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Bacterial etiology and antimicrobial resistance in hospital-acquired respiratory infections: a six-year retrospective study in northern Iran

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Abstract

Hospital-acquired respiratory infections are important healthcare-associated complications, particularly among critically ill patients, and are frequently associated with antimicrobial resistance. Local surveillance of bacterial pathogens and their antimicrobial susceptibility profiles is essential for informing infection prevention and antimicrobial stewardship. This study aimed to investigate the bacterial etiology and antimicrobial resistance patterns of hospital-acquired respiratory infections in Northern Iran. This retrospective descriptive study reviewed medical records and hospital infection-control data for patients with hospital-acquired respiratory infections at Razi Teaching Hospital, Rasht, Iran, between 2018 and 2023. Demographic characteristics, hospital ward, length of stay, discharge outcomes, bacterial isolates, and antimicrobial susceptibility results were extracted. Bacterial identification and susceptibility findings were obtained from routine microbiology laboratory records. Among 3,726 recorded hospital-acquired infections, 1,231 (33.0%) were classified as respiratory infections. Ventilator-associated pneumonia (VAP) accounted for 1,215 cases (98.7%). The mean patient age was 61.15 ± 17.55 years, and 61.0% of patients were male. The mean hospital stay was 30.88 ± 30.29 days, and in-hospital mortality was 60.2%. Klebsiella spp. was the most frequently recorded bacterial group (40.2%), followed by Pseudomonas aeruginosa (15.2%), Acinetobacter spp. (14.3%), and Enterobacter spp. (9.6%). High resistance rates were reported across several organism-antimicrobial combinations, including cefazolin resistance in Klebsiella spp. (99.1%) and imipenem resistance in Acinetobacter spp. (99.2%). Hospital-acquired respiratory infections represented a substantial proportion of recorded healthcare-associated infections and were characterized by the predominance of Gram-negative bacteria, high reported antimicrobial resistance, and considerable in-hospital mortality. Strengthening infection prevention, validating susceptibility data, and implementing continuous local microbiological surveillance may support more effective infection control and antimicrobial stewardship.

Keywords: Hospital-acquired infections, Respiratory tract infections, Ventilator-associated pneumonia, Antimicrobial resistance, Bacterial etiology

1. Introduction

Healthcare-associated infections remain a substantial challenge to patient safety and healthcare delivery. They can complicate treatment, extend hospitalization, increase resource use, and contribute to antimicrobial resistance (1, 2). The World Health Organization has emphasized that effective infection-prevention and control programmes are central to reducing healthcare-associated infections and their consequences (3).

Hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) are particularly important in critically ill patients. Their bacterial causes and antimicrobial susceptibility profiles vary across hospitals and over time, making local surveillance important when selecting empirical treatment (4). Clinical practice guidelines recommend that hospitals regularly generate and disseminate local antibiograms and that empirical regimens be informed by the organisms and susceptibility patterns observed in the relevant patient population (5).

Gram-negative bacteria, including Enterobacterales, Pseudomonas aeruginosa, and Acinetobacter species, are frequently encountered in healthcare settings and can present substantial treatment challenges when resistant to multiple antimicrobial classes (6). However, the distribution of pathogens and resistance cannot safely be assumed to be identical across institutions. Hospital-specific data are therefore needed to guide prevention, diagnostic practices, and antimicrobial-stewardship priorities (7).

Despite the importance of local antimicrobial-resistance surveillance, the distribution of bacterial pathogens and their susceptibility profiles may change over time, highlighting the need for continuous assessment of hospital-based microbiological data. Therefore, longitudinal evaluation of bacterial isolates and their antimicrobial susceptibility profiles is important for supporting context-specific clinical and epidemiological decision-making. Accordingly, this six-year retrospective study aimed to investigate the bacterial etiology and antimicrobial-resistance patterns of hospital-acquired respiratory infections in Northern Iran.

2. Methods

2.1 Study design and setting

This descriptive cross-sectional study was conducted at Razi Teaching Hospital in Rasht, Iran. Records for patients documented as having hospital-acquired respiratory infections between 2018 and 2023 were reviewed retrospectively. The study protocol was reviewed and approved by the Ethics Committee of Guilan University of Medical Sciences, Rasht, Iran (approval code: **IR.GUMS.REC.1404.024**). Given the retrospective design of the study and the use of previously collected medical records and laboratory data, the requirement for informed consent was waived by the ethics committee. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional requirements.

Data were extracted from medical records and the hospital infection-control information system. Variables included age, sex, hospital ward, length of stay, discharge outcome, recorded bacterial etiology, and antimicrobial susceptibility results. The respiratory infection codes as VAP, pneumonia (PNEU), and ear, nose, and throat infection (ENT).

Bacterial isolates and antimicrobial susceptibility results were retrospectively extracted from the microbiology laboratory records. Respiratory specimens were processed using routine clinical microbiology procedures. Specimens were cultured on appropriate bacteriological media and incubated under suitable conditions according to the suspected bacterial pathogens. Bacterial growth was assessed based on colony morphology, Gram staining, and relevant standard biochemical tests. Bacterial isolates were identified to the species level when supported by the laboratory identification procedures and records.

Antimicrobial susceptibility testing was performed using the disk-diffusion method, where documented in the laboratory records. Briefly, a standardized bacterial suspension equivalent to a 0.5 McFarland turbidity standard was inoculated onto Mueller–Hinton agar, and antimicrobial disks were applied to the inoculated agar surface. Following incubation under organism-appropriate conditions, inhibition-zone diameters were measured in millimeters and interpreted as susceptible, intermediate, or resistant according to the Clinical and Laboratory Standards Institute (CLSI) performance standards for antimicrobial susceptibility testing, 33rd edition (M100, 2023) (8). The antimicrobial agents included in the analysis were those tested and recorded by the hospital laboratory; their selection and interpretation were based on the applicable organism-specific CLSI recommendations. Quality-control procedures for antimicrobial susceptibility testing should be documented in accordance with the applicable CLSI recommendations.

Data were analyzed using SPSS software, version 21 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the study variables. The normality of continuous variables was assessed before descriptive analysis. Categorical variables, including bacterial species and antimicrobial susceptibility results, were presented as frequencies and percentages, while continuous variables were summarized as means.

3. Results

Between 2018 and 2023, 3,726 hospital-acquired infections were recorded at the study center, of which 1,231 (33.0%) were classified as respiratory infections. The infection-control system recorded 1,215 cases as VAP (98.7%), 14 as pneumonia (1.1%), and 2 as ENT infections (0.2%).

The mean age was 61.15 ± 17.55 years (median, 64; range, 10–99 years). There were 751 male patients (61.0%) and 480 female patients (39.0%). The largest ward groups were the intensive care unit (ICU; 348 cases, 28.3%) and medical intensive care unit (MICU; 342 cases, 27.8%); 449 cases (36.4%) were grouped under other wards. The mean hospital stay was 30.88 ± 30.29 days (median, 22; range, 2–398 days). During hospitalization, 741 patients (60.2%) died and 490 (39.8%) were discharged.

Klebsiella spp. was the most frequently recorded bacterial group, accounting for 495 cases (40.2%), followed by P. aeruginosa (187; 15.2%), Acinetobacter spp. (176; 14.3%), Enterobacter spp. (118; 9.6%), and Citrobacter spp. (78; 6.3%). Escherichia coli was reported in 33 cases (2.7%). Other recorded organisms included Staphylococcus aureus (34; 2.8%), Staphylococcus epidermidis (28; 2.3%), Micrococcus spp. (15; 1.2%), Moraxella catarrhalis (11; 0.9%), Proteus spp. (10; 0.8%), and several less frequent organisms. The etiology was recorded as unspecified in 19 cases (1.5%).

Antibiotic susceptibility results revealed that for Klebsiella spp., resistance was highest to cefazolin (99.1%) and lowest to amikacin (89.3%) **(Table 1)**. For P. aeruginosa, the highest reported resistance was to imipenem (90.9%) and the lowest to gentamicin (75.9%). For Acinetobacter spp., resistance was highest to imipenem (99.2%) and lowest to doxycycline (84.6%). For Enterobacter spp., resistance was highest to cefepime (91.8%) and lowest to gentamicin (71.4%). For Citrobacter spp., resistance was highest to ciprofloxacin (93.6%) and lowest to piperacillin–tazobactam (76.5%). For E. coli, the highest resistance was to cefazolin (77.8%), whereas the lowest was to meropenem (20.0%). Among staphylococci, the highest reported resistance was to penicillin (95.4%) and the lowest to gentamicin (59.3%).

4. Discussion

Hospital-acquired respiratory infections remain a major challenge in clinical care because their outcomes are influenced by patients' underlying conditions, exposure to invasive devices, pathogen distribution, and antimicrobial susceptibility (9, 10). Continuous local surveillance is essential for identifying changes in bacterial epidemiology and informing infection-prevention and antimicrobial-stewardship strategies (11). In the present study, respiratory infections accounted for approximately one-third of all recorded hospital-acquired infections, and the cases were characterized by a high proportion of patients in intensive care settings, a long mean hospital stay, and substantial in-hospital mortality. Klebsiella spp., P. aeruginosa, and Acinetobacter spp. were the leading recorded bacterial groups.

In this study, the majority of respiratory infections were recorded as VAP. This predominance highlights the importance of reviewing ventilator-associated infection-prevention practices, including adherence to evidence-based respiratory care protocols, appropriate ventilator management, and consistent implementation of infection-prevention measures. However, the exceptionally high proportion of VAP may also reflect institutional surveillance definitions or coding practices. Therefore, it should not be interpreted as the true distribution of respiratory infections without further validation of the diagnostic classifications (12). International recommendations emphasize the importance of systematic surveillance and evidence-based prevention strategies for reducing healthcare-associated infections (13).

Klebsiella spp. was the most frequently recorded bacterial group, followed by P. aeruginosa, Acinetobacter spp., and Enterobacter spp. These findings demonstrate the predominance of Gram-negative bacteria in the study population. Such organisms are important causes of hospital-acquired and VAP, particularly among critically ill patients (14-16). Nevertheless, their relative distribution differs between hospitals according to patient characteristics, local epidemiology, infection-control practices, and previous antimicrobial exposure. Accordingly, the present findings should be interpreted as a local microbiological profile rather than a representative estimate for all hospitals in Northern Iran.

Table 1. Antimicrobial susceptibility pattern of bacterial isolates from hospital-acquired respiratory infections (n = 1,231), 2018–2023.

		Antimicrobial resistance (%)		
Causative organism	**Antimicrobial agent**	**Resistant**	**Intermediate**	**Susceptible**
Klebsiella spp.	Amikacin	89.3%	3.8%	6.9%
Klebsiella spp.	Imipenem	94.8%	1.9%	3.3%
Klebsiella spp.	Piperacillin-tazobactam	92.1%	3.6%	4.3%
Klebsiella spp.	Gentamicin	91.5%	2.8%	5.7%
Klebsiella spp.	Cefazolin	99.1%	0.0%	0.9%
Klebsiella spp.	Cefepime	95.4%	1.5%	3.1%
Klebsiella spp.	Ceftazidime	96.1%	0.6%	3.3%
Klebsiella spp.	Ciprofloxacin	96.4%	0.9%	2.7%
Klebsiella spp.	Trimethoprim-sulfamethoxazole	94.4%	0.8%	4.8%
Klebsiella spp.	Meropenem	95.3%	1.9%	2.8%
P. aeruginosa	Amikacin	80.8%	3%	16.2%
P. aeruginosa	Imipenem	90.9%	2.8%	6.3%
P. aeruginosa	Piperacillin-tazobactam	85.9%	2.9%	11.2%
P. aeruginosa	Gentamicin	75.9%	8.6%	15.5%
P. aeruginosa	Ceftazidime	88.2%	2.4%	9.4%
P. aeruginosa	Ciprofloxacin	85.1%	0.5%	14.4%
P. aeruginosa	Meropenem	89.7%	5.2%	5.1%
Acinetobacter spp.	Amikacin	90%	6.3%	3.7%
Acinetobacter spp.	Imipenem	99.2%	0.8%	0.0%
Acinetobacter spp.	Tetracycline	97.8%	0.0%	2.2%
Acinetobacter spp.	Gentamicin	87.3%	6%	6.7%
Acinetobacter spp.	Doxycycline	84.6%	0.7%	14.7%
Acinetobacter spp.	Ceftazidime	97.8%	0.0%	2.2%
Acinetobacter spp.	Ciprofloxacin	96.9%	1.3%	1.8%
Acinetobacter spp.	Trimethoprim-sulfamethoxazole	96.2%	0.0%	3.8%
Acinetobacter spp.	Meropenem	96.7%	0.0%	3.3%
Enterobacter spp.	Amikacin	79.1%	6.6%	14.3%
Enterobacter spp.	Imipenem	84.1%	6.8%	9.1%
Enterobacter spp.	Piperacillin-tazobactam	86.4%	6%	7.6%
Enterobacter spp.	Gentamicin	71.4%	7.2%	21.4%
Enterobacter spp.	Cefepime	91.8%	2.7%	5.5%
Enterobacter spp.	Ceftazidime	87.4%	2.1%	10.5%
Enterobacter spp.	Ciprofloxacin	85.7%	2.9%	11.4%
Enterobacter spp.	Trimethoprim-sulfamethoxazole	84.5%	1.1%	14.4%
Enterobacter spp.	Meropenem	91.3%	4.4%	4.3%
Citrobacter spp.	Amikacin	79.2%	8.3%	12.5%
Citrobacter spp.	Imipenem	83.6%	9.9%	6.5%
Citrobacter spp.	Piperacillin-tazobactam	76.5%	14.7%	8.8%
Citrobacter spp.	Gentamicin	80.3%	5.6%	14.1%
Citrobacter spp.	Cefazolin	92.6%	3%	4.4%
Citrobacter spp.	Cefepime	93.5%	2.2%	4.3%
Citrobacter spp.	Ceftazidime	90.2%	3.3%	6.5%
Citrobacter spp.	Ciprofloxacin	93.6%	3.2%	3.2%

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		Antimicrobial resistance (%)		
Causative organism	**Antimicrobial agent**	**Resistant**	**Intermediate**	**Susceptible**
Citrobacter spp.	Trimethoprim-sulfamethoxazole	85.2%	5.5%	9.3%
Citrobacter spp.	Meropenem	90%	10%	0.0%
Escherichia coli	Amikacin	57.7%	7.7%	34.6%
Escherichia coli	Imipenem	46.1%	15.4%	38.5%
Escherichia coli	Piperacillin-tazobactam	55.6%	0.0%	44.4%
Escherichia coli	Gentamicin	61.3%	0.0%	38.7%
Escherichia coli	Cefazolin	77.8%	3.7%	18.5%
Escherichia coli	Cefepime	72.2%	11.1%	16.7%
Escherichia coli	Ceftazidime	65.2%	8.7%	26.1%
Escherichia coli	Ciprofloxacin	75.9%	0.0%	24.1%
Escherichia coli	Trimethoprim-sulfamethoxazole	75%	0.0%	25%
Escherichia coli	Meropenem	20%	0.0%	80%
Staphylococcus spp.	Erythromycin	90.9%	0.0%	9.1%
Staphylococcus spp.	Penicillin	95.4%	0.0%	4.6%
Staphylococcus spp.	Tetracycline	76.8%	0.0%	23.2%
Staphylococcus spp.	Gentamicin	59.3%	3.6%	37.1%
Staphylococcus spp.	Doxycycline	77.2%	0.0%	22.8%
Staphylococcus spp.	Cefoxitin	69.2%	2%	28.8%
Staphylococcus spp.	Ciprofloxacin	77.4%	0.0%	22.6%
Staphylococcus spp.	Clindamycin	80.4%	0.0%	19.6%
Staphylococcus spp.	Trimethoprim-sulfamethoxazole	71.7%	2.2%	26.1%
Micrococcus spp.	Erythromycin	90%	0.0%	10%
Micrococcus spp.	Amikacin	40%	0.0%	60%
Micrococcus spp.	Penicillin	91.7%	0.0%	8.3%
Micrococcus spp.	Tetracycline	36.4%	0.0%	63.6%
Micrococcus spp.	Gentamicin	53.9%	0.0%	46.1%
Micrococcus spp.	Doxycycline	46.7%	0.0%	53.3%
Micrococcus spp.	Cefoxitin	88.9%	0.0%	11.1%
Micrococcus spp.	Ciprofloxacin	84.6%	0.0%	15.4%
Micrococcus spp.	Clindamycin	90%	0.0%	10%
Micrococcus spp.	Trimethoprim-sulfamethoxazole	83.4%	8.3%	8.3%

Abbreviations: AMK, amikacin; IPM, imipenem; TZP, piperacillin-tazobactam; GEN, gentamicin; CFZ, cefazolin; CFP, cefepime; CAZ, ceftazidime; CIP, ciprofloxacin; SXT, trimethoprim-sulfamethoxazole; MEM, meropenem; TET, tetracycline; DOX, doxycycline; ERY, erythromycin; PEN, penicillin; FOX, cefoxitin; CLI, clindamycin.

The mean hospital stay was 30.88 days, and in-hospital mortality was 60.2%. These observations indicate that the recorded infections occurred in a population with substantial healthcare needs and an unfavorable overall outcome profile. However, the retrospective descriptive design does not establish that respiratory infections or antimicrobial resistance directly caused these deaths. The absence of information about underlying diseases, severity of illness, timing of infection, and other prognostic factors prevents assessment of the independent contribution of infection to mortality (17, 18). Similarly, without a suitable comparison group, the additional length of hospitalization attributable to respiratory infection cannot be estimated.

The reported susceptibility results raise substantial concerns regarding antimicrobial resistance. Among Klebsiella spp., resistance was highest to cefazolin and lowest to amikacin (89.3%). For These findings suggest that several antimicrobial agents may have limited activity against the corresponding isolates. Resistance also varied across the other bacterial groups. Although

these differences may inform future surveillance priorities, the results do not establish which antimicrobial agent should be selected for empirical treatment. Such decisions require reliable organism-specific susceptibility estimates, clinical assessment, and consideration of antimicrobial stewardship principles (14, 19-21).

Clinical practice guidelines recommend that empirical treatment for hospital-acquired and VAP be guided by local microbiological data, relevant resistance risk factors, and the severity of illness, with subsequent adjustment according to culture and susceptibility results. Accordingly, developing a regularly updated hospital-specific antibiogram, preferably stratified by clinical unit and organism, would be a useful application of the present findings. Before implementation, however, the susceptibility data should be validated, with explicit reporting of the number of isolates tested for each antimicrobial agent and the criteria used to classify susceptibility.

Limitations

This study has several limitations. First, its retrospective, single-center design limits generalizability and may be affected by incomplete records or inconsistencies in infection classification. Second, the marked predominance of VAP requires clarification of the diagnostic definitions and surveillance procedures used. These omissions limit the reproducibility and interpretation of the reported resistance percentages.

5. Conclusion

This six-year retrospective study identified Gram-negative bacteria as the predominant bacterial groups recorded in hospital-acquired respiratory infections at a teaching hospital in Northern Iran. The reported susceptibility profiles raise concerns about substantial antimicrobial resistance, particularly among Gram-negative organisms. These findings support strengthened infection-prevention measures, systematic microbiological surveillance, and antimicrobial stewardship informed by validated local susceptibility data. Verification of resistance estimates and standardized reporting are essential before these results are used to inform empirical treatment policies. Further multicenter studies incorporating annual resistance trends, detailed clinical characteristics, and adjusted outcome analyses are needed to establish the broader epidemiological significance of these findings.

6. Declarations

Ethical Approval and Consent to Participate

The study protocol was reviewed and approved by the Ethics Committee of Guilan University of Medical Sciences, Rasht, Iran (approval code: **IR.GUMS.REC.1404.024**). Given the retrospective design of the study and the use of previously collected medical records and laboratory data, the requirement for informed consent was waived by the ethics committee. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional requirements.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest

No potential conflict of interest was reported by the authors.

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This research was self-funded.

Author's contributions

Investigation, data collection, writing original draft: FTN, SPB. Conceptualization, project administration, validation, review and editing: LA, TYK. All authors have read and approved the final version of the manuscript.

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Artificial intelligence statement

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 publi-

cation ethics recommendations and journal policies.

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