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Healthcare-Associated Infections and Antimicrobial Resistance Rates Developing in Intensive Care Units

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ABSTRACT

Objective: The aim of this study is to evaluate the incidence, infection types, distribution of causative microorganisms, and antimicrobial resistance (AMR) patterns of healthcare-associated infections (HAIs) developing in intensive care units (ICUs).

Materials and Methods: This retrospective and observational study was conducted between January 1, 2023, and January 1, 2025. HAI diagnoses were made according to Centers for Disease Control and Prevention and National Healthcare-Associated Infections Surveillance Network (USHIESA) criteria. Total number of patients, patient-days, invasive device-days, infection types, and resistance profiles of causative pathogens were analyzed. Infection rates were calculated based on 1000 patient-days and 1000 device-days.

Results: During the study period, 6,152 patients and 28,129 patient-days were monitored. The rate of HAIs was 0.40%, and the incidence density was found to be 0.88/1000 patient-days. Ninety-six percent of the cases were catheter-related urinary tract infections, and 4% were central venous catheter-related bloodstream infections while ventilator-associated pneumonia was not detected. Seventy-six percent of the isolates pathogens were Gram-negative, and 24% were Gram-positive bacteria. The most frequently isolated Gram-negative bacteria were *Myroides* spp. (47.36%), followed by *Acinetobacter baumannii* (26.31%), *Klebsiella pneumoniae* (21.05%), and *Pseudomonas aeruginosa* (5.26%). All Gram-positive agents were identified as *Enterococcus* spp. High levels of AMR were detected in the isolates.

Conclusion: Although the incidence of HAI in the ICU is below the national reference threshold, the prevalence of *Myroides* spp. and resistant Gram-negative pathogens is noteworthy. The findings highlight the need to maintain effective surveillance systems and strengthen strategies to combat AMR.

Keywords: Antimicrobial resistance, Device-associated infections, Healthcare-associated infections, Intensive care unit, *Myroides* spp

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INTRODUCTION

Although hospital admission is primarily for diagnostic and therapeutic purposes, it exposes patients to a significant risk of healthcare-associated infections (HAIs). HAIs are a leading cause of morbidity and mortality worldwide, creating serious clinical and economic problems for healthcare systems. According to the World Health Organization, approximately 7–15% of hospitalized patients develop at least one HAI.[1,2] This rate is higher in healthcare systems with limited resources and is closely associated with infection control infrastructure deficiencies, insufficient trained personnel, substandard disinfection practices, and problems related to the use of personal protective equipment.[1,3]

Intensive care units (ICUs) are among the highest-risk areas for HAIs. The prevalence of invasive procedures, immunosuppressed patient populations, and severe clinical cases facilitate the infection development which, in return, prolongs hospital stays, increases treatment costs, and negatively impacts clinical outcomes. Furthermore, HAIs are strongly associated with the development and spread of antimicrobial resistance (AMR).[4,5] Inappropriate and excessive use of antimicrobials, inadequacies in infection prevention and control practices, and deficiencies in surveillance systems create a breeding ground for the selection and spread of resistant strains.[4] Current global estimates indicate that AMR is associated with millions of deaths annually, and this burden is projected to increase substantially over the coming decades unless effective preventive and control measures are implemented.[6,7]

Türkiye is among the countries with high AMR rates.[6,8] In addition, antibiotic-resistant infections are responsible for tens of thousands of deaths each year in European Union countries. In this context, systematic evaluation of the incidence of HAIs, infection types, causative microorganism distribution, and antimicrobial susceptibility profiles in ICUs are critically important for both rationally planning empirical treatment approaches and developing targeted infection control programs.

This study aims to comprehensively analyze the epidemiological characteristics of HAIs developing in ICUs and the AMR patterns of the causative microorganisms and to contribute to evidence-based strategies to reduce the infection burden and the spread of resistant strains based on the findings obtained.

MATERIALS AND METHODS

Study Design and Environment

This retrospective, observational study was conducted at the ICU of Yalova Training and Research Hospital between January 1, 2023, and January 1, 2025. The hospital, which provides tertiary healthcare services, has a total of 44 ICU beds during the study period, including 34 tertiary and 10 secondary level beds. Infection surveillance in ICUs is carried out daily by the Infection Control Committee using an active surveillance method, and all data are regularly recorded.

Study Population

All patients followed in ICU during the study period were included in the evaluation. However, patients followed in the ICU for <1 day and cases with only colonization were excluded from the study.

Data Collection and Definitions

In this study, the total number of hospitalized patients, the number of patient-days, the number of HAIs, the rates of invasive device use, isolated pathogenic micro-organisms, and their AMR profiles were analyzed. HAI definitions were established based on the Centers for Disease Control and Prevention criteria and the National Healthcare-Associated Infections Surveillance Network (USHIESA) diagnostic criteria.[9,10] In cases where members of the skin flora, such as coagulase-negative staphylococci, were isolated, the patient's clinical findings and laboratory parameters were evaluated in detail. Single positive blood culture was considered contamination in cases without clinical findings suggestive of infection and/or an increase in acute phase reactants. Blood cultures were taken in two sets, and if growth was observed in only one set while appropriate clinical findings were not present, the result was interpreted as contamination. Microorganisms were identified using an automated identification system (VITEK®). Antimicrobial susceptibility testing was performed and interpreted according to the criteria established by the European Committee on Antimicrobial Susceptibility Testing.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences version 22.0 (IBM Corp., Armonk, NY, USA) statistical package program. The invasive device-associated HAI (DA-HAI) rate was calculated by multiplying the ratio of the number of DA-HAIs developing in the relevant period to the total number of hospitalized patients by 100 (DA-HAI rate=[number of DA-HAIs developing/number of hospitalized patients]×100). Invasive device-related infection rates were calculated by multiplying the ratio of the number of DA-HAIs developing in the relevant period to the relevant device-day by 1000 (rate=[number of DA-HAIs developing/device-day]×1000).

Ethical Approval

Ethical approval for the study was obtained from the Yalova University Ethics Committees Coordination Office (Decision

No: 2025/176, Date: 07.05.2025). The study was conducted in accordance with the principles of the Helsinki Declaration.

RESULTS

A total of 6,152 patients were followed up in ICUs for 28,129 patient-days during the study period. Data obtained on the total number of invasive device days used in the ICU during this period were as follows: 25,123 urinary catheter days, 9,825 central venous catheter days, and 3,993 ventilator days. The total rate of HAIs developing in the ICU was determined to be 0.40% (25/6,152). The incidence density of HAIs was found to be 0.88/1000 patient-days (25/28,129). Invasive device usage rates, types of infections developed, and comparative analyses with USHIESA 2024 national reference data are presented in Table 1.

When the distribution of developing HAIs was examined, it was determined that 24 cases (96.0%) were catheter-associated urinary tract infection (CAUTI) and 1 case (4.0%) was central line-associated bloodstream infection (CLABSI). No cases of ventilator-associated pneumonia (VAP) were observed during the study period (Table 1).

Microbiological evaluation revealed that 76.0% of the isolated pathogens were Gram-negative bacteria (GNB) and 24.0% were Gram-positive bacteria (GPB). The most frequently isolated GNBs were *Myroides* spp. (47.36%), *Acinetobacter baumannii* (26.31%), *Klebsiella pneumoniae* (21.05%), and *Pseudomonas aeruginosa* (5.26%), respectively. The proportion of Myroides spp. among all 25 HAI isolates was 36.0%. All GPBs were found to be caused by *Enterococcus* spp. A detailed distribution of the pathogens causing HAIs is presented in Figure 1. Antimicrobial susceptibility results showed high levels of resistance among HAI isolates (Table 2). GNB, particularly *Myroides* spp., *A. baumannii*, *Klebsiella* spp., and *P. aeruginosa*, exhibited extensive resistance to most tested antibiotics, with several isolates showing 100% resistance to multiple classes (Table 2). Among GPB, *Enterococcus* spp. demonstrated high resistance to ampicillin, gentamicin, and levofloxacin, while reduced susceptibility to vancomycin and teicoplanin was observed; linezolid remained fully active (Table 2).

Table 1. Comparison of invasive device utilization rates and invasive device-related infection rates in intensive care units with USHIESA 2024 data

Parameters	ICU mean	USHIESA 2024 mean
Invasive device utilization ratios		
Urinary catheter utilization ratio	0.89	0.97
Central line utilization ratio	0.34	0.62
Ventilator utilization ratio	0.14	0.53
Device-associated healthcare-associated ınfection rates*		
Catheter-associated urinary tract ınfection	0.95	1.0
Central line-associated bloodstream ınfection	0.10	4.7
Ventilator-associated pneumonia	0	3.9

*Infection rates were calculated per 1,000 device-days. ICU: Intensive care units

DISCUSSION

Despite all advances in medicine and healthcare, HAIs remain a major public health problem, particularly in ICUs, where they are among the most common causes of morbidity and

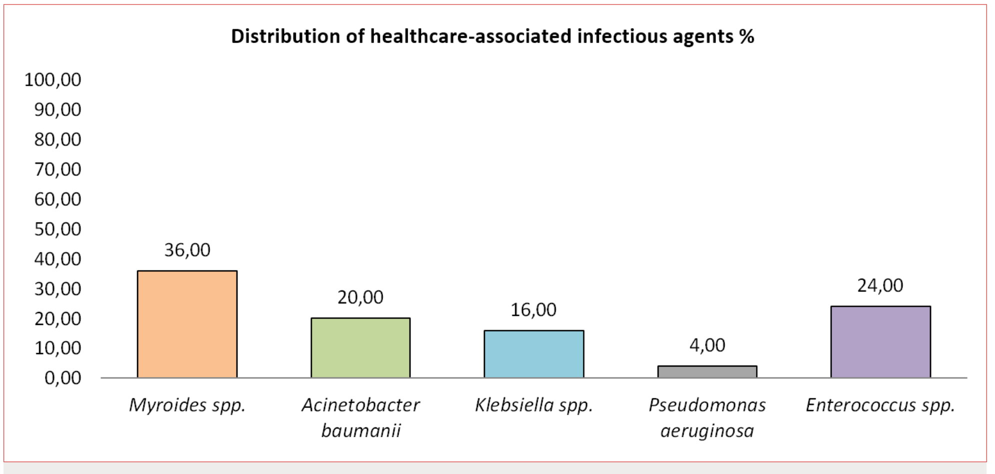

Figure 1. Distribution of pathogens causing healthcare-associated infections developing in the intensive care unit (%).

Table 2. Antimicrobial resistance rates of healthcare-associated infectious agents (%)

Gram-negative bacteria

Microorganism	CRO	CAZ	FEP	CXM	AMP	CIP	AK	GN	TZP	ETP	IMP	MEM	TGC	SXT	ATM
Myroides spp.	3 (100)	9 (100)	–	–	–	9 (100)	–	9 (100)	9 (100)	–	9 (100)	–	–	9 (100)	9 (100)
Acinetobacter baumannii	2 (100)	–	–	–	–	5 (100)	–	2 (100)	5 (100)	–	5 (100)	3 (75)	3 (100)	5 (100)	–
Klebsiella spp.	4 (100)	4 (100)	4 (100)	4 (100)	3 (100)	4 (100)	2 (50)	4 (100)	4 (100)	3 (75)	3 (75)	–	–	2 (50)	2 (100)
Pseudomonas aeruginosa	1 (100)	1 (100)	–	–	–	1 (100)	–	–	1 (100)	–	1 (100)	1 (100)	–	–	–

Gram-positive bacteria

Microorganism	AMP	GN	LEV	VAN	TEC	LNZ
Enterococcus spp.	5 (83)	3 (100)	5 (100)	1 (20)	1 (33)	0

CRO: Ceftriaxone, CAZ: Ceftazidime, FEP: Cefepime, CXM: Cefuroxime axetil, AMP: Ampicillin, CIP: Ciprofloxacin, AK: Amikacin, GN: Gentamicin, TZP: Piperacillin-tazobactam, ETP: Ertapenem, IMP: Imipenem, MEM: Meropenem, TGC: Tigecycline, SXT: Trimethoprim-sulfamethoxazole, ATM: Aztreonam, LEV: Levofloxacin, VAN: Vancomycin, TEC: Teicoplanin, LNZ: Linezolid. "–": Not tested

mortality.[11] This increase in HAI incidence further highlights the importance of strategies aimed at the prevention and control of infections. Determining the incidence of HAIs in ICUs, invasive device utilization ratios, distribution of causative pathogens, and antibiotic susceptibility profiles is crucial for the appropriate planning of empirical treatment approaches.[12] In this study, the epidemiological characteristics of HAIs developing in the ICU and AMR rates were evaluated.

HAI rates may vary across countries, regions, and hospitals due to differences in patient profiles, care processes, frequency of invasive procedures, and surveillance methods.[12] According to the 2021 epidemiological report published by the European Centre for Disease Prevention and Control (ECDC), at least one ICU-acquired HAI was reported in 15.6% of patients who stayed in the ICU for more than 2 days.[13] In a meta-analysis examining the burden and determinants of HAIs in ICUs in Sub-Saharan Africa, the prevalence of HAIs was found to be 28.22% (95% confidence interval [CI]: 23.61–32.81), while a study conducted in Saudi Arabia reported an ICU HAI prevalence of 15.38%.[14,15] Studies conducted in Türkiye have shown that HAI rates range between 1.2% and 11.48%.[16,17] In the present study, the HAI rate in ICUs was determined to be 0.40%. Compared with the literature, the relatively low HAI rate may be attributed to the effectiveness of infection control practices in our center as well as differences in patient characteristics and device utilization profiles.

In our study, the majority of HAI cases consisted of CAUTI (96%); only one case of CLABSI was identified, and no cases of VAP were observed. According to the report of the ECDC (2021), among HAIs developing in ICUs, 10% were pneumonia, 8% were bloodstream infections, and 4% were urinary tract infections; of these, 66% of pneumonia cases were VAP, 38% of bloodstream infections were CLABSI, and 97% of urinary tract infections were CAUTI.[13] According to data from the International Nosocomial Infection Control Consortium (INICC), the rates per 1,000 device-days in ICUs were reported as 11.96 for VAP, 2.91 for CAUTI, and 4.55 for CLABSI.[18] In a study conducted by Izadi et al.,[19] the most common infections in ICUs were reported to be urinary tract infections (19.76%; 19.09/1000 patients, and 3.32/1000 patient-days), followed by pneumonia (15.21%; 14.69/1000 patients, and 2.55/1000 patient-days) and bloodstream infections (13.23%; 12.78/1000 patients, and 2.22/1000 patient-days).

The absence of VAP cases in our study is a noteworthy finding. This observation may be attributed to increased awareness and improved adherence to infection control measures among healthcare workers. In particular, heightened attention to hand hygiene, strict compliance with ventilator care bundles, and more consistent implementation of infection prevention protocols may have contributed to this outcome. Furthermore, sustained behavioral changes and strengthened infection control practices, especially during and after the COVID-19 period, may have played a significant role in reducing the risk of VAP development in our ICUs.

In a meta-analysis by Odoom and Donkor, the prevalence distribution of ICU-acquired HAIs was reported as 54.0%

(95% CI 31.0–76.0%, I^2=98%, p<0.01) for VAP, 34.0% (95% CI 25.0–42.0%, I^2=98%, p<0.01) for bloodstream infections, and 26.0% (95% CI 17.0–35.0%, I^2=98%, p<0.01) for urinary tract infections.[20] Similarly, studies conducted in our country have shown variability in the distribution; infection rates per 1,000 device-days were highest for VAP (4.5), followed by CAUTI (0.3) and CLABSI (0.2).[16] In addition, in the study by Güleç and Benlican, the rates were reported as 12.45% for VAP, 8.26% for CLABSI, and 0.48% for CAUTI.[21] These findings indicate that the distribution of infections in ICUs may vary considerably between centers depending on patient characteristics, frequency of invasive procedures, device utilization ratios, and infection control practices.

In a study conducted by the INICC, across 398 ICUs in China, which evaluated device-associated infections and causative microorganisms, the most frequently isolated pathogen was *A. baumannii* (19.1%), followed by *P. aeruginosa* (17.2%), *K. pneumoniae* (11.9%), and *Staphylococcus aureus* (11.9%).[22] The leading HAI pathogens were *K. pneumoniae* (16.4%), *A. baumannii* (14.4%), *S. aureus* (11.8%), and *Escherichia coli* (11.4%)[23] in a multicenter study conducted in southern Poland. A study performed in an ICU in Aljouf, Saudi Arabia, reported *K. pneumoniae* (35.0%) and *A. baumannii* (27.5%), pathogens frequently associated with multidrug resistance, as the most commonly isolated agents.[15] In a study conducted in Türkiye, *Pseudomonas* spp. (30.4%) was the most prevalent HAI pathogen, followed by *Acinetobacter* spp. (14.3%), *E. coli* (12.5%), *S. aureus* (7.2%), *K. pneumoniae* (5.3%), *Candida albicans* (5.3%), and *Candida parapsilosis* (5.3%).[21] Another national study reported that the most frequently isolated pathogens were GNB, primarily *A. baumannii*, *K. pneumoniae*, and *E. coli*.[16] Similarly, in our study, GNB predominated among HAI cases (76%), with the most frequently isolated microorganisms being *Myroides* spp., *Enterococcus* spp., *A. baumannii*, *Klebsiella* spp., and *P. aeruginosa*. Our findings are consistent with previously reported data, highlighting the prominent role of GNB in ICUs. However, they also suggest that pathogen distribution may vary between centers depending on patient characteristics, antibiotic usage patterns, and infection control practices.

The antimicrobial susceptibility profiles of the HAI isolates demonstrate a concerning burden of multidrug resistance, particularly among GNB (Table 2). Notably, *Myroides spp.*, *A. baumannii*, *Klebsiella spp.*, and *P. aeruginosa* exhibited high to complete resistance against most tested antibiotic classes, including third- and fourth-generation cephalosporins, fluoroquinolones, and piperacillin-tazobactam, indicating severely limited therapeutic options. Carbapenem resistance was also prominent, especially in *A. baumannii* and *Klebsiella spp.*, suggesting the emergence of extensively drug-resistant phenotypes in the clinical setting. Among GPB, *Enterococcus spp.* showed high resistance to ampicillin, aminoglycosides, and fluoroquinolones, while reduced susceptibility to glycopeptides (vancomycin and teicoplanin) raises concern for the potential development of vancomycin-resistant enterococci; however, linezolid retained full activity. Overall, these findings underscore the dominance of highly resistant nosocomial pathogens and highlight the critical need for continuous surveillance and stringent antimicrobial stewardship strategies to preserve the efficacy of remaining therapeutic agents.

HAIs caused by *Myroides* spp. have been reported particularly in ICU patients who were exposed to invasive procedures, had prolonged hospital stays, and received broad-spectrum antibiotics. The multidrug-resistant nature of these micro-organisms limits treatment options and complicates infection control processes. The literature emphasizes that *Myroides* spp. is most often isolated as a colonizing organism, but in an appropriate host and under environmental conditions, it can lead to infection.[24] In Türkiye, Kutlu et al.,[25] reported an outbreak of six urinary tract infections caused by *Myroides odoratimimus* in an ICU. In another study conducted in an adult ICU, nine *Myroides* spp. isolates were identified over a 3-month period; seven of these were associated with pyuria, while two isolates were considered colonization.[24] In the study by Gülmez et al.,[26] among 228 patients with *Myroides* spp. isolates, asymptomatic bacteriuria was detected in 210 cases (92.1%), whereas only 18 cases (7.9%) were associated with true infection. All patients had indwelling catheters in a study evaluating 36 ICU patients from whom *Myroides* spp. was isolated from urinary catheters. After catheter replacement, follow-up control cultures showed persistent growth in only four patients, while no growth was detected in cultures at 24- and 72-h intervals in the remaining patients. The investigators emphasized that in patients with prolonged hospitalization and urinary catheter use, the organism may predominantly lead to colonization; therefore, catheter replacement, careful monitoring of clinical symptoms, and avoidance of unnecessary antimicrobial therapy are critical.[27] In our study, *Myroides* spp. was the most frequently isolated pathogen among HAIs (47.36%). During the study period, a marked increase in *Myroides* spp. isolation was observed in the ICU, prompting rapid implementation of infection control screening and initiation of a source investigation. Subsequent analysis suggested that a potential association with urine collection containers, and comprehensive infection control interventions successfully contained the situation before it could develop into a large-scale outbreak. These findings demonstrate that, although a rare pathogen, *Myroides* spp. has the potential to cause outbreaks in ICU settings under favorable conditions, highlighting the critical importance of early surveillance and effective infection control practices. The relatively high frequency of *Myroides* spp. in our ICU may also be associated with potential environmental sources, particularly contamination of urine collection containers, as well as patient-related factors such as prolonged catheterization, extended ICU stay, and prior exposure to broad-spectrum antibiotics, which may facilitate colonization and subsequent infection.

Limitations

The study's limitations include its single-center and retrospective design, limited case numbers, and the absence of molecular type determination. These factors restrict the generalizability of the findings and a complete assessment of the outbreak dynamics of the pathogens. However, the systematic investigation of the role of the rare and multidrug-resistant *Myroides* spp. in ICU infections, the rapid response to the increase in isolations, and the presentation of comparative data with the literature constitute the study's strengths.

CONCLUSION

HAIs in ICUs remain an important patient safety concern. In this study, the observed lower HAI rate compared with the literature suggests the effectiveness of infection control practices; however, the distribution of infection types and causative organisms varies across centers. The predominance of CAUTIs and GNB highlights the need for strict surveillance of invasive device use and AMR. The emergence of *Myroides spp.* as a predominant pathogen further emphasizes the outbreak potential of uncommon opportunistic organisms. Overall, continuous surveillance, rational antibiotic use, and strict infection control measures are essential to reduce the burden of HAIs in ICU settings.

DECLARATIONS

Ethics Committee Approval: The study protocol was approved by the Yalova University Ethics Committee (No: 2025/176, Date: 07/05/2025).

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Authorship Contributions: Concept – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Design – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Supervision – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Materials – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Data collection &/or processing – EYE, HIK, GK; Analysis and/or interpretation – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Literature search – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Writing – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH; Critical review – GK, EYE, BGG, SK, HIK, ZE, HE, SA, DO, SS, MO, RH.

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