



Device-associated hospital-acquired infections in a tertiary cardiac hospital in northern Iran: A six-year retrospective study

Arshia Forouzan¹, Seyed Mehdi Mousavi¹, Tofigh Yaghubi Kalurazi^{1*}, Meysam Hasannejad-Bibalan^{2*},
Fatemeh Kheradkish³, Avasadat Hosseini¹

1. Razi Clinical Research Development Unit, Razi Hospital, Guilan University of Medical Sciences, Rasht, Iran
2. Department of Microbiology, School of Medicine, Guilan University of Medical Sciences, Rasht, Iran
3. Shahid Beheshti Hospital, Guilan University of Medical Sciences, Anzali, Iran

ABSTRACT

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Device-associated healthcare-associated infections (DA-HAIs) remain a major challenge in hospitalized patients, particularly among those requiring invasive medical devices. This study aimed to describe the epidemiological characteristics, distribution of causative microorganisms, and clinical outcomes of DA-HAIs in a tertiary cardiac hospital in northern Iran. In this retrospective descriptive study, hospital records and infection surveillance data of patients with DA-HAIs were reviewed from March 21, 2018, to March 21, 2024. Eligible cases included hospitalized patients with documented exposure to invasive devices, including urinary catheters, vascular devices, or mechanical ventilation. Demographic characteristics, hospitalization-related variables, device-associated infection types, microbiological findings, and in-hospital outcomes were collected using a structured data extraction. A total of 320 episodes of DA-HAIs were identified. The median age of affected patients was 67 years (IQR: 59–75), and 67.5% were female. Catheter-associated urinary tract infection (CAUTI) was the most frequent infection type, accounting for 88.1% of cases, followed by ventilator-associated events/pneumonia (9.1%), peripheral intravenous catheter-associated bloodstream infections (1.9%), and central line-associated bloodstream infections (0.9%). *Escherichia coli* was the predominant microorganism, responsible for 57.5% of all isolates, with Gram-negative bacteria representing the majority of identified pathogens. Overall, 42 patients (13.1%) died during hospitalization. This study demonstrates a substantial burden of DA-HAIs in a tertiary cardiac hospital, characterized by a predominance of CAUTI and Gram-negative bacterial pathogens. Continuous device-associated infection surveillance, optimization of device utilization, and targeted infection prevention strategies are essential to reduce the clinical impact of these infections in specialized cardiac care settings.

*Corresponding Author(s):

Meysam Hasannejad-Bibalan, PhD

Address: Department of Microbiology, School of Medicine, Guilan University Campus, 7th Km of Rasht-Tehran Highway, Rasht, Guilan, Iran

Tel: +98 13 33368540

E-mail: hasannejad@gums.ac.ir, meysam.hasannejad@gmail.com

Tofigh Yaghubi Kalurazi, MD

E-mail: tofigh_yaghubi@yahoo.com



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1. Introduction

Healthcare-associated infections (HAIs) remain a major challenge for patient safety and healthcare delivery, particularly among critically ill patients who require intensive monitoring and invasive supportive interventions [1]. Among HAIs, those associated with central venous catheters, mechanical ventilation, and urinary catheters represent important and potentially preventable complications of critical care [2,3].

Device-associated healthcare-associated infections (DA-HAIs) primarily include central line-associated bloodstream infections (CLABSI), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infections (CAUTIs) [4]. These infections are associated with substantial morbidity, prolonged hospital and intensive care unit (ICU) stays, increased healthcare costs, antimicrobial exposure, and, in some patient populations, an increased risk of mortality [5,6]. The use of invasive devices is often indispensable in the management of critically ill patients; however, the duration and intensity of device exposure may increase the opportunity for microbial colonization and subsequent infection [7].

The epidemiology of DA-HAIs varies considerably across healthcare settings and is influenced by patient characteristics, ICU case mix, patterns of device utilization, duration of exposure, infection prevention practices, antimicrobial prescribing, and the local distribution of bacterial pathogens [8,9]. Evidence from Iran indicates that HAIs remain an important concern, particularly in intensive care settings [10]. Analysis of national nosocomial infection surveillance data has shown that ICUs have among the highest rates of HAIs in the country, with device-, catheter-, and ventilator-associated infections accounting for a considerable proportion of reported infections [11]. These findings highlight the importance of locally generated surveillance data, particularly because infection rates and pathogen profiles may differ according to hospital characteristics, patient populations, and regional healthcare practices.

Patients hospitalized in specialized cardiac centers may represent a particularly vulnerable population for HAIs. Moreover, the clinical consequences of infection in patients with severe cardiovascular disease may be substantial because infection can complicate an already critical clinical condition and may adversely affect treatment outcomes [12]. Despite the clinical importance of this population, data specifically describing the epidemiology and long-term trends of device-associated infections in specialized cardiac hospitals remain relatively limited, particularly in the context of healthcare settings in northern Iran. Therefore, this study aimed to investigate the epidemiology of DA-HAIs among patients admitted to the ICUs of a tertiary cardiac hospital in northern Iran over a six-year period. The findings may contribute to a better understanding of the local burden of DA-HAIs

and provide evidence to support infection prevention and control strategies in specialized cardiac critical care settings.

2. Materials and Methods

2.1 Study design and setting

This hospital-based retrospective study was conducted to investigate the epidemiology, and associated factors of DA-HAIs among patients admitted to a tertiary-level specialized cardiac hospital (Dr. Heshmat Educational and Remedial Center) in northern Iran. The study covered a six-year period from March 21, 2018, to March 21, 2024. The study was based on a retrospective review of routinely collected hospital records and infection surveillance data.

2.2 Ethical considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee of Guilan University of Medical Sciences (Approval No. IR.GUMS.REC.1403.346). Because the study involved retrospective analysis of existing medical records and did not require direct patient contact, the requirement for written informed consent was waived by the ethics committee, where applicable. Patient identifiers were removed from the analytical dataset, and access to the study data was restricted to authorized members of the research team. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable national regulations governing research involving human participants.

2.3 Study population and eligibility criteria

The study population comprised all patients who were admitted to hospital during the study period and had a hospital stay sufficient for assessment of hospital-acquired infection and were exposed to at least one invasive medical device during their admission. Patients were eligible for inclusion if they met the following criteria: (1) hospitalization more than two days during the study period; (2) availability of demographic and clinical information in the hospital medical records; and (3) availability of information regarding the use of invasive devices, including mechanical ventilation, central venous catheters, and urinary catheters. Patients with incomplete medical records that did not permit determination of infection status or device exposure were excluded from the final analysis. The study population was identified from hospital admission records, and infection control surveillance records. Where multiple admissions occurred for the same patient during the study period, each admission was assessed as a separate hospitalization episode only when the corresponding device exposure and infection surveillance data could be independently determined.

Otherwise, the first eligible admission was considered for analysis to avoid potential duplication of observations.

2.4 Data sources and data collection

Data were retrospectively extracted from patients' medical records and the hospital infection surveillance database using a structured data extraction form developed specifically for the study. The data collection form was designed based on variables commonly used in hospital-acquired infection surveillance studies and included demographic, clinical, hospitalization-related, device-related, microbiological, and outcome variables. The Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) surveillance framework followed for evaluating an episode of hospital-acquired infection and device-associated infections [4,13].

2.5 Statistical analysis

Data were entered into a computerized database and analyzed using IBM SPSS Statistics, version 21.0 (IBM Corp., Armonk, NY, USA). Normally distributed continuous variables were presented as mean $\pm$ standard deviation (SD), whereas non-normally distributed variables were summarized using median and interquartile range (IQR). Categorical variables were presented as frequencies and percentages. Continuous variables were assessed for normality using the Shapiro-Wilk test and graphical methods. Binary logistic regression analysis was performed to evaluate the association between infection type and in-hospital mortality. The outcome variable was coded as 0 for discharge and 1 for in-hospital death. Infection type was entered into the model as a categorical variable with three categories: CAUTI, ventilator-associated event/pneumonia (VAE/VAP), and vascular device-associated infection (VAS). CAUTI was considered the reference category. Odds ratios (ORs) with 95% confidence intervals (CIs) were estimated. A two-sided P-value <0.05 was considered statistically significant.

3. Results

During the six-year study period, a total of 320 episodes of DA-HAI were identified among hospitalized patients who met the study eligibility criteria. The median age of patients with DA-HAIs was 67 years (IQR, 59–75 years). Female patients accounted for 216 cases (67.5%), whereas 104 cases (32.5%) occurred among male patients.

The median length of hospitalization among patients DA-HAI was 10 days (IQR, 7–18 days). The median duration from device insertion to the diagnosis of a device-associated infection was 4 days (IQR, 2–7 days).

The highest proportion of DA-HAI was identified among patients hospitalized in the Internal Medicine

wards, accounting for 137 cases (42.8%), followed by the coronary care unit (CCU), with 132 cases (41.3%). Electrophysiology (EP) wards accounted for 31 cases (9.7%), while 13 cases (4.1%) occurred in surgical wards. A smaller proportion of infections was identified in the ICU (5 cases, 1.6%) and pediatric wards (2 cases, 0.6%).

CAUTI was the predominant type of DA-HAI, accounting for 282 of 320 episodes (88.1%). VAE/VAP was identified in 29 cases (9.1%), whereas peripheral intravenous catheter-associated bloodstream infection (PIVC-associated BSI) accounted for 6 cases (1.9%). CLABSI was the least frequently reported infection type, with 3 cases (0.9%).

The distribution of microorganisms isolated from DA-HAI episodes is shown in Table 1. *Escherichia coli* was the most frequently identified microorganism, accounting for 184 isolates (57.5%) of all reported infections. Coagulase-negative staphylococci (CoNS) were identified in 31 cases (9.7%), followed by *Klebsiella* spp. in 29 cases (9.1%) and *Enterobacter* spp. in 28 cases (8.8%). Overall, Gram-negative organisms predominated among the reported etiological agents, with *E. coli* accounting for more than half of all identified microorganisms.

Table 1. Distribution of organisms causing device-associated infections

Bacteria	Frequency	Percent
<i>E. coli</i>	184	57.5
CoNS	31	9.7
<i>Klebsiella</i> spp.	29	9.1
<i>Enterobacter</i> spp.	28	8.8
<i>Pseudomonas</i> spp.	12	3.8
<i>S. aureus</i>	12	3.8
<i>Candida</i> spp.	10	3.1
<i>Citrobacter</i> spp.	10	3.1
<i>Proteus</i> spp.	3	0.9
<i>Salmonella</i> spp.	1	0.3
Total	320	100.0

CoNS: Coagulase negative staphylococci

The distribution of microorganisms according to the specific type of DA-HAI is presented in Table 2. Among the 282 CAUTI episodes, *E. coli* was the predominant causative organism, accounting for 173 cases (61.3%). The next most frequently identified organisms were CoNS (27 cases, 9.6%), *Klebsiella* spp. (24 cases, 8.5%), and *Enterobacter* spp. (23 cases, 8.2%). Among the three CLABSI episodes, *E. coli* was identified in two cases (66.7%), whereas *S. aureus* was isolated in one case (33.3%). Among the six PIVC-associated bloodstream infections, *E. coli* was the most frequently identified organism, accounting for four cases (66.7%). Among the 29 VAE/VAP episodes, *E. coli*, *Klebsiella* spp., and *Pseudomonas* spp. were each identified in 5 cases (17.2%).

Among the 320 identified infection episodes, 278 patients (86.9%) were discharged from the hospital, whereas 42 patients (13.1%) died during hospitalization.

Table 2. Distribution of organisms causing device-associated infections based on type of infection

Infection type	Bacteria	Frequency	Percent
CAUTI	<i>S. aureus</i>	8	2.8
	<i>Candida</i> spp.	7	2.5
	<i>Citrobacter</i> spp.	10	3.5
	<i>E. coli</i>	173	61.3
	CoNS	27	9.6
	<i>Enterobacter</i> spp.	23	8.2
	<i>Klebsiella</i> spp.	24	8.5
	<i>Proteus</i> spp.	3	1.1
	<i>Pseudomonas</i> spp.	6	2.1
	<i>Salmonella</i> spp.	1	.4
	Total	282	100.0
CLABSI	<i>S. aureus</i>	1	33.3
	<i>E. coli</i>	2	66.7
	Total	3	100.0
PIVCs	<i>E. coli</i>	4	66.7
	<i>Enterobacter</i> spp.	1	16.7
	<i>Pseudomonas</i> spp.	1	16.7
	Total	6	100.0
VAE/VAP	<i>S. aureus</i>	3	10.3
	<i>Candida</i> spp.	3	10.3
	<i>E. coli</i>	5	17.2
	CoNS	4	13.8
	<i>Enterobacter</i> spp.	4	13.8
	<i>Klebsiella</i> spp.	5	17.2
	<i>Pseudomonas</i> spp.	5	17.2
	Total	29	100.0

CoNS: Coagulase negative staphylococci

Binary logistic regression demonstrated a significant association between infection type and in-hospital mortality ($\chi^2=62.23$, $df=2$, $P<0.001$). Compared with patients with CAUTI, those with VAP had significantly higher odds of in-hospital mortality (OR=30.76, 95% CI: 12.33–76.74, $P<0.001$). Similarly, patients with vascular device-associated infections had significantly higher odds of in-hospital mortality compared with those with CAUTI (OR=6.92, 95% CI: 1.60–29.86, $P=0.010$).

4. Discussion

DA-HAIs remain an important quality-of-care and patient-safety problem because their occurrence reflects the interaction between invasive device exposure, underlying illness, duration of hospitalization, and infection-prevention practices [9]. The present six-year retrospective study provides valuable data from a tertiary cardiac hospital in northern Iran and identifies a marked predominance of CAUTI, a predominance of Gram-negative organisms, and substantial differences in mortality according to infection type. These findings provide a useful basis for evaluating local infection-prevention priorities while highlighting the need for cautious interpretation of mortality associations in a retrospective, single-center dataset.

The most prominent finding was the predominance of CAUTI, which accounted for 282 (88.1%) of all identified episodes, whereas VAE/VAP and vascular infections constituted considerably smaller proportions. The high proportion of CAUTI may reflect the frequency of urinary catheter exposure in this hospital

population and the inclusion of patients from general medical and coronary care settings. Iranian surveillance studies have demonstrated substantial variation in device-associated infection patterns according to hospital and ICU characteristics. In a multicenter hospital-based study in Tehran, reported rates were 10.20, 21.08, and 7.42 per 1,000 central-line, ventilator, and urinary-catheter days for CLABSI, VAP, and CAUTI, respectively [10]. Similarly, another multicenter Iranian surveillance study reported CAUTI, VAP, and CLABSI rates of 8.99, 7.88, and 5.84 per 1,000 device-days, respectively [14]. Another international report showed the pooled rates of 5.5 CAUTIs per 1,000 urinary-catheter days, 16.8 VAPs per 1,000 ventilator days, and 4.9 CLABSIs per 1,000 central-line days across 503 ICUs in 43 countries [1]. These differences emphasize the importance of reporting DA-HAIs when comparing infection burden across institutions.

The microbiological profile of the present study was characterized by a pronounced predominance of Gram-negative organisms. *E. coli* accounted for 57.5% of isolates and was particularly dominant among CAUTI episodes, where it accounted for 61.3% of infections. The predominance of Gram-negative organisms is broadly consistent with previous evidence demonstrating their major contribution to healthcare-associated infections in developing healthcare systems [8,14]. However, the particularly high proportion of *E. coli* in the present study differs from some ICU-based surveillance studies in which *Candida*, *Klebsiella*, or other species constitute a larger proportion of isolates [15–18]. Such differences may reflect variation in patient populations, anatomical sources of infection, device utilization, antimicrobial exposure, and local infection-control practices.

A clinically important finding was the association between infection type and in-hospital mortality. Overall, 42 of 320 episodes (13.1%) were associated with in-hospital death. Compared with CAUTI, VAE/VAP and vascular device-associated infections were associated with greater odds of mortality. These findings are directionally consistent with the established clinical importance of ventilator- and intravascular-device-associated infections. A meta-analysis of individual patient data from randomized prevention studies estimated an attributable mortality of approximately 13% for VAP, although the magnitude varied substantially according to patient characteristics and illness severity [19]. Likewise, a systematic review and meta-analysis of CLABSI found increased odds of in-hospital death associated with CLABSI, although the association was attenuated in studies with better adjustment for severity and other confounding factors [20].

The predominance of CAUTI in the present study also has practical implications. Although CAUTI was associated with lower mortality than the other device-associated infection categories, it should not be

considered clinically unimportant. Previous systematic evidence has linked CAUTI with increased mortality and prolonged ICU and hospital stay in unmatched observational analyses, while showing that the mortality association may substantially diminish after adjustment for other predictors. This distinction supports a prevention strategy focused not only on treating established infections but also on avoiding unnecessary urinary catheterization, maintaining appropriate catheter care, and removing catheters as early as clinically feasible [21].

Several limitations should be considered. First, the retrospective single-center design limits causal inference and generalizability to other cardiac hospitals or healthcare systems. Second, the study analyzed infection episodes rather than device-days; therefore, direct comparison of infection rates with surveillance studies using standardized device-day denominators is not possible. Finally, the logistic regression model included infection type as the principal explanatory variable and did not adjust for important potential confounders such as disease severity, comorbidities, mechanical ventilation duration, or other clinical factors.

This six-year study demonstrates a substantial and clinically relevant burden of device-associated hospital-acquired infections in a tertiary cardiac hospital in northern Iran, with CAUTI accounting for the majority of identified episodes and *E. coli* representing the predominant pathogen. Importantly, VAE/VAP and vascular device-associated infections were associated with markedly higher odds of in-hospital mortality than CAUTI. The findings support continued, device-specific surveillance and targeted infection-prevention interventions, particularly strategies aimed at minimizing unnecessary device exposure and improving the prevention and management of ventilator- and intravascular-device-associated infections. Future multicenter prospective surveillance using standardized device-day denominators and multivariable risk adjustment would be valuable for determining the reproducibility and independent clinical impact of these findings.

Declaration of artificial intelligence (AI) in the writing process

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

Authors' contributions

Conceptualization, Methodology, project supervision, Validation, Review and editing: SMM, TYK, MHB. Investigation, data collection, and writing of the original draft: AF, FK, AH. All authors read and approved the final version of the manuscript.

Conflict of interest

No potential conflict of interest was reported by the authors.

Ethical declarations

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