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Research Article

Assessment of Surgical Antibiotic Prophylaxis and Microbial Spectrum in Patients with Surgical Site Infection at Imam Reza Hospital, Northeast Iran: Retrospective Cross-Sectional Study

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Abstract

Surgical site infections (SSI) rank among the most prevalent healthcare-associated infections, leading to increased use of antibiotics, higher healthcare costs, extended hospital stays, and elevated rates of morbidity and mortality. This study focuses on assessing the proper use of surgical antibiotic prophylaxis and analyzing the microbial spectrum in one of the largest hospitals in northeastern Iran. This retrospective, hospital-based cross-sectional study was conducted at Imam Reza Hospital from September 2018 to 2019, focusing on patients diagnosed with surgical site infections (SSI) according to the criteria established by the Centers for Disease Control and Prevention (CDC). Data were collected through a review of medical records, encompassing patient demographics, underlying conditions, reasons for surgery, type and location of the operation, classification of the surgical wound, prophylactic antibiotic used, prophylaxis duration, and the infection site's microbial profile. The study included 82 patients with a mean age of 43.2 ± 15.5 years, 61 (74.4%) female. Most surgical site infection (SSI) cases were associated with the obstetrics and gynecology ward (39.0%). Preoperative antibiotic prophylaxis was administered to 42.7% of patients, with ceftriaxone and metronidazole being the most prescribed regimen (40%). Antibiotics were administered more than 120 minutes before the surgical incision in 54.3% of cases. The antibiotic type adhered to the protocol in only 33 patients (40.2%), while the correct dosage was administered to just 16 patients (19.5%). The abdomen was the most frequently affected surgical site, accounting for 73.2% of SSIs, with 61.7% of infections occurring in incisions below the umbilicus. Cesarean section was the most common procedure leading to SSI (34.1%). Clean wounds were reported in 62.2% of cases. None of the cardiovascular surgery patients received antibiotics appropriately postoperatively, and only 16.9% of patients undergoing other procedures were given prophylactic antibiotics at the correct time after surgery. The most frequently isolated microorganism from wound cultures was *Staphylococcus epidermidis* (25.8%). The study revealed poor adherence to established protocols for administering antibiotic prophylaxis in surgical wards. It highlights the need for developing standardized and comprehensive local hospital guidelines tailored to various surgical procedures. Additionally, surgical residents should receive targeted training on the appropriate indications, selection, and duration of prophylactic antibiotic administration to improve compliance and patient outcomes.
Keywords: Antibiotic; Prophylaxis; Surgical site infection.

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1. Introduction

Surgical site infections (SSIs) are among the most prevalent and costly infections in healthcare. [1, 2]. According to the Centers for Disease Control and Prevention (CDC), SSIs are infections related to an operative procedure, occurring within 30 days post-surgery or 90 days if prosthetic material is implanted, typically at or near the surgical incision. While SSIs often remain confined to the incision area, they can extend into deeper tissues. [3]. SSIs are among the most frequent healthcare-associated infections, contributing to approximately 20% of hospital-acquired infections. They affect an estimated 2% to 5% of patients undergoing inpatient surgical procedures annually. [4, 5]. Antimicrobial prophylaxis prevents SSIs by reducing microbial presence at the surgical site during procedures. [6]. Studies have shown that the appropriate administration of preoperative antibiotics can significantly reduce the rate of surgical site infections (SSIs), with evidence from breast surgeries indicating a notable decrease in infection rates by up to 3.5%. [7]. However, antibiotic selection, timing, and duration inaccuracies are standard in clinical practice. [8]. Such inappropriate use not only contributes to the rise in antibiotic resistance but also leads to adverse drug reactions and higher postoperative morbidity and mortality. [9, 10]. SSI development is influenced by multiple factors, including wound contamination, operative and environmental conditions, and patient characteristics. [11]. Addressing these multifactorial contributors is essential for effective SSI prevention. This study aims to evaluate the use of antibiotic prophylaxis, along with patient demographics, underlying conditions, surgical cause, type and region of operations, wound classification, prophylaxis type and duration, and microbial profiles of surgical sites in patients with SSIs at Imam Reza Hospital. The findings are intended to support improved SSI control measures and the rational use of antibiotic prophylaxis.

2. Materials and Methods

This retrospective cross-sectional study was conducted at Imam Reza Hospital, Mashhad, Iran, between September 2018 and September 2019. The study received ethical approval from the Mashhad University of Medical Sciences Ethics Committee (Code: IR.MUMS.MEDICAL.REC.1398.730). As one of Iran's largest teaching and referral hospitals, Imam Reza Hospital has 17 wards and serves patients nationwide.

The study included patients with a history of surgery who were readmitted more than one month postoperatively and met the definition of surgical site infection (SSI) based on the National Healthcare Safety Network (NHSN) or CDC criteria. Patients with multiple recent surgeries or those who underwent minor surgeries not requiring respiratory support or anesthesia were excluded.

Data were collected through a standardized medical chart review. They included patients' sociodemographic characteristics, comorbidities, operation duration and type, wound classification, incision site, length of preoperative and postoperative hospital stays, and details of antibiotic use (selection, dosage, duration, frequency, and timing of administration). The appropriateness of antibiotic use was evaluated based on CDC guidelines for surgical antibiotic prophylaxis, which recommend the following:

1. **Timing**: Antibiotics should be administered 60 minutes before the surgical incision or within 120 minutes for drugs with longer infusion times (e.g., vancomycin or fluoroquinolones).
2. **Selection**:
   - **Cefazolin** is recommended for most clean surgeries due to its effectiveness against common pathogens (Staphylococcus aureus, Staphylococcus epidermidis).
   - For patients with beta-lactam allergies, **clindamycin** or **vancomycin** are alternatives.
   - Specific surgeries may require additional coverage:
     - **Colorectal surgeries**: Coverage for anaerobes (e.g., cefazolin + metronidazole or cefoxitin).
     - **Urological procedures**: Antibiotics targeting urinary pathogens (e.g., ciprofloxacin or cefazolin).
     - **Cardiac or thoracic surgeries**: Cefazolin or cefuroxime.
3. **Dosing**: Dosage adjustments are required for obese patients.
4. **Redosing**: Redosing is necessary during prolonged surgeries exceeding two half-lives of the antibiotic or in cases of significant blood loss (>1500 mL).
5. **Duration**: Prophylactic antibiotics should not continue beyond 24 hours postoperatively for clean

or clean-contaminated surgeries, except in specific cases such as cardiac surgery (up to 48 hours) [12].

The data were categorized and analyzed using SPSS version 26. Continuous variables were summarized with mean and standard deviation (SD), while categorical variables were reported as numbers and percentages. Results were presented in tables and bar graphs for clarity.

3. Results and Discussion

This study was performed on 82 patients with a mean age of 43±15.5 years. Twenty-one patients (25.6%) were male, and 61 (74.4%) were female. Patient histories were reviewed for smoking, substance use, and underlying medical conditions, including obesity, diabetes, hypertension, and cancer. Among the participants, 10 patients (12.1%) were smokers, 9 patients (11%) were opium users, 17 patients (20.7%) had diabetes, 7 patients (8.5%) had cancer, and 20 patients (24.3%) were obese (BMI ≥30). Other factors were observed in less than 5% of patients, as detailed in **Table 1.**

Table 1: Patient characteristics

Variables		Frequency (%)
Age	14-22	3 (3.7%)
	23-31	20 (24.4%)
	32-40	21 (25.6%)
	41-49	11 (13.4%)
	50-58	12 (14.6%)
	59-67	9 (11.0%)
	68-76	4 (4.9%)
	77-85	1 (1.2%)
	86-94	1 (1.2%)
Sex	Male	21 (25.6%)
	Female	61 (74.4%)
Patient comorbidity	Absent	55 (67.1%)
	Diabetes mellitus	17 (20.7%)
	Obesity	20 (24.3%)
	Cancer	7 (8.5%)
	Hypertension	1 (1.2%)
	Preeclampsia	1 (1.2%)
	Hypothyroidism	2 (2.4%)
Social history	Smoker	10 (12.1%)
	Opioid addiction	9 (11.0%)

Patients were admitted for various surgical procedures, with 39% undergoing elective operations and 61% undergoing emergency surgeries. The highest proportion of SSI cases occurred in the gynecology and obstetrics ward (39%). The abdomen was the most common surgical site associated with SSI (73.2%), followed by the chest (13.4%), with 61.7% of infections linked to incisions below the umbilicus. The cesarean section was the most frequent procedure leading to SSI (34.1%), followed by appendectomy and cardiac surgery (13.4%). Most SSIs were observed in patients with clean wounds (62.2%), followed by clean-contaminated wounds (34.1%).

Blood transfusions were required during surgery for 29.3% of patients. The mean surgery duration was 2.4 ± 1.7 hours, while the average preoperative and postoperative hospital stays were 1.9 ± 3.8 and 4.4 ± 6 days, respectively. Additionally, 73.2% of patients underwent a second surgery during their readmission. SSI resulted in a mortality rate of 2.4%, as summarized in **Table 2**.

Preoperative antibiotic prophylaxis was administered to 42.7% of patients. The most commonly prescribed regimen was a combination of ceftriaxone and metronidazole (40%), followed by cefazolin (28.6%) and ceftriaxone (8.6%). Antibiotics were administered more than 120 minutes before the surgical incision in 54.3% of cases. Intraoperative prophylaxis was provided in 17.1% of cases, with cefazolin being the most frequently used antibiotic (64.3%). Protocol adherence was observed in 40.2% for antibiotic selection, 19.5% for dosage, and 8.5% for redosing during surgery.

Postoperative antibiotics were given to 90.2% of patients. Among cardiovascular surgery patients, 77.8% received antibiotics for more than 48 hours, while 22.2% received them for less than 24 hours, with none receiving antibiotics at the correct postoperative time. For other surgeries, 29.3% of patients received prophylactic antibiotics for up to 24 hours, and 41.5% received them for more than 48 hours. Cefazolin was the most used antibiotic for postoperative prophylaxis. Detailed data are presented in **Table 3**.

Table 2: Patient operation characteristics

Variables		Frequency (%)
Nature of operation	Elective	32 (39.0%)
	Emergency	50 (61.0%)
Surgical ward	Obstetrics and Gynecology	32 (39.0%)
	General surgery	30 (36.6%)
	Cardiac surgery	10 (12.2%)
	Urology	5 (6.1%)
	Others	5 (6.1%)
Surgical procedure	Cesarean section	28 (34.1%)
	Cardiac surgery	11 (13.4%)
	Appendectomy	11 (13.4%)
	Other elective surgeries	9 (11.0%)
	Biliary surgery	8 (9.7%)
	Urologic surgery	5 (6.1%)
	Colorectal surgery	3 (3.7%)
	Hysterectomy	3 (3.7%)
	Other emergency surgeries	2 (2.4%)
	Diagnostic laparotomy	2 (2.4%)
Site of surgery	Abdomen	60 (73.2%)
	Chest	11 (13.4%)
	Perineum	8 (9.7%)
	Flank	1 (1.2%)
	Head and neck	1 (1.2%)
	Breast and axilla	1 (1.2%)
Site of abdominal incision	Below umbilicus	37 (61.7%)
	Above umbilicus	6 (10.0%)
	Midline	11 (18.3%)
	Laparoscopic	6 (10.0%)
Wound class	Clean	51 (62.2%)
	Clean-contaminated	28 (34.1%)
	Contaminated	2 (2.4%)
	Dirty	1 (1.2%)
Blood transfusion during surgery	Yes	24 (29.3%)
	No	58 (70.7%)
Duration of procedure	≤1h	22 (26.8%)
	>1h	60 (73.2%)
Preoperative duration of hospitalization	≤1day	63 (76.8%)
	>1day	19 (23.2%)
Postoperative duration of hospitalization	≤3days	50 (61.0%)
	>3days	32 (39.0%)
Surgical procedures in the second hospitalization	Yes	60 (73.2%)
	No	22 (26.8%)
Patients' outcomes in the second hospitalization	Recovery	76 (92.7%)
	Death	2 (2.4%)
	Discharge with personal consent	4 (4.9%)

Table 3: Characteristics of prophylactic antibiotics administration

Variables		Frequency (%)
Preoperative prophylaxis	Yes	35 (42.7%)
	No	47 (57.3%)
Timing of preoperative prophylactic antibiotics	0 min	10 (28.6%)
	30 min	1 (2.9%)
	60 min	2 (5.7%)
	90 min	2 (5.7%)
	120 min	1 (2.9%)
	>120 min	19 (54.3%)
Preoperative prophylaxis drug	Ceftriaxone (1 gr) + Metronidazole (500 mg)	14 (40.0%)
	Cefazolin (1 gr)	10 (28.6%)
	Ceftriaxone (1 gr)	3 (8.6%)
	Ampicillin (1 gr) + Gentamicin (200 mg)	2 (5.7%)
	Six other regimens	1 (2.9%) each
Intraoperative prophylaxis	Yes	14 (17.1%)
	No	68 (82.9%)
Intraoperative prophylactic antibiotic	Cefazolin (1 gr 1 time)	6 (42.9%)
	Cefazolin (1 gr 2 times)	3 (21.4%)
	Gentamicin (80 mg 1 time)	2 (14.3%)
	Three other regimens	1 (7.1%) each
Postoperative prophylaxis	Yes	74 (90.2%)
	No	8 (9.8%)
Timing of postoperative prophylaxis in cardiac surgeries	≤24h	2 (22.2%)
	24-48h	0 (0.0%)
	>48h	7 (77.8%)
Timing of postoperative prophylaxis in other surgeries	≤24h	19 (29.3%)
	24-48h	19 (29.2%)
	>48h	27 (41.5%)
Postoperative prophylaxis drug	Cefazolin (1 gr q6h)	20 (27.0%)
	Ceftriaxone (1 gr q24h) + Metronidazole (500 mg q8h)	11 (14.9%)
	Cefazolin (1 gr q6h) + Cephalexin (500 mg q6h)	4 (5.4%)
	Ceftriaxone (1 gr q24h)	3 (4.1%)
	Cefazolin (1 gr q12h)	3 (4.1%)
	Cephalexin (500 mg q6h)	3 (4.1%)
	Ceftriaxone (1 gr q12h)	2 (2.7%)
	Cefazolin (1 gr q8h)	2 (2.7%)
	Cephalexin (500 mg q8h)	2 (2.7%)
	Cefazolin (1 gr q8h) + Metronidazole (500 mg q8h)	2 (2.7%)
	22 other regimens	1 (1.4%) each

The most common microorganism cultured from the wound site was *Staphylococcus epidermis* (29.6%), followed by *Escherichia coli* and methicillin-resistant *Staphylococcus aureus* (MRSA) (14.8%), as shown in **Table 4**.

3.1. Discussion

The effectiveness of antibiotic prophylaxis in preventing surgical site infections (SSIs) has been extensively demonstrated. Its primary goals include reducing the incidence of SSIs, associated morbidity and mortality, healthcare costs, and adverse drug reactions, while minimizing its impact on the microbial flora of patients and healthcare facilities. [13]. To achieve these outcomes, antimicrobial prophylaxis must adhere to proper dosing, precise timing, and the shortest effective duration. [14].

Table 4: Wound culture result

Variables		Frequency (%)
Culture result	Not ordered	51 (28.6%)
	Negative	4 (28.6%)
	Positive	27 (28.6%)
The type of microorganism reported	*Staphylococcus epidermidis*	8 (29.6%)
	MRSA	4 (14.8%)
	Escherichia coli	4 (14.8%)
	MRSA + *Enterococcus*	2 (7.4%)
	Pseudomonas aeruginosa	2 (7.4%)
	Klebsiella pneumoniae	1 (3.7%)
	Staphylococcus haemolyticus	1 (3.7%)
	Candida	1 (3.7%)
	Acinetobacter	1 (3.7%)
	Enterococcus	1 (3.7%)
	Klebsiell apneumoniae + Candida	1 (3.7%)
	S. epidermidis +E.coli+ Candida	1 (3.7%)

MRSA: Methicillin-resistant *Staphylococcus aureus*

Our study, conducted on 82 confirmed cases of SSI, revealed that only 40.2% of cases adhered to recommended protocols for antibiotic selection, and a mere 19.5% adhered to the recommended dose (**Figure 1**).

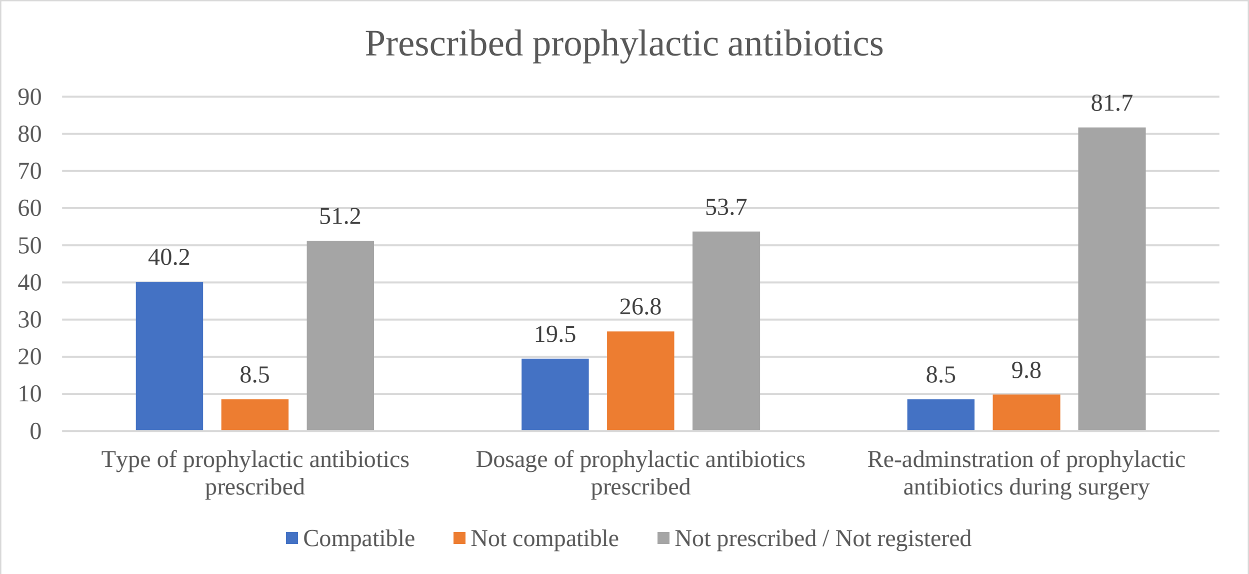

Figure 1: Compatibility of antibiotics prescribed according to CDC

These findings may reflect potential knowledge gaps among surgical residents regarding prophylactic antibiotic administration or the influence of patient-specific factors, such as comorbidities or surgical complexity. These results align with other studies. For instance, a study from a tertiary care teaching hospital in Southeast Iran reported low compliance with antimicrobial prophylaxis protocols, particularly regarding timing and dose adherence [15]. Similarly, a multicenter study involving 825 hospitals in the United States found that only 59% of surgical prophylaxis practices adhered to established guidelines, including the appropriate selection, timing, and dosing of antibiotics [16].

Timing of antibiotic administration is particularly critical in minimizing SSIs. Current guidelines recommend initiating prophylaxis within 60 minutes before surgical incision to ensure optimal antibiotic concentrations at the surgical site [12, 14]. However, our findings show that 54.3% of patients received antibiotics more than 120 minutes before the incision, 28.57% at the time of incision, and only 8.57% within the recommended 60-minute window. Prior studies have emphasized the importance of appropriate timing, showing that antibiotic administration within 60 minutes before incision is associated with the lowest risk of SSIs [17]. Conversely, administration more than 120 minutes before or during the incision increases the risk of SSIs due to suboptimal antibiotic concentrations at the surgical site [18, 19]. These results highlight significant deviations from recommended guidelines for surgical antibiotic prophylaxis (SAP).

The variability in compliance with SAP protocols across regions further underscores the complexity of addressing this issue. In the United States, non-compliance with national guidelines was observed in 41% of cases [16]. In Turkey, compliance was notably low at 19%, with some patients receiving inappropriate prescriptions [20]. Another multicenter study involving nine hospitals in Brazil found that only 10% of neurosurgical procedures fully complied with SAP guidelines [21]. In other studies, this rate differed from 11.2% to 76.4%.[22-25]. Regionally, compliance with SAP timing has also been suboptimal. For example, a study conducted at Ghaem Hospital, Mashhad, Iran, found that 43% of patients received SAP for longer durations than recommended in clinical guidelines [26]. This mirrors our findings, suggesting that prolonged or poorly timed administration remains a critical issue in healthcare systems, particularly in resource-limited settings. These studies underscore the critical need for targeted interventions, standardized guidelines, and robust monitoring systems to enhance SAP compliance globally.

The timing of postoperative antibiotic administration is crucial in reducing the risk of SSIs, as widely recognized in the literature. In this study, only 29.3% of patients undergoing non-cardiovascular surgeries received antibiotics for an appropriate duration, highlighting suboptimal adherence to recommended guidelines. In cardiovascular surgeries, 77.8% of patients received antibiotics for more than 48 hours. This finding deviates from current guidelines, which recommend limiting the duration of antibiotic administration to no more than 48 hours postoperatively for cardiovascular procedures. Such discrepancies underscore the need for improved adherence to evidence-based protocols to optimize SSI prevention while minimizing unnecessary antibiotic exposure. A systematic review and meta-analysis by de Jonge et al., encompassing 52 trials and 19,273 participants, found no significant reduction in surgical site infections with prolonged postoperative prophylaxis. Both de Jonge et al. and World Health Organization (WHO) guidelines emphasize that timely preoperative dosing and intraoperative re-dosing are sufficient, and prolonged antibiotic use increases the risk of antimicrobial resistance. These findings underscore the importance of limiting postoperative prophylaxis to optimize outcomes and reduce unnecessary antibiotic exposure [27, 28].

Our findings identified *Staphylococcus epidermidis* as the most common pathogen in SSIs (29.6%), followed by *Escherichia coli* and methicillin-resistant *Staphylococcus aureus* (MRSA) (14.8% each). This aligns with de Jonge et al.'s systematic review and meta-analysis, which included 86 studies and highlighted Gram-positive cocci, particularly Staphylococcus species, as predominant pathogens in SSIs across various surgical procedures [27]. However, our results also underscore the notable contribution of Gram-negative bacteria like *E. coli*, reflecting the microbial diversity in different surgical contexts. In a study of surgical site infections, most of the microorganisms were *E. coli* and Pseudomonas spp. [29]. In other studies, *S. aureus* was the most common pathogen [30-32]. Studies show that the most common microorganism in different centers has significant differences that indicate the need for studies to investigate the most common microorganism in each center. Our finding suggests that experimental therapies should be more targeted at covering coagulase-negative staphylococci in this center.

Considering the low adherence rate to the protocol for prophylactic antibiotic administration before and after surgery observed in our study at Imam Reza Hospital, we recommend implementing the following measures to enhance compliance and improve patient outcomes:

Design a standardized form to accurately document the timing, type, and dosage of prophylactic antibiotics administered before surgery.

1. Record the duration of surgical procedures and ensure re-administration of antibiotics if the half-life is exceeded, particularly for longer surgeries such as neurosurgical procedures.
2. Introduce an automated alert system to guide the discontinuation of prophylactic antibiotics, ensuring continuation only when clinically indicated, such as up to 24 hours post-surgery for general procedures and up to 48 hours for cardiovascular surgeries.
3. Conduct regular reviews and updates of the hospital's internal guidelines for prophylactic antibiotic use, incorporating the latest evidence from infectious disease, surgical, and internal medicine references. Ensure these guidelines are practical, agreed upon by relevant stakeholders, and effectively monitored for adherence in all departments.
4. Establish direct oversight by the department head, operating surgeon, and infection control officer, supported by feedback sessions to evaluate the performance of surgical units in accurately completing the designed forms for recording prophylactic antibiotic use.

This study had limitations and strengths. The evaluation was restricted to the dose and timing of antibiotic administration, leaving some other important parameters unassessed. Additionally, the retrospective design and incomplete or inconsistent documentation in some cases made it difficult to verify the accuracy of antibiotic administration. Furthermore, the absence of detailed records on the total number of surgeries performed at the center hindered the ability to calculate or evaluate the SSI rate. Despite these limitations, a key strength of this study was its focus on patients with a confirmed diagnosis of SSI, providing more targeted and relevant insights compared to previous studies that primarily assessed all surgical patients.

4. Conclusion

The present study reveals a low rate of accurate antibiotic administration in the surgical wards of Imam Reza Hospital, one of the largest teaching hospitals in Iran. This finding underscores the urgent need to develop standardized and comprehensive local hospital guidelines covering all types of surgeries, focusing on the indication, selection, and duration of antibiotic administration. Effective implementation and sustained adherence to these guidelines will require close collaboration between hospital administrators and medical staff, emphasizing the importance of a coordinated effort to improve antibiotic stewardship and patient outcomes.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Using artificial intelligence chatbots

There was no use of artificial intelligence in the making of this article.

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