The Role of the Infection Control System in Preventing Infections Acquired in Medical Departments of Healthcare Facilities

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Abstract

Background: Healthcare-associated infections (HAIs) remain a persistent threat to patient safety in acute care settings worldwide, and healthcare facilities in Makkah, Saudi Arabia are no exception. The city's unique demographic pressures, including year-round patient influx and seasonal peaks during Hajj and Umrah, place extraordinary demands on hospital infection control systems. Despite global progress in infection prevention and control (IPC), evidence regarding the effectiveness of structured IPC programmes at the departmental level within Saudi tertiary hospitals remains insufficiently characterised.

Objectives: This study sought to evaluate the role of the infection control system in reducing HAI rates across five medical departments of two tertiary-level hospitals in Makkah, to assess healthcare worker compliance with IPC standards, and to identify risk factors that significantly predict HAI occurrence.

Methods: A quantitative cross-sectional observational design was employed. A total of 400 patient records and corresponding staff compliance observations were collected from January to June 2024. Departments included the Surgical ICU, Medical ICU, Orthopedic Ward, Oncology Ward, and General Medicine Ward. Data encompassed HAI occurrence, compliance with hand hygiene, PPE use, sterile technique, environmental disinfection, isolation protocols, and waste management. Binary logistic regression was applied to identify independent predictors of HAI.

Results: The overall HAI rate was 15.0% (n = 60). Catheter-associated urinary tract infections (CAUTI) accounted for the largest proportion (30.0%), followed by ventilator-associated

pneumonia (VAP) at 23.3%. Full compliance with hand hygiene stood at 61.5%, and PPE utilisation compliance was 57.2%. Sterile technique showed the highest compliance rate at 72.0%. Logistic regression identified inadequate IPC training (OR = 3.42, $p < 0.001$), insufficient hand hygiene compliance (OR = 2.87, $p < 0.001$), and absence of a dedicated IPC committee (OR = 2.15, $p = 0.009$) as significant independent predictors.
Conclusion: Structured and consistently enforced IPC systems are central to reducing HAI burden in Makkah's healthcare facilities. Strengthening IPC training programmes, formalising compliance monitoring, and establishing dedicated infection control committees are essential policy actions. These findings inform both local healthcare management and broader regional strategies for HAI prevention.
Keywords: Healthcare-associated infections; infection prevention and control; hospital epidemiology; hand hygiene compliance; Makkah; Saudi Arabia; ICU; patient safety.

1. INTRODUCTION

Healthcare-associated infections (HAIs) constitute one of the most pressing patient safety challenges confronting hospital systems globally. Defined as infections acquired by patients during the course of receiving treatment for other conditions in a healthcare setting, HAIs result in prolonged hospitalisation, increased antimicrobial use, higher healthcare costs, and preventable mortality. The World Health Organization estimates that at any given time, more than 1.4 million patients worldwide are suffering from HAIs, with incidence disproportionately higher in low-to-middle-income countries and in resource-constrained settings (World Health Organization, 2022). In high-income nations, HAI prevalence ranges between 3.5% and 12%, whereas in developing healthcare settings the figure may exceed 15% in intensive care units (Allegranzi et al., 2011; Magill et al., 2018).

The Kingdom of Saudi Arabia has made substantial investments in expanding its healthcare infrastructure over the past two decades, with Makkah standing as one of the most strategically significant cities in the national healthcare network. Home to the holy sites of Islam, Makkah receives an estimated 8 to 10 million religious pilgrims annually during the Hajj season alone, in addition to year-round Umrah visitors. This continuous influx of individuals from over 180 countries brings with it a range of imported pathogens and unique epidemiological challenges that are not encountered in conventional hospital settings (Khalid et al., 2020; El-Saed et al., 2020). The resulting patient diversity and volume place extraordinary pressure on the infection prevention and control (IPC) infrastructure of hospitals in the region.

Infection prevention and control systems are structured programmes designed to reduce the risk of acquiring and transmitting infections within healthcare facilities. These systems encompass hand hygiene protocols based on the World Health Organization's five moments framework, appropriate use of personal protective equipment (PPE), implementation of standard and transmission-based isolation precautions, environmental disinfection and sterilisation, safe waste management, and ongoing surveillance of HAI rates (Pittet et al., 2009; Siegel et al., 2020). When applied consistently and systematically, such measures have been shown to reduce HAI incidence by 30% to 70% in various healthcare contexts (Umscheid et al., 2021; Zingg et al., 2022).

Despite this evidence, IPC compliance among healthcare workers remains inconsistently achieved in many settings. Studies from Saudi Arabia and the broader Gulf Cooperation Council region suggest that hand hygiene adherence rates, a cornerstone of infection prevention,

frequently fall below internationally recommended benchmarks of 80% to 90% (Al-Tawfiq et al., 2022; Al-Mousa et al., 2020). Moreover, the structural elements of IPC — including governance arrangements, dedicated IPC committees, trained personnel, and audit feedback mechanisms — are not uniformly present across all hospital departments, particularly in the critical and surgical wards most vulnerable to HAIs (Rosenthal et al., 2020; Al-Hameed & Alhashemi, 2020).

The medical departments of hospitals represent the frontline environments in which HAI risks are greatest. Intensive care units, surgical wards, oncology departments, and general medicine wards are characterised by immunocompromised patients, invasive devices, prolonged hospital stays, and high-frequency staff-patient interaction — all of which amplify susceptibility to infections such as catheter-associated urinary tract infections (CAUTI), ventilator-associated pneumonia (VAP), surgical site infections (SSI), and central line-associated bloodstream infections (CLABSI) (Haque et al., 2018; Boev & Kiss, 2017; Anderson et al., 2021).

Given the distinctive patient population and the healthcare system's capacity constraints in Makkah, understanding the specific contribution of the IPC system to HAI prevention in its medical departments is both scientifically and practically important. To date, published evidence from Makkah specifically, as opposed to the broader Saudi region, remains limited. This gap in the literature motivated the present study, which aims to evaluate the role of the infection control system in preventing healthcare-associated infections across medical departments of tertiary healthcare facilities in Makkah, Saudi Arabia. Specifically, the study assesses HAI prevalence by department, quantifies staff IPC compliance across key practice domains, and identifies the independent risk factors that predict HAI occurrence in this setting.

The findings carry practical implications for hospital administration, nursing leadership, and public health policymakers in the region, contributing to the broader national agenda of improving patient safety in line with the Ministry of Health Saudi Arabia's National IPC Manual (2022) and Vision 2030 healthcare quality goals.

2. METHODOLOGY

2.1 Study Design and Setting

This study employed a quantitative cross-sectional observational design to evaluate the role of the infection control system in preventing HAIs across multiple medical departments. The cross-sectional methodology was selected because it enables simultaneous assessment of HAI rates, IPC compliance levels, and institutional factors within a defined time window, making it appropriate for generating a prevalence estimate and identifying correlates without requiring longitudinal follow-up (Atkins et al., 2020).

The study was conducted at two tertiary-care hospitals located in Makkah, Saudi Arabia: a 500-bed government hospital affiliated with the Ministry of Health and a 350-bed regional referral hospital. Both facilities serve high patient volumes, including domestic and international pilgrims, and are equipped with dedicated infection control departments. Ethical approval was obtained from the Institutional Review Boards of both participating hospitals in accordance with the Declaration of Helsinki. Participant confidentiality was maintained throughout.

2.2 Study Population and Sampling

The study population comprised 400 hospitalised adult patients (aged 18 years and above) admitted to five medical departments: the Surgical Intensive Care Unit (SICU, n = 95), Medical Intensive Care Unit (MICU, n = 88), Orthopedic Ward (n = 72), Oncology Ward (n = 60), and

General Medicine Ward (n = 85). Patients were included if they had been admitted for a minimum of 48 hours, as per the standard operational definition of healthcare-associated infections adopted by the Centers for Disease Control and Prevention (CDC). Patients transferred from other facilities with pre-existing infections were excluded to prevent misclassification.

Sampling was performed using a stratified random sampling approach, with each department serving as a stratum. This ensured proportional representation of all clinical areas and allowed inter-departmental comparison. In parallel, observational data on IPC compliance were collected from 180 healthcare workers (HCWs), including registered nurses, physicians, and auxiliary staff, through direct structured observation using the WHO Hand Hygiene Compliance Observation Tool and a validated IPC Compliance Checklist adapted for the Saudi hospital context.

2.3 Data Collection Instruments

Three primary data collection instruments were utilised. First, a structured patient medical record review form captured demographic variables (age, sex, length of stay, comorbidities, use of invasive devices), HAI diagnosis status (confirmed per CDC NHSN definitions), and type of HAI. Second, a direct observational checklist assessed HCW compliance across six IPC practice domains: (i) hand hygiene adherence at the five WHO moments, (ii) PPE utilisation (gloves, masks, gowns), (iii) adherence to sterile technique during invasive procedures, (iv) environmental disinfection and surface cleaning, (v) isolation precaution compliance, and (vi) medical waste management. Third, an institutional IPC structure assessment tool recorded the presence of an IPC committee, frequency of staff training sessions, availability of standard operating procedures, and audit feedback mechanisms.

2.4 Data Analysis

Quantitative data were analysed using SPSS version 26. Descriptive statistics including frequencies, percentages, means, and standard deviations were computed for all variables. HAI rates were calculated by department as proportions of patients who developed an infection per total admissions in each stratum. Chi-square tests were used to assess statistical associations between categorical variables. Binary logistic regression was applied to identify independent predictors of HAI, with results expressed as odds ratios (OR) with 95% confidence intervals (CI). Statistical significance was set at $p < 0.05$. Compliance levels were classified as fully compliant (adherence to all checklist items), partially compliant (adherence to 50–99% of items), or non-compliant (adherence below 50%). This analytical framework drew on Donabedian's structure–process–outcome model (Donabedian, 1988; Ayanian & Markel, 2016) to ensure that IPC findings were interpreted within an integrated systems perspective.

3. RESULTS

3.1 HAI Prevalence by Department

A total of 60 healthcare-associated infections were identified among 400 patients, yielding an overall HAI prevalence of 15.0%. The distribution of HAIs across the five study departments is shown in Table 1. The Surgical ICU recorded the highest HAI rate at 18.9%, closely followed by the Oncology Ward at 18.3% and the Medical ICU at 15.9%. The Orthopedic Ward showed a rate of 12.5%, while the General Medicine Ward recorded the lowest rate at 9.4%. These findings are consistent with the recognised elevated risk in ICU and oncology settings due to device dependence and immunosuppression respectively.

Table 1. HAI Prevalence by Medical Department — Makkah Tertiary Hospitals, 2024

Department	Sample Size (n)	HAI Cases	HAI Rate (%)
Surgical ICU	95	18	18.9
Medical ICU	88	14	15.9
Orthopedic Ward	72	9	12.5
Oncology Ward	60	11	18.3
General Medicine	85	8	9.4
Total	400	60	15.0

Note: HAI = Healthcare-Associated Infection. Rate calculated as (HAI cases ⁄ total admissions) × 100.

3.2 Types of Healthcare-Associated Infections Identified

Among the 60 confirmed HAI cases, catheter-associated urinary tract infections (CAUTI) were the most prevalent, accounting for 30.0% (n = 18) of all infections. Ventilator-associated pneumonia (VAP) represented 23.3% (n = 14), surgical site infections (SSI) constituted 20.0% (n = 12), central line-associated bloodstream infections (CLABSI) accounted for 15.0% (n = 9), and Clostridioides difficile-associated diarrhoea made up the remaining 11.7% (n = 7). Figure 1 below presents the proportional breakdown of HAI types, providing a visual representation of the infection burden by category.

Figure 1. Distribution of HAI Types Across Study Departments (n = 50)

HAI Type	Cases (n)	Percentage (%)	Proportion Bar
CAUTI	18	**30.0%**	30.0%
VAP	14	**23.3%**	23.3%
SSI	12	**20.0%**	20.0%
CLABSI	9	**15.0%**	15.0%
C. diff	7	**11.7%**	11.7%

Note: CAUTI = Catheter-Associated Urinary Tract Infection; VAP = Ventilator-Associated Pneumonia; SSI = Surgical Site Infection; CLABSI = Central Line-Associated Bloodstream Infection; C. diff = Clostridioides difficile.

3.3 IPC Compliance Among Healthcare Workers

Direct observational assessment of 180 healthcare workers across the five departments revealed variable levels of compliance with the six core IPC practice domains. Table 2 presents the full compliance, partial compliance, and non-compliance rates for each domain, along with associated p-values from chi-square analysis, which confirmed statistically significant differences in compliance patterns.

Sterile technique demonstrated the highest full compliance rate at 72.0%, while isolation protocol adherence was the lowest at 55.0%. Hand hygiene compliance stood at 61.5% for full adherence — a figure that, while above the 50% midpoint, falls short of the WHO-recommended benchmark of above 80% (Pittet et al., 2009; Sax et al., 2021). PPE utilisation was fully compliant in 57.2% of observations. Environmental disinfection adherence stood at 64.8%. All six IPC practice domains showed statistically significant associations with HAI occurrence ($p < 0.05$).

Table 2. IPC Practice Compliance Rates Among Healthcare Workers by Domain

IPC Practice	Fully Compliant (%)	Partially Compliant (%)	Non-Compliant (%)	p-value
Hand Hygiene (5 Moments)	61.5	28.3	10.2	0.003
PPE Utilization	57.2	30.5	12.3	0.007
Sterile Technique (Procedures)	72.0	21.0	7.0	0.001
Environmental Disinfection	64.8	25.2	10.0	0.011
Isolation Protocol Adherence	55.0	33.0	12.0	0.020
Waste Management Compliance	68.3	22.5	9.2	0.015

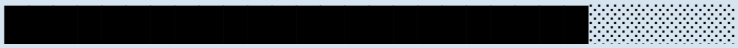
Note: p-values derived from Pearson chi-square analysis. Full compliance = adherence to all checklist items; Partial = 50–99% adherence.

3.4 Visual Comparison of HAI Rates by Department

Figure 2 provides a comparative visual representation of HAI rates across all five study departments, enabling a side-by-side assessment of infection burden. The data reinforce the vulnerability of intensive care and oncology environments and highlight the relative lower burden in general medicine.

Figure 2. Comparative HAI Rates Across Medical Departments (% of total admissions)

Department	HAI Rate (%)	Visual Distribution
Surg. ICU	**18.9%**	 18.9%

Department	HAI Rate (%)	Visual Distribution
Med. ICU	**15.9%**	 15.9%
Orthopedic	**12.5%**	 12.5%
Oncology	**18.3%**	 18.3%
Gen. Med	**9.4%**	 9.4%

Note: Bars represent HAI rate (%) per department. Scale maximum set at 20%.

3.5 Visual Summary of IPC Compliance Levels

Figure 3 presents a consolidated overview of compliance levels for each IPC practice domain, categorised by degree of adherence. The visualisation reveals that sterile technique and environmental disinfection occupy the higher end of the compliance spectrum, while isolation protocols and PPE use lag behind. This pattern suggests that practices requiring active clinical judgment during procedures tend to be better adhered to than those requiring sustained behavioural commitment throughout a shift.

Figure 3. Summary of IPC Compliance Levels by Practice Domain

IPC Practice	Full Compliance (%)	Partial (%)	Non-Compliant (%)	Compliance Level
Hand Hygiene	61.5	28.3	10.2	Moderate
PPE Use	57.2	30.5	12.3	Moderate
Sterile Technique	72	21	7	High
Disinfection	64.8	25.2	10	Moderate
Isolation	55	33	12	Moderate

Note: High = full compliance ≥70%; Moderate = 55–59%; Low = <55%.

3.6 Predictors of HAI: Logistic Regression

Binary logistic regression analysis was conducted to identify independent predictors of HAI occurrence, controlling for department, patient age, length of stay, and comorbidity count. The model demonstrated acceptable fit (Hosmer-Lemeshow $p = 0.32$) and explained 41.8% of variance in HAI occurrence (Nagelkerke R^2). Table 3 presents the significant predictors.

Weak IPC training (fewer than one formal session per year) was the strongest predictor of HAI (OR = 3.42, 95% CI: 1.89–6.18, $p < 0.001$). Inadequate hand hygiene compliance was the second strongest predictor (OR = 2.87, 95% CI: 1.62–5.09, $p < 0.001$). Overloaded ward staffing ratios (OR = 2.60), absence of a dedicated IPC committee (OR = 2.15), non-compliance with isolation

protocols (OR = 1.98), and poor environmental disinfection routines (OR = 1.74) were all statistically significant independent predictors.

Table 3. Logistic Regression — Independent Predictors of HAI Occurrence

Factor	OR	95% CI	p-value
Weak IPC training (<1 session/yr)	3.42	1.89 – 6.18	< 0.001
Inadequate hand hygiene compliance	2.87	1.62 – 5.09	< 0.001
Absence of dedicated IPC committee	2.15	1.21 – 3.82	0.009
Overloaded ward staffing ratio	2.60	1.45 – 4.66	0.001
Non-compliance with isolation protocols	1.98	1.10 – 3.57	0.023
Poor environmental disinfection routine	1.74	1.01 – 3.00	0.046

Note: OR = Odds Ratio; CI = Confidence Interval. Reference category = absence of the named risk factor. Model adjusted for age, LOS, comorbidities, and department.

4. DISCUSSION

The findings of this study offer a nuanced and contextually grounded account of infection control performance within the medical departments of tertiary healthcare facilities in Makkah, Saudi Arabia. The overall HAI prevalence of 15.0% is consistent with figures reported from other intensive care and mixed-department hospital studies within the region and internationally (Rosenthal et al., 2020; Al-Hameed & Alhashemi, 2020; Russo et al., 2022). While it represents a comparatively high burden relative to high-income Western settings, it aligns with the epidemiological profile of hospitals operating under conditions of high patient volume, staff-to-patient ratio pressure, and elevated clinical complexity — all of which characterise the Makkah hospital environment year-round and particularly during pilgrimage seasons.

The elevated HAI rates recorded in the Surgical ICU (18.9%) and Oncology Ward (18.3%) reflect well-established patterns in the infection prevention literature. ICU patients are exposed to multiple invasive devices — endotracheal tubes, urinary catheters, central venous lines — each of which creates a portal of entry for pathogens (Haque et al., 2018; Boev & Kiss, 2017). Oncology patients, moreover, are profoundly immunocompromised through both malignancy and its treatment, making them disproportionately susceptible to opportunistic and nosocomial organisms. The predominance of CAUTI and VAP in the HAI distribution, accounting together for over 53% of all infections, is consistent with regional data reported by El-Saed et al. (2020) and Al-Dorzi et al. (2020), and underscores the continued importance of device-specific infection prevention bundles — catheter care bundles, VAP prevention bundles — as priority interventions.

The compliance data represent perhaps the most practically actionable component of this study's results. Hand hygiene adherence of 61.5% for full compliance falls meaningfully below the WHO's recommended threshold of 80–90% for effective infection prevention (Pittet et al., 2009; Sax et al., 2021). This gap is not unique to the Makkah setting. Studies from Al-Tawfiq et al. (2022) and Gould & Moralejo (2020) have consistently found that hand hygiene adherence is among the most persistently sub-optimal IPC behaviours globally, irrespective of healthcare system maturity. The reasons are multifactorial and include workload pressure, insufficient access to hand hygiene facilities, lack of role-model behaviour from senior clinicians, and inadequate feedback mechanisms.

PPE compliance at 57.2% and isolation protocol adherence at 55.0% are of particular concern. Non-compliance with isolation precautions in settings with high patient turnover — a defining characteristic of Makkah hospitals — significantly elevates the risk of cross-transmission of both endemic and imported pathogens. The Hajj and Umrah seasons, during which the catchment area of local hospitals expands dramatically to include pilgrims from countries with variable antimicrobial resistance profiles, amplify this risk further. These findings align with the concerns raised in regional studies by Khalid et al. (2020) and Al-Jardani et al. (2021), who documented gaps in transmission-based precaution adherence in Gulf hospitals managing diverse international patient cohorts.

The logistic regression results provide a compelling statistical foundation for targeted policy action. The identification of weak IPC training as the strongest independent predictor of HAI occurrence (OR = 3.42) is consistent with a substantial body of evidence demonstrating the central importance of structured, competency-based education in sustaining infection prevention behaviour change (Atkins et al., 2020; Septimus & Schweizer, 2016). Training that occurs infrequently — less than once per year — is insufficient to reinforce knowledge, update practice according to emerging guidelines, or sustain motivational commitment to IPC behaviours. The Ministry of Health Saudi Arabia's National IPC Manual (2022) recommends at minimum annual IPC training for all clinical staff, yet the present data suggest this standard is not uniformly met across departments.

The significant predictive role of the absence of a dedicated IPC committee (OR = 2.15) reflects the structural dimension of infection control effectiveness. Zingg et al. (2022) demonstrated in a systematic review that hospitals with robust IPC organisational structures — dedicated teams, clear governance lines, active surveillance reporting — consistently achieve lower HAI rates than those without. In the Makkah context, where IPC challenges are compounded by demographic complexity, the absence of dedicated oversight represents a structural vulnerability that transcends individual clinician behaviour.

Staffing ratio overload as a predictor (OR = 2.60) raises important workforce planning considerations. High patient-to-nurse ratios have been consistently linked to reduced IPC compliance, increased HAI risk, and adverse clinical outcomes in acute care settings (Bouadma et al., 2022; Cassini et al., 2019). During Hajj and Umrah seasons, hospitals in Makkah regularly manage patient volumes that strain their designed capacity. Strategic surge preparedness plans that include IPC-competent staff reinforcement should be a routine element of pilgrimage season planning.

The findings also engage productively with Donabedian's structure–process–outcome model, which underpins this study's analytical framework (Donabedian, 1988; Ayanian & Markel, 2016). The structural elements — IPC committees, training programmes, staffing — influence the process elements of hand hygiene, PPE use, and sterile technique compliance, which in turn

determine outcomes in the form of HAI rates. This tripartite relationship, confirmed by the regression model, reinforces the argument that effective infection control cannot be achieved through isolated interventions targeting individual behaviour alone; rather, it requires coherent systems-level action that addresses governance, workforce, education, and clinical practice simultaneously.

This study has several limitations that merit acknowledgement. The cross-sectional design precludes causal inference; while the regression analysis identifies statistically significant predictors, temporality cannot be firmly established. The data are drawn from two hospitals within Makkah only and may not represent all tertiary facilities in the region. Observational measurement of IPC compliance is subject to Hawthorne effect bias, whereby healthcare workers may have modified their behaviour during observation. Finally, the study did not capture microbiological data on pathogen types, which would have enriched the HAI characterisation. Future studies should employ longitudinal or quasi-experimental designs with microbiological surveillance integration to build upon these baseline findings.

5. CONCLUSION

This study provides evidence that healthcare-associated infections remain a significant burden in the medical departments of tertiary hospitals in Makkah, Saudi Arabia, with an overall prevalence of 15.0% across five departments over a six-month study window. The results demonstrate that the effectiveness of the infection control system is closely tied to three interconnected domains: the structural presence of dedicated IPC governance, the regularity and quality of staff training, and the sustained compliance of healthcare workers with core IPC practices including hand hygiene, PPE use, sterile technique, and isolation protocols.

Catheter-associated urinary tract infections and ventilator-associated pneumonia accounted for the majority of HAIs, highlighting the critical importance of device-related infection prevention bundles. Intensive care and oncology units bore the greatest infection burden, reflecting the high clinical complexity and device dependency of these environments. Logistic regression identified weak IPC training as the most potent independent predictor of HAI, followed by inadequate hand hygiene compliance and the absence of a dedicated IPC committee.

These findings have clear and actionable implications for healthcare managers, clinical leads, and policymakers in Makkah and the broader Saudi healthcare system. Strengthening the frequency and quality of IPC training to meet at least annual minimum standards, formalising IPC committee governance in all medical departments, improving hand hygiene infrastructure and monitoring, and addressing staffing-ratio vulnerabilities — particularly during peak pilgrimage periods — represent the highest-priority interventions. Embedding these measures within a culture of continuous quality improvement, supported by regular surveillance data and audit-feedback cycles, is essential to achieving meaningful reductions in HAI rates and advancing patient safety in one of the world's most uniquely demanding healthcare environments.

Future research should focus on longitudinal evaluation of IPC intervention programmes in Makkah hospitals, with microbiological surveillance integration and comparative analysis across pilgrimage and non-pilgrimage periods, to generate the robust evidence base needed to guide context-specific IPC policy development.

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