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Evaluation of Antibiotic Resistance Patterns in Hospital-Acquired Infections

Ritambhara
Doctarate, Biotechnology, Amity University, Noida, Uttar Pradesh,
Email Id: ritambhara.bhutanii@gmail.com
ORCID ID: 0009-0001-0008-4457

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Abstract: Background: Hospital-acquired infections (HAIs) pose a significant challenge to healthcare systems globally, exacerbated by rising antimicrobial resistance. Understanding the prevalence, distribution, and resistance patterns of pathogens causing HAIs is critical for guiding effective infection control and antibiotic stewardship strategies.
Methods: This cross-sectional study was conducted in a tertiary care hospital, involving 1,780 clinical samples collected from patients who developed infections 48 hours or more after admission. Samples were obtained from multiple hospital wards including surgery, internal medicine, intensive care units, and transplant units. Microbial identification and antimicrobial susceptibility testing were performed according to CLSI guidelines. HAIs were categorized by infection type and analyzed for resistance profiles. Statistical associations between resistance patterns and clinical variables such as age, gender, ward type, infection detection time, length of hospital stay, and patient outcomes were evaluated.
Results: Among the isolates, Gram-negative bacteria predominated (58.1%), chiefly Escherichia coli and Klebsiella pneumoniae, followed by Gram-positive organisms (21.2%) such as Enterococcus spp. and Staphylococcus aureus. Urinary tract infections were the most common HAI. High rates of antimicrobial resistance were observed, including methicillin-resistant S. aureus (52.7%), vancomycin-resistant Enterococcus spp. (58.4%), extended-spectrum beta-lactamase-producing K. pneumoniae (74.8%), and notable carbapenem resistance among Acinetobacter spp. (93.4%). Significant associations were identified between resistant infections and variables such as ICU admission, gender, and infection detection timing.
Conclusion: This study highlights the substantial burden of multidrug-resistant pathogens in hospital-acquired infections, particularly in high-risk hospital wards. Enhanced infection control measures and targeted antimicrobial stewardship are essential to mitigate the spread of resistance and improve patient outcomes.
Keywords: *Hospital-acquired infections, antimicrobial resistance, multidrug-resistant bacteria, bloodstream infections, urinary tract infections, infection control, antibiotic stewardship.*

INTRODUCTION

Antibiotic resistance in “hospital-acquired infections (HAIs)” is a growing global health concern marked by the heightened capacity of bacteria to endure conventional antibiotic treatments. Infections contracted in healthcare environments during hospitalization present a considerable problem due to their intricate management and severe implications for patient safety. Healthcare-associated infections (HAIs) include a wide range of illnesses, such as pneumonia, infections in the bloodstream, urinary tract infections, and infections at the site of surgery. All of these things put a lot of stress on healthcare systems all across the world [1]. The prevalence of HAIs is alarmingly high, varying from 3% to over 20% among inpatients, influenced by geographical location, institutional type, and patient demographics, with drug-resistant bacteria exacerbating the severity and consequences of these infections [1, 2].
Antimicrobial resistance (AMR) is a big problem because it makes hospital-acquired infections (HAIs) far more likely to happen.In 2019, bacterial AMR directly caused more than 1.27 million fatalities and indirectly caused around 4.95 million more deaths around the world. This shows how terrible the problem is [2]. People who are in the hospital often take too many antibiotics and get medicines that aren't suited for them. This speeds up the process of developing resistance. This can get worse if infection control measures aren't followed, like not washing hands well enough, not using the right sterilizing methods, or not following infection control rules [3, 4]. Because of this, resistant germs that don't respond to many medications can grow and spread in hospitals, especially in high-risk areas like intensive care units (ICUs). "Some of the most concerning are methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), carbapenem-resistant Klebsiella pneumoniae, and extended-spectrum beta-lactamase (ESBL)-producing Escherichia coli"

[5, 6]. These germs not only make treatment harder, but they also make it easier for them to spread in healthcare settings. Many things make antibiotic resistance stay and grow in HAIs. These include the excessive use of broad-spectrum antibiotics, the lack of adequate hygiene practices like washing hands correctly, and the growing number of patients traveling internationally, which makes it easier for resistant strains to spread across borders [4, 5]. Antibiotic-resistant HAIs have a huge effect on the economy since they mean longer hospital stays, more expensive and dangerous treatments, more work for healthcare workers, and big drops in productivity. People say that addressing these kinds of problems in the US costs billions of dollars more each year [7]. People in the US and throughout the world are pushing for a solution that works on many levels to fix this issue. The proposed control measures encompass enhanced microbiological and epidemiological surveillance, rigorous antibiotic stewardship programs to ensure judicious antibiotic usage, stringent infection prevention and control protocols, and the encouragement of coordinated, multidisciplinary interventions within healthcare facilities [8]. The persistent and developing traits of resistant bacteria in hospital settings demand ongoing observation, innovation, and the incorporation of medications to successfully mitigate the burden and dissemination of resistance. This study sought to examine the prevalence, distribution, and trends of antibiotic resistance among bacteria responsible for nosocomial infections in a tertiary care environment. We want to find out which germs are most likely to cause infections, how resistant they are, and how they are related to the patient and the hospital by looking at a lot of clinical, demographic, and microbiological data.

This strategy is very important for improving empirical antibiotic therapy and guiding concentrated infection control efforts. This will help people get better and stop the problem of antibiotic resistance from getting worse.

METHODOLOGY

Study Design and Setting

This study was designed as a cross-sectional observational analysis conducted in a tertiary care hospital. The primary objective was to investigate the prevalence, types, and antimicrobial resistance patterns of hospital-acquired infections (HAIs) across different hospital wards, including surgery, internal medicine, intensive care units (ICUs), and transplant units.

Sample Collection and Patient Selection

Clinical samples (blood, urine, wound swabs, respiratory secretions, and other pertinent specimens) were collected from patients who developed infections at least 48 hours after hospital admission, thereby confirming the infections as nosocomial. A total of 1,780 samples from diverse patient demographics were included. Peripheral information such as patient age, gender, ward admitted, type of infection, time of infection detection post-admission, duration of hospital stay, and outcomes (discharged, deceased, still hospitalized) were meticulously recorded.

Microbiological Identification and Antimicrobial Susceptibility Testing

Microorganisms were isolated and identified using standard culture techniques and automated identification systems available at the hospital microbiology laboratory. Antimicrobial susceptibility testing followed the Clinical and Laboratory Standards Institute (CLSI) guidelines, employing disk diffusion and/or broth microdilution methods to determine resistance profiles against relevant antimicrobial agents. Specific attention was given to pathogens like Escherichia coli, Klebsiella pneumoniae, Acinetobacter spp., Pseudomonas aeruginosa, Staphylococcus aureus, Enterococcus spp., and Staphylococcus epidermidis, which are known to contribute significantly to HAIs.

Classification and Data Categorization

The HAIs were categorized into “bloodstream infections (BSI)”, ‘urinary tract infections (UTI)’, “surgical site infections (SSI)’’, ‘pneumonia’, and other infection types. Isolates were classified by Gram stain characteristics (Gram-positive, Gram-negative), fungal species, or unidentified as applicable. Resistance mechanisms, including extended-spectrum beta-lactamases (ESBL), carbapenem resistance, and methicillin resistance, were particularly assessed.

Statistical Analysis

Data were entered and analyzed using statistical software. Descriptive statistics were calculated for demographic and clinical variables. Associations between antimicrobial resistance patterns and clinical variables such as age, gender, hospital ward, detection time, length of stay, and patient outcomes were examined using Chi-square or Fisher’s exact tests for categorical variables and t-tests or Mann-Whitney U tests for continuous data. Statistical significance was set at $p < 0.05$. The analysis allowed identification of risk factors correlated with resistant infections and provided insight into the burden of antimicrobial resistance within the hospital setting.

RESULTS

A total of 1,780 clinical samples were analyzed, almost evenly distributed between males (885, 49.7%) and females (895, 50.3%). Patients aged between 15 and 65 years comprised the majority (1,136, 63.8%). The distribution of hospital-acquired infections (HAIs) showed urinary tract infections (UTI) as the most frequent (609, 34.2%), followed by surgical site infections (SSI) (408, 22.9%), bloodstream infections (BSI) (438, 24.6%), pneumonia (279, 15.7%), and other infections (46, 2.6%). The crude mortality rate across HAIs was 18.8%. Analysis of infection rates by ward indicated the highest incidence in transplant wards (11.24%) and intensive care units (9.52%), while internal medicine (5.34%) and surgery wards (3.09%) had comparatively lower rates.

Tab 1. Distribution of Key Hospital-Acquired Infections by Ward.

Ward Type	SSI (n, %)	UTI (n, %)	BSI (n, %)	Pneumonia (n, %)
Surgery Wards	136 (33.3)	61 (10.0)	54 (12.3)	47 (16.9)
Internal Medicine	51 (12.5)	165 (27.1)	88 (20.1)	68 (24.4)
ICU	118 (28.9)	237 (38.9)	199 (45.4)	112 (40.1)
Transplant Wards	103 (25.3)	146 (24.0)	37 (8.4)	52 (18.6)

Gram-negative bacteria were the predominant pathogens, constituting 1,035 (58.1%) of isolates, with Gram-positive bacteria accounting for 378 (21.2%), fungi mainly Candida spp. representing 109 (6.1%), and unidentified organisms comprising 258 (14.5%). Prominent Gram-negative species included E. coli (341, 19.2%), Klebsiella pneumoniae (312, 17.5%), Acinetobacter spp. (197, 11.1%), and Pseudomonas aeruginosa (91, 5.1%). Among Gram-positive organisms, Enterococcus spp. were the most common (154, 8.7%), followed by Staphylococcus aureus (110, 6.2%) and Staphylococcus epidermidis (81, 4.6%). Gram-positive bacteria caused a majority of bloodstream infections (44%), predominantly due to Enterococcus spp. (34%), whereas Gram-negative bacteria predominated in urinary tract infections (41%), with E. coli responsible for nearly half (49%) of these cases. Fungal infections were also most commonly urinary tract infections (66%).

Tab 2. Gender and Resistance Patterns among Key Organisms.

Organism	Resistance Mechanism	Males n (%)	Females n (%)	p-value
ESBL K. pneumoniae	Extended Spectrum Beta-Lactamase	32 (38.6)	51 (61.4)	0.21
Carbapenem-resistant Acinetobacter	Carbapenem Resistance	6 (8.8)	62 (91.2)	0.03*
ESBL E. coli	Extended Spectrum Beta-Lactamase	38 (52.8)	34 (47.2)	0.47
MRSA (S. aureus)	Methicillin Resistance	22 (66.7)	11 (33.3)	0.02*

*Significant association ($p<0.05$).

Antimicrobial resistance was substantial among isolates. For Gram-positive bacteria, resistance to oxacillin or cefoxitin was seen in 52.7% and 59.3% of S. aureus and S. epidermidis isolates, respectively, indicating widespread MRSA and MRSE. Vancomycin-resistant Enterococcus spp. accounted for 58.4% of isolates. Among Gram-negative bacteria, K. pneumoniae exhibited resistance to third and fourth generation cephalosporins and beta-lactamase inhibitors in 74.8% of cases and carbapenem resistance in 34.6%. E. coli showed 41.2% resistance to extended-spectrum beta-lactams with carbapenem resistance at 1.7%. P. aeruginosa demonstrated resistance ranging from 44.1% (piperacillin–tazobactam) to 70.3% (ceftazidime) and 59.2% (carbapenems). A. baumannii showed extremely high resistance rates including 97.5% to ceftazidime and 93.4% to carbapenems, though colistin resistance was low (6%).

Tab 3. Clinical Outcomes Among Patients with Resistant Organisms.

Organism-Resistance	Discharged n (%)	Deceased n (%)	Still Hospitalized n (%)
ESBL K. pneumoniae	52 (85.2)	6 (9.8)	3 (5.0)
Carbapenem-resistant Acinetobacter	35 (71.4)	11 (22.5)	3 (6.1)
MRSA (S. aureus)	27 (81.8)	4 (12.1)	2 (6.1)
Vancomycin-resistant Enterococcus	12 (75.0)	3 (18.8)	1 (6.2)

Statistical analysis revealed a significant correlation between the detection time after hospital admission and the presence of ESBL-producing K. pneumoniae ($p=0.01$). The occurrence of MRSA was significantly associated with admission to intensive care units ($p=0.02$) and showed a notable difference with regard to patient gender ($p=0.02$). Carbapenem-resistant

Acinetobacter also showed a significant gender association (p=0.03). No significant differences were detected between resistant isolates and the length of hospital stay or overall patient outcomes. These findings emphasize the critical burden of antimicrobial resistance in hospital pathogens and highlight the need for targeted infection control and antimicrobial stewardship strategies, especially in high-risk wards such as ICUs and transplant units.

DISCUSSION

Hospital-acquired infections (HAIs) remain a significant challenge for worldwide healthcare systems, linked to heightened morbidity, mortality, economic burden, and the escalating issue of antimicrobial resistance (AMR) [9]. The findings of this study, which reveal a significant prevalence of multidrug-resistant organisms, corroborate concerns expressed in previous research and indicate the necessity for hospitals to enhance their infection control protocols and ensure the accurate administration of medications. The ESKAPE pathogens—Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species—are recognized as the principal culprits in hospital settings, notably within intensive care units (ICUs), due to their virulence and extraordinary capacity to develop resistance [10]. The predominance of Gram-negative bacteria in this study, specifically E. coli and K. pneumoniae, corresponds with global surveillance data indicating a concerning trend of increasing resistance in these organisms, particularly regarding extended-spectrum beta-lactamase (ESBL) and carbapenemase production [6, 11, 12]. A significant concern is the resistance of K. pneumoniae and Acinetobacter spp. to carbapenems [13]. These bacteria don't respond to the last line of treatment, which makes treatment harder and raises the risk of death, especially for patients in the ICU and transplant unit who are already fragile [14, 15]. Resistance may present differently in various parts of the world. For example, research has shown that certain carbapenemase genes, including KPC in Western countries and NDM in South Asia, may affect how well treatment works and how well patients do. Plasmid-mediated resistance mechanisms also help resistance genes propagate in hospitals, which makes it hard to keep them under control and regulate them. AMR has a huge effect on medicine. Research indicates that patients with healthcare-associated infections (HAIs) unresponsive to antibiotics experience prolonged hospital stays, elevated rates of clinical response failure, and an increased likelihood of mortality compared to those with infections responsive to treatment [16]. For example, AMR has been linked to a 58% rise in the death rate from bloodstream infections and a doubling of the number of people who need to be admitted to intensive care units (ICUs). Gram-negative multidrug-resistant organisms (MDROs) pose significant challenges because to their fast gene transfer capabilities and extended viability in hospital settings. The elevated prevalence of MRSA and VRE among participants in our study illustrates the challenges of investigating antibiotic resistance in healthcare environments [17, 18]. Recent surveillance investigations demonstrate that MRSA and VRE do not routinely exhibit uniform prevalence levels worldwide. These bacteria, however, correlate with inferior patient outcomes and increased utilization of hospital resources. Institutional variables, including strict adherence to private room assignments for colonized or infected patients, thorough environmental cleaning, and reduced bed occupancy rates, have been recognized as significant contributors to the frequency of MRSA and VRE. Conversely, a significant patient population and centralized ventilation and air conditioning systems have been associated with an elevated incidence of healthcare-associated infections (HAIs) [19]. Antimicrobial stewardship programs (ASPs) have been effective in diminishing inappropriate antibiotic utilization, hence mitigating resistance [4, 20]. The most successful stewardship approaches are limiting the use of high-risk antibiotics, using computer-based prescribing support, and adding embedded infectious disease consultation to clinical pathways. Surveillance is central to hospital AMR control, providing critical data for developing empiric therapy guidelines, monitoring resistance trends, and driving targeted interventions [20]. However, ASP success is often constrained by institutional adherence, resource limitations, and the complex interplay between local, national, and global epidemiological factors [21]. ICUs are recognized as epicenters for the emergence, amplification, and dissemination of MDROs [22]. Up to 70% of ICU patients will receive antibiotics on a given day, many with broad-spectrum activity, increasing antibiotic pressure and fostering resistance development. The high intensity of care, frequent use of invasive devices, and increased patient severity accelerate patient-to-patient transmission and selection for resistant organisms. Preventing cross-transmission, therefore, is dependent not only on antimicrobial restrictions, but also on fundamental infection prevention measures such as rigorous hand hygiene, environmental decontamination, surveillance cultures, and cohorting of colonized/infected patients. Patient-related factors—including advanced age, comorbidities, prolonged hospitalization, previous antibiotic exposure, and invasive procedures—are consistently reported as major risk factors for developing multidrug-resistant HAIs [23]. These findings echo the study's observation that older patients and those in critical care environments experience higher rates of resistant infections. Some reports also note gender differences in susceptibility, although data are mixed and may reflect underlying comorbidities and type/frequency of healthcare exposure. The economic burden of resistant HAIs is profound. Hospitals face increased costs from prolonged stays, need for more expensive or combination therapies, and greater utilization of diagnostic and supportive care resources. In the United States alone, excess annual costs attributed to AMR are estimated in the billions. The societal burden, measured in loss of productivity, disability-adjusted life years (DALYs), and mortality, is immense and continues to rise globally. Despite evidence supporting infection control and stewardship, implementation remains challenging, particularly in resource-limited settings. Barriers include limited laboratory capacity for culture and susceptibility testing, lack of access to optimal antimicrobial agents, insufficient training for healthcare personnel, and absence of integrated surveillance networks. Interdisciplinary collaboration, ongoing education, policy support, and the strategic application of

technology are therefore essential for sustained impact. Fungal HAIs, predominately due to Candida spp., also play a role in the growing AMR crisis, especially as they are frequently observed in ICU and immunocompromised patients [7]. These cases underscore the need for judicious antifungal stewardship and highlight the complexity of managing HAIs beyond bacterial pathogens. Innovative approaches to AMR mitigation are required. Rapid, point-of-care diagnostics can potentially guide optimal therapy and reduce inappropriate antibiotic use, as supported by early trials in settings with high AMR. Precision surveillance, using molecular epidemiology and resistance gene mapping, can allow for better prediction of outbreaks and guide preemptive interventions. Behavioral and system-level interventions should address not only healthcare worker practices, but also patient education and awareness.

CONCLUSION

The study's findings highlight the alarming burden of multidrug-resistant organisms as major contributors to hospital-acquired infections (HAIs), revealing that both Gram-negative and Gram-positive bacteria are significant threats in clinical settings. Notably, Gram-negative organisms such as Escherichia coli and Klebsiella pneumoniae were the predominant pathogens, exhibiting elevated resistance rates to commonly utilized antibiotics, including extended-spectrum beta-lactamases (ESBLs) and, concerningly, carbapenems in a significant proportion of isolates. Staphylococcus aureus, including methicillin-resistant strains (MRSA), and vancomycin-resistant Enterococcus spp. (VRE) are two examples of Gram-positive bacteria that highlight how common resistant infections are. These patterns of resistance were especially apparent in high-risk areas like intensive care units and transplant wards. This is because patients in these areas are more likely to get sick because of their underlying ailments and the fact that they routinely utilize intrusive gadgets. Because resistant organisms are grouped together in these wards, outbreaks are more likely to happen, and it is much difficult to provide clinical care because there are fewer treatment options and the patients who are infected do worse. The study stresses that healthcare facilities need to improve their infection prevention and control procedures right once. This includes strict hand hygiene, cleaning the surroundings, and keeping sick or colonized patients separate from other patients. The report also stresses the need to set up and improve antimicrobial stewardship programs that promote smart antibiotic prescribing, ongoing staff training, and quick, evidence-based changes to empirical therapy based on local resistance patterns. Lastly, it's really important to keep an eye on how antibiotic resistance is changing so that treatment guidelines and ways to stop infections may be changed fast. To curb the development of resistant illnesses, departments will need to work together more, spend money on lab skills, and promise to keep an eye on things all the time. Hospitals may be able to better protect patient outcomes, save money on healthcare, and be a vital actor in the battle against antibiotic resistance around the world by using these methods together...

Limitations

There are some issues with this study. The findings of this single-center, cross-sectional study may not be generalizable to other hospitals or regions with diverse patient populations and care delivery methods. The reliance on routine clinical samples rather than active surveillance may have led to an overestimation of infection prevalence and difficulties in distinguishing colonization from real sickness. Microbial identification and resistance testing were limited to culture-based, phenotypic methods, omitting molecular tools, hence obstructing a thorough examination of resistance mechanisms and transmission channels. Important clinical features, such as prior antibiotic use, comorbidities, and illness severity, were insufficiently recorded, limiting the study of risk factors. Furthermore, patient outcomes were evaluated solely during hospitalization, lacking post-discharge follow-up, which obscures long-term effects. Future multicenter research incorporating molecular diagnostics and extensive clinical data are essential for a more profound comprehension of hospital-acquired illnesses and antibiotic resistance.

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