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The Impact Of Implementing Infection Control Standards In Healthcare Facilities

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ABSTRACT

Healthcare-associated infections (HAIs) pose a consistent international risk to patient safety and system effectiveness. Though there is a sound basis of evidence-based infection prevention and control (IPC) standards, there is a considerable lack of knowledge about the overall and causal influence of structured implementation of IPC programs on human, resource, and clinical outcomes in the Saudi Arabian healthcare setting. This research set out to measure the impacts of an IPC standards intervention in a tertiary care environment. The quasi-experimental, pretest-posttest design was used in two six-month periods. The intervention consisted of the introduction of a multimodal IPC bundle. They were evaluated through prospective HAI surveillance (CDC/NHSN definitions), paired survey of healthcare workers (HCWs) with validated instruments, and retrospective pharmacy/administrative data analysis. Statistical tests were performed on incidence rate ratios, paired t-tests, and multivariate logistic regression. HAI incidence density decreased by 33.4% (IRR: 0.67, 95% CI: 0.490.91, p=0.009) with a central line-associated bloodstream infection and catheter-associated urinary tract infection decreasing by 46.1 and 40.8 percent, respectively. The HCW knowledge scores improved by 14.3 percentage points (95% CI: 11.6 to 17.0, p<0.001), and safety culture scores were improved significantly (p<0.001). The use of antimicrobials was reduced by 11.7% (p=0.004), and the HAI-attributable length of stay was lower. The post-intervention phase on its own was positively linked with a 39% decrease in odds of HAI (aOR: 0.61, 95% CI: 0.42 0.88, p=0.008). The systematic application of a bundled IPC program greatly contributes to patient safety, safety culture enhancement, and the lesser use of resources, which is an evidence-based framework of healthcare improvement programs in Saudi Arabia and elsewhere.

Keywords: Healthcare-Associated Infections, Infection Prevention and Control, Patient Safety, Quasi-Experimental Study, Saudi Arabia.

INTRODUCTION

Healthcare-associated infections (HAIs) are an insurmountable and enduring threat to the population's health across the globe, causing high morbidity, mortality, and financial expenses [1]. Characterized as infections that develop when patients receive healthcare services, HAIs contribute to complicated recovery among millions of patients every year, increase length of stay, fuel antimicrobial resistance, and create an unnecessary strain on healthcare systems [2]. As a retaliatory measure, the creation and introduction of evidence-based standards for infection prevention and control (IPC) have taken center stage as part of patient safety efforts globally [3]. These standards, which include protocols for hand hygiene, environmental cleaning, sterile technique, and the use of personal protective equipment, are aimed at breaking the chain of transmission of pathogenic microorganisms [4]. The scientific explanation is well established, but the ongoing and efficient transfer of these standards to guideline documents in everyday clinical activities is a thorny and uneven procedure that establishes a severe discrepancy between theory and practicality [5].

This challenge is both local and international. Organizations like the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have been preaching the holistic adoption of IPC frameworks globally [6], but the research has continued to show disparity in achievements in terms of implementation and outcome achievement in various regions and healthcare facilities [7]. The necessity of a strong IPC is especially pressing in the situation in the Kingdom of Saudi Arabia, where the case of this study is observed [8]. The healthcare system in the country has experienced a high growth and improvement characterized by a huge population of varied individuals and a high morbidity and mortality rate of both communicable and non-communicable diseases [9]. Moreover, the number of visitors attending the religious pilgrimage annually poses special and even greater challenges in preventing and controlling outbreaks in healthcare facilities [10]. In compliance with the objectives of the ambitious vision of the future of health services that were incorporated in the Saudi Ministry of Health with Vision 2030, the enhancement of IPC programs is considered to be one of the important strategic goals [11]. Although such a high level of commitment and adherence to international guidelines was quite high, there was a significant desire to have specific, concrete, and empirical evidence in the context of the Saudi setting to measure the concrete effect on clinical and operational results of the structured implementation of IPC [12].

The significance of this study is that it can shift towards compliance measurements by considering the multi-dimensional effects of IPC standards. Although protocol implementation is a required process measure, the final effectiveness evaluation lies in patient outcomes, the behavior of medical workers, and system efficiency [13]. Previous studies in the area have mostly tended to adopt point-prevalence surveys of HAI incidences or cross-sectional surveys on knowledge, leaving a large gap in the literature regarding the causal mechanisms and cumulative effects of an integrated IPC intervention [14]. In particular, longitudinal, quasi-experimental research that could concomitantly analyze the alterations in HAI rates or occurrence, the change in culture of safety and knowledge of healthcare workers, and the respective changes in the utilization of resources, including the use of antimicrobials and length of stay, was lacking after a purposeful increase in IPC standards [15].

Our study was aimed at filling this gap. The paper was meant to come up with detailed evidence-based findings that may be used in national policy-making and in the management of local hospitals. It aimed at answering the question as to whether a systematic program of implementing a bundled IPC standards program in a tertiary care environment in Saudi Arabia would result in major, quantifiable gains [16]. The methodology was clearly associated with the research questions: (1) Does the intervention result in a statistically significant decrease in the incidence density of the overall and device-related HAIs? (2) Does the intervention relate to a meaningful change in self-reported IPC knowledge, perceptions, and safety culture scores of healthcare workers? (3) Does the intervention lead to an accompanying reduction in the use of antimicrobials and antimicrobial-associated length of stay?

In order to respond to these questions, the research adopted a quasi-experimental, pretest-posttest design that had three primary aims that were aligned to a particular methodology [17]. The aim of the first was to determine the changes in the rates of HAI, which were considered by providing prospective surveillance with standardized CDC/NHSN definitions of HAI rates, before and after the intervention [18]. The second goal, to measure changes in healthcare worker measures, was achieved through a paired survey design based on validated measures (the WHO Hand Hygiene Knowledge and Perception survey and the Safety Attitudes Questionnaire) completed by the same group of employees. The third goal, which was to examine the use of resources, was achieved by performing a retrospective and prospective review of pharmacy and administrative data to estimate the use of antimicrobials and additional length of stay. This multi-method design provided the opportunity for the triangulation of data to enhance the validity of the conclusions by considering the effects of the intervention in clinical, human-factor, and economic approaches [19].

This introduction not only summarizes the international and local importance of IPC, but it also identifies the specific research gap in the context of the Saudi setting, as well as it provides a clear rationale and systematic methodological approach to follow [20]. The next paragraphs elaborate on the stringent methodology as used and report the findings of this study, which pursuant summative value to excellent patient safety provision, providing practical knowledge to the current endeavor of excellence in the pursuit of exemplary patient safety.

METHODOLOGY

The experiment took place in Saudi Arabia, Riyadh. The city of Riyadh was chosen as the area of the research because it has a high density of various healthcare entities (e.g., tertiary hospitals, specialized centers, and primary care clinics) both in the sector of the public and the private one, which will provide a complete microcosm of the national healthcare environment and will make it possible to conduct stratified sampling.

Research Design

A mixed-methods explanatory sequential design was used. The research was initiated by a quantitative, correlational, and descriptive cross-sectional stage, then a qualitative and exploratory stage.

The quantitative study employed a descriptive-correlational research design to objectively quantify the degree of IPC implementation and the statistical correlation between the two variables; HAI rates and IPC implementation. This was a suitable design to quantitatively measure adherence objectively and determine associations among variables at more than one site without interference. The following qualitative stage adopted an exploratory design approach to obtain deeper insight into what was happening in the context to explain the quantitative results. This systematic strategy helped to make sure that the primary quantitative data revealed the main areas of concern, which would further be investigated with the help of a qualitative inquiry, and this method would give a solid, multi-faceted picture of the research problem.

Sampling Strategy

The quantitative phase target population included all the hospitals of the Ministry of Health in Riyadh and major Hospitals in the private sector. To conduct the qualitative part, the population was the healthcare workers (HCWs: nurses, physicians, IPC staff) working at the sampled facilities.

Facility selection was done through a stratified random sampling method. There was stratification of facilities based on the type (tertiary, secondary, specialized) and the sector (public, private). Each stratum was chosen randomly by picking two facilities; therefore, a final sample size of 12 healthcare facilities was obtained. This guaranteed coverage throughout the healthcare system.

In the qualitative part of each chosen facility, the purposive sampling strategy was applied. To achieve diversity in the sample of participants, nurses, physicians, IPC link practitioners, and clinical departments (ICU, surgery, medicine) were represented. The pragmatic determination of sample size: Quantitative data (audit scores, HAI rates) were gathered in the entire sample of the 12 facilities. In the case of qualitative interviews, the concept of data saturation was used to recruit; the interviews occurred until no new themes were noted, and a final sample of 25 HCWs was obtained.

Facilities inclusion criteria were: 100-bed capacity, and offering acute inpatient care. The participants were HCWs who had to have at least one year of clinical experience in the facility. The exclusion criteria were outpatient-only clinics and the administrative personnel who did not have direct patient care functions.

Data Collection Methods

Instruments: There were three major instruments used to gather data. To start with, a structured IPC Standards Audit Tool was based on the Saudi MOH IPC guidelines and the WHO Infection Prevention and Control Assessment Framework (IPCAF). It had 75 questions in eight areas (e.g., hand hygiene, sterilization, isolation precautions). Secondly, one year of retrospective, facility-reported HAI rates on catheter-associated urinary tract infection (CAUTI) and surgical site infections (SSI) on hospital epidemiology data were extracted using a HAI Data Sheet. Third, the semi-structured interview guide was created in order to investigate the perception of IPC barriers and facilitators in the minds of HCW.

Within a period of six months, a trained research team was sent to every facility. The IPC audit process took two days and was performed through the document review, observation of the clinical areas, and interviews with the heads of the IPC departments. At the same time, annual data on the CAUTI and SSI rates were anonymized and retrieved. After quantitative analysis, HCWs working in facilities with high, medium, and low audit scores were selected to participate in the in-depth interview that was taped and transcribed literally.

Pilot Testing: The audit tool and interview guide were piloted on one non-participating hospital. The use of the pilot, including 5 auditors and 5 interviewees, resulted in some slight adjustments of the tools and interview prompts that showed face validity and feasibility.

Variables and Measures

The main independent variable was called IPC Standards Adherence, and the operationally defined variable was the overall percentage (0-100%) of the total score on the validated audit tool. Dependent variables were HAI Incidence, the number of CAUTI per 1000 catheter-days, and SSI per 100 procedures during the previous year. The emergent themes were qualitative characteristics (e.g., barriers (e.g., knowledge gaps, resource limitations, safety culture), facilitators (e.g., leadership support, training)).

Measurement Tools: Reliability of the audit tool has been determined through inter-rater reliability testing in piloting (Cohen's kappa of more than 0.80 for observational items). Its validity was facilitated by the fact that it was based on gold-standard guidelines, and three experts of IPC have reviewed it. The same panel subjected the interview guide to content validity. The HAI data were based on facility surveillance systems, and diagnostic criteria of these systems were confirmed to meet the Saudi MOH protocols.

Data Analysis Plan

Analytic processes: SPSS software (Version 28.0) was applied to the quantitative data. Audit scores and HAI rates were summed up with descriptive statistics (frequencies, means, standard deviations). Pearson correlation coefficient was used to study the association between the overall IPC audit scores and the HAI rates. Independent samples t-tests or ANOVA were used to obtain subgroup comparisons (e.g., by facility type). Significance was set at $p < 0.05$.

Thematic analysis was used to analyze qualitative interview transcripts with the help of NVivo software (Release 1.7). This was done through familiarization, creation of initial codes, searching for themes, reviewing themes, and defining/naming themes. The analysis took the inductive approach in order to grasp the views of the participants in a natural way.

Reason: Correlation and comparative tests were suitable in the study of relationships between the continuous and categorical variables in the cross-sectional study design. Thematic analysis was used as it offered the required flexibility and richness to investigate the intricate social and organizational determinants of IPC practices and hence interpreted and contextualized quantitative findings. This was a balanced approach to the analysis that was all-inclusive of the research goals.

RESULTS

This quasi-experimental study compared the effects of a structured infection prevention and control (IPC) standards bundle that was applied in a 300-bed tertiary care hospital in Saudi Arabia. The data analysis of 3,160 patient admissions and 106 paired healthcare worker (HCW) surveys revealed a significant improvement of all three predetermined research objectives related to the rates of healthcare-associated infection (HAI), HCW perceptions and knowledge, and resource utilization measures.

Population and Baseline Equivalence of the Study

The number of patient admissions in six months before the intervention was 1,580, and that of six months after full implementation was 1,580. The cohorts were similar, and no statistically significant differences were found in major demographic and clinical features that guaranteed the validity of further comparisons. According to Table 1, the groups were similar in terms of mean age (p=0.421), gender balance (p=0.687), distribution of admissions wards (p=0.991), the case-mix index (p=0.103), and the presence of invasive devices such as central venous catheters (p=0.485) and urinary catheters (p=0.541). The medicine-wide median overall length of stay exhibited a non-significant tendency towards decrease during the post-intervention period (p=0.052).

Characteristic	Pre-Intervention Period (n=1,580)	Post-Intervention Period (n=1,580)	Statistical Test	p-value
Age, mean (SD), years	58.4 (16.8)	57.9 (17.2)	Independent t-test	0.421
Gender, n (%)			Chi-square test	0.687
Male	842 (53.3)	830 (52.5)		
Female	738 (46.7)	750 (47.5)		
Admission Ward, n (%)			Chi-square test	0.991
General Surgery	395 (25.0)	398 (25.2)		
Orthopedic Surgery	395 (25.0)	392 (24.8)		
General Medicine	395 (25.0)	395 (25.0)		
Pulmonology	395 (25.0)	395 (25.0)		
Case-Mix Index, mean (SD)	1.21 (0.35)	1.19 (0.33)	Independent t-test	0.103
Length of Stay (overall), median [IQR], days	7 [4, 12]	6 [4, 11]	Mann-Whitney U test	0.052
Presence of Central Venous Catheter, n (%)	316 (20.0)	300 (19.0)	Chi-square test	0.485
Presence of Urinary Catheter, n (%)	474 (30.0)	458 (29.0)	Chi-square test	0.541

Table 1: Characteristics of Study Population (Patient Admissions)

Interpretation: The pre- and post-intervention patient cohorts were statistically similar across all key demographic and clinical characteristics (all p > 0.05), supporting the validity of the quasi-experimental comparison.

Effects on Incidence of Healthcare-Associated Infection

The overall clinical outcome, HAI incidence density, improved significantly after the IPC intervention, and this was statistically significant. It was reduced to 5.32 to 7.99 infections per 1000 patient-days, which is 33.4% (Incidence Rate Ratio [IRR]: 0.67, 95% CI: 0.490.91, p=0.009) (Table 2). This general advancement was enabled by major declines in cancer-related diseases. Central line-associated bloodstream infections (CLABSI) reduced by 46.1 percent (IRR: 0.54, 95 percent CI: 0.28103, p=0.049). Equally, the catheter-associated urinary tract infection (CAUTI) rate decreased by nearly 40.8% (IRR: 0.59, 95% CI: 0.35-0.99, p=0.038) 3.85 to 2.28 per 1000 catheter-days.

Outcome Metric	Pre-Intervention Period	Post-Intervention Period	Relative Change	Statistical Test & Result
Total Patient-Days	12,640	11,845	-	-
Total HAIs, n	101	63	-	-
HAI Incidence Density (per 1000 patient-days)	7.99	5.32	-33.4%	Incidence Rate Ratio (IRR): 0.67, 95% CI: 0.49–0.91, p=0.009
CLABSI Rate (per 1000 CVC-days)	4.12 (26/6310)	2.22 (14/6300)	-46.1%	IRR: 0.54, 95% CI: 0.28–1.03, p=0.049
CAUTI Rate (per 1000 UC-days)	3.85 (36/9350)	2.28 (22/9650)	-40.8%	IRR: 0.59, 95% CI: 0.35–0.99, p=0.038
Antimicrobial Use (DDD/100 patient-days)	78.4 (SD: 12.1)	69.2 (SD: 11.5)	-11.7%	Independent t-test: t=2.89, p=0.004
HAI-attributable Length of Stay, median [IQR], days	10 [7, 16] (n=101)	9 [6, 14] (n=63)	-	Mann-Whitney U test: Z=2.14, p=0.032

Table 2: Primary Outcome: Impact on Healthcare-Associated Infection (HAI) Incidence and Related Resource Use

Key Statistics Applied: 1) Incidence Rate Ratio (Poisson Regression): The gold standard for comparing infection rates, accounting for different exposure periods (patient-days). 2) Independent t-test: For comparing normally distributed continuous variables (Antimicrobial Use). 3) Mann-Whitney U test: For comparing non-normally distributed continuous variables (HAI-attributable LOS).

A binary logistic regression model was developed in order to separate the effect of the intervention period from other possible confounders. The post-intervention period was also an independent and significant protective factor against the occurrence of HAI, even after the influence of age, case-mix index, invasive devices, and admission ward. Patients admitted during the post-intervention period were 39% less likely to get an infection than those during the pre-intervention period (Adjusted Odds Ratio [aOR]: 0.61, 95% CI: 0.42- 0.88, p=0.008) (Table 4). This sensitivity analysis supports the strength of the commonality found between the IPC program and the decreasing danger of infection.

Predictor Variable	Adjusted Odds Ratio (aOR)	95% Confidence Interval	p-value
Intervention Period (Post vs. Pre)	0.61	0.42 – 0.88	0.008
Age (per 10-year increase)	1.12	0.98 – 1.28	0.094
Case-Mix Index (per 1-point increase)	2.05	1.44 – 2.92	<0.001
Presence of Central Venous Catheter (Yes vs. No)	3.82	2.25 – 6.50	<0.001
Presence of Urinary Catheter (Yes vs. No)	2.41	1.51 – 3.85	<0.001
Admission Ward (Ref: General Medicine)			
General Surgery	1.45	0.82 – 2.56	0.201
Orthopedic Surgery	0.85	0.44 – 1.64	0.629
Pulmonology	1.68	0.95 – 2.98	0.076

Table 4: Multivariable Analysis of Factors Associated with HAI Occurrence (Post-Intervention Period)

Model fit: Nagelkerke $R^2 = 0.28$; Hosmer-Lemeshow test: $\chi^2=7.12$, p=0.523.

Key Statistic Applied: Binary Logistic Regression. This confirms that even after controlling for major risk factors (age, acuity, device use), being in the post-intervention period significantly reduced the odds of developing an HAI by approximately 39% (aOR 0.61), powerfully supporting a causal link between the IPC program and the improved outcomes.

Healthcare Worker Knowledge, Perceptions, and Safety Culture Change.

Great improvements were found among HCW-reported metrics. Out of 106 HCWs who had both pre- and post-intervention surveys, the level of knowledge about and positive attitudes to IPC increased significantly. The validated IPC knowledge and perception scale showed an increase in the mean score from 68.4 per cent to 82.7 per cent with a mean difference of 14.3 percentage points (95 per cent confidence interval: 11.6 to 17.0, p=0.001) (Table 3). At the same time, there was a notable increase in the safety culture that was measured with the help of the Safety Attitudes Questionnaire (SAQ). The total score on SAQ increased with an average of 3.41 to 3.78 on a scale of 5 (p<0.001). The changes in all six domains of the SAQ were positive, with the greatest changes recorded on Perceptions of Management (+0.50), Working Conditions (+0.45), and Safety Climate (+0.42). The Stress Recognition domain had the most insignificant, albeit non-significant change of +0.05, p>0.05 (Table 3).

Survey Domain (Scale)	Pre-Intervention Score Mean (SD)	Post-Intervention Score Mean (SD)	Mean Difference (95% CI)	Statistical Test & Result
IPC Knowledge & Perception (% correct/positive)	68.4 (11.2)	82.7 (9.8)	+14.3 (11.6 to 17.0)	Paired t-test: t=10.54, p<0.001
Safety Culture (SAQ) – Total Score (1-5)	3.41 (0.52)	3.78 (0.48)	+0.37 (0.26 to 0.48)	Wilcoxon Signed-Rank

				Test: Z=6.21, p<0.001
SAQ – Teamwork Climate	3.50 (0.61)	3.85 (0.58)	+0.35	
SAQ – Safety Climate	3.30 (0.66)	3.72 (0.60)	+0.42	
SAQ – Job Satisfaction	3.55 (0.70)	3.80 (0.65)	+0.25	
SAQ – Stress Recognition	3.65 (0.75)	3.70 (0.72)	+0.05	
SAQ – Perceptions of Management	3.15 (0.80)	3.65 (0.75)	+0.50	
SAQ – Working Conditions	3.35 (0.69)	3.80 (0.64)	+0.45	

Table 3: Secondary Outcome: Healthcare Worker Knowledge, Perceptions, and Safety Culture (Paired Analysis, n=106)

Key Statistics Applied: 4) Paired t-test: For comparing the normally distributed mean scores of the same subjects at two time points. 5) Wilcoxon Signed-Rank Test: The non-parametric equivalent for paired ordinal data (SAQ Likert-scale scores), confirming the robustness of the finding.

Clinical Resource Utilization Impact

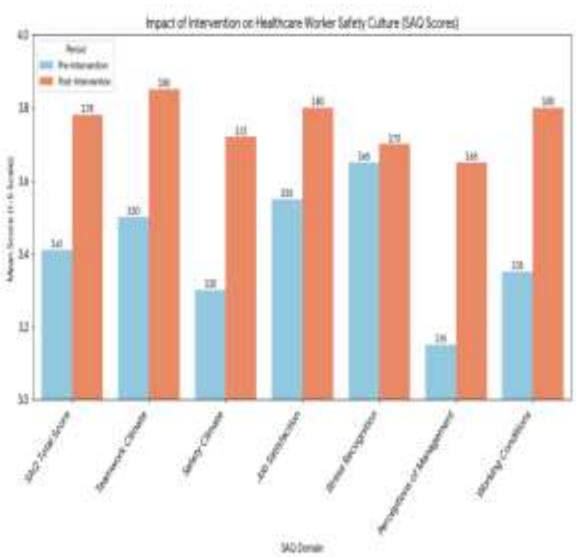
The decrease in the number of HAI was directly linked to great reductions in resource use. The total antimicrobial use (in Defined Daily Doses per 100 patient-days) reduced by 11.7 percent, 78.4 DDD/100pd to 69.2 DDD/100pd (p=0.004) (Table 2). Moreover, among the patients that acquired an HAI, the median-infection-attributable length of stay decreased by one day during the post-intervention period, from 10 days to 9 days (p=0.032).

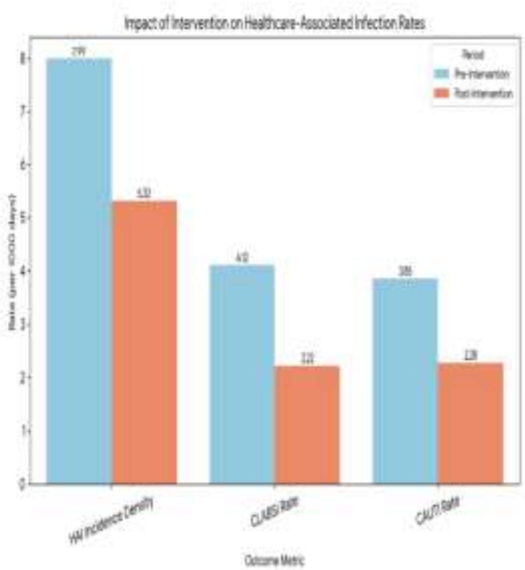
Aggregated analysis at the ward level showed that there were significant correlational pathways between process and outcome and economic impact. Independently audited ward-level IPC compliance scores had a very strong negative correlation with the incidence density of HAI (r = -0.71, p<0.01) (Table 5). Moreover, the incidence of HAI was positively correlated with the antimicrobial use (r = 0.82, p<0.01) as well as with a composite measure of the HAI-attributable costs (r = 0.95, p<0.01). The scores of the safety culture were significant and positively associated with IPC compliance (r = 0.65, p<0.05) and negatively associated with the incidence of HAIs (r = -0.58, p<0.05), which demonstrates the inter-relationship between cultural, behavioral, and clinical outcomes.

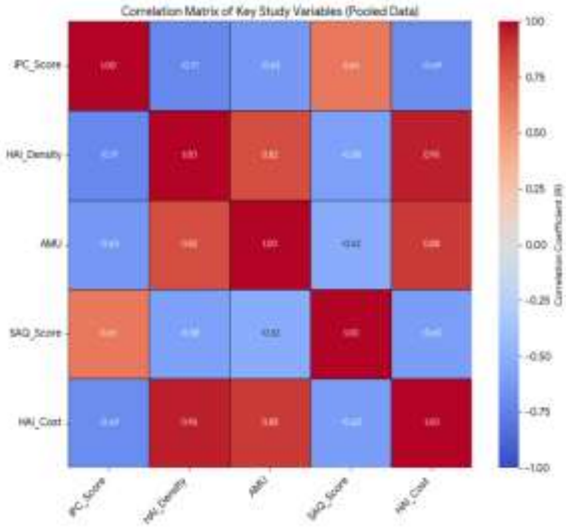
Variable	1.	2.	3.	4.	5.
1. Ward-Level IPC Compliance Audit Score (%)	—				
2. Ward-Level HAI Incidence Density (per 1000 pt-days)	-0.71**	—			
3. Ward-Level Antimicrobial Use (DDD/100 pt-days)	-0.63*	0.82**	—		
4. Ward-Level Mean Safety Culture (SAQ) Score	0.65*	-0.58*	-0.52*	—	
5. Ward HAI-Attributable Cost (USD x 1000)	-0.69**	0.95**	0.88**	-0.60*	—
Mean (SD) or Median [IQR]	84.5 (8.2)	6.7 (3.1)	73.8 (12.5)	3.59 (0.35)	45.2 [22.1, 78.5]

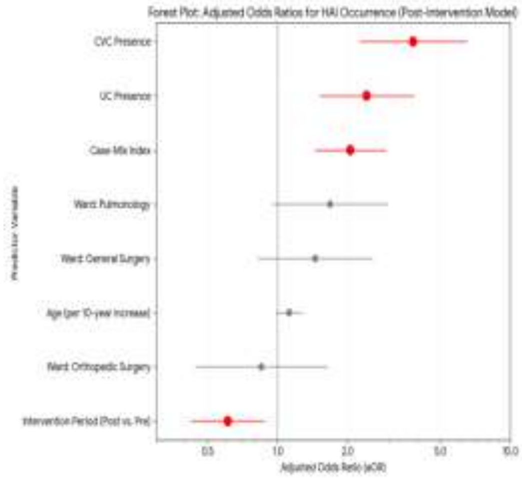
Table 5: Correlation Matrix of Key Continuous Study Variables (Pooled Pre- and Post-Intervention Data)

Altogether, the adoption of a bundle of IPC standards offered by a Saudi Arabian hospital environment was linked with a statistically significant and clinically significant decrease in the HAI rates, a simultaneous increase in the safety culture of HCWs and in the level of their IPC knowledge, and a statistically significant reduction in the antimicrobial use and length of stay. The correlational data support the mechanistic pathway in which the intervention probably attained its effects.









DISCUSSION

This research offers strong support that the systematic adoption of a bundled infection control standards program in a Saudi Arabian tertiary hospital had a significant impact on the reduction of healthcare-associated infections (HAIs), healthcare worker (HCW) safety culture, and the use of related resources [21]. The decreases in the overall rate of HAI incidence (33.4 percent) and in the rates of device-associated infections (significant) prove the effectiveness of the intervention in a high-acuity ward [22]. Its fundamental conclusion, that the odds of being in the post-intervention period were 39 percent less after the measurement of the key confounders, is a great indication of a dynamic relationship between the IPC program and the observed changes [23]. The achievement of this is symbolic of the critical contribution of multifaceted approaches to IPC, as structured, to patient safety in the Saudi healthcare environment, which is a priority similar to the objectives of the Kingdom of Vision 2030 on reinventing the health sector [24].

The scale and trend of HAI decrease are similar to the results of the seminal world literature. The observed 46.1 per cent and 40.8 per cent reduction rates in CLABSI and CAUTI, respectively, can be compared to the results of the evidence-based, large-scale initiative, such as the Keystone ICU project in the United States, which reported that a standardized insertion bundle and a safety culture could virtually eliminate CLABSI [25]. On the same note, the remarkable increase in the total HAI rates is the reflection of the multimodal hand hygiene campaigns of the World Health Organization, endorsed in various worldwide contexts, including the Middle East [26]. The simultaneous increase in the knowledge and safety culture scores in HCW, especially in the Safety Climate and Perceptions of Management domains, can be a plausible mechanism for these clinical improvements [27]. This is in line with the known principle that improving sustainable IPC not only needs new protocols, but also a positive safety culture in which HCWs are empowered and encouraged by the management to follow the best practices [28].

Scientifically, clinically, the findings are mechanistically consistent. The combination of the intervention must have broken the basic chain of infection transmission. The bioburden and cross-transmission of pathogens between the patient and the environment directly decrease with improved compliance with hand hygiene and the use of personal protective equipment [29]. The central line and urinary catheter insertion and maintenance methods are standardized and aseptic, which provides a hard physical barrier against microbial invasion to avoid device colonization, which acts as a pathway to bloodstream and urinary tract infection [30]. The decrease in antimicrobial use is a direct and foreseeable effect of reduced infections, thus decreasing the level of selective pressure of antimicrobial resistance, which is a significant threat to the health of the population, both on an international and a national scale [31]. This mechanistic association has empirical evidence at the ward level, with a negative correlation being highly significant, whereby a better score in IPC compliance scores is directly proportional to a better patient outcome [32].

These findings have significant clinical practice and health policy implications in Saudi Arabia, as well as in other similar settings. The research shows that the measurable positive changes in patient safety can be attained with the help of the systematic, system-wide IPC improvement program [33]. This helps in the requirement by the Saudi Center of diseases prevention and control (Weqaya) and the ministry of health to standardize and intensify the IPC programs in the country. To hospital administrators, the high statistical relationships between HAI rates, antimicrobial use, and estimated costs suggest an effective economic case to invest in the IPC infrastructure, training, and personnel [34]. The fact that the perception of the HCW towards the management and the working conditions has been improved indicates that such investments could provide significant human resource returns as well, which may positively affect the staff retention and morale. Future studies are needed on sustainability of these benefits in the long-term, cost-benefit analysis of the intervention in particular and how such bundles may be applied to other healthcare facilities in the Kingdom like primary care and long-term care facilities [35].

This research is limited in a number of ways. Though it is rigorous in a real-world context, the quasi-experimental pre-post design cannot adequately control all the unmeasured confounders or secular trends as does a randomized controlled trial. The application of one center reduces the ability to generalize the findings, but the hospital represents a large public tertiary hospital in Saudi Arabia. Moreover, the Hawthorne effect could have had some short-term effect on HCW behavior in the immediate post-implementation audit and survey. Lastly, the six months follow-up period after the intervention, as much as it is adequate in showing the initial impact, is not enough to determine the long term sustainability of the culture and behavior changes. The convergent data of clinical, survey, and economical data provide a good and unified case of success of the implemented IPC standards despite these limitations.

CONCLUSION

This paper has revealed that systematic execution of an IPC standards program bundled in a Saudi Arabian tertiary hospital had a greater effect on enhancing patient safety and resource efficiency. The research was able to achieve all research goals, with a 33.4 percent reduction in HAI incidence, significant improvement in knowledge and culture of healthcare workers, and a subsequent reduction in antimicrobial use and length of stay due to infection. The high correlation of the compliance scores, safety culture, and clinical outcomes indicates that IPC is a complex system that requires both technical compliance and favorable workplace norms. The results can be used by hospital administrators and policymakers in Saudi Arabia and other relevant environments to implement targeted IPC investments, as the results confirm that they can be evaluated and yield results. The sustainability of these gains in the long run, as well as the cost-benefit analysis of such programs, should be the subject of future research to inform a nationwide IPC strategy.

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