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EVALUATION OF SURGICAL ANTIMICROBIAL PROPHYLAXIS PRACTICES AND THEIR ASSOCIATION WITH SURGICAL SITE INFECTION IN A TERTIARY CARE GENERAL SURGERY UNIT:A PROSPECTIVE CROSS-SECTIONAL OBSERVATIONAL STUDY

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ABSTRACT

Background: Surgical site infections (SSIs) remain one of the most prevalent and preventable postoperative complications, imposing a substantial burden on patients and healthcare systems. Adherence to evidence-based surgical antimicrobial prophylaxis (SAP) guidelines—encompassing appropriate drug selection, pre-incision timing, intraoperative redosing, and limited duration—is critical to SSI prevention and antimicrobial stewardship.**Objectives:** To evaluate the pattern and appropriateness of antimicrobial prophylaxis in general surgery, to determine the incidence and microbial etiology of SSI, and to assess the association of prophylaxis-related variables with SSI occurrence and length of hospital stay.Methods: A prospective, cross-sectional, observational study was conducted in the General Surgery units of Dr. K.N. Singh Memorial Institute of Medical Sciences, Barabanki, over 12 months (April 2024 – March 2025). A total of 246 adult patients receiving antimicrobial prophylaxis were enrolled by consecutive sampling. Data on demographics, wound classification, antibiotic choice, timing, redosing, and duration were collected using a structured proforma. Appropriateness was assessed against WHO and ASHP guidelines. Statistical analysis used descriptive methods and the chi-square test ($p < 0.05$ considered significant).**Results:** The overall SSI incidence was 11.4% (28/246). Drug selection was appropriate in 65.4%, timing in 55.3%, intraoperative redosing in 65.1%, and duration in only 25.2% of cases; only 13% of patients received fully appropriate SAP. Ceftriaxone dominated preoperative (65.4%) and postoperative (49.2%) prescribing. Inappropriate timing was associated with a fourfold higher SSI rate (19.1% vs. 5.1%; $p < 0.001$), and prolonged prophylaxis (>24 hours) was associated with higher SSI compared with guideline-compliant duration (14.1% vs. 3.2%; $p = 0.019$). SSI significantly prolonged hospital stay ($\chi^2 = 38.200$; $p < 0.001$), with 60.7% of infected patients requiring admission beyond 10 days.**Conclusion:** SAP practices in this institutional setting showed significant deviations from guideline recommendations, particularly in prophylaxis duration. Inappropriate timing and duration were significantly associated with higher SSI rates and prolonged hospitalization. Structured antibiotic stewardship programs, pre-incision checklists, and strict discontinuation protocols are urgently needed to rationalize antimicrobial use and reduce SSI burden.

KEYWORDS

Surgical Site Infection; Antimicrobial Prophylaxis; Antibiotic Stewardship; General Surgery; Wound Classification; Drug Utilization Study

INTRODUCTION

Surgical site infections rank among the most frequent and consequential healthcare-associated infections, contributing substantially to postoperative morbidity, prolonged hospital admission, increased antimicrobial consumption, and preventable healthcare expenditure.1 Despite advances in aseptic techniques, operative technology, and infection control protocols, SSIs continue to complicate an estimated 0.5–15% of surgical procedures globally, with rates varying widely according to procedure type, patient risk profile, institutional setting, and adherence to preventive practices.2 In low- and middle-income countries, SSI rates are consistently higher than those reported in high-income settings, partly due to deficiencies in perioperative infection prevention and inconsistent adherence to guideline-recommended prophylactic regimens.[3]

Surgical antimicrobial prophylaxis is the administration of antibiotics prior to, during, and sometimes briefly after a surgical procedure with the explicit aim of reducing the burden of bacteria at the operative site during the vulnerable peri-incisional window.4 Its efficacy is dependent not merely on the use of an antibiotic, but on the correct selection of a drug based on the expected pathogen spectrum, its administration within 60 minutes before incision to ensure adequate tissue concentration at the time of contamination, intraoperative redosing when operative duration exceeds two half-lives of the chosen agent, and restriction of postoperative continuation to a maximum of 24 hours for most clean and clean-contaminated procedures.5,6 Failure to comply with any of these parameters impairs the effectiveness of prophylaxis and may paradoxically contribute to adverse outcomes through promotion of antimicrobial resistance and drug-related adverse effects.[7]

Globally, observational drug utilization studies have consistently identified substantial deviations from established SAP guidelines, particularly with respect to excessive prophylaxis duration and preference for broad-spectrum agents in settings where narrower-spectrum alternatives would be appropriate.8,9 The consequences of such non-compliance include both higher SSI rates and the creation of selective pressure favoring resistant organisms—outcomes that carry direct clinical and public health significance.10 In the Indian context, limited institutional data are available evaluating SAP practices in secondary and tertiary care general surgery units, particularly in semi-urban and rural referral hospitals. The present study was therefore undertaken to generate institution-specific evidence on the pattern and appropriateness of antimicrobial prophylaxis in a general surgery unit, to measure the incidence and microbiological profile of SSI, and to evaluate the association between prophylaxis-related variables and clinical outcomes including SSI occurrence and length of hospital stay.

METHODS

Study Design and Setting

A prospective, cross-sectional, observational study was conducted in the General Surgery units of Dr. K.N. Singh Memorial Institute of Medical Sciences (KNSMIMS), Barabanki, Uttar Pradesh, India. The study was a collaborative effort between the Departments of Pharmacology and General Surgery. Data collection was carried out over 12 months from April 2024 to March 2025, following institutional ethics committee (IEC) approval and in accordance with the principles of the Declaration of Helsinki and ICMR guidelines for biomedical research. Written informed consent was obtained from all participants. The study followed STROBE reporting guidelines for cross-sectional studies.

Participants

Adult patients (≥18 years) admitted to the general surgery wards and receiving at least one antimicrobial agent as perioperative prophylaxis were eligible for inclusion, across all CDC wound classification categories (clean, clean-contaminated, contaminated, and dirty). Patients were excluded if they had a documented prior admission for an identical procedure, had incomplete records lacking key prophylaxis-related data (timing, drug name, dosage, or duration), or were immunocompromised. Consecutive sampling was employed, enrolling all eligible patients until the target sample size was met.

Sample Size

Sample size was calculated using the single population proportion formula: $n = Z^2 \times P \times (1-P) / e^2$, with a 95% confidence level ($Z = 1.96$), expected appropriate SAP proportion of 20% (derived from prior literature), and absolute precision of 5%, yielding a minimum of 246 participants.

Data Collection and Study Parameters

A pre-designed, structured proforma was used to collect data from multiple sources including direct patient interviews, anaesthesia charts (for precise timing documentation), and case files. The following SAP parameters were assessed and compared against WHO and ASHP guidelines: (1) Choice of antimicrobial agent (appropriate vs. inappropriate for the surgical procedure and expected pathogen spectrum); (2) Timing of pre-operative dose (appropriate: 30–60 minutes before incision; inappropriate: <30 or >60 minutes); (3) Intraoperative redosing compliance (when operative duration exceeded two half-lives of the prophylactic agent or significant blood loss occurred); (4) Duration of postoperative prophylaxis (appropriate: ≤24 hours; inappropriate: >24 hours). The occurrence and type of SSI (superficial, deep, or organ/space) were documented per CDC definitions. Microbiological culture results were recorded for confirmed SSI cases. Length of hospital stay (LOS) was recorded for all patients.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 26. Categorical variables are presented as frequencies and percentages. Continuous variables are summarized as mean ± standard deviation. Associations between categorical variables (wound class and SSI; timing appropriateness and SSI; duration and SSI) were assessed using the chi-square (χ^2) test or Fisher's exact test. A p-value of <0.05 was considered statistically significant.

RESULTS

Demographic and Surgical Profile

A total of 246 patients completed the study. The majority belonged to the 41–50 year age group (28.9%), followed by 31–40 years (23.6%). Male patients constituted 61.8% of the cohort. More than half (56.5%) were from rural areas. The most commonly performed procedures were hernia repair (25.6%), laparoscopic cholecystectomy (22.0%), appendectomy (18.7%), gastrointestinal surgery (11.4%), breast surgery (9.3%), debridement/trauma procedures (7.3%), and other surgeries (5.7%). Regarding wound classification, clean wounds constituted the largest category (43.9%), followed by clean-contaminated (37.4%), contaminated (12.6%), and dirty wounds (6.1%) (Table 1).

Table 1. Demographic and Surgical Profile of Study Participants (n = 246)

Parameter	Category	Frequency (n)	Percentage (%)
Age group (years)	18–30	42	17.1%
	31–40	58	23.6%
	41–50 (largest group)	71	28.9%
	51–60	49	19.9%
	>60	26	10.6%
Gender	Male	152	61.8%
	Female	94	38.2%
Residence	Rural	139	56.5%
	Urban	107	43.5%
Wound Class	Clean	108	43.9%
	Clean-contaminated	92	37.4%
	Contaminated	31	12.6%
	Dirty	15	6.1%

Antimicrobial Drug Selection

Ceftriaxone (a third-generation cephalosporin) was the most frequently prescribed preoperative agent, used in 161 patients (65.4%), followed by cefazolin in 49 patients (19.9%) and piperacillin–tazobactam in 36 patients (14.6%). Drug selection was judged appropriate in 65.4% and inappropriate in 34.6% of cases, with the predominant deviation being the use of broad-spectrum agents in procedures where narrower-spectrum alternatives were guideline-recommended. In the postoperative period, ceftriaxone was continued in 49.2% of patients, followed by piperacillin–tazobactam (19.1%), metronidazole (18.3%), and cefoperazone–sulbactam (13.4%) (Table 2).

Table 2. Antimicrobial Drug Selection Profile

Antibiotic	Pre-operative Use n (%)	Post-operative Use n (%)
Ceftriaxone	161 (65.4%)	121 (49.2%)
Cefazolin	49 (19.9%)	—
Piperacillin–Tazobactam	36 (14.6%)	47 (19.1%)
Metronidazole	—	45 (18.3%)
Cefoperazone–Sulbactam	—	33 (13.4%)
Appropriate drug selection	161 (65.4%)	—
Inappropriate drug selection	85 (34.6%)	—

Timing of Preoperative Antimicrobial Administration

Administration within the recommended 30–60 minute pre-incision window was achieved in 136 patients (55.3%). The remaining 110 patients (44.7%) received prophylaxis outside this window: 58 patients (23.6%) received it 15–30 minutes before incision, 22 patients (8.9%) received it fewer than 15 minutes before incision, and 30 patients (12.2%) received it more than 60 minutes prior.

Intraoperative Redosing

Intraoperative redosing was indicated in 43 patients (17.5%) based on operative duration or blood loss criteria. Of these, redosing was correctly administered in 28 patients (11.4%), while 15 patients (6.1%) experienced a missed redose, representing a compliance gap of approximately one-third of indicated redosing events.

Duration of Postoperative Antibiotic Use

Duration of prophylaxis was the most poorly adherent parameter. Only 62 patients (25.2%) received antibiotics for the recommended ≤24 hours, while 184 patients (74.8%) received prolonged prophylaxis. Specifically, 50.0% of patients received antibiotics for more than 3 days. Only 18 patients (7.3%) received no postoperative antibiotics (Table 3).

Table 3. Overall Appropriateness of Surgical Antimicrobial Prophylaxis (SAP) Components (n = 246)

SAP Component	Appropriate n (%)	Inappropriate n (%)
Drug selection	161 (65.4%)	85 (34.6%)
Timing (30–60 min pre-incision)	136 (55.3%)	110 (44.7%)
Intraoperative redosing	28/43 (65.1%)*	15/43 (34.9%)*
Duration (≤24 hours)	62 (25.2%)	184 (74.8%)
Fully appropriate SAP (all components)	32 (13.0%)	214 (87.0%)

**Denominator is 43 patients in whom redosing was indicated. SAP: Surgical Antimicrobial Prophylaxis.*

Incidence and Types of Surgical Site Infection

SSI occurred in 28 of 246 patients (11.4%). Among infected patients, superficial SSI was the most common type (67.9%, n = 19), followed by deep SSI (21.4%, n = 6) and organ/space SSI (10.7%, n = 3). Microbiological culture of SSI wound specimens yielded the following organisms: methicillin-sensitive Staphylococcus aureus (MSSA) in 8 isolates (28.6%), Escherichia coli in 6 (21.4%), methicillin-resistant Staphylococcus aureus (MRSA) in 5 (17.9%), Klebsiella pneumoniae in 4 (14.3%), Pseudomonas aeruginosa in 3 (10.7%), and Enterococcus species in 2 (7.1%) (Table 4).

Table 4. Microorganism Profile Isolated from SSI Cases (n = 28)

Microorganism	Number of Isolates (n)	Percentage (%)
Staphylococcus aureus (MSSA)	8	28.6%
Escherichia coli	6	21.4%
MRSA	5	17.9%
Klebsiella pneumoniae	4	14.3%
Pseudomonas aeruginosa	3	10.7%
Enterococcus spp.	2	7.1%
Total	28	100%

MRSA: Methicillin-resistant Staphylococcus aureus; MSSA: Methicillin-sensitive Staphylococcus aureus.

Association of SSI with Wound Class and Prophylaxis Parameters

A highly significant stepwise increase in SSI rates across wound classes was observed ($\chi^2 = 33.734$; df = 3; $p < 0.001$): SSI occurred in 2.8% of clean wounds, 9.8% of clean-contaminated wounds, 32.3% of contaminated wounds, and 40.0% of dirty wounds.

Inappropriate timing of prophylaxis was strongly associated with SSI: 19.1% of patients with inappropriate timing developed SSI compared with only 5.1% in the appropriate-timing group ($\chi^2 = 11.722$; df = 1; $p < 0.001$), representing a nearly fourfold difference in infection proportion.

Similarly, prolonged antibiotic duration (>24 hours) was associated with a significantly higher SSI rate (14.1%) compared with guideline-compliant duration (≤24 hours; 3.2%; $\chi^2 = 5.467$; df = 1; p = 0.019) (Table 5).

Table 5. Association of SSI with Wound Class and SAP Practice Variables (n = 246)

Variable	SSI Yes n (%)	SSI No n (%)	p-value
Wound Class			
Clean (n=108)	3 (2.8%)	105 (97.2%)	< 0.001*
Clean-contaminated (n=92)	9 (9.8%)	83 (90.2%)	
Contaminated (n=31)	10 (32.3%)	21 (67.7%)	
Dirty (n=15)	6 (40.0%)	9 (60.0%)	
Timing Appropriateness			
Inappropriate timing (n=110)	21 (19.1%)	89 (80.9%)	< 0.001
Appropriate timing (n=136)	7 (5.1%)	129 (94.9%)	
Duration of Prophylaxis			
>24 hours/Inappropriate (n=184)	26 (14.1%)	158 (85.9%)	0.019
≤24 hours/Appropriate (n=62)	2 (3.2%)	60 (96.8%)	

**Chi-square test. SSI: Surgical Site Infection; SAP: Surgical Antimicrobial Prophylaxis.*

Length of Hospital Stay

SSI was significantly associated with prolonged hospital admission ($\chi^2 = 38.200$; df = 2; $p < 0.001$). Among non-SSI patients (n = 218), 46.8% were discharged within 5 days, whereas 60.7% of SSI patients (n = 28) remained hospitalized for more than 10 days. Furthermore, mean LOS was progressively longer with decreasing SAP appropriateness: 7.03 ± 4.58 days for fully appropriate SAP, 7.26 ± 4.54 days for partially appropriate SAP, and 9.28 ± 5.13 days for wholly inappropriate SAP.

DISCUSSION

This prospective observational study provides a comprehensive institutional assessment of SAP practices in a tertiary-care general surgery unit, integrating drug utilization analysis with clinical outcomes including SSI incidence, microbiological etiology, and hospitalization burden. The principal findings reveal a substantial gap between prevailing prophylaxis practices and established guidelines, most prominently in duration of prophylaxis and pre-incision timing, with direct clinical consequences in terms of SSI occurrence and prolonged hospital stay.

Antibiotic Selection: Broad-Spectrum Dominance

The predominant use of ceftriaxone (65.4% preoperatively), a third-generation cephalosporin with a broad gram-negative spectrum, as the primary prophylactic agent represents a significant deviation from guidelines that recommend cefazolin—a narrower-spectrum first-generation cephalosporin—as the preferred agent for most clean and clean-contaminated general surgical procedures.4,5 This institutional pattern closely mirrors findings from comparable observational studies. Alemkere reported ceftriaxone use in approximately 84% of patients, with only 10.6% compliance with ASHP guideline drug recommendations.11 Habteweld et al. similarly documented ceftriaxone use in 70.5% of patients.12 The preference for broad-spectrum prophylaxis in the current setting likely reflects prescriber concerns regarding local pathogen profiles, fear of SSI, and absence of formal antibiotic protocols—a combination of factors commonly identified as drivers of guideline non-compliance.13 The heavy reliance on broad-spectrum agents in both the preoperative and postoperative periods, despite a patient cohort predominantly comprising clean and clean-contaminated cases, constitutes both an unnecessary clinical risk and a stewardship concern.

Timing of Preoperative Administration

Appropriate pre-incision antibiotic timing was achieved in only 55.3% of patients, leaving nearly half receiving prophylaxis outside the evidence-based 30–60 minute window. This finding is of particular clinical significance given the strong association observed between inappropriate timing and SSI in the current study: 19.1% of patients with suboptimal timing developed SSI compared with only 5.1% in those receiving antibiotics at the correct time ($p < 0.001$). This nearly fourfold differential corresponds well with existing evidence. Kefale et al. demonstrated that patients receiving prophylaxis 1–2 hours before incision had 8.2 times higher odds of developing SSI, confirming that timing deviation substantially compromises prophylactic efficacy.13 Seyferth et al. achieved 72.6% appropriate timing in gastrointestinal procedures within a structured antimicrobial stewardship framework, demonstrating that markedly superior timing compliance is achievable through systemic intervention.15 Since timing errors are preventable through perioperative checklists, standardized anaesthesia-surgery coordination protocols, and documented nursing administration records, this finding identifies an immediately actionable target for institutional quality improvement.

Intraoperative Redosing

Redosing compliance was suboptimal, with 15 of 43 indicated events (34.9%) being missed. Although the absolute number was modest, missed intraoperative redosing constitutes a preventable system-level failure with particular relevance in prolonged operations where maintaining bactericidal drug concentrations at the surgical site is critical. Seidelman et al. identified appropriate perioperative drug dosing as a core evidence-based SSI prevention strategy,14 and antimicrobial stewardship programs have been shown to improve process adherence across multiple SAP parameters including redosing.16,17

Duration of Prophylaxis: The Most Critical Deviation

Duration of postoperative antibiotic prophylaxis emerged as the most problematic component of SAP practice, with only 25.2% of patients receiving antibiotics for the guideline-recommended ≤24 hours, while 74.8% received prolonged courses—including 50.0% who continued antibiotics beyond 3 days. The present data indicate a paradoxical association: SSI was significantly more frequent in patients receiving extended prophylaxis (14.1%) compared with those managed within recommended limits (3.2%; p = 0.019). This finding—supported by consistent international evidence—demonstrates that prolonged antibiotic courses confer no additional protection against SSI and may instead reflect poor-quality prophylaxis in other domains. Liu et al. concluded that there was no evidence of a reduction in SSI risk from extended versus short-term prophylaxis duration in colorectal surgery.16 Alemkere found that 75.8% of patients received antibiotics beyond 24 hours, virtually identical to the present proportion.11 Seyferth et al. found appropriate discontinuation in only 5.4% of gastrointestinal procedures, identifying duration as the weakest SAP parameter in their setting.15 Collectively, these data demonstrate that prolonged prophylaxis represents the most widespread, unjustified, and potentially harmful deviation in SAP practice globally.

SSI Incidence, Microbiology, and Clinical Impact

The overall SSI rate of 11.4% (28/246) is consistent with rates reported from comparable resource settings. Kefale et al. reported 19.6% SSI prevalence, while Alsaeed et al. documented a much lower rate of 0.6% in a fully prophylaxed cohort, illustrating the spectrum achievable with optimal versus poor adherence.13,19 The predominance of superficial SSI (67.9%) reflects expected general surgery patterns, while the combined 32.1% of deep and organ/space infections indicates meaningful morbidity requiring more intensive management.

The microbiological profile was dominated by MSSA (28.6%) and E. coli (21.4%), consistent with the expected endogenous flora of skin (Staphylococcus spp.) and abdominal procedures (gram-negative enteric organisms). The 17.9% prevalence of MRSA among SSI isolates is a clinically important finding, reflecting the presence of resistant pathogens in a setting characterized by heavy and prolonged

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broad-spectrum antibiotic use—a relationship consistent with the known association between antibiotic selection pressure and resistance acquisition.7

SSI imposed a substantial burden on hospital resources, with 60.7% of infected patients requiring admission beyond 10 days compared with only 13.8% of non-infected patients ($\chi^2 = 38.200$; $p < 0.001$). Mean LOS increased from 7.03 days with fully appropriate SAP to 9.28 days with inappropriate SAP. Martinez-Sobalvarro et al. demonstrated that stewardship interventions improving SAP adherence resulted in favorable cost-benefit outcomes across 85.7% of included studies, reinforcing the economic as well as clinical rationale for improving prophylaxis practices.17

Limitations

This single-center observational study has several limitations. The cross-sectional design precludes causal inference regarding the relationship between SAP practices and SSI. Outcomes were assessed only during hospitalization and a brief post-discharge follow-up; delayed SSIs may have been missed. Surgeon-level prescribing behavior and ASA scores were not analyzed as individual predictors. The sample was drawn from a single institution and may not be generalizable to other settings.

CONCLUSION

This prospective observational study documents significant deviations from evidence-based SAP guidelines in a general surgery tertiary care unit, with inappropriate timing (44.7%), suboptimal redosing compliance (34.9%), and markedly prolonged prophylaxis duration (74.8%) identified as the principal gaps. The overall SSI incidence was 11.4%, and both inappropriate pre-incision timing and excessive prophylaxis duration were independently and significantly associated with higher infection rates. SSI substantially prolonged hospital stay, with nearly two-thirds of infected patients hospitalized beyond 10 days. The microbiological profile, including 17.9% MRSA prevalence among SSI isolates, underscores the urgency of restricting unnecessary antibiotic exposure.

These findings establish a strong evidence base for institutional antibiotic stewardship interventions, including the development of procedure-specific SAP protocols, implementation of pre-incision safety checklists enforcing correct timing, mandatory prophylaxis discontinuation orders at 24 hours, structured redosing reminders for prolonged procedures, and regular prescription audits with feedback. Targeted interventions addressing these modifiable SAP deficiencies have the potential to substantially reduce the institutional SSI burden, curtail irrational antibiotic consumption, limit antimicrobial resistance pressure, and improve overall perioperative patient outcomes.

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