Infection and Drug Resistance

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ORIGINAL RESEARCH

Applying Value-Based Healthcare Principles in Optimizing Post-Operative Oral Antibiotic Prophylaxis: A Pre-Post Intervention Study in a Single Center in Saudi Arabia

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Background: Routinely continuing postoperative antibiotic prophylaxis beyond 24 hours runs against global standards and increases the risk of antimicrobial resistance (AMR). This study explored the effect of Value-Based Healthcare (VBHC)-influenced antimicrobial stewardship program (ASP) activities on postoperative oral antibiotic prescription at a tertiary hospital in Saudi Arabia. The Health Sector Transformation Program aims to shift the healthcare service in Saudi Arabia to value-based service by implementation of VBHC models. The intervention performed in SGH-Hail support the Vision 2030 objective of Saudi Arabia. VBHC is based on the premise that healthcare value should be measured by the health outcomes achieved relative to the cost (in dollars) incurred rather than by the number of services (volume) delivered.

Methods: This pre-post design intervention study was conducted at the Saudi German Hospital in Hail. Data were obtained from all surgical patients (elective and emergency, analyzed jointly) both pre- and post-implementation of a fully VBHC-focused stewardship program that included educational activities, mandatory documentation, prospective audits and feedback, clinical decision support, and multidisciplinary stewardship. The primary outcome was the proportion of patients who received postoperative oral antibiotics beyond 24 hours of prophylaxis. Effect sizes were quantified using the Odds Ratio (OR) and Absolute Risk Reduction (ARR) with 95% confidence intervals.

Results: A total of 4,103 surgical patients were analyzed (pre-VBHC: n=633; post-VBHC: n=3,470). Post-operative antibiotic prescribing decreased significantly from 75.9% to 15.9% following implementation ($p<0.001$), with an OR of 0.060 (95% CI: 0.049–0.074) and an ARR of 60.0 percentage points. Documentation of clinical justification improved from 1.0% to 88.6% ($p<0.001$). The intervention effect was consistent across all major surgical departments (all $p<0.001$) and both genders. Surgical site infection rates remained below institutional and international benchmarks throughout the study period.

Conclusion: The application of VBHC principles led to a clinically and statistically significant reduction in unnecessary postoperative antibiotic prescriptions (OR 0.060; ARR 60.0 percentage points) and a marked increase in guideline compliance. The components of this intervention provide a framework that other healthcare organizations can implement to make surgical prophylaxis practices evidence-informed.

Keywords: value-based healthcare, surgical prophylaxis, postoperative antibiotics, antimicrobial stewardship, quality improvement, Saudi Arabia

Introduction

The domain of Value-Based Healthcare (VBHC) is reshaping modern medicine by redefining how healthcare systems measure success and how resources are distributed and managed. According to Porter and Teisberg, VBHC is based on the premise that healthcare value should be measured by the health outcomes achieved relative to the cost (in dollars)

https://doi.org/10.2147/IDR.S595284
Received: 10 February 2026
Accepted: 29 April 2026
Published: 7 May 2026

incurred rather than by the number of services (volume) delivered.[1,2] Porter is the pioneer of this concept and articulated a three-tier outcomes hierarchy that includes health status achieved, the recovery process, and sustainable health. These principles resonate well with infection prevention and optimization of antimicrobials.[3] The value-based approach has gained traction worldwide. However, the application of value-based principles to antimicrobial stewardship programs (ASP) has been documented very rarely. VBHC principles can be applied to surgical antibiotic prophylaxis.[4,5]

The impact of AMR is especially concerning in Saudi Arabia. Zowawi described frightening resistance rates of 32% methicillin-resistant *Staphylococcus aureus* (MRSA) prevalence, extended-spectrum beta-lactamase (ESBL) rates of 29% in *Escherichia coli*, 65% in *Klebsiella pneumoniae*, and a drastic reduction of *Acinetobacter baumannii* carbapenem susceptibility, from 64–81% in 2006 to only 8–11% by 2012.[6] However, a national survey found that, by 2017, only 26% of Saudi Ministry of Health hospitals had ASP, and 82% had no knowledge of how to implement them.[7]

Saudi hospitals have shown gaps in the application of surgical prophylaxis across a range of studies, with inappropriate antibiotic selection and extended duration.[8,9] Alghamdi et al showed that during 2020, 82.4% of the surgical patients received systemic antibiotics. Ceftriaxone (28.44%) and metronidazole (26.36) were the most prescribed antibiotics. Only 1.08% of the patients received antibiotics for 24 hours. The study also found that most of the patients received antibiotics for seven days or for five days, and only 1.08% of the patients received antibiotics appropriately for a maximum of one day.[8]

Aspects of antimicrobial prophylaxis, as noted by the Centers for Disease Control and Prevention (CDC), American Society of Health-System Pharmacists (ASHP), Infectious Disease Society of America (IDSA), need to be limited to 24 hours after the end of every surgical procedure.[10,11] The CDC's 2017 guidance on preventing surgical site infections does not recommend prescribing any additional systemic prophylactic antimicrobial medication after the surgical wound has been closed, even when drains are left in place.[12] The World Health Organization (WHO) concluded that prophylactic antimicrobial use beyond 24 h provides no more clinical benefit.[13,14] The 2022 Global Burden of Disease study found AMR to be one of the top killers in the world, with 4.95 million deaths due to bacterial AMR in 2019 alone.[15] In addition to the above AMR deaths, there is a real danger to many patients from the unnecessary antibiotics that will be used.[16]

Branch-Elliman and others showed that extended periods of surgical prophylaxis fail to protect against surgical site infections but do lead to dose-dependent increases in acute kidney injury (aOR 1.72 at 48–72 hours).[17] Additionally, Tamma et al reported that 20% of hospitalized patients experienced antibiotic-associated adverse events.[18]

A systematic review of 221 studies found that stewardship interventions increased guideline compliance from 43 to 58% and reduced the hospital length of stay.[19] Moreover, a meta-analysis revealed a 35% reduction in mortality (RR 0.65; 95% CI 0.54–0.80) with guideline-adherent empiric therapy.[20] The CDC Core Elements of Hospital Antibiotic Stewardship Programs provide an operational framework that incorporates leadership and management commitment, accountability, pharmacy and clinical expertise, interventions, monitoring and feedback, and education.[21] Multicomponent strategies that include education, audit, feedback, and documentation have been particularly effective because education alone often leads to temporary changes.[22]

At the Saudi German Hospital in Hail, Saudi Arabia, a preliminary audit revealed a pattern of prescribing postoperative oral antibiotics for 5–7 days in the absence of infection or clinical indications, which contradicted international guidelines and presented an opportunity for VBHC-driven improvement. Therefore, the primary objective of this study was to assess the impact of implementing VBHC principles on postoperative oral antibiotic prophylaxis. The secondary objectives were to evaluate surgeons' compliance with guidelines during the postoperative recovery phase, as evidenced by antibiotic documentation, and to assess the consistency of the intervention effects across surgical specialties and patient populations.

Methods

Study Design

The study design is a pre-post intervention. This study started from July 2023 to September 2025. The pre-VBHC implementation period started from July 2023 to November 2023. The post-VBHC implementation period started from

December 2023 till September 2025. The aim of the study is to examine the implementation of VBHC principles in postoperative oral antibiotic prescribing practices. This study examined the outcomes of VBHC-based ASP implementation with respect to antibiotic prescribing patterns and guideline adherence, both pre- and post-implementation. This study design is best suited because it enables the evaluation of intervention effects in a real-world setting, accounting for the organization's environment and established practice patterns.

Study Setting

This study was conducted at the Saudi German Hospital in Hail, Kingdom of Saudi Arabia. This is a tertiary care facility with an extensive surgical practice in multiple disciplines, including General Surgery, Obstetrics and Gynecology, Orthopedic Surgery, Ear, Nose, and Throat (ENT), Urosurgery, Plastic Surgery, Neurosurgery, Dental Surgery, Vascular Surgery, Bariatric Surgery, and Pediatric Surgery. The hospital serves a diverse population in Hail and the surrounding regions. All surgical procedures, including both elective and emergency cases, regardless of complexity or infection risk category, were covered.

Study Population

The study population comprised all patients who underwent surgery at the hospital before and after the intervention. Both elective (scheduled) and emergency (unscheduled) cases were included and analyzed jointly as a single cohort, as the international guideline recommendation to limit surgical antibiotic prophylaxis to 24 hours applies equally regardless of surgical urgency classification. The inclusion criteria were as follows: (1) patients of all ages undergoing elective or emergency surgical procedures; (2) patients with documentation of postoperative antibiotic prescription in their medical records; and (3) procedures performed in all surgical departments. The exclusion criteria were as follows: (1) patients with documented preoperative infections who were on therapeutic (non-prophylactic) antibiotics; (2) patients with incomplete medical records on antibiotic prescribing status or the intervention period; and (3) patients who were transferred to another healthcare institution before postoperative review on their antibiotic status could be entirely done.

Intervention Description

The ASP intervention driven by VBHC was multifaceted. It was designed to improve and align postoperative antibiotic prescribing with international guidelines from the American Society of Health-System Pharmacists (ASHP) and the Infectious Diseases Society of America (IDSA), which recommend limiting surgical antibiotic prophylaxis to 24 hours after surgery in most situations. However, the intervention comprised five components. First, educational activities conducted by clinical pharmacists on monthly bases included ASHP Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery, Saudi Ministry of Health antibiotics surgical prophylaxis guidelines, Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017 on the duration of surgical prophylaxis, the risks of unnecessary antibiotics (eg., antimicrobial resistance [AMR], Clostridium difficile infection, and adverse drug reactions), and value-based health care principles, which were taught to surgeons, surgical residents, pharmacists and nursing staff members. Second, documentation of clinical justification for extended postoperative antibiotic orders by physicians in the pharmacy remarks of the antibiotic order on the health information system was mandated, thereby creating accountable and active documentation of the clinical rationale supporting the examination of prescription appropriateness. Third, an audit-and-feedback system was established to facilitate the reporting of departmental antibiotic prescriptions against benchmarks and peers and to improve the consistency of audit-and-feedback data, the data was discussed in the ASP committee every quarter. Monthly report was disseminated by Email for each surgical department every quarter. Fourth, clinical decision support (CDS) tools were integrated into the electronic prescribing system as medical reference platform (UpToDate), used by physicians and pharmacists. An alert for discharge medications is generated by an electronic system to facilitate pharmacist audit on antibiotic orders. Fifth, an ASP committee was formed, comprising an infectious disease specialist, clinical pharmacist, surgeon, infection prevention practitioner, and a representative from hospital administration, to manage the ASP and maintain active solutions to barriers to continued program engagement.

https://doi.org/10.2147/IDR.S595284

A multidisciplinary VBHC team was created to guide and monitor the VBHC process including Medical Director, Quality and Patient Safety Director, Pharmacy Director, Clinical Pharmacists, Inpatient Pharmacy Supervisor, Surgery Head of Department, and several surgical specialties. Internal MEMO from the Medical Director that post-operative antibiotics either oral or IV for more than 24 hours will not be dispensed without a written justification in the physician order. Quality and Patient Safety Director align the project with the national standards such as Saudi Central Board for Accreditation of Healthcare Institutions, and the International frameworks eg., Joint Commission International, and guided the use of FOCUS-PDCA Model for the project. Pharmacy Director ensures appropriate implementation of the projects and collaboration of all departments. Clinical pharmacists rule include orientation for physicians and pharmacists about the surgical antimicrobial prophylaxis guidelines, and coordination of the ASP committee. Inpatient supervisor rule include enforcement of strict implementation of the antibiotic prescription guidelines. Surgery Head of Department rule is to discuss the report of the departmental antibiotic prescriptions against benchmarks, and all the surgical site infection cases.

Data Collection

Data were collected by trained data extractors using a standardized template to retrospectively extract data from the electronic medical records and pharmacy dispensing systems. The collected data included a unique patient identifier (later anonymized), demographic data (sex), surgical department, intervention time frame classification (pre-VBHC or post-VBHC), postoperative antibiotic prescription (yes/no), and clinical justification for antibiotic prescription (yes/no). Data quality was assessed through double-entry verification of every tenth record.

Outcome Measures

The primary outcome was the percentage of patients who underwent surgery and received postoperative oral antibiotics beyond the 24-hour surgical prophylaxis cutoff. This outcome directly assessed the alignment of care with the ASHP and Infectious Diseases Society of America (IDSA) guidelines, the primary focus of the VBHC intervention. The secondary outcomes included (1) the determination of the absence or presence of clinical justification in antibiotic prescriptions, documentation of compliance guidelines, and prompt post-operative antibiotic prescribing, which was a measure of prescribers' evidence-based clinical decisions. (2) The effect of the intervention was consistent across all surgical departments. (3) The effect of the intervention was consistent in different demographic groups according to the patient's sex to validate the findings.

Statistical Analysis

All statistical analyses were performed using SAS 9.4. Elective and emergency surgical cases were pooled and analyzed jointly, as the 24-hour prophylaxis guideline applies irrespective of surgical urgency; no separate stratification by urgency classification was performed. Categorical variables were presented numerically and as percentages. We used the chi-square (χ^2) test to compare categorical variables between the groups before and after the adoption of the VBHC model. For the primary outcome, several measures were used to quantify the effects of interventions: absolute risk reduction (ARR) as the difference between the pre- and post-intervention rates of antibiotic prescribing; relative risk reduction (RRR), calculated using the formula RRR = (ARR / pre-intervention rate) × 100, which expresses the proportional reduction in antibiotic prescribing relative to the baseline rate; odds ratio (OR), and 95% confidence intervals (CIs) calculated using standard approaches for 2×2 contingency tables; and the number needed to treat (NNT) calculated as the inverse of the ARR. The handling of missing data extended beyond simple case exclusion. During data collection, double-entry verification of every tenth record was conducted to minimize data entry errors. Records were excluded only when critical outcome variables (antibiotic prescribing status or intervention period classification) were missing and could not be ascertained from alternative fields in the electronic medical record or pharmacy dispensing system. Exclusion occurred in two stages: first, 48 of 4,151 records (1.2%) were excluded for missing intervention period classification; subsequently, an additional 358 records were excluded from the primary outcome analysis owing to missing antibiotic prescribing status data, yielding 3,745 patients for the primary analysis. Sensitivity analysis was not performed, as the overall proportion of excluded records was small and unlikely to alter the conclusions. We made the initial plans for the surgery department and patient sex for subgroup analysis. Departments for specialty-level analyses were limited to those with sufficient patient samples (n ≥ 5 per study period) to maintain statistical significance. We assumed that all statistical tests were two-tailed. A p-value ≤ 0.05 was considered statistically significant.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and the local regulations. The study protocol was scrutinized, and approval was granted by the Research Ethics Committee (REC) of the University of Hail, Kingdom of Saudi Arabia, on 8/12/2025 (number H-2025-1002). Due to the retrospective data collection, the nature of the intervention, which is a quality improvement initiative, and the fact that the data had been fully anonymized, the IRB waived the requirement to obtain informed consent from the individual patients. Patient data were obtained and processed in accordance with applicable data protection regulations, and patient confidentiality was preserved at all stages of the study. Patient identifiers were replaced with study IDs, and the data were stored in a secure location accessible only to study personnel authorized to access them.

Results

Study Population and Baseline Characteristics

Initially, 4,151 surgical patient records were reviewed for this study. After excluding 48 records with missing intervention period data, 4,103 patients were included in the final analysis. Of these, 633 patients (15.4%) underwent surgery during the pre-VBHC implementation period, whereas 3,470 patients (84.6%) were treated during the post-VBHC implementation period. The larger sample size in the post-intervention period reflects the extended duration of data collection following the implementation of the VBHC of ASP at Saudi German Hospital in Hail. The ASP committee mandated the implementation of the VBHC interventions in December 2023 due to the escalation in the cost of the unjustified antibiotic prescriptions. In the pre- VBHC phase data collection and analysis were conducted over a 5- month period. Prescription patterns and costs of unjustified antibiotics prescription baseline metrics were established. In the Post-VBHC Phase, an intentional extended observation was conducted to capture long term sustainability in the VBHC model resulting in a larger sample size. The second phase focused on monitoring the physician prescribing compliance to guidelines, long term adherence to the stewardship guidelines, and the SSI rate. However, Baseline demographic characteristics were comparable between the two study periods (Table 1). Among patients with documented gender information, females comprised 54.0% (n = 307) and 50.7% (n = 1,672) of patients in the pre-VBHC and post-VBHC cohorts, respectively. Males represented 46.0% (n = 261) and 49.3% (n = 1,623) in the pre- and post-VBHC groups, respectively. The chi-square test revealed no statistically significant difference in gender distribution between the two periods (χ^2 = 1.989, df = 1, p = 0.158), indicating that the study groups were well balanced with respect to patient sex.

The distribution of surgical procedures across the departments is presented in Table 2. General Surgery was the most common surgical specialty in both periods, accounting for 34.4% (n = 218) and 34.7% (n = 1,205) of procedures in the pre- and post-VBHC periods, respectively. Obstetrics and Gynecology was the second most frequent department, representing 27.5% (n = 174) of pre-VBHC cases and 22.9% (n = 793) of post-VBHC cases. Other major contributing departments included Orthopedic Surgery (13.6% vs. 15.0%), Otolaryngology (8.8% vs. 6.7%), and Urology (6.2% in both periods). The chi-square test of departments with cases in both periods showed no significant difference in surgical

Table 1 Baseline Demographic Characteristics of Surgical Patients.

Characteristic	Pre-VBHC (n = 633)	Post-VBHC (n = 3,470)	p-value
Gender, n (%)	n = 568	n = 3,295	0.158
Female	307 (54.0)	1,672 (50.7)	
Male	261 (46.0)	1,623 (49.3)	

Notes: The chi-square test was used to compare categorical variables. Missing gender data: Pre-VBHC n = 65; Post-VBHC n = 175.
Abbreviation: VBHC, Value-Based Healthcare.

Table 2 Distribution of Surgical Procedures by Department

Surgical Department	Pre-VBHC, n (%)	Post-VBHC, n (%)
General Surgery	218 (34.4)	1,205 (34.7)
Obstetrics and Gynecology	174 (27.5)	793 (22.9)
Orthopedic Surgery	86 (13.6)	519 (15.0)
Ear, Nose, and Throat	56 (8.8)	234 (6.7)
Urosurgery	39 (6.2)	215 (6.2)
Plastic Surgery	31 (4.9)	178 (5.1)
Neurosurgery	19 (3.0)	97 (2.8)
Dental Surgery	6 (0.9)	56 (1.6)
Pediatric Surgery	4 (0.6)	11 (0.3)
Vascular Surgery	0 (0.0)	99 (2.9)
Bariatric Surgery	0 (0.0)	22 (0.6)
Other*	0 (0.0)	41 (1.2)
Total	633 (100.0)	3,470 (100.0)

Notes: *Other includes Dental Surgery Pediatric (n = 34), ICU (n = 2), and Neurology (n = 5).
Chi-square test for common departments: χ^2 = 10.522, *df* = 8, p = 0.230.

case distribution (χ^2 = 10.522, df = 8, p = 0.230), indicating that the surgical case mix remained consistent across intervention periods.

Primary Outcome: Post-Operative Antibiotic Prescribing

The primary outcome analysis included 3,745 patients with complete antibiotic prescription data (619 pre-VBHC and 3,126 post-VBHC). The implementation of VBHC principles resulted in a dramatic and statistically significant reduction in postoperative oral antibiotic prescriptions (Table 3). Before the intervention, 470 of 619 patients (75.9%) received postoperative oral antibiotics beyond the recommended 24-hour prophylaxis window. Following VBHC implementation, this rate decreased substantially to 498 of 3,126 patients (15.9%). Moreover, the chi-square analysis demonstrated a highly significant difference between the two periods (χ^2 = 967.279, df = 1, p < 0.001). The magnitude of this effect was substantial, with an ARR of 60.0 percentage points and RRR of 79.0%, the latter calculated as (ARR / pre-intervention rate) × 100 = (60.0 / 75.9) × 100. The OR for receiving postoperative antibiotics in the post-VBHC period compared to the pre-VBHC period was 0.060 (95% CI: 0.049–0.074). This OR was derived from the standard 2×2 contingency table comparing antibiotic receipt (yes/no) across the two study periods using logistic regression-equivalent calculations. An OR of 0.060 corresponds to a 94% reduction in odds, computed as (1 − OR) × 100 = (1 − 0.060) × 100 = 94%. It is important to note that this figure represents a reduction in odds rather than in risk (relative risk), given that the

Table 3 Post-Operative Oral Antibiotic Prescribing Patterns (Primary Outcome)

Outcome Measure	Pre-VBHC (n = 619)	Post-VBHC (n = 3,126)	p-value
Antibiotic prescribing, n (%)			<0.001
Received antibiotics	470 (75.9)	498 (15.9)	
No antibiotics prescribed	149 (24.1)	2,628 (84.1)	

Notes: Chi-square test: χ^2 = 967.279, *df* = 1, p < 0.001. Missing data on antibiotics were excluded from the analysis.

Table 4 Effect Size Analysis: Reduction in Post-Operative Antibiotic Use

Parameter	Value (95% CI)
Pre-VBHC antibiotic prescribing rate	75.9%
Post-VBHC antibiotic prescribing rate	15.9%
Absolute risk reduction (ARR)	60.0 percentage points
Relative risk reduction (RRR)	79.0%
Odds Ratio (Post-VBHC vs. Pre-VBHC)	0.060 (0.049–0.074)
Number needed to treat (NNT)	1.67

Notes: ARR = Pre-rate − Post-rate; RRR = (Pre-rate − Post-rate)/Pre-rate × 100; NNT = 1/ARR. CI, confidence interval.

OR and relative risk diverge when the outcome prevalence is high, as in the present study where the baseline rate was 75.9%. The OR provides a valid measure of association from the contingency table analysis and should be interpreted as follows: following the VBHC intervention, the odds of a patient receiving unnecessary postoperative antibiotics were 94% lower compared to the pre-intervention period. The NNT, calculated as the inverse of the ARR (1/0.600), was 1.67, indicating that for approximately every 2 patients managed under the VBHC-driven ASP, one fewer patient received unnecessary postoperative antibiotics (Table 4).

Secondary Outcome: Guideline Compliance and Documentation

A total of 691 patients with complete justification data were included in this analysis (201 pre-VBHC and 490 post-VBHC patients). The results demonstrated remarkable improvements in documentation practices following the VBHC intervention (Table 5). However, in the pre-VBHC period, only 2 of 201 patients (1.0%) who received antibiotics had documented clinical justification for prescription. This increased dramatically to 434 of 490 patients (88.6%) during the post-VBHC period. The chi-square test confirmed that this difference was highly statistically significant (χ^2 = 465.727, df = 1, p < 0.001).

Subgroup Analysis by Surgical Department

To evaluate the consistency of the intervention effect across surgical specialties, subgroup analyses were performed for departments with adequate sample sizes (n ≥ 5 in both periods), as presented in Table 6. The VBHC intervention significantly reduced antibiotic prescriptions across all major surgical departments. However, the most substantial reductions were observed in neurosurgery, where antibiotic prescribing decreased from 88.9% (16/18) to 12.5% (12/96), representing an absolute reduction of 76.4 percentage points (p < 0.001). Similarly, the Ear, Nose, and Throat department showed a decrease from 94.6% (53/56) to 20.7% (48/232), with an absolute reduction of 74.0 percentage points (p < 0.001). Moreover, General Surgery, the largest department by volume, showed a reduction from 89.3% (184/206) to 23.9% (235/983), representing a 65.4 percentage-point absolute reduction (p < 0.001). While Obstetrics and Gynecology showed a comparable pattern, the prescribing rates decreased from 80.5% (140/174) to 16.0% (122/762), representing an absolute reduction of 64.4 percentage points (p < 0.001). Furthermore, in Orthopedic Surgery, the

Table 5 Guideline Compliance: Documentation of Antibiotic Justification

Documentation Status	Pre-VBHC (n = 201)	Post-VBHC (n = 490)	p-value
Documented justification present	2 (1.0)	434 (88.6)	<0.001
No documented justification	199 (99.0)	56 (11.4)	

Notes: Analysis restricted to patients who received post-operative antibiotics. Chi-square test: χ^2 = 465.727, *df* = 1, p < 0.001.

https://doi.org/10.2147/IDR.S595284

Table 6 Subgroup Analysis: Post-Operative Antibiotic Use by Surgical Department

Department	Pre-VBHC n/N (%)	Post-VBHC n/N (%)	ARR (%)	p-value
Neurosurgery	16/18 (88.9)	12/96 (12.5)	76.4	<0.001
ENT	53/56 (94.6)	48/232 (20.7)	74.0	<0.001
General Surgery	184/206 (89.3)	235/983 (23.9)	65.4	<0.001
Obstetrics/Gynecology	140/174 (80.5)	122/762 (16.0)	64.4	<0.001
Dental Surgery	5/6 (83.3)	15/45 (33.3)	50.0	0.056
Orthopedic Surgery	44/86 (51.2)	23/504 (4.6)	46.6	<0.001
Urosurgery	14/39 (35.9)	13/197 (6.6)	29.3	<0.001
Plastic Surgery	12/30 (40.0)	16/148 (10.8)	29.2	<0.001

Notes: Only departments with n ≥ 5 in both the study periods were included. Chi-square tests were used for all the comparisons.
Abbreviations: ARR, Absolute Risk Reduction; ENT, Ear, Nose, and Throat.

percentage decreased from 51.2% (44/86) to 4.6% (23/504), representing a 46.6 percentage-point decrease ($p < 0.001$). Urosurgery and Plastic Surgery showed reductions of 29.3 and 29.2 percentage points, respectively (both $p < 0.001$). The only department that did not reach statistical significance was Dental Surgery (83.3% vs. 33.3%, $p = 0.056$), likely due to the limited sample size in the pre-intervention period (n = 6).

Subgroup Analysis by Gender

The effect of the VBHC intervention was also examined stratified by patient gender (Table 7). Among female patients, antibiotic prescribing decreased from 78.7% (240/305) in the pre-VBHC period to 15.5% (242/1,563) in the post-VBHC period, representing an absolute reduction of 63.2 percentage points ($\chi^2 = 529.222$, df = 1, $p < 0.001$). Male patients showed a similar pattern, with prescribing rates decreasing from 70.3% (175/249) to 17.1% (238/1,394), an absolute reduction of 53.2 percentage points ($\chi^2 = 315.011$, df = 1, $p < 0.001$). The slightly larger reduction observed in female patients may be attributable to the higher baseline prescription rate in this group.

The implementation of VBHC principles to optimize postoperative oral antibiotic prophylaxis resulted in a 79.0% relative reduction in unnecessary antibiotic prescriptions (from 75.9% to 15.9%, $p < 0.001$) and an 87.6 percentage-point improvement in documentation compliance (from 1.0% to 88.6%, $p < 0.001$).

Surgical Site Infection Rates

Importantly, the reduction in postoperative antibiotic prescribing did not adversely affect patient safety outcomes. Surgical site infection (SSI) rates were monitored throughout the study period as part of the hospital's routine infection surveillance program and remained consistently below both the SGH benchmark (1.2 per 100 surgeries) and the international benchmark (1.9 per 100 surgeries). SSI rates were not subjected to formal statistical comparison between the pre- and post-VBHC periods because SSI data were collected at the aggregate hospital level (monthly rates) rather than at the individual patient level, which precluded patient-level inferential testing. However, descriptive trends were

Table 7 Subgroup Analysis: Post-Operative Antibiotic Use by Gender

Gender	Pre-VBHC n/N (%)	Post-VBHC n/N (%)	ARR (%)	p-value
Female	240/305 (78.7)	242/1,563 (15.5)	63.2	<0.001*
Male	175/249 (70.3)	238/1,394 (17.1)	53.2	<0.001†

Notes: *χ^2 = 529.222, *df* = 1; †χ^2 = 315.011, *df* = 1. Patients with missing gender data were excluded.
Abbreviation: ARR, Absolute Risk Reduction.

 https://doi.org/10.2147/IDR.S595284

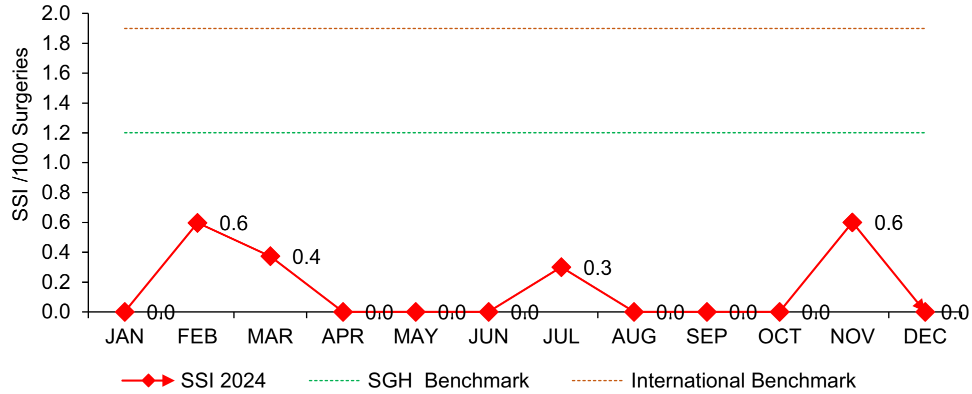

Figure 1 Surgical Site Healthcare Associated Infections 2024. Surgical site infection (SSI) rates were monitored throughout the study period as part of the hospital's routine infection surveillance program and remained consistently below both the SGH benchmark (1.2 per 100 surgeries) and the international benchmark (1.9 per 100 surgeries). During 2024, SSI rates ranged from 0.0 to 0.6 per 100 surgeries across all months, with most months reporting zero infections.

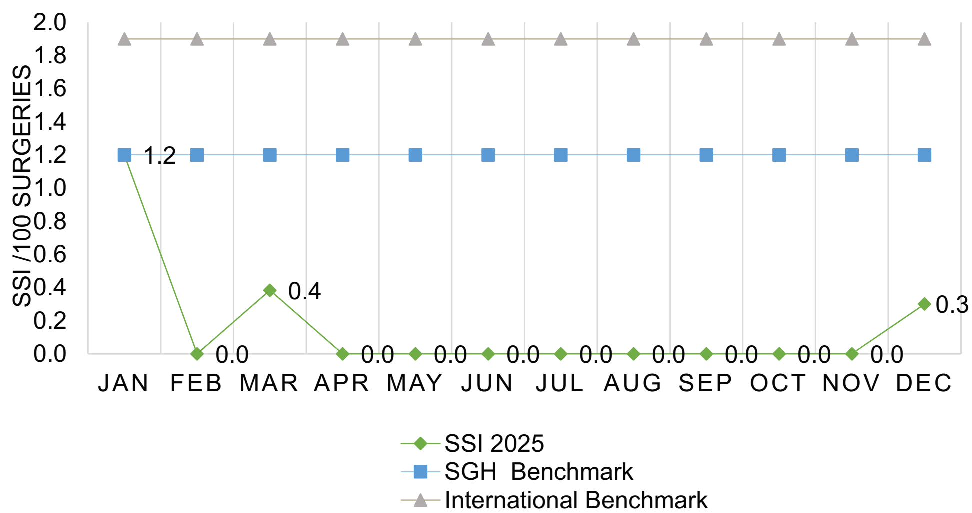

Figure 2 Surgical Site Healthcare Associated Infection 2025. Following the VBHC implementation in 2025, SSI rates remained low, ranging from 0.0 to 1.2 per 100 surgeries, with 0.0 per 100 surgeries from April through September 2025.

examined. During 2024, SSI rates ranged from 0.0 to 0.6 per 100 surgeries across all months, with most months reporting zero infections. Following the VBHC implementation in 2025, SSI rates remained low, ranging from 0.0 to 1.2 per 100 surgeries, with 0.0 per 100 surgeries from April through September 2025 (Figures 1 and 2). These findings demonstrate that optimizing antibiotic prophylaxis using VBHC principles did not compromise infection prevention outcomes, supporting the safety and effectiveness of the intervention.

Discussion

The VBHC principles in our study were effective in achieving significant reductions in unnecessary postoperative antibiotic prescriptions. Our intervention, from 75.9% to 15.9% ($p < 0.001$), resulted in a 79.0% relative reduction, one of the most significant reported in ASP to date. Most notably, the post-intervention period showed 94% lower odds of receiving unnecessary postoperative antibiotics, with an OR of 0.060 (95% CI: 0.049–0.074), calculated as $(1 - \text{OR}) \times 100$. Equally impressive was the increase in the documentation of standards, which improved from 1.0% to 88.6% ($p < 0.001$). This wide range of findings benefits ASP improves healthcare processes and systems and supports global initiatives to mitigate AMR. The outstanding outcomes achieved during the project are a direct reflection of the support and commitment provided by the hospital administration. Applying the concept of VBHC through prioritizing patient

https://doi.org/10.2147/IDR.S595284

outcomes relative to the cost of care has proven to be sustainable and effective. Similar results could be achieved in other facilities through adopting similar administrative frameworks.

Clinically, the long-term observation in the second phase ensures that there is a major shift in the institutional practice resulting in reduction of the post-operative antibiotic use, no effect on the Surgical Site Infection Rate was noticed. The ASP manager of SGH Group the update of the hospital surgical prophylaxis policy of the group across 7 branches in line with the VBHC model.

Baseline Prescribing Patterns and Regional Context

The pre-implementation VBHC cohort's baseline prescribing rate of 75.9% indicates a substantial level of non-adherence to the guidelines, which, to the best of our knowledge, has not been documented in Saudi Arabia or the broader Middle East.[8,9] Ahmed et al documented antibiotic selection and duration nonadherence at a Riyadh government hospital, noting that physicians prescribed ceftriaxone when guidelines recommended a first- or second-generation cephalosporin.[8] Prescribing practices in which the 24-hour rule is violated may stem from longstanding prescribing practices, poor understanding of the infection-control benefits of antibiotics, unawareness of the consequences of extended antibiotic therapy, and a history of limited control and monitoring by hospital administration. However, the relatively unstructured ASP in Saudi Arabia's healthcare systems, with only 26% of Ministry of Health hospitals reporting implementation, at the very least, serve a dual purpose.[7] The 2017 Saudi National Action Plan to Combat AMR, which has been extended to 2022–2025, has begun to lay the groundwork for policy development to expand stewardship programs.[23] However, national policy remains to be supplemented by institution-specific strategies, a gap that the VBHC framework is designed to address.

Comparison with Published Literature

In our study, we report positive magnitude changes that exceed those documented in the largest systematic reviews and meta-analyses. Davey et al reported that stewardship interventions increased guideline compliance from 43% to 58%, a 15-percentage-point increase.[19] A meta-analysis conducted by Baur et al found a 19.1% reduction in the total volume of antimicrobials prescribed after ASP implementation.[24] We report an absolute decrease of 60 percentage points, which is four times the median value reported in the previously mentioned studies. This can be attributed to the vast diversity present in our multi-component intervention, the high initial prescribing rate from which we identified a distinct gap, the strong commitment to VBHC, and the incorporation of non-negotiable documentation that served as a positive behavior change mechanism. Our findings align with those of studies reporting data from comprehensive bundles or quality improvement initiatives with strong institutional support. However, a five-year ASP intervention in Costa Rica reported results comparable to those of our study, with the proportion of appropriate surgical prophylaxis selection increasing from 20% to 80%.[25] A multisite intervention across a set of Dutch hospitals demonstrated a 35% reduction in antibiotic use, as reported by Van Kasteren et al[26] Martinez-Sobalvarro et al conducted a systematic review that confirmed that ASP interventions for surgical prophylaxis promote protocol adherence and improve the cost-benefit ratio.[27]

Transformation in Documentation Practices

The increase in documentation adherence from 1.0% to 88.6% indicates a change in the transparency of the prescribing practices. Before the interventions, there was no documentation of the rationale for antibiotic prescriptions. This omission suggests that extended prophylaxis was routine rather than a reasoned practice in this setting. The VBHC Strategy documentation requirement that prescribers justify antibiotic prescriptions was the first step toward establishing accountability. The primary goal of the new documentation practice was to shift prescribers' thinking regarding the necessity of each antibiotic prescription. The combination of this behavior-guided approach and educational interventions, including audit-and-feedback exercises, appears to have shifted prescribers' behavior in a meaningful and sustainable way rather than only temporarily. The IDSA/SHEA Guidelines on Implementing ASP state that education alone yields only limited and often unsustainable improvements and therefore should be paired with other strategies.[22] The combination of education, documentation requirements, prospective audits with feedback, clinical decision support, and a multidisciplinary committee exemplifies the recommendations. These guidelines have extended this approach to explain the remarkable results.

Consistency of Effects Across Subgroups

The consistency of the intervention's effects across the surgical departments enhances confidence in the generalizability of the findings. From Neurosurgery (76.4 percentage-point reduction) to Plastic Surgery (29.2 percentage-point reduction), Extreme Novice Inter-Professional Collaborative (ENIC) workshops led to cuts across all major surgical specialties. All departments, except Dental Surgery, achieved this substantially ($p < 0.001$). The differences in effect sizes across departments are most likely due to variability in baseline prescribing patterns, with specialties with higher baseline rates tending to have larger absolute reductions. The lack of statistical significance in Dental Surgery ($p = 0.056$) was attributable to the small number of participants in the pre-intervention period ($n = 6$), not to an absence of effect. Moreover, there were notable variations in the reduction in postoperative prescribed antibiotics between male and female patients. For female patients, the proportion decreased by 63.2 percentage points (from 78.7% to 15.5%), and for male patients, it decreased by 53.2 percentage points (from 70.3% to 17.1%). Both reductions were statistically significant ($p < 0.001$). The greater number of initial prescriptions in that group may explain the larger reduction in women. This may be attributable to the composite obstetric and gynecological procedures performed in the cohort. The intervention was successful in patients of both sexes, indicating that the VBHC approach can be used to address a range of problems.

VBHC as a Stewardship Framework

VBHC principles applied to ASP are arguably useful. Antibiotic stewardship programs have generally been perceived through an antibiotic-containment lens, with cost reductions as the primary measure rather than patient outcomes.[28,29] The VBHC approach is based on this, focusing on the value achieved for a given patient outcome (avoidance of antibiotics and associated adverse events, protection of the microbiome, and avoidance of resistance selection) and on appropriate ASP (use of antibiotics within the given guidelines). This reframing of the problem may facilitate clinician acceptance by emphasizing that there is no restriction, but rather a defined value to be achieved. However, analyzing our interventions through the prism of Porter's outcomes hierarchy is beneficial.[3] Tier 1 (health status achieved) indicates that avoiding the prescription of unnecessary antibiotics minimizes health risks, including adverse events such as Clostridioides difficile infection, acute kidney injury, and allergic reactions.[12,13] Tier 2 (postoperative recovery) indicates that shorter prophylactic durations simplify postoperative care while preventing surgical site infections. Tier 3 (sustainability) highlights that reducing the use of prescribed antibiotics helps preserve antimicrobial effectiveness in future patients. This multi-tiered value creation distinguishes the VBHC approach from the reductionist focus on cost containment.

Public Health and Economic Implications

Interventions aimed at eliminating antibiotic over-prescription are necessary from a public health perspective.[12] The reduction in antibiotic prescriptions can be substantial when employing a systematic VBHC approach, as evidenced by our study. Although we did not conduct a direct cost analysis in this study, we believe that there may be significant economic implications associated with our intervention. Fewer antibiotic prescriptions mean less money spent on medications. Furthermore, there is greater avoidance of downstream costs in the healthcare system, with adverse reactions to antibiotics occurring in 20% of those receiving antibiotics[18] and causing approximately 142,505 ED visits each year in the United States,[30] making it the most significant.[30] C. difficile infections lead to approximately 500,000 cases and $4.8 billion in costs for acute inpatient care annually.[31] To exemplify the core principle of VBHC, these savings, coupled with improved patient outcomes, demonstrate the principle of maximizing value for all the stakeholders.

Strengths and Limitations

The significant strengths of this study include a large sample size ($n = 4,103$), which provides sufficient statistical power and enables a meaningful analysis of subgroups by department and other demographic factors. Additionally, the study's design reflects real-world complexity, which extends beyond the application of various evidence-based stewardship

 https://doi.org/10.2147/IDR.S595284

factors within an explicit VBHC framework. Moreover, assessing prescribing behavior, combined with evaluating documentation compliance, provides complementary and practical outcome measures. Additionally, the multi-departmental scope strengthens external validity in the surgical context, and the comparison of baseline characteristics (sex, p = 0.158; department distribution, p = 0.230) supports comparability between the study groups. This study has a few limitations. First, the pre-post design study, which is not random, does not have concurrent controls; therefore, it is susceptible to temporal confounding effects. Secular trends in antibiotic awareness and national policies related to the Saudi AMR Action Plan, as well as to other concurrent initiatives within the hospital, could have contributed to the observed changes before the intervention. Other than the magnitude and timing of the improvement, which seems to suggest the effects of the intervention. Second, surgical site infection (SSI) rates were monitored descriptively but were not subjected to formal statistical testing because SSI data were collected at the aggregate hospital level (monthly rates) rather than at the individual patient level. While descriptive trends showed no increase in SSI rates, future studies should incorporate patient-level SSI data to enable formal inferential comparison as a safety endpoint. Third, the unequal sample sizes across the study periods (633 pre-VBHC vs. 3,470 post-VBHC) indicate adaptability in the data collection process and raise the possibility of selection bias. However, the baseline comparisons showed no divergence. Cost data, for example, were not appropriately documented, which limited the systematic data available to measure the economic impacts. Findings from a single center may not generalize to all healthcare environments and ecosystems, which vary in organizational culture, resource levels, and baseline practices.

Conclusions

This study demonstrates the value of implementing the principles of value-based healthcare to reduce unnecessary postoperative antibiotic prescriptions significantly and sustainably. This change was documented across all surgical units, providing the strongest evidence of generalizability across institutions. If healthcare entities guide their operations toward improving the integration of evidence-based clinical practices, they should be able to enhance patient safety, reduce the risk of AMR, and improve the efficiency of resource use. The efficacy of our multicomponent intervention provides a model that can be adopted in various healthcare environments dealing with similar prolonged surgical prophylaxis challenges. These findings underscore the importance of systematic, evidence-based strategies to change prescribing behavior and improve clinical outcomes. VBHC and ASP integrated strategies will be vital in combating the threat of AMR and preserving the efficacy of antimicrobial use for future generations.

Data Sharing Statement

The de-identified datasets generated and analyzed in this study are available from the corresponding author upon reasonable request, subject to institutional data-sharing policies and ethical approval requirements.

Ethics Approval and Consent to Participate

This study was reviewed and approved by the Research Ethics Committee (REC) of the University of Hail, Kingdom of Saudi Arabia, on 8/12/2025 (number H-2025-1002). Given the retrospective nature of the data collection and the intervention's quality-improvement focus, the requirement for individual patient informed consent was waived. All procedures were performed in accordance with the Declaration of Helsinki.

Acknowledgments

The authors gratefully acknowledge the surgical teams, pharmacy staff, nursing personnel, and hospital administration at Saudi German Hospital, Hail, for their dedication to ASP and cooperation throughout this quality improvement initiative. We also thank the members of the ASP Committee for their leadership and sustained commitment to optimizing antibiotic use.

Funding

This research did not receive any specific grants from funding agencies in the public, commercial, or not-for-profit sectors. The study was conducted as part of routine quality improvement activities at the Saudi German Hospital in Hail.

Disclosure

The authors declare that they have no competing interests, financial or otherwise, related to the conduct or reporting of this study.

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