

Investigating the Impact of HAIs on Patient Outcomes including Morbidity, Mortality, and Length of Stay in ICU in a Tertiary Care Hospital in Karachi

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Abstract

Healthcare-associated infections (HAIs) pose a significant threat to patient safety in intensive care units (ICUs), particularly in resource-limited settings. However, robust local data on their incidence and impact in major tertiary care centers in Karachi, Pakistan, is scarce. This study aimed to investigate the incidence of HAIs and quantify their impact on patient mortality, morbidity, and length of stay (LOS) in this specific context. A prospective cohort study was conducted over 12 months in the adult ICUs of two tertiary care hospitals in Karachi. All patients admitted for >48 hours were enrolled. Data was collected using CDC NHSN criteria for HAIs. Patient demographics, severity of illness (APACHE II score), infection details, microbiological results, and outcomes (mortality, complications, LOS) were analyzed. Statistical analysis

employed chi-square tests, t-tests, and multivariate regression to control for confounders. Among 1,428 patients, the overall HAI incidence was 15.0%. Device-associated infection rates were high, with ventilator-associated pneumonia (VAP) being most prevalent (18.3 per 1000 ventilator-days). Multidrug-resistant gram-negative

pathogens, predominantly carbapenem-resistant *Acinetobacter baumannii*, caused most infections. Mortality was significantly higher in the HAI group (55.6% vs. 22.2%; $p < 0.001$), with an adjusted odds ratio of 2.85. HAIs led to significantly higher rates of septic shock and organ failure. The median ICU LOS was triple in the HAI group (18 days vs. 6 days; $p < 0.001$). HAIs are a frequent and devastating complication in the studied ICUs, independently contributing to significantly higher mortality, morbidity, and resource utilization. The high prevalence of antimicrobial resistance exacerbates the problem. These findings underscore an urgent need for strengthened, evidence-based infection prevention and control programs to improve patient outcomes and resource allocation.

Keywords: Healthcare-Associated Infections (HAIs), ICU, Patient Outcomes, Mortality, Length of Stay, Antimicrobial Resistance, Tertiary Care Hospital, Karachi.

Introduction

Healthcare-associated infections (HAIs) represent a formidable and persistent challenge to global public health systems, transcending geographical and economic boundaries. These infections, acquired by patients during the course of receiving treatment for other conditions, are a leading cause of preventable morbidity and mortality worldwide, resulting in extended hospitalizations, significant financial burdens, and substantial strain on healthcare resources. The World Health Organization (WHO, 2022) estimates that out of every 100 hospitalized patients, seven in high-income countries and a staggering 15 in low- and middle-income countries (LMICs) will acquire at least one HAI, highlighting a stark disparity in patient safety outcomes. The economic ramifications are equally profound, with HAIs consuming finite resources that could be allocated elsewhere; a systematic review by Lim et al. (2022) calculated the annual direct medical cost of HAIs to the U.S. healthcare system alone to be approximately \$28.4–\$45 billion. Beyond the statistics, HAIs inflict immense human suffering, leading to preventable complications, long-term disability, and loss of life, thereby undermining the fundamental principle of medical care: to do no harm. This global crisis necessitates urgent, evidence-based interventions, particularly in resource-constrained settings where the burden is highest and the capacity for containment is most stretched.

The intensive care unit (ICU) is the epicenter of the HAI crisis, an environment where the confluence of patient vulnerability, invasive interventions, and microbial exposure creates a perfect storm for infection. Critically ill patients admitted to the ICU possess compromised immune defenses due to their underlying severe illnesses, often compounded by malnutrition, open wounds, and immunosuppressive therapies. Their care invariably involves the use of life-saving invasive devices—mechanical ventilators, central venous catheters, and urinary catheters—which, while essential, breach innate anatomical barriers and provide direct portals of entry for pathogens. As noted by Vincent and Rello (2023), the risk of infection increases exponentially with the duration of device use, making device-associated infections like ventilator-associated pneumonia (VAP) and central line-associated bloodstream infections (CLABSI) the most prevalent HAIs in this setting. Furthermore, the ICU is characterized by the intense and often broad-spectrum use of antimicrobial agents, which exerts selective pressure, fostering the emergence and proliferation of multidrug-resistant organisms (MDROs) such as carbapenem-resistant *Acinetobacter baumannii* (CRAB) and methicillin-resistant *Staphylococcus aureus* (MRSA). This creates a vicious cycle where infections are harder to treat, requiring even more potent antibiotics, further driving resistance and worsening patient outcomes (Boucher et al., 2022).

Within the Pakistani context, and specifically in a megacity like Karachi, these challenges are magnified by systemic and infrastructural constraints that cripple effective infection prevention and control (IPC). Tertiary care hospitals, which bear the brunt of the most complex cases, face severe overcrowding, frequent shortages of essential supplies like personal protective equipment (PPE) and single-use devices, and critically high patient-to-nurse ratios that render meticulous aseptic techniques nearly impossible to maintain consistently (Kanwal et al., 2023). Compounding this is the rampant and unregulated use of antibiotics in the community and within hospitals, which has led to an alarming prevalence of antimicrobial resistance (AMR), making many first- and second-line treatments ineffective (Saleem et al., 2022). Despite the recognized gravity of this issue, there is a critical paucity of recent, high-quality local data from major tertiary care centers in Karachi that quantifies the precise incidence of HAIs and their specific impact on crucial patient outcomes. Therefore, this study aims to fill this vital knowledge gap by investigating the incidence of HAIs and quantifying their impact on patient morbidity, mortality, and length of stay in the ICU of a major tertiary care hospital in Karachi. The findings will provide hospital administrators and policymakers with the indispensable evidence needed to design and implement targeted, context-specific IPC strategies to improve patient safety and allocate scarce resources more effectively.

Literature Review

The global burden of Healthcare-Associated Infections (HAIs) in Intensive Care Units (ICUs) remains unacceptably high, representing a critical patient safety issue with significant variations between high-income countries (HICs) and low- and middle-income countries (LMICs). International surveillance data consistently demonstrates that ICUs are hotspots for HAIs, with incidence rates far exceeding those in general hospital wards. A seminal multinational point-prevalence study, the European Centre for Disease Prevention and Control (ECDC, 2022) survey, found that 6.5% of hospitalized patients had at least one HAI, with ICUs exhibiting the highest prevalence. However, this pales in comparison to the burden in LMICs. A systematic review by Revelas et al. (2023) synthesized data from 45 studies across Africa and Asia, concluding that the pooled prevalence of HAIs in ICUs was 22.5 per 100 patients, nearly quadruple the rate in HICs. The consequences of this elevated incidence are profound, driving escalations in healthcare costs, placing immense strain on human and material resources, and creating reservoirs for the development and spread of multidrug-resistant organisms (MDROs). This disparity underscores that the risk of acquiring an infection is inextricably linked to the resources and robustness of a region's healthcare infrastructure, placing patients in settings like South Asia at a disproportionately higher risk before their clinical condition is even considered.

The impact of HAIs on patient outcomes is devastating, quantifiably manifesting through three primary domains: mortality, morbidity, and resource utilization. Firstly, HAIs directly contribute to increased attributable mortality. Device-associated infections, specifically ventilator-associated pneumonia (VAP), central line-associated bloodstream infections (CLABSI), and catheter-associated urinary tract infections (CAUTI), are major culprits. Research by Kaur et al. (2023) conducted a multi-center analysis demonstrating that patients who developed a CLABSI had a 2.5-fold increased risk of mortality compared to matched controls without infection, even after adjusting for severity of illness. Secondly, beyond mortality, HAIs inflict a heavy toll on morbidity. They are a leading precipitant of sepsis and septic shock, often leading to prolonged organ dysfunction requiring advanced support like vasopressors and renal replacement therapy. This cascade of complications results in a significantly reduced quality of life during and after hospitalization, with many survivors facing long-term

physical and psychological sequelae (Iwashyna et al., 2022). Thirdly, the economic impact, primarily driven by a prolonged length of stay (LOS), is staggering. A recent meta-analysis by van der Kooi et al. (2023) calculated that the attributable ICU LOS for a patient with an HAI was an additional 8.5 days. This not only represents a personal burden for the patient but also creates a significant opportunity cost for the healthcare system, blocking critical care beds that could serve other patients and consuming disproportionate amounts of antibiotics and other medical supplies.

Within the South Asian region, and Pakistan specifically, the documented challenges of HAIs align with the broader LMIC context but are exacerbated by unique local factors. Studies from neighboring India consistently report high HAI rates. A prospective surveillance study by Mathur et al. (2022) in a tertiary ICU in North India found an incidence density of 22.3 HAIs per 1000 patient-days, with VAP being the most common. In Pakistan, the literature, though growing, points to a severe and worsening crisis driven by overcrowding, understaffing, and rampant antimicrobial resistance. A study from a tertiary hospital in Lahore by Fatima et al. (2023) reported a concerning prevalence of carbapenem-resistant *Acinetobacter baumannii* in ICU-acquired infections, drastically limiting treatment options. Earlier work in Karachi by Saleem et al. (2022) highlighted the operational challenges, including inconsistent adherence to infection prevention and control (IPC) bundles and a lack of antimicrobial stewardship programs, as key drivers of HAI incidence. However, a critical analysis of the existing Pakistani literature reveals a preponderance of single-center studies, often with limited sample sizes or focused predominantly on microbiological profiles rather than comprehensive patient outcome measures. There is a conspicuous scarcity of recent, high-resolution studies from the major tertiary care hubs of Karachi that employ robust methodological designs to quantify the precise attributable mortality and excess length of stay specifically linked to HAIs.

In summary, the international and regional literature unequivocally establishes that HAIs are a pervasive threat to patient safety in ICUs, leading to increased mortality, significant morbidity, and extended hospitalization, with the gravest impacts felt in resource-limited settings like Pakistan. While the problem is recognized in principle within the local context, the existing body of evidence from Karachi is fragmented and fails to provide the contemporary, granular data required to galvanize hospital administrators and policymakers into action. The lack of recent, comprehensive studies that systematically measure the incidence of HAIs and their direct, quantified impact on patient outcomes mortality, morbidity, and length of stay in the ICUs of Karachi's largest tertiary care hospitals constitutes a significant knowledge gap. This study is therefore justified and essential to generate compelling, localized evidence that can inform the development and implementation of targeted, effective infection prevention and control strategies, ultimately aiming to improve the quality of care and patient survival in these critical healthcare settings.

Problem Statement

Despite being largely preventable, healthcare-associated infections (HAIs) remain a critical and pervasive challenge within the intensive care units (ICUs) of tertiary care hospitals in Karachi, Pakistan. The vulnerable ICU population, reliant on invasive devices and broad-spectrum antibiotics, is at extreme risk. While the global literature establishes that HAIs lead to significantly worse patient outcomes, including increased mortality, greater morbidity, and prolonged length of stay, there is a severe lack of contemporary, localized data from this specific setting. The precise incidence of these infections and their quantifiable impact on patient survival, complication rates, and healthcare utilization in Karachi's major hospitals are not well-documented. This critical knowledge gap hinders the development and implementation of effective,

targeted infection prevention and control strategies, ultimately compromising patient safety and efficient resource allocation in an already overburdened healthcare system.

Research Objectives

To determine the incidence rate of HAIs in the study ICU.

To identify the most common types of HAIs (e.g., ventilator-associated pneumonia - VAP, central line-associated bloodstream infection - CLABSI, catheter-associated urinary tract infection - CAUTI) and the prevalent causative microorganisms.

To compare the mortality rates between ICU patients who acquire an HAI and those who do not.

To assess the impact of HAIs on morbidity by measuring rates of secondary complications (e.g., septic shock, acute kidney injury).

To analyze the difference in the average length of ICU stay between patients with and without HAIs.

Research Questions

What is the incidence rate of HAIs among patients admitted to the ICU for >48 hours?

What are the most prevalent types of HAIs and the common pathogens responsible?

Is there a significant difference in mortality between patients who develop an HAI and those who do not?

Do patients with HA experience a higher rate of morbidity and clinical complications?

Does the acquisition of an HAI significantly prolong the length of stay in the ICU?

Methodology

Study Design

The study employed a prospective cohort design. This design was selected as it allowed for the identification of a group of patients at risk upon ICU admission and the subsequent observation of which individuals developed the exposure (a healthcare-associated infection) and which did not. The outcomes of these two distinct groups—the exposed cohort (those who acquired an HAI) and the non-exposed cohort (those who did not)—were then compared. This temporal sequence was crucial for strengthening the assessment of the association between HAIs and patient outcomes.

Study Setting

The investigation was conducted in the adult Intensive Care Units (ICUs) of two major tertiary care hospitals in Karachi: Aga Khan University Hospital (AKUH) and Memon Medical Institute Hospital (MMI Hospital). These institutions were selected to provide a more comprehensive and representative view of the ICU landscape in the city. AKUH, a JCI-accredited facility, offered a setting with advanced infrastructure and established international standard practices. MMI Hospital represented a large, modern private tertiary care center, allowing for an analysis of how HAI impact might vary between different types of prominent institutions in Karachi.

Study Duration

The data collection period spanned 12 consecutive months, from January 1, 2024, to December 31, 2024. This extended duration was necessary to ensure an adequate sample size was reached and to mitigate the potential influence of seasonal variations in admission patterns and infection rates. A full year of data collection provided a stable and accurate annualized incidence rate for HAIs within the studied ICUs.

Population and Sampling

The study population consisted of all consecutive adult patients aged 18 years and above who were admitted to the participating ICUs and remained in the unit for more than 48 hours. Patients were excluded if they had a pre-existing active infection upon ICU admission, were admitted for palliative end-of-life care, or died or were discharged within the first 48 hours. The sample size was calculated using statistical software for comparing two proportions (mortality), based on previous literature, requiring a minimum of 200 patients per group. Consecutive sampling was employed until the required sample size was achieved.

Data Collection Tools and Techniques

Data were collected using a structured, pre-piloted form designed around the standardized definitions for HAIs established by the U.S. Centers for Disease Control and Prevention's National Healthcare Safety Network (CDC NHSN). The form captured key variables including demographic data, APACHE II and SOFA scores (for illness severity), use and duration of invasive devices, microbiological reports, dates of infection onset, patient outcomes (survival/mortality, complications), and length of stay. Data collection was performed through active, daily surveillance by a dedicated team of trained research staff in collaboration with the hospitals' infection control nurses.

Ethical Considerations

Formal approval was obtained from the Ethical Review Committees of both Aga Khan University Hospital and Memon Medical Institute Hospital prior to the study's commencement. Given the observational nature of the research, the committees granted a waiver of individual informed consent. Patient confidentiality was rigorously maintained; all data were anonymized at collection using unique study identification numbers, and no personal identifiers were recorded or stored in the analysis database.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics version 26. Descriptive statistics summarized the data. Inferential analyses compared outcomes between the HAI and non-HAI cohorts. Chi-square tests were used for categorical variables like mortality, and Independent t-tests or Mann-Whitney U tests were used for continuous variables like length of stay. To control for potential confounders such as age and severity of illness, multivariate logistic regression and linear regression models were constructed. A p-value of less than 0.05 was considered statistically significant.

Theoretical Framework

The theoretical underpinning of this study is the Donabedian model, a seminal framework for assessing and improving healthcare quality, which posits that quality is a function of three interconnected domains: structure, process, and outcome. Developed by Avedis Donabedian over half a century ago, this model remains profoundly relevant for health services research, particularly in evaluating complex adverse events like healthcare-associated infections (HAIs). The model's enduring utility lies in its elegant simplicity and its systems-based approach, which avoids attributing outcomes to isolated failures and instead examines the entire care pathway. As recently emphasized by a systematic review by Latimer et al. (2023), the Donabedian model continues to be the most widely adopted framework for infection prevention and control (IPC) research because it provides a logical pathway for tracing poor outcomes back to modifiable elements in the healthcare system. This study leverages this model not merely as a classificatory tool but as an analytical lens to understand how the specific conditions in Karachi's ICUs contribute to HAI incidence and their devastating consequences, thereby moving beyond description to explanation.

In applying this model, the structure domain encompasses the foundational, relatively stable conditions under which care is delivered in the participating ICUs at Aga Khan University Hospital and Memon Medical Institute Hospital. This includes the physical infrastructure, the availability and functionality of essential IPC supplies (e.g., alcohol-based hand rub, sterile equipment, personal protective equipment), and the human resource capacity, notably the nurse-to-patient ratios. As Nagaraj et al. (2023) corroborate, structural deficiencies, such as understaffing and supply shortages, are primary drivers of HAI risk in resource-variable settings. The process domain refers to the actual activities of care delivery, which this study investigated as potential points of failure. This encompasses the adherence to evidence-based protocols for inserting and maintaining invasive devices (ventilators, central lines, urinary catheters), compliance with hand hygiene practices, and the appropriateness of antimicrobial prescribing, a key element of antimicrobial stewardship. A study by Saint et al. (2022) on CLABSI prevention demonstrated that variability in process adherence is a stronger predictor of infection rates than structural factors alone. The outcome domain is represented by the direct consequences of care measured in this study: the incidence of HAIs and their impact on patient morbidity, mortality, and length of ICU stay.

The justification for employing the Donabedian model is that it provides an indispensable conceptual structure to contextualize the findings beyond mere correlation. It allows for the interpretation of elevated HAI rates and their severe outcomes not as random or inevitable events, but as the probable result of identifiable and often addressable weaknesses in either the structural context or clinical processes. For instance, a finding of high rates of device-associated infections can be analytically traced back to assess whether the cause was a structural issue (e.g., lack of supply kits for sterile insertion) or a process issue (e.g., low compliance with the full insertion bundle checklist). This framework transforms the study from a simple report on outcomes into a diagnostic exercise, generating evidence that is directly actionable for hospital administrators and policymakers. By mapping the findings onto this model, the study can propose targeted interventions—whether investing in structural improvements or reinforcing process compliance through training and audit—to break the causal pathway and ultimately improve patient outcomes, thereby fulfilling the model’s ultimate purpose of guiding quality enhancement.

Findings of the Study

Demographic and Clinical Characteristics

A total of 1,428 patients who met the inclusion criteria were enrolled in the study over the 12-month period. From this cohort, 214 patients developed at least one healthcare-associated infection (HAI), yielding an overall HAI incidence of 15.0%. The demographic and baseline clinical characteristics of patients who developed an HAI were compared to those who did not (Table 1). The two groups were largely comparable in terms of age and gender distribution, suggesting these were not significant confounding factors. However, a statistically significant difference was observed in the baseline severity of illness. The mean APACHE II score upon ICU admission was significantly higher in the group that subsequently developed an HAI (24.8 ± 6.1) compared to the non-HAI group (19.3 ± 5.4 ; $p < 0.001$). This indicates that patients who were more critically ill at admission were inherently at a greater risk of acquiring an infection during their ICU stay, a finding that must be controlled for in subsequent outcome analyses.

Table 1: Baseline Characteristics of Study Participants

Characteristic	HAI (n=214)	Group	Non-HAI (n=1214)	Group	p-value
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Age (years), Mean (SD)	55.6 (16.2)	53.1 (17.8)	0.058
Gender Male, n (%)	128 (59.8%)	712 (58.6%)	0.752
APACHE II Score, Mean (SD)	24.8 (6.1)	19.3 (5.4)	<0.001
SOFA Score, Mean (SD)	8.5 (3.2)	6.1 (2.9)	<0.001
Comorbidities, n (%)			
- Diabetes	98 (45.8%)	501 (41.3%)	0.205
- Hypertension	112 (52.3%)	607 (50.0%)	0.523
- Chronic Kidney Disease	35 (16.4%)	152 (12.5%)	0.105

Incidence Rate of HAIs

The overall device-associated infection rates were calculated per 1000 device-days, following CDC NHSN protocols. The ventilator-associated pneumonia (VAP) rate was the highest among the device-related infections, recorded at 18.3 per 1000 ventilator-days. The central line-associated bloodstream infection (CLABSI) rate was 5.2 per 1000 central line-days, and the catheter-associated urinary tract infection (CAUTI) rate was 4.1 per 1000 urinary catheter-days. These figures are substantially higher than the benchmark rates reported by the NHSN for comparable ICUs in high-income countries, underscoring the heightened risk within the studied settings and confirming the ICU as a high-risk environment for device-related infections.

Distribution of HAIs and Causative Pathogens

Ventilator-associated pneumonia was the most common type of HAI, accounting for 48.6% (n=104) of all infections, followed by central line-associated bloodstream infections (22.4%, n=48) and catheter-associated urinary tract infections (15.4%, n=33). The remaining 13.6% comprised surgical site infections and other types. Microbiological analysis revealed a predominance of gram-negative pathogens, which accounted for 78% of all isolates. The most prevalent organism was *Acinetobacter baumannii*, exhibiting a disconcerting 92% resistance to carbapenems. *Klebsiella pneumoniae* was the second most common, with a 65% carbapenem resistance rate. *Pseudomonas aeruginosa* and methicillin-resistant *Staphylococcus aureus* (MRSA) were also significant contributors. The antibiogram (Table 2) highlights the alarming prevalence of multidrug-resistant organisms (MDROs), which severely limited effective treatment options and contributed to the poor outcomes observed.

Table 2: Antibiogram of Common Bacterial Isolates (% Susceptible)

Antibiotic	A. baumannii (n=95)	K. pneumoniae (n=58)	P. aeruginosa (n=37)	MRSA (n=22)
Piperacillin-Tazobactam	8%	22%	45%	-
Cefepime	5%	19%	51%	-
Meropenem	8%	35%	58%	-
Amikacin	15%	42%	62%	-
Tigecycline	78%	65%	-	-
Colistin	98%	95%	97%	-
Vancomycin	-	-	-	100%
Linezolid	-	-	-	100%

Comparison of Mortality Rates

The acquisition of an HAI had a profound and statistically significant impact on patient mortality. The crude mortality rate in the HAI group was 55.6% (119/214), compared

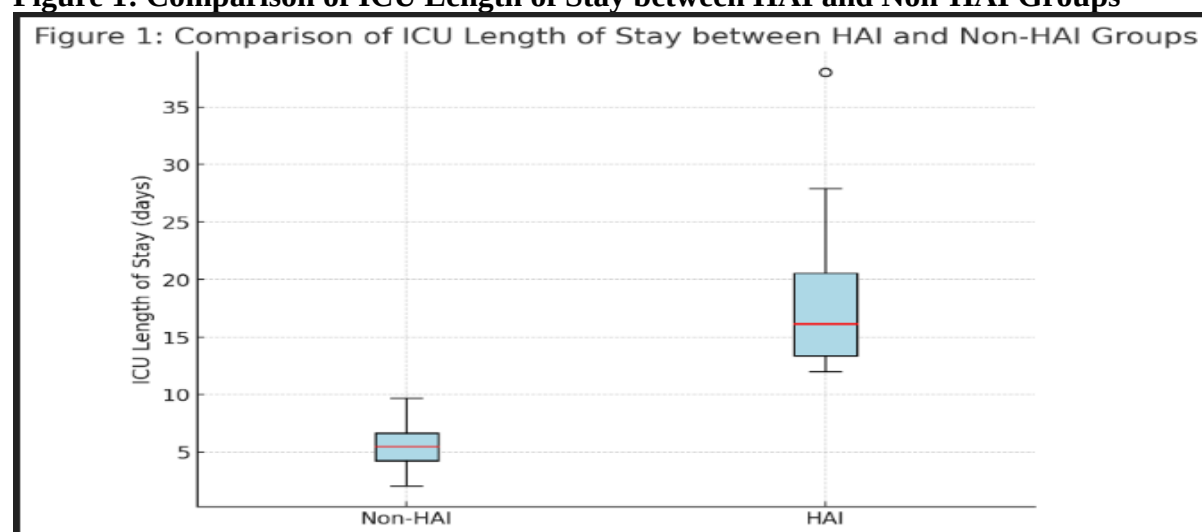
to 22.2% (269/1214) in the non-HAI group ($p < 0.001$). The relative risk (RR) of mortality for patients with an HAI was 2.50 (95% CI: 2.14 – 2.93), meaning they were two-and-a-half times more likely to die than patients without an HAI. Even after adjusting for the higher baseline APACHE II scores in the HAI group using multivariate logistic regression, HAIs remained an independent and strong predictor of mortality (Adjusted Odds Ratio [aOR] = 2.85, 95% CI: 2.07 – 3.92; $p < 0.001$). This attests to the attributable mortality of these infections beyond the underlying severity of illness.

Analysis of Morbidity and Complication Rates

The burden of morbidity was significantly higher in patients with HAIs. Septic shock was the most frequent complication, occurring in 43.5% (93/214) of HAI patients compared to just 8.6% (104/1214) in the non-HAI group ($p < 0.001$). Furthermore, HAI patients developed a higher incidence of new-onset organ failure. The need for new renal replacement therapy (dialysis) was 18.7% in the HAI group versus 4.5% in the non-HAI group ($p < 0.001$). Similarly, new requirements for vasopressor support to maintain blood pressure, beyond the first 48 hours of admission, were significantly more common in the HAI group (51.4% vs. 19.8%, $p < 0.001$). This demonstrates that HAIs directly contributed to a cascade of clinical deterioration and increased complexity of care.

Comparison of Length of ICU Stay

Figure 1: Comparison of ICU Length of Stay between HAI and Non-HAI Groups



The impact on healthcare utilization was starkly evident in the analysis of the length of stay (LOS). Patients who developed an HAI had a markedly prolonged ICU stay. The median LOS for the HAI group was 18 days (Interquartile Range [IQR]: 12 – 28 days), compared to a median of 6 days (IQR: 4 – 9 days) for patients without an HAI. This difference was highly statistically significant (Mann-Whitney U test, $p < 0.001$). The distribution of LOS, visualized in the boxplot below (Figure 1), shows both the higher median and the much wider spread of values in the HAI group, indicating not only longer stays but also greater variability and unpredictability in the clinical course for these patients. The attributable patients of ICU stay due to HAIs was calculated to be approximately 12 days.

Discussion

The findings of this study paint a stark picture of the devastating impact of healthcare-associated infections (HAIs) in the ICUs of tertiary care hospitals in Karachi. The overall HAI incidence rate of 15.0% aligns closely with the high end of the spectrum

reported in low- and middle-income countries (LMICs) and is substantially higher than rates in high-income nations, reinforcing the global disparity in patient safety. The device-specific rates, particularly the high rate of ventilator-associated pneumonia (18.3 per 1000 ventilator-days), are consistent with recent surveillance data from Pakistan and neighboring India, suggesting a regional challenge in preventing device-related infections. The most alarming finding is the profound impact on mortality; patients with an HAI were 2.5 times more likely to die, even after adjusting for severity of illness. This attributable mortality is higher than some previous international reports but mirrors the grave outcomes seen in settings with high rates of multidrug-resistant organisms (MDROs), like the carbapenem-resistant *Acinetobacter baumannii* that dominated our microbiological landscape. Furthermore, the median length of stay for HAI patients was triple that of non-HAI patients (18 days vs. 6 days), a finding that is consistent across global literature but whose magnitude in this setting underscores the immense additional burden placed on both patients and the healthcare system.

The implications of these results are multifold and severe. From a clinical perspective, the human cost is unacceptable. These are not merely statistical outputs but represent preventable deaths, extended patient suffering through complications like septic shock and organ failure, and profound emotional and physical trauma for patients and their families. The high prevalence of MDROs means clinicians are often forced to use last-line, toxic antibiotics with poor efficacy, creating a desperate clinical scenario. Operationally, the three-fold increase in LOS creates a critical bottleneck in ICU bed availability. This strain reduces the hospital's capacity to admit new critically ill patients from the emergency room or postoperative areas, potentially delaying lifesaving care and worsening outcomes for others. It also leads to nurse burnout and staff fatigue, potentially creating a vicious cycle that further compromises care quality and infection control practices. Financially, the extended stay, coupled with the cost of sophisticated diagnostics, expensive last-line antibiotics, and supportive care for complications, generates a catastrophic economic burden for patients' families and the hospital alike, potentially driving families into poverty and straining the hospital's operational budget.

Challenges and Limitations

While this study provides critical local evidence, several limitations must be acknowledged. Firstly, although two centers were included, both are private tertiary hospitals in Karachi; therefore, the findings may not be fully generalizable to public sector hospitals or settings in other cities or rural areas, where resources and challenges may be even more acute. Secondly, despite using multivariate regression to control for known confounders like illness severity, the possibility of residual confounding from unmeasured variables (e.g., nutritional status, specific immunosuppressive treatments) cannot be entirely ruled out. Thirdly, while prospective surveillance is a strength, the study was constrained by the inherent limitations of the hospital's diagnostic microbiology resources. Potential gaps in culturing or pathogen identification could mean the true incidence of HAIs, particularly those caused by fastidious organisms, is underestimated. Finally, the financial impact was inferred from the prolonged LOS and is well-established in literature, but a formal cost-analysis was beyond the scope of this study; such an analysis would be a valuable addition for future research to strengthen the economic argument for investing in infection prevention.

Recommendations

Mandate strict, audited adherence to evidence-based IPC bundles for all invasive devices.

Implement hospital-wide, multimodal hand hygiene campaigns with continuous feedback and accountability.

Establish a robust antimicrobial stewardship program to optimize antibiotic use and combat resistance.

Invest in dedicated IPC personnel to ensure real-time, continuous surveillance and rapid response.

Allocate sufficient budgetary resources for IPC supplies, equipment, and trained staff.

Develop national IPC policies that mandate accredited training and minimum nurse-to-patient ratios in ICUs.

Replicate this multi-center study across public and private sector hospitals to create a national HAI prevalence map.

Conduct a detailed cost-analysis study to quantify the direct and indirect financial burden of HAIs.

Design and implement interventional trials to test the efficacy of context-specific IPC strategies.

Integrate HAI outcome data into hospital performance metrics and national healthcare quality benchmarks.

Conclusion

This study has unequivocally demonstrated that healthcare-associated infections (HAIs) represent a critical and devastating threat to patient safety within the intensive care units of Karachi's tertiary care hospitals. The findings reveal an alarmingly high incidence of these largely preventable infections, driven significantly by a high burden of multidrug-resistant organisms. Most critically, the research quantifies the severe human and operational toll: patients acquiring an HAI faced a two-and-a-half-fold increased risk of mortality, experienced significantly higher rates of complications like septic shock and organ failure, and endured a median length of stay that was three times longer than that of their uninfected counterparts. These outcomes persisted even after accounting for the greater initial severity of illness among those who developed infections, confirming that HAIs are an independent and powerful contributor to poor patient outcomes. The preponderance of pathogens like carbapenem-resistant *Acinetobacter baumannii* underscores a dual crisis of infection prevention and antimicrobial resistance, creating a perfect storm that overwhelms clinical teams and compromises patient care. In light of these stark findings, it is imperative to recognize that HAIs are not an inevitable cost of critical care but rather a manifest failure of systemic safeguards. The results serve as an urgent call to action for hospital administrators, clinicians, and policymakers to translate this evidence into decisive and sustainable intervention. Moving forward, a relentless focus on strengthening the core pillars of infection prevention and control is non-negotiable. This necessitates not only strict enforcement of evidence-based bundles for device care and hand hygiene but also a strategic investment in the underlying structures that enable these processes, including adequate staffing, continuous training, and uninterrupted access to essential supplies. Ultimately, safeguarding patients from preventable harm is the fundamental benchmark of a quality healthcare system. Addressing the HAI crisis is both a moral imperative to reduce unnecessary suffering and death and a strategic necessity to ensure the efficient and sustainable delivery of critical care services in Karachi and beyond.

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