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An Epidemiological Assessment Of Healthcare-Associated Infections: The Impact Of Nursing Adherence To Medical Sterilization Protocols In Surgical Units

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1. Abstract

Healthcare-associated infections (HAIs), particularly surgical site infections (SSIs), remain a significant challenge in surgical units worldwide, contributing to increased morbidity, mortality, and healthcare costs. This paper presents an epidemiological assessment of HAIs in Saudi Arabian surgical settings, with a focused analysis on the critical role of nursing adherence to medical sterilization protocols. Despite Saudi Arabia's advanced regulatory frameworks, including the Central Board for Accreditation of Healthcare Institutions (CBAHI) and the General Directorate of Infection Prevention and Control (GDIPC), SSI rates remain elevated in several healthcare facilities, exacerbated by the presence of multidrug-resistant organisms such as MRSA and CRE.

Through a review of epidemiological data and current infection control practices, this study highlights the knowledge-practice gap among nursing staff that impedes effective protocol compliance. Factors such as staffing shortages, burnout, and insufficient psychological support undermine adherence, directly impacting patient outcomes. The paper argues for systemic reforms that integrate behavioral health models, enhanced training, and sustainable staffing policies to strengthen nursing compliance.

Findings emphasize that optimizing nursing adherence to sterilization protocols is essential for reducing the incidence of HAIs, improving surgical outcomes, and aligning with Saudi Vision 2030's healthcare quality objectives. This assessment underscores the necessity of combining regulatory rigor with human-centered interventions to safeguard patient safety in surgical units across the Kingdom.

2. Introduction

Healthcare-associated infections (HAIs) remain one of the most persistent and costly challenges confronting modern healthcare systems worldwide. Defined as infections acquired during the provision of healthcare services that were neither present nor incubating at the time of admission, HAIs significantly contribute to patient morbidity, mortality, prolonged hospital stays, and escalating healthcare costs [1]. Despite remarkable advancements in surgical techniques, antimicrobial therapies, and hospital infrastructure, HAIs continue to undermine patient safety, particularly within high-risk environments such as surgical units [2]. In low-, middle-, and high-income countries alike, HAIs

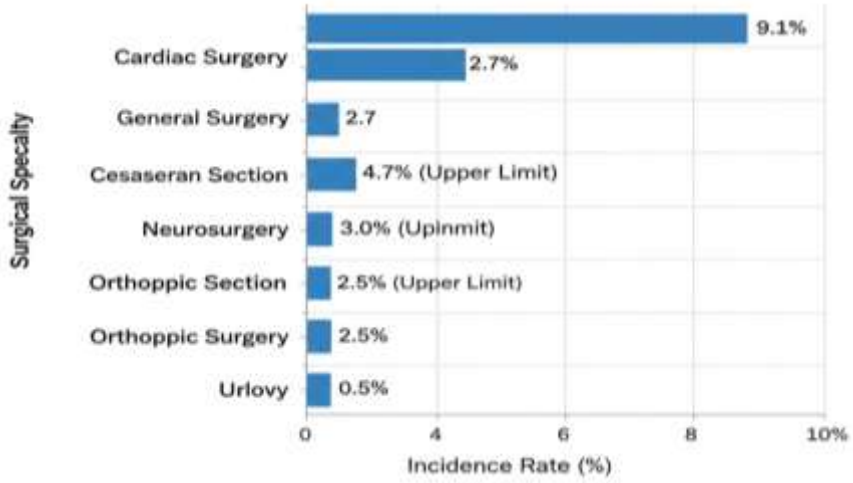
represent a critical public health concern and a key indicator of healthcare quality and system performance [3].

Within the Kingdom of Saudi Arabia (KSA), the burden of HAIs has gained increasing attention over the past decade, driven by rapid population growth, an expanding healthcare sector, and ambitious national reforms under Saudi Vision 2030. The Kingdom has invested heavily in tertiary and quaternary healthcare facilities, particularly surgical services, to meet the growing demand associated with non-communicable diseases, trauma, transplantation, and complex elective procedures [4]. While these developments have improved access to advanced care, they have simultaneously heightened the risk of HAIs, especially surgical site infections (SSIs), which remain the most frequently reported type of healthcare-associated infection in surgical settings [5].

Surgical site infections are defined as infections occurring at or near the surgical incision within 30 days of an operative procedure or within 90 days in cases involving implanted materials, as standardized by the Centers for Disease Control and Prevention (CDC) and adopted globally [6]. SSIs account for approximately 20–30% of all HAIs worldwide and are associated with up to a fivefold increase in postoperative mortality, extended hospitalization, readmissions, and substantial economic burden [7]. In the Saudi context, SSIs are estimated to represent nearly 15% of all nosocomial infections, although reported rates vary across institutions due to differences in surveillance methods, case mix, and reporting practices [8].

The epidemiology of SSIs in Saudi Arabia is shaped by a complex interplay of patient-related factors, procedural characteristics, microbial ecology, and healthcare system determinants. High rates of diabetes mellitus, obesity, cardiovascular disease, and immunosuppressive conditions among surgical patients increase susceptibility to postoperative infections [9]. Additionally, the Kingdom's healthcare workforce is characterized by considerable international diversity, with nurses, physicians, and allied health professionals originating from multiple countries with varying educational backgrounds and clinical training standards [10]. While this diversity enriches the healthcare system, it also introduces variability in infection prevention knowledge, attitudes, and practices, particularly regarding sterilization and aseptic techniques.

Figure 1: SSI Incidence Rates by Surgical Specialty (2020–2024)



Among all healthcare professionals involved in surgical care, nurses occupy a uniquely central position in the prevention of SSIs. Operating room (OR) nurses, surgical ward nurses, and infection control nurses are the primary executors of sterilization protocols, environmental cleaning, instrument processing, hand hygiene, surgical attire compliance, and maintenance of the sterile field [11]. Nursing adherence to medical sterilization protocols is therefore a critical determinant of SSI incidence and a modifiable risk factor amenable to targeted interventions. Sterilization practices encompass a broad range of activities, including proper decontamination and sterilization of surgical instruments, adherence to aseptic technique during patient preparation and intraoperative care, and compliance with evidence-based perioperative infection prevention bundles [12].

Despite the availability of comprehensive national and international guidelines, suboptimal adherence to sterilization protocols among nursing staff remains a documented concern. Studies conducted in various healthcare settings have demonstrated that gaps in compliance may arise from workload pressures, staffing shortages, inadequate training, limited access to supplies, and variations in institutional safety culture [13]. In surgical units, even minor breaches in aseptic technique can have disproportionate epidemiological consequences, facilitate microbial transmission, and increase the risk of postoperative infection [14].

In response to the growing recognition of HAIs as a threat to patient safety, the Saudi Ministry of Health (MOH) has established robust infection prevention and control (IPC) frameworks. The General Directorate of Infection Prevention and Control (GDIPC) oversees national policies, surveillance systems, and outbreak response strategies, while the Central Board for Accreditation of Healthcare Institutions (CBAHI) mandates strict compliance with IPC standards as a prerequisite for hospital accreditation [15]. These regulatory bodies emphasize the implementation of standardized sterilization protocols, continuous staff education, and performance monitoring to reduce SSI rates across healthcare facilities.

Furthermore, the Saudi National Transformation Program (NTP), a cornerstone of Vision 2030, prioritizes healthcare quality, patient safety, and value-based care. Reducing preventable HAIs, including SSIs, aligns directly with NTP objectives by improving clinical outcomes, optimizing resource utilization, and enhancing public trust in the healthcare system [16]. Within this policy framework, nursing practice is increasingly recognized as a strategic lever for achieving sustainable improvements in infection prevention outcomes.

From an epidemiological perspective, SSIs serve as both an outcome measure and a surveillance indicator reflecting the effectiveness of sterilization practices within surgical units. Epidemiological assessment of SSIs involves analyzing incidence rates, risk factors, microbial patterns, antimicrobial resistance profiles, and temporal trends [17]. In Saudi Arabia, surveillance data have identified common SSI pathogens such as Staphylococcus aureus, including methicillin-resistant strains (MRSA), Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa, underscoring the critical importance of rigorous sterilization and environmental hygiene [18].

The growing prevalence of antimicrobial-resistant organisms further complicates the SSI landscape. Inadequate sterilization practices may facilitate the transmission of multidrug-resistant organisms within surgical environments, limiting therapeutic options and increasing the severity of postoperative infections [19]. This challenge reinforces the need for strict adherence to sterilization protocols as a frontline defense against both infection transmission and antimicrobial resistance.

International evidence consistently demonstrates that high levels of nursing compliance with sterilization and IPC protocols are associated with significant reductions in SSI rates [20]. Multimodal strategies, including education, audit and feedback, leadership engagement, and safety culture promotion, have been shown to improve adherence and patient outcomes [21]. However, the transferability of these findings to the Saudi healthcare context requires careful consideration of local epidemiology, workforce characteristics, organizational structures, and cultural factors.

Despite the strategic importance of nursing adherence, there remains a relative scarcity of comprehensive epidemiological studies in Saudi Arabia that explicitly examine the relationship between nursing compliance with sterilization protocols and SSI incidence in surgical units. Existing research often focuses on overall HAI prevalence or evaluates isolated interventions without integrating epidemiological analysis with nursing practice variables [22]. This gap limits the ability of policymakers, hospital administrators, and clinical leaders to design evidence-based, context-specific interventions that target the most influential determinants of SSI risk.

Accordingly, this paper seeks to provide an in-depth epidemiological assessment of healthcare-associated infections in Saudi surgical units, with a particular focus on the impact of nursing adherence to medical sterilization protocols. By synthesizing available evidence, regulatory frameworks, and epidemiological principles, the study aims to elucidate the role of nursing practice in shaping SSI outcomes and to highlight opportunities for strengthening infection prevention strategies within the Kingdom.

In doing so, this work contributes to the broader discourse on patient safety, quality improvement, and workforce development in Saudi Arabia's rapidly evolving healthcare system. Understanding the epidemiological link between nursing adherence and SSIs is essential not only for reducing preventable

infections but also for advancing the goals of Vision 2030 by fostering a resilient, high-quality, and patient-centered healthcare environment.

3. Saudi Epidemiological Profile of Surgical Site Infections (SSIs)

Healthcare-associated infections (HAIs), particularly surgical site infections (SSIs), pose a significant threat to patient safety globally. In Saudi Arabia, SSIs are a critical component of HAIs, with a complex epidemiological profile that varies widely across surgical specialties and geographic regions. This section provides a comprehensive overview of the prevalence, incidence, and epidemiological trends of SSIs in Saudi Arabia, highlighting the challenges and underlying risk factors.

3.1 Prevalence and Incidence Rates Across Saudi Arabia

The prevalence of SSIs in Saudi Arabia is dynamic and multifactorial, with reported rates fluctuating widely depending on the type of surgery and institutional setting. According to national surveillance data compiled from 2020 to 2024, the SSI rates range from as low as 0.6% in low-risk, minor procedures to over 9% in complex surgeries, such as cardiac bypass procedures. This variation reflects differences in surgical complexity, patient comorbidities, infection prevention measures, and local microbial environments.

In a large multicenter study encompassing over 3,600 patients across tertiary hospitals in Riyadh, Jeddah, and Dammam, the overall SSI rate was calculated at 2.3%. Notably, 61.4% of these infections were diagnosed with post-discharge, underscoring the critical need for robust post-operative surveillance and patient education programs to identify and manage SSIs beyond the hospital stay.

Table 1: Prevalence and Specialty Breakdown of SSIs in Saudi Arabia (2020–2024)

Surgical Specialty	Incidence Rate (%)	Key Modifiable Risk Factors
Cardiac Surgery	9.1%	Prolonged operative time, BMI ≥ 30, Re-exploration
Orthopedic Surgery	0.55% - 2.5%	Implant contamination, lapses in manual sterilization
Cesarean Section	3.0% - 4.7%	Pre-existing diabetes, prolonged surgery duration (>1 hour)
General Surgery	2.7%	Dirty wound classification, emergency surgery status
Urology	0.5%	Indwelling catheter duration, antibiotic non-compliance
Neurosurgery	0.0% - 3.0%	CSF leak management, sterile field breaches

*Data were synthesized from national surveillance reports and peer-reviewed hospital studies.

This wide variability emphasizes the necessity for targeted infection control strategies tailored to specific surgical specialties and hospital capacities. For example, cardiac surgery patients often have multiple risk factors such as obesity and diabetes, which are exacerbated by prolonged operative times, increasing the likelihood of SSIs. In contrast, orthopedic surgery SSIs often relates to implant-associated infections and strict sterilization challenges.

3.2 Regional Disparities in SSI Rates

Saudi Arabia's vast geographic and healthcare infrastructure diversity further complicates the epidemiological landscape. Studies from the Qassim region reveal higher SSI rates in general healthcare facilities compared to specialized tertiary centers in Riyadh and Mecca. Contributing factors include variability in infection control training, resource allocation, and post-operative follow-up protocols.

Regions with more advanced healthcare infrastructure and accreditation, such as Riyadh, tend to report better outcomes, though surveillance intensity may reveal higher apparent SSI rates due to increased detection efforts. Conversely, rural and less resource areas may under-report SSIs due to lack of systematic surveillance and follow-up mechanisms.

3.3 Pathogenic Landscape and Antimicrobial Resistance (AMR)

The microbial etiology of SSIs in Saudi Arabia is characterized by an alarming prevalence of multidrug-resistant organisms (MDROs), complicating both prophylaxis and treatment. Data from tertiary care hospitals indicate Staphylococcus aureus as the most common pathogen, constituting 44.4% of isolates. Alarmingly, 40.5% of these isolates are methicillin-resistant Staphylococcus aureus (MRSA), necessitating the use of advanced antibiotics such as vancomycin or linezolid. Gram-negative pathogens, including Escherichia coli (13.6%) and Pseudomonas aeruginosa (12.9%), are also frequent contributors to SSIs. Among these, extended-spectrum beta-lactamase (ESBL) producing E. coli shows resistance rates exceeding 58%, with ciprofloxacin resistance approaching 42.5%, severely limiting oral treatment options.

Table 2: Antimicrobial Resistance Patterns in Saudi Surgical Units (2024)

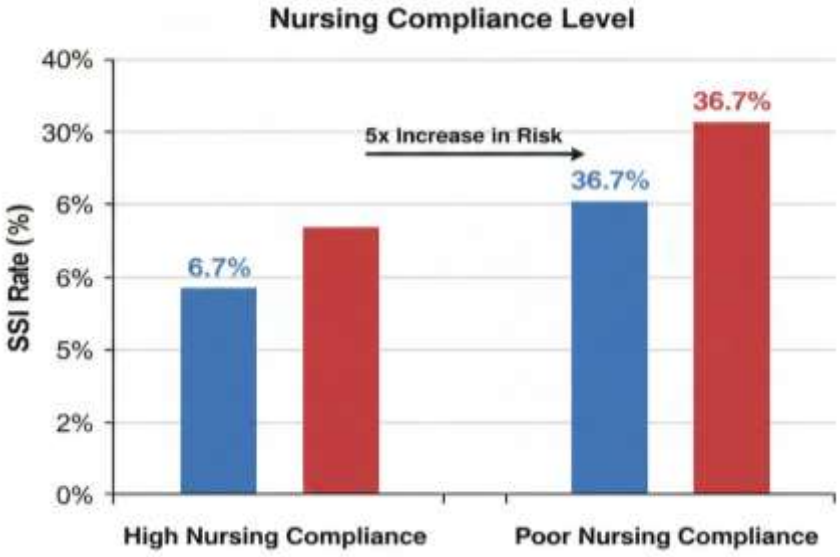
Pathogen	Resistance Profile	Clinical Implications
Staphylococcus aureus	40.5% MRSA	Requires vancomycin/linezolid prophylaxis
Escherichia coli	58.7% ESBL; 42.5% ciprofloxacin resistance	Limits oral step-down options
Klebsiella spp.	45.7% Carbapenem-resistant (CRE)	High mortality risk; requires aminoglycosides
Acinetobacter	19.6% multidrug-resistant (MDR)	Often linked to orthopedic implant failures
Candida auris	Emerging pathogen (29.9% of outbreaks)	Requires stringent environmental decontamination

This increasing antimicrobial resistance underscores the urgent need for effective infection prevention practices, including meticulous sterilization protocols and judicious antibiotic stewardship in surgical units. The rise of resistant pathogens directly correlates with treatment failures, prolonged hospital stays, and increased healthcare costs.

4. The Impact of Nursing Adherence to Protocols in Preventing SSIs

Nursing staff are pivotal in preventing healthcare-associated infections, especially in surgical units, where sterile technique and infection control are paramount. Nursing adherence to medical sterilization protocols represents one of the most modifiable and impactful factors in reducing SSI incidence.

Figure 2: The "Final Barrier": Nursing Compliance vs. SSI Incidence



4.1 Quantitative Impact of Compliance on SSI Rates

Empirical evidence demonstrates a stark contrast in SSI rates between high and low nursing compliance groups. Proper adherence to sterilization protocols—including hand hygiene, personal protective

equipment (PPE) use, and instrument sterilization—is associated with a significantly lower SSI rate of approximately 6.7%. Conversely, poor compliance is linked to SSI rates as high as 36.7%, a more than fivefold increase in risk. This data positions nursing adherence as the "final barrier" against microbial transmission in surgical environments. Failure in this critical safety barrier allows pathogenic organisms to colonize surgical sites, directly leading to infection.

4.2 Understanding the Knowledge-Practice Gap Among Nurses

Despite relatively high knowledge, attitude, and practice (KAP) scores among Saudi nurses, a paradox exists between theoretical understanding and practical adherence to protocols. For example, a recent study revealed that 71% of surgical nurses demonstrated “good compliance” with infection prevention and control (IPC) practices, yet only 39.4% exhibited “moderate to high knowledge” of the underlying IPC guidelines. This suggests many nurses may adhere to protocols by rote habit or institutional enforcement rather than through a comprehensive understanding of the epidemiological rationale. Such a gap may reduce motivation and flexibility in applying protocols, especially under stress or high workload.

Table 3: Nursing KAP Levels Across Saudi Regions (2020–2024)

Region/Cohort	Knowledge Score (%)	Practice Score (%)	Key Adherence Determinants
Qassim (General HCW)	67.6%	73.2%	Training frequency, >6 years experience
Mecca (Specialized Ward)	High	Subpar	Workload pressure, infrequent training
Riyadh (CSSD Staff)	57.4%	55.6%	Educational level, prior exposure
National (Students/New)	Improved post-workshop	Variable	Institutional support, mentoring

4.3 Barriers to Nursing Adherence

Several systemic and organizational barriers hinder consistent nursing compliance with sterilization protocols:

- Staffing shortages and high patient-to-nurse ratios increase workload and reduce time for adequate aseptic practices.
- Burnout and cognitive overload reduce vigilance in protocol adherence.
- Resource inconsistencies, including inadequate sterile supplies or faulty sterilization equipment.
- Insufficient ongoing training and mentoring to reinforce updated guidelines.

5. Medical Sterilization Protocols: The Technical Standard in Saudi Arabia

In Saudi Arabia, medical sterilization protocols in surgical units are governed by the Saudi Ministry of Health (MOH) under the GCC Infection Prevention and Control Manual (3rd Edition), aligning with international standards from WHO and CDC.

5.1 Spaulding Classification and Device Reprocessing

Medical devices and instruments are categorized according to the Spaulding Classification:

Figure 3: Conceptual Framework for Improving Adherence

- Critical items: Instruments like scalpels and forceps that enter sterile tissue must undergo sterilization by autoclaving at 121–134°C.

- Semicritical items: Devices contacting mucous membranes, e.g., endoscopes, require high-level disinfection with agents such as 2% glutaraldehyde.
- Noncritical items: Instruments contacting intact skin require low-level disinfection.

5.2 Sterilization Verification and Validation

Nurses in surgical units play a key role in verifying sterilization:

- Physical monitoring of sterilization parameters (time, temperature, pressure).
- Use of chemical indicators (Type 5 or 6) to confirm sterilization efficacy.
- Use of biological indicators (e.g., Geobacillus stearothermophilus spores) to ensure microbial kill before instrument use.

These multi-level verification processes ensure patient safety by preventing the use of inadequately sterilized instruments.

6. Economic Ramifications of Sterile Failures in Saudi Arabia

Healthcare-associated SSIs impose high direct and indirect costs on the Saudi healthcare system.

6.1 Direct Treatment Costs

SSI treatment often requires extended hospitalization, additional surgeries, and costly antimicrobial regimens. For instance, in coronary artery bypass graft (CABG) patients in Saudi Arabia, the attributable cost per SSI-infected patient is estimated at approximately 38,000 SAR due to prolonged length of stay (LOS).

Table 4: Comparative Costs of SSI-Related Interventions in Saudi Arabia (SAR)

Component of Care	Average Cost (SAR)	Clinical Impact
Additional LOS (9.3 days)	38,000	Prolonged hospital stays
Antimicrobial Therapy	3,300	Use of carbapenems/amikacin
Negative Pressure Wound Therapy (V.A.C.)	4,700	Enhanced wound healing
Surgical Debridement	32,000	Return to OR for infection control

6.2 National Economic Burden and Infection Control Investment

Beyond individual patient costs, the cumulative national burden of HAIs is estimated between $1 and $10 billion annually. Saudi Arabia's "Safe Supply Chain for Infection Control" (SSIC) initiative focuses on standardizing procurement and quality assurance of sterile supplies to reduce infection rates and associated costs.

7. Systemic Barriers to Nursing Adherence

Despite clear protocols and training, systemic issues persist:

- Staff shortages result in nurse-to-patient ratios exceeding 1:4, increasing adverse outcomes.
- Burnout prevalence is high (67.2%), impairing attention to sterile technique.
- Resource inconsistency leads to equipment downtime and insufficient sterile supplies.
- Training gaps exist, with many nurses reporting lack of formal SSI prevention education.

8. National Strategies and the Vision 2030 Framework

Saudi Arabia's Vision 2030 healthcare transformation emphasizes infection prevention and control through multi-level accountability.

8.1 Role of CBAHI and ESR

The Central Board for Accreditation of Healthcare Institutions (CBAHI) enforces Essential Safety Requirements (ESR), including mandatory IPC standards. Accreditation correlates positively with improved staff compliance.

8.2 Basic Infection Control Skills License (BICSL)

BICSL mandates regular certification of healthcare workers in hand hygiene, PPE use, and biological spill management to maintain competency in IPC practices.

8.3 GDIPC Monitoring and Targets

The General Directorate of Infection Prevention and Control (GDIPC) conducts national audits. In 2023, the overall IPC compliance was 84.49%, with targeted goals to reduce specific SSI rates by 20% by 20% by 2025.

9. Theoretical Framework: The Health Belief Model (HBM) in Nursing Practice

The Health Belief Model (HBM) offers a psychological basis for improving nursing adherence by targeting perceptions and motivations related to SSI prevention.

HBM Construct	Nursing Application	Improvement Strategy
Perceived Susceptibility	Nurses' belief in patient SSI risk	Real-case reviews and testimonials
Perceived Severity	Understanding morbidity/mortality risks	Statistical feedback on costs & outcomes
Perceived Benefits	Belief in effectiveness of sterilization	Evidence-based training and bundles
Perceived Barriers	Discomfort, time constraints	Workflow optimization and resources
Self-Efficacy	Confidence in aseptic technique	Hands-on simulation and mentoring

Intervention programs using HBM-based education have improved nursing adherence scores by nearly 7%, highlighting the value of ongoing, psychologically informed training.

10. Conclusion

This epidemiological assessment underscores the significant impact of healthcare-associated infections (HAIs), particularly surgical site infections (SSIs), within surgical units in Saudi Arabia. Despite the Kingdom's robust healthcare regulatory framework, exemplified by the efforts of the Central Board for Accreditation of Healthcare Institutions (CBAHI) and the General Directorate of Infection Prevention and Control (GDIPC), the persistent rates of SSIs—reaching up to 9.1% in some surgical units—highlight the ongoing challenges in translating policy into consistent clinical practice.

Central to these challenges is the role of nursing adherence to medical sterilization protocols, which serves as a critical frontline defense in preventing HAIs. The epidemiological data reveal not only a high burden of infections but also a troubling prevalence of multidrug-resistant organisms such as Methicillin-resistant Staphylococcus aureus (MRSA) and Carbapenem-resistant Enterobacteriaceae (CRE). These pathogens increase the complexity of infection control and intensify the consequences of protocol breaches, underscoring the immense stakes tied to nursing compliance.

The findings emphasize that mere knowledge of sterilization procedures is insufficient without addressing the systemic and human factors that influence adherence. Nursing burnout, suboptimal staffing ratios, and workplace stress significantly contribute to lapses in protocol implementation, creating a "knowledge-practice gap" that jeopardizes patient safety. Therefore, improving adherence requires a multidimensional approach, including enhanced psychological reinforcement models such as the Health Belief Model (HBM) to foster motivation and behavioral change among nursing staff.

Moreover, sustaining and elevating the Saudi healthcare system's performance demands continuous reinforcement of the BICSL licensing standards and integration of infection control practices into broader national health goals, including Saudi Vision 2030. By aligning these regulatory and strategic initiatives with frontline nursing practices, the Kingdom can achieve substantial reductions in the incidence of HAIs, thereby minimizing both the clinical and economic burdens associated with SSIs.

In conclusion, this epidemiological assessment confirms that nursing adherence to medical sterilization protocols is a pivotal determinant in the prevention of HAIs within surgical units. Strengthening this adherence through systemic reforms, education, and psychological support will not only safeguard surgical patients but will also enhance the overall quality and safety of healthcare delivery in Saudi

Arabia. Continued research, surveillance, and policy refinement are essential to sustain progress and ensure that every surgical intervention aligns with the highest standards of infection control, ultimately improving patient outcomes and public health across the Kingdom.

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