient outcomes.

2- MATERIALS AND METHODS

2-1. Study Design

This study was conducted as a narrative systematic review to comprehensively examine and compare the rates, causes, and risk factors of hospital-acquired infections (HAIs) in pediatric intensive care units (PICUs) in Iran and developed countries.

2-2. Literature Search

The literature search was conducted up to April 2025. Two independent reviewers used relevant keywords—such as "hospital-acquired infections," "nosocomial infections," "pediatric intensive care unit," "PICU infections," "Iran," "developed countries," "antimicrobial resistance," and their Persian equivalents—to identify pertinent articles. Searches were conducted in international databases (PubMed, Scopus, Web of Science, Google Scholar) and Persian databases (SID, CIVILICA) in both English and Persian. Any disagreements in article selection and data extraction were resolved through discussion and consensus.

2-3. Inclusion and Exclusion Criteria

Included were research articles, systematic and narrative reviews, and relevant reports published up to the search date that addressed HAIs in PICUs in Iran and developed countries. Only studies published in Persian or English with full-text access were considered. Excluded were studies unrelated to the pediatric population or PICU settings, those with insufficient data or lacking scientific rigor, and duplicate publications.

2-4. Data Extraction

Two independent reviewers extracted data using a structured form. Studies were selected based on predefined inclusion criteria relevant to HAIs in PICUs in Iran and developed countries. Extracted variables included infection incidence

rates, prevalent pathogens, associated risk factors such as device use, infection control practices, and antimicrobial resistance patterns.

2-5. Ethical Considerations

As this study involved analysis of published data from scientific sources, it did not require ethical approval. Nonetheless, ethical principles regarding research selection, analysis, and reporting were strictly followed.

3- RESULTS

This review aimed to comprehensively examine and compare the rates, causes, and risk factors of hospital-acquired infections (HAIs) in pediatric intensive care units (PICUs) in Iran and developed countries. Findings reveal notable differences in infection rates, pathogen profiles, associated risk factors, antimicrobial resistance, and healthcare infrastructure, summarized in **Table 1**.

3-1. Infection Rates in PICUs

In Iran, HAI incidence in PICUs reaches up to 96.61 per 1,000 patient-days, substantially higher than the 5 to 20 per 1,000 patient-days reported in developed countries (1, 10-12). This disparity reflects differences in healthcare quality, infection control policies, and resources. Similar elevated rates are consistently reported in multiple Iranian studies, highlighting ongoing prevention challenges (13-15).

3-2. Pathogen Diversity and Prevalence

Iranian PICUs predominantly report multidrug-resistant Acinetobacter spp. and Klebsiella spp. (15-17). Developed countries show a broader pathogen spectrum, including methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant Enterococci (VRE), fungal, and viral pathogens (18-20). Enhanced diagnostics and antimicrobial stewardship support wider pathogen identification in developed settings.

3-3. Risk Factors Associated with Device Use

Device-associated infections, especially from central venous catheters and mechanical ventilation, greatly contribute to HAIs in both settings (1, 15, 21-25). However, developed countries implement stricter aseptic protocols and bundled interventions, leading to lower infection risks (20, 26).

3-4. Antimicrobial Resistance (AMR) Challenges

Iran faces alarmingly high antimicrobial resistance (AMR) rates, notably in multidrug-resistant *Acinetobacter baumannii* and carbapenem-resistant *Klebsiella pneumoniae*, which hinder effective infection control and substantially increase morbidity, mortality, and economic burdens (15, 16, 27, 28). In contrast, developed countries successfully mitigate AMR impacts through robust antimicrobial stewardship programs (ASPs) and stringent infection prevention measures, yielding better clinical outcomes and reduced resistance prevalence (8, 18).

3-5. Healthcare Infrastructure and Infection Control Practices

Iran faces challenges including limited infrastructure, inadequate infection control, staff shortages, and insufficient antibiotic stewardship programs (15, 16). In contrast, developed countries benefit from robust surveillance systems, specialized infection control teams, and advanced technologies that collectively enhance infection prevention (9, 13, 29).

These findings underscore the urgent need to strengthen infection control, antimicrobial management, and resource allocation in Iranian PICUs to reduce the high burden of HAIs and close the gap with developed countries.

Table 1: Key Comparative Indicators of Hospital-Acquired Infections in PICUs in Iran and Developed Countries.

Indicator	Iran	Developed Countries	References
Infection rate (per 1,000 patient-days)	Up to 96.61	5–20	1, 10-15
Common pathogens	MDR Acinetobacter spp., Klebsiella spp.	Diverse: MRSA, VRE, fungi, viruses	15-20
Antimicrobial resistance rate	High, major clinical challenge	Controlled, decreasing trends	8, 15, 16, 18, 27, 28
Device-associated infection risk	High, due to incomplete protocol adherence	Reduced via strict bundles and training	1, 15, 20-26
Infection control & infrastructure	Inadequate resources, limited training	Advanced surveillance, specialized teams	9, 13, 15, 16, 29

PICU: Pediatric Intensive Care Unit, MDR: Multidrug-Resistant, MRSA: Methicillin-Resistant Staphylococcus aureus, VRE: Vancomycin-Resistant Enterococci.

4- DISCUSSION

A comparative analysis of the rates, causes, and risk factors for hospital-acquired infections (HAIs) in pediatric intensive care units (PICUs) reveals significant disparities between Iran and developed countries. These differences arise from variations in healthcare quality, infrastructure, adherence to infection control protocols, and antimicrobial resistance (AMR) status.

In Iran, the incidence of HAIs in PICUs has been reported as high as 96.61 per 1,000 patient-days, markedly exceeding the average rate reported in developed countries, which typically ranges from 5 to 20 per 1,000 patient-days (1, 30–33). This substantial gap highlights inequalities in quality of care, consistency of infection control implementation, and availability of resources.

The main pathogens responsible for HAIs in Iranian PICUs are multidrug-resistant (MDR) organisms such as *Acinetobacter* spp. and *Klebsiella* spp., which complicate clinical management, prolong hospitalization, and elevate mortality rates (16, 17). These pathogens often exhibit high resistance to carbapenems and other critical antibiotics, reflecting the severity of AMR in these settings (7, 14, 15, 28). In contrast, developed countries report a broader range of infectious agents, including resistant Gram-positive bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococci* (VRE), as well as fungal and viral pathogens—an outcome attributed to advanced diagnostic capacity and effective antimicrobial stewardship programs (18, 19, 35–37).

Device-associated infections, particularly those related to mechanical ventilation and central venous catheters, constitute major contributors to HAIs in both contexts. However, consistent adherence to evidence-based protocols and bundled preventive strategies in developed countries substantially reduces these infection risks (1, 22, 26, 38).

The high prevalence of AMR among Gram-negative bacteria in Iran has aggravated the disease burden and increased treatment complexity, resulting in higher mortality and healthcare costs (16, 17, 28, 39). Developed nations have mitigated these impacts through comprehensive AMR management—particularly antimicrobial stewardship and robust infection control measures—thereby achieving markedly improved patient outcomes (8, 9, 18, 40, 41).

Iran’s healthcare system continues to face challenges such as a shortage of

specialized infection control personnel, limited surveillance infrastructure, and resource constraints—all of which hinder effective infection prevention (15–17, 42). In contrast, developed countries benefit from dedicated infection control teams, advanced monitoring technologies, and resilient healthcare systems that enable significant reductions in HAIs (9, 13, 18, 43).

4-1. Summary and Recommendations

Despite gradual improvements, the persistence of high HAI and AMR rates remains a major challenge in Iranian PICUs. Addressing these issues requires comprehensive strategies including continuous training for healthcare workers, strengthened infection surveillance, optimized antibiotic stewardship, and the expansion of specialized infection control teams. Such integrated and sustained efforts are critical to reducing HAIs and improving pediatric patient outcomes (16, 17, 22, 34).

5- CONCLUSION

This review underscores substantial differences in the incidence, etiology, and risk factors of hospital-acquired infections (HAIs) in pediatric intensive care units (PICUs) between Iran and developed countries. Reported HAI rates in Iran reach up to 96.61 per 1,000 patient-days, markedly higher than the 5–20 per 1,000 patient-days observed in developed settings. Multidrug-resistant pathogens such as Acinetobacter spp. and Klebsiella spp. predominate in Iranian PICUs, complicating therapeutic management and increasing mortality, whereas developed countries report a broader spectrum of infectious agents, aided by advanced diagnostic capabilities and well-established antimicrobial stewardship programs. Although device-associated infections are prevalent in both settings, strict adherence to standardized infection control bundles in developed nations substantially mitigates these risks.

Iran continues to face critical challenges, including widespread antimicrobial resistance, limited healthcare infrastructure, inadequate infection surveillance, and shortages of trained personnel—all contributing to higher morbidity and mortality rates. In contrast, developed countries benefit from comprehensive infection control systems, specialized multidisciplinary teams, and adequate resource allocation, resulting in consistently lower HAI rates. Bridging this gap in Iran will require an integrated approach emphasizing strengthened infection control infrastructure, continuous professional education, robust antimicrobial stewardship, and enhanced surveillance programs to effectively reduce HAIs and improve pediatric patient outcomes.

6- CONFLICT OF INTEREST: None.

7- REFERENCES

1. Izadi N, Eshrati B, Etemad K, Mehrabi Y, Hashemi-Nazari SS. Rate of the incidence of hospital-acquired infections in Iran based on the data of the national nosocomial infections surveillance. New Microbes New Infect. 2020 Sep 28;38:100768. doi: 10.1016/j.nmni.2020.100768. PMID: 33093962; PMCID: PMC7568181.

2. Mello MJ, Albuquerque Mde F, Lacerda HR, Souza WV, Correia JB, Britto MC. Risk factors for healthcare-associated infection in pediatric intensive care units: a systematic review. Cad Saude Publica. 2009;25 Suppl 3:S373-91. doi: 10.1590/s0102-311x2009001500004. PMID: 20027386.

3. Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 2022 Feb 12;399(10325):629-655. doi: 10.1016/S0140-6736(21)02724-0. Epub 2022 Jan 19. Erratum in: Lancet. 2022 Oct 1;400(10358):1102. doi: 10.1016/S0140-6736(21)02653-2. PMID: 35065702; PMCID: PMC8841637.

4. World Health Organization (WHO). Antimicrobial resistance, 2023. Available from: https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance.

5. Raoofi S, Pashazadeh Kan F, Rafiei S, Hosseinipalangi Z, Noorani Mejareh Z, Khani S, et al. Global prevalence of nosocomial infection: A systematic review and meta-analysis. PLoS One. 2023 Jan 27;18(1):e0274248. doi: 10.1371/journal.pone.0274248. PMID: 36706112; PMCID: PMC9882897.

6. Ghashghaee A, Behzadifar M, Azari S, Farhadi Z, Bragazzi N L, Behzadifar M, et al . Prevalence of nosocomial infections in Iran: A systematic review and meta-analysis . Med J Islam Repub Iran 2018; 32 (1):273-82. URL: http://mjiri.iums.ac.ir/article-1-4993-en.html.

7. Meybodi MME, Foroushani AR, Zolfaghari M, Abdollahi A, Alipour A, Mohammadnejad E, Mehrjardi EZ, Seifi A. Antimicrobial resistance pattern in healthcare-associated infections: investigation of in-hospital risk factors. Iran J Microbiol. 2021 Apr;13(2):178-182. doi: 10.18502/ijm.v13i2.5978. PMID: 34540152; PMCID: PMC8408023.

8. Laxminarayan R, Duse A, Wattal C, Zaidi AK, Wertheim HF, Sumpradit N, **et al**. Antibiotic resistance-the need for global solutions. Lancet Infect Dis. 2013 Dec;13(12):1057-98. doi: 10.1016/S1473-3099(13)70318-9. Epub 2013 Nov 17. Erratum in: Lancet Infect Dis. 2014 Jan;14(1):11. Erratum in: Lancet Infect Dis. 2014 Mar;14(3):182. PMID: 24252483.

9. Zimlichman E, Henderson D, Tamir O, Franz C, Song P, Yamin CK, Keohane C, Denham CR, Bates DW. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. JAMA Intern Med. 2013 Dec 9-23;173(22):2039-46. doi: 10.1001/jamainternmed.2013.9763. PMID: 23999949.

10. Gunasekaran S, Mahadevaiah S. Healthcare-associated Infection in Intensive Care Units: Overall Analysis of Patient Criticality by Acute Physiology and Chronic Health Evaluation IV Scoring and Pathogenic Characteristics. Indian J Crit Care Med. 2020 Apr;24(4):252-257. doi: 10.5005/jp-journals-10071-23384. PMID: 32565635; PMCID: PMC7297239.

11. Alp E, Damani N. Healthcare-associated infections in intensive care units: epidemiology and infection control in low-to-middle income countries. J Infect Dev Ctries. 2015 Oct 29;9(10):1040-5. doi: 10.3855/jidc.6832. PMID: 26517477.

12. Healthcare-associated infections acquired in intensive care units - Annual Epidemiological Report for 2020.Available from: https://www.ecdc.europa.eu/en/publications-data/healthcare-associated-infections-acquired-intensive-care-units-annual.

13. Northway T, Langley JM, Skippen P. Health Care–Associated Infection in the Pediatric Intensive Care Unit: Epidemiology and Control—Keeping Patients Safe. Pediatric Critical Care. 2011:1349–63. German. doi: 10.1016/B978-0-323-07307-3.10097-7. Epub 2011 Apr 29. PMCID: PMC7152412.

14. Salarvan S, Abdollahi A, Afarinesh Khaki P, Norouzi Shadehi M, Beigh Mohammadi MT, Miratashi Yazdi SA, Nazar E. Antibiotic Resistance Pattern in Intensive Care Units in a Large Referral Hospital in Iran. Iran J Pathol. 2023;18(4):433-438. doi: 10.30699/IJP.2023.1990807.3073. Epub 2023 Oct 15. PMID: 38024549; PMCID: PMC10646743.

15. Esfahani, B. N., Basiri, R., Mahdy Mirhosseini, S. M., Moghim, S., Dolatkhah, S. Nosocomial Infections in Intensive Care Unit: Pattern of Antibiotic-resistance in Iranian Community. Advanced Biomedical Research, 2017; 2017(May): 1-5.

16. Masoudifar M, Gouya MM, Pezeshki Z, Eshrati B, Afhami S, Farzami MR, Seifi A. Health care-associated infections, including device-associated infections, and antimicrobial resistance in Iran: The national update for 2018. J Prev Med Hyg. 2022 Jan 31;62(4):E943-E949. doi: 10.15167/2421-4248/jpmh2021.62.4.1801. PMID: 35603257; PMCID: PMC9104666.

17. Rimaz S, Tajzadeh P, Bahrami M, Nooghabi M, Eshrati B, Effati S, Yaghoobi M. Epidemiological features, antimicrobial resistance profile and clinical outcomes of healthcare-associated infections in Islamic Republic of Iran. East Mediterr Health J. 2023 Sep 9;29(9):688-698. doi: 10.26719/emhj.23.043. PMID: 37776130.

18. Magill SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, et al. Multistate point-prevalence survey of health care-associated infections. N Engl J Med. 2014 Mar 27;370(13):1198-208. doi: 10.1056/NEJMoa1306801. Erratum in: N Engl J Med. 2022 Jun 16;386(24):2348. doi: 10.1056/NEJMx210023. PMID: 24670166; PMCID: PMC4648343.

19. Centers for Disease Control and Prevention (CDC). (2019). National Healthcare Safety Network (NHSN) data summary. Available from: https://www.cdc.gov/nhsn/datastat/index.html.

20. Kannan A, Pratyusha K, Thakur R, Sahoo MR, Jindal A. Infections in Critically Ill Children. Indian J Pediatr. 2023 Mar;90(3):289-297. doi: 10.1007/s12098-022-04420-9. Epub 2022 Dec 20. PMID: 36536264; PMCID: PMC9763084.

21. Sodhi J, Satpathy S, Sharma DK, Lodha R, Kapil A, Wadhwa N, Gupta SK. Healthcare associated infections in Paediatric Intensive Care Unit of a tertiary care hospital in India: Hospital stay & extra costs. Indian J Med Res. 2016 Apr;143(4):502-6. doi: 10.4103/0971-5916.184306. PMID: 27377508; PMCID: PMC4928558.

22. Alshagrawi, S., Alhodaithy, N. Determinants of hand hygiene compliance among healthcare workers in intensive care units: a qualitative study. BMC Public Health 2024;24:2333. https://doi.org/10.1186/s12889-024-19461-2.

23. Musu M, Lai A, Mereu NM, Galletta M, Campagna M, Tidore M, Piazza MF, Spada L, Massidda MV, Colombo S, Mura P, Coppola RC. Assessing hand hygiene compliance among healthcare workers in six Intensive Care Units. J Prev Med Hyg. 2017 Sep;58(3):E231-E237. PMID: 29123370; PMCID: PMC5668933.

24. Haque A, Ahmed SA, Rafique Z, Abbas Q, Jurair H, Ali SA. Device-associated infections in a paediatric intensive care unit in Pakistan. J Hosp Infect. 2017 Jan;95(1):98-100. doi: 10.1016/j.jhin.2016.10.021. Epub 2016 Nov 4. PMID: 27890335.

25. Elnasser Z, Obeidat H, Amarin Z. Device-related infections in a pediatric intensive care unit: The Jordan University of Science and Technology experience. Medicine (Baltimore). 2021 Oct 29;100(43):e27651. doi: 10.1097/MD.0000000000027651. PMID: 34713857; PMCID: PMC8556052.

26. Pronovost P, Needham D, Berenholtz S, Sinopoli D, Chu H, Cosgrove S, Sexton B, Hyzy R, Welsh R, Roth G, Bander J, Kepros J, Goeschel C. An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med. 2006 Dec 28;355(26):2725-32. doi: 10.1056/NEJMoa061115. Erratum in: N Engl J Med. 2007 Jun 21;356(25):2660. PMID: 17192537.

27. Bonyani A, Mesgarpour B, Taheri F, Nasiri M J, Soleimani F, et al. Antibiotic Resistance Clinical Research in Iran: A Scoping Review.Arch Clin Infect Dis.2023;18(5):e137094.https://doi.org/10.5812/archcid-137094.

28. Shahsavand A, Golestani A, Akbarpour S, Salehi M, Seifi A, Mohammadi K, Shafaati M. Burden of antimicrobial resistance and estimated economic impact of Klebsiella pneumoniae in Iran- A 2000 to 2021 analysis. New Microbes New Infect. 2025 Nov 20;68:101675. doi: 10.1016/j.nmni.2025.101675.PMID: 41377034; PMCID: PMC12686640.

29. KHosravi N, Alami A, Aelami MH, KHosrovan S. Improving Hand Hygiene Compliance of Intensive Care Unit by Using Pender's Model. Ethiop J Health Sci. 2021 May;31(3):553-560. doi: 10.4314/ejhs.v31i3.12. PMID: 34483612; PMCID: PMC8365475.

30. Vincent JL, Sakr Y, Singer M, Martin-Loeches I, Machado FR, Marshall JC, et al. Prevalence and Outcomes of Infection Among Patients in Intensive Care Units in 2017. JAMA. 2020 Apr 21;323(15):1478-1487. doi:

10.1001/jama.2020.2717. PMID: 32207816; PMCID: PMC7093816.

31. Weinstein RA. Epidemiology and control of nosocomial infections in adult intensive care units. Am J Med. 1991 Sep 16;91(3B):179S-184S. doi: 10.1016/0002-9343(91)90366-6. PMID: 1928162.

32. Kockuzu E, Bayrakcı B, Kesici S, Cıtak A, Karapınar B, Emeksiz S, et al. Comprehensive Analysis of Severe Viral Infections of Respiratory Tract admitted to PICUs during the Winter Season in Turkey. Indian J Crit Care Med. 2019 Jun;23(6):263-269. doi: 10.5005/jp-journals-10071-23177. PMID: 31435144; PMCID: PMC6698354.

33. Al-Eyadhy A, Almazyad M, Hasan G, Almuhaideb Q, AbuDujain N, Alhaboob AAN, et al. The burden of viral infections in pediatric intensive care unit between endemic and pandemic coronavirus infections: A tertiary care center experience. J Infect Chemother. 2023 Jan;29(1):20-25. doi: 10.1016/j.jiac.2022.09.007. Epub 2022 Sep 11. PMID: 36103948; PMCID: PMC9464359.

34. Hoffmann M, Sendlhofer G, Gombotz V, Pregartner G, Zierler R, Schwarz C, Tax C, Brunner G. Hand hygiene compliance in intensive care units: An observational study. Int J Nurs Pract. 2020 Apr;26(2):e12789. doi: 10.1111/ijn.12789. Epub 2019 Oct 31. PMID: 31670442; PMCID: PMC9285823.

35. Mazzeffi M, Galvagno S, Rock C. Prevention of Healthcare-associated Infections in Intensive Care Unit Patients. Anesthesiology. 2021 Dec 1;135(6):1122-31. doi: 10.1097/ALN.0000000000004017. PMID: 34731244.

36. Klatte JM. Pediatric Antimicrobial Stewardship Programs: Current Perspectives. Pediatric Health Med Ther. 2020 Jul 21;11:245-255. doi: 10.2147/PHMT.S224774. PMID: 32801990; PMCID: PMC7383043.

37. Same RG. The Current State and Future Directions of Inpatient Pediatric Antimicrobial Stewardship. Infect Dis Clin North Am. 2022 Mar;36(1):173-186. doi: 10.1016/j.idc.2021.12.001. PMID: 35168709.

38. Safdar N, Dezfulian C, Collard HR, Saint S. Clinical and economic consequences of ventilator-associated pneumonia: a systematic review. Crit Care Med. 2005 Oct;33(10):2184-93. doi: 10.1097/01.ccm.0000181731.53912.d9. PMID: 16215368.

39. Mosadeghrad A, Afshari M, Isfahani P. Prevalence of Nosocomial Infection in Iranian Hospitals: A Systematic Review and Meta-Analysis. irje 2021; 16(4):352-62. URL: http://irje.tums.ac.ir/article-1-6871-fa.html.

40. Boucher HW, Talbot GH, Bradley JS, Edwards JE, Gilbert D, Rice LB, Scheld M, Spellberg B, Bartlett J. Bad bugs, no drugs: no ESKAPE! An update from the Infectious Diseases Society of America. Clin Infect Dis. 2009 Jan 1;48(1):1-12. doi: 10.1086/595011. PMID: 19035777.

41. Tacconelli E, Carrara E, Savoldi A, Harbarth S, Mendelson M, Monnet DL, et al. WHO Pathogens Priority List Working Group. Discovery, research, and development of new antibiotics: the WHO priority list of antibiotic-resistant bacteria and tuberculosis. Lancet Infect Dis. 2018 Mar;18(3):318-327. doi: 10.1016/S1473-3099(17)30753-3.

42. Nasiri N, Mangolian Shahrbabaki P, Sharifi A, Ghasemzadeh I, Khalili M, Karamoozian A, Khalooei A, Haghdoost A, Sharifi H. Barriers and Problems in Implementing Health-Associated Infections Surveillance Systems in Iran: A Qualitative Study. Med J Islam Repub Iran. 2023 May 23;37:57. doi: 10.47176/mjiri.37.57. PMID: 37457414; PMCID: PMC10349358.

43. European Centre for Disease Prevention and Control (ECDC). Healthcare-associated infections: surveillance and epidemiology in Europe. Annual Epidemiological Report. 2020. Available from: https://www.ecdc.europa.eu/sites/default/files/documents/healthcare-associated-infections-intensive-care-units-annual-epidemiological-report-2020.pdf.