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Original Research Article

Surgical Site Infections (SSIs) and Prevention Strategies: Review SSI Rates, Pathogens, and Prevention Measures

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Abstract

Background: Surgical site infections (SSIs) are one of the most common Healthcare-Associated infections (HAIs), associated with increased morbidity after surgery, longer hospital stay, antimicrobial resistance and healthcare costs. Early identification of pathogen(s) and appropriate prevention measures are crucial for providing good surgical outcomes.

Methods: A cross-sectional observational study was done in the Department of General Surgery, PMCH, from January to June 2025 in postoperative patients (n=100). A structured proforma was used to obtain clinical data, and wound swab or pus aspirate specimens from suspected cases with SSI were cultured for identification of bacteria and Antimicrobial Susceptibility Testing (AST) following Clinical and Laboratory Standards Institute (CLSI) guidelines.

Results: A total of 24 patients (24%) had surgical site infections, and 76 patients (76%) did not have any evidence of infection. The most common types of SSI were superficial incisional (58.3%), deep incisional (29.2%), and organ/space (12.5%). The most common isolates were Staphylococcus aureus (29.2%), followed by Escherichia coli (20.8%), Klebsiella pneumoniae (16.7%) and Pseudomonas aeruginosa (12.5%). The activity against Gram-negative organisms was excellent with meropenem (87.5%) and piperacillin–tazobactam (79.2%), whereas linezolid and vancomycin were 100% active against Gram-positive organisms. Diabetes mellitus, obesity, smoking, emergency surgery and operative duration were significantly associated with SSI ($P < 0.05$).

Conclusion: The occurrence of SSI is a significant postoperative complication at PMCH. Effective antimicrobial stewardship and proper surveillance, combined with evidence-based infection prevention strategies, are key to reducing SSI rates and enhancing patient outcomes.

Keywords: Surgical Site Infection, Postoperative Infection, Staphylococcus Aureus, Antimicrobial Resistance, Infection Prevention, Healthcare-Associated Infection, PMCH Patna.

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Introduction

SSIs are one of the most prevalent HAIs and continue to be a major contributor to morbidity and mortality after surgery, especially in the developing world [1]. The Centers for Disease Control and Prevention (CDC) define an SSI as an infection at or around the surgical incision site that develops within 30 days after surgery or 1 year after the placement of an implant [2].

SSI can be categorized as superficial incisional SSI, which affects the skin and subcutaneous tissue; deep incisional SSI, which involves the fascia and muscle; and organ/space SSI, which occurs in any organ or body cavity where surgery was performed [3]. The prevalence of SSI is between 2% and 20% across the world, and significantly higher in low- and middle-income countries [4]. SSI is still a significant problem in India, with prevalence rates reported between 5% and 30% of patients affected, and where there is a lack of increased adherence to infection prevention protocols [5]. SSIs have a major impact on patient outcomes and healthcare systems. These cause delayed healing of the wound, increase post-operative pain and can cause serious complications such as sepsis, abscess and wound dehiscence. A significant association exists between SSIs and mortality, especially among older and immunocompromised patients [6,7].

Moreover, there is significantly greater antibiotic resistance and more expensive healthcare for infected patients, as these patients often need to be hospitalized for long periods of time, undergo more surgical procedures and receive prolonged courses of antibiotics [8]. Thus, preventing SSIs becomes a crucial aspect of surgical success and decreases the strain on healthcare resources. Two types of risk factors (patient-related and procedure-related) may contribute to the occurrence of SSI [9]. Diabetes mellitus, obesity, malnutrition, smoking, advanced age and other conditions that affect immunity and wound healing are important patient-related risk factors [10]. Other factors are related to the procedure (emergency surgery, long surgery, contaminated surgical wounds, implants, and poor aseptic practices), which also increase the risk of infection. Most commonly isolated pathogens are Staphylococcus aureus, including methicillin-resistant Staphylococcus aureus (MRSA), Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Acinetobacter baumannii and Enterococcus species [11,12]. Many of these organisms are known for their multidrug resistance and it is therefore important to have the appropriate microbiological diagnosis and antimicrobial susceptibility testing for successful treatment.

There is a need to adopt a multi-faceted approach to prevention of SSIs with evidence-based interventions before, during and after surgery. Pre-operative measures include prompt administration of prophylactic antibiotics, adequate skin cleansing with antiseptic, clipping of hair if needed, and optimum blood sugar control. Intraoperative strategies include strict aseptic technique, surgical hand preparation, maintaining room order and keeping patients normothermic. Post-surgical management focuses on the proper management of the wound, sterile dressing changes, hand hygiene and constant monitoring for the early signs of infection. These interventions are recommended by international guidelines as a way to lower the rate of SSI and enhance patient safety. Continuous surveillance should be conducted in tertiary care hospitals like Patna Medical College and Hospital (PMCH) to monitor the trend of infections, to identify common pathogens, to assess the infection prevention practices and to improve the infection control measures and thereby enhance the quality of surgical care.

Objectives

- To find the prevalence of SSI among postoperative patients admitted in PMCH.
- To determine the bacterial pathogens associated with SSIs.
- To determine antimicrobial susceptibility patterns.
- To evaluate patient- and procedure-related risk factors.
- To assess adherence to SSI prevention measures.

Materials and Methods

Study Design and Setting: A observational cross-sectional study conducted at PMCH, Patna, Bihar in the hospital-based Department of General Surgery. The study aimed to evaluate the prevalence of SSIs, identify the causative pathogens and to determine the adherence to infection prevention strategies among postoperative patients over a six-month period from January 2025 to June 2025.

Study Population: A total of 100 postoperative patients aged 18 years old and above who had undergone surgical procedures, both elective and emergency were included in the study. Patients who presented with clinical symptoms suggestive of SSI during the hospital stay or follow-up and gave written informed consent were included. Patients were excluded if they had had a pre-existing wound infection prior to surgery, attended another health care organisation for surgery, refused consent or had incomplete medical records.

Data Collection: A structured case record form was used for data collecting. Demographics were age and gender. Clinical parameters included diabetes mellitus, hypertension, Body Mass Index (BMI), smoking habits and other comorbidities. Surgical information was collected such as type of surgery, elective versus emergency surgery, duration of surgery, wound classification, American Society of Anesthesiologists (ASA) classification, and if they were using an implant. Data on SSI information (day of onset of SSI, clinical signs, type of SSI, isolated microorganism, and antimicrobial susceptibility pattern) were also gathered. Patient records and operative notes were used to assess compliance with preventive measures including the timing of the administration of prophylactic antibiotic, mode of hair removal, antisepsis of skin, hand hygiene, sterile dressing technique and duration of the antibiotic prophylaxis.

Specimen Collection and Laboratory Methods: Specimens of wounds or aspiration of wound pus were obtained aseptically from patients with possible SSIs prior to the start of antimicrobial therapy. Standard microbiological methods were used to culture the specimens on Blood agar and MacConkey agar. The bacterial isolates were determined by their colony morphology, Gram staining and conventional biochemical reactions. All bacteria were tested for their susceptibility to the antibiotics using the Kirby–Bauer disc diffusion method and interpreted following CLSI recommendations.

Statistical Analysis: The collected data were analyzed using SPSS version 26. Continuous

variables were reported as mean ± SD and categorical variables as frequencies and percentages.

Relationships of risk factors with occurrence of SSI were analysed using Chi-square test or Fisher's exact test as appropriate and the independent t-test was used for continuous variables. P values <0.05 were considered to be statistically significant.

Ethical Considerations: The study protocol was ethically approved by the PMCH, Patna's Institutional Ethical Committee. All participants gave their written informed consent prior to their enrollment. The confidentiality of patients' data was respected during the study and the data used only for research purposes.

Results

Demographic Characteristics: In total, 100 postoperative patients were used in the study. The majority of patients belonged to the 41–60 years age group (38%), followed by 21–40 years (32%), more than 60 years (20%), and 18–20 years (10%). There were 62% male and 38% female patients in the study.

Table 1: Demographic Characteristics of Study Participants (n = 100)

Variable	Frequency (n)	Percentage (%)
Age (years)		
18–20	10	10.0
21–40	32	32.0
41–60	38	38.0
>60	20	20.0
Sex		
Male	62	62.0
Female	38	38.0

Clinical Characteristics: Diabetes mellitus (30%), hypertension (36%), obesity (BMI ≥ 30 kg/m²) (24%), smoking history (28%) and other pathological conditions (18%) (Chronic kidney disease, chronic obstructive pulmonary disease) were present among the enrolled patients.

Table 2: Clinical Characteristics

Variable	Frequency (n)	Percentage (%)
Diabetes mellitus	30	30.0
Hypertension	36	36.0
Obesity (BMI ≥30 kg/m²)	24	24.0
Smoking	28	28.0
Other comorbidities	18	18.0

Surgical Characteristics: The most common surgical procedures were general surgery (45%), gastrointestinal (25%), orthopedic (18%), and urologic surgery (12%). Of the 400 patients, elective procedures were performed on 65% while emergency surgery was performed on 35%. The duration of most operations ranged from 1 to 3 hours (54%) and for 22% of patient's implants were used.

Table 3: Surgical Characteristics

Variable	Frequency (n)	Percentage (%)
Type of surgery		
General surgery	45	45.0
Gastrointestinal	25	25.0
Orthopedic	18	18.0
Urological	12	12.0
Nature of surgery		
Elective	65	65.0
Emergency	35	35.0
Duration of surgery		
<1 hour	20	20.0
1–3 hours	54	54.0
>3 hours	26	26.0
Wound class		
Clean	42	42.0
Clean-contaminated	34	34.0
Contaminated	18	18.0
Dirty	6	6.0
Implant use	22	22.0

Prevalence and Types of Surgical Site Infection: The prevalence of SSI in this study was 24% (24 of 100) patients who developed SSI and 76% (76 of 100) patients with no evidence of postoperative wound infection. Superficial incisional SSI was the most frequently observed (58.3%) followed by deep incisional SSI (29.2%) and organ/space SSI (12.5%) of the infected cases.

Table 4: Prevalence of Surgical Site Infection

SSI Status	Frequency (n)	Percentage (%)
SSI present	24	24.0
SSI absent	76	76.0

Table 5: Types of Surgical Site Infection

Type of SSI	Frequency (n)	Percentage (%)
Superficial incisional	14	58.3
Deep incisional	7	29.2
Organ/space	3	12.5

Bacterial Isolates and Antimicrobial Susceptibility: A total of 24 bacteria were isolated from infected wound after surgery. The most common organisms encountered were Staphylococcus aureus (29.2%), Escherichia coli (20.8%), Klebsiella pneumoniae (16.7%), Pseudomonas aeruginosa (12.5%), methicillin resistant Staphylococcus aureus (MRSA) (8.3%), Acinetobacter baumannii (8.3%), and Enterococcus species (4.2%). Susceptibility of the most of the Gram-negative isolates was good to meropenem, piperacillin–tazobactam, and amikacin, while that of the Gram-positive isolates was highly to linezolid and vancomycin.

Table 6: Distribution of Bacterial Isolates

Organism	Frequency (n)	Percentage (%)
Staphylococcus aureus	7	29.2
MRSA	2	8.3
Escherichia coli	5	20.8
Klebsiella pneumoniae	4	16.7
Pseudomonas aeruginosa	3	12.5
Acinetobacter baumannii	2	8.3
Enterococcus spp.	1	4.2

Table 7: Antibiotic Susceptibility Pattern of Isolates

Antibiotic	Sensitive n (%)
Ceftriaxone	9 (37.5)
Piperacillin–Tazobactam	19 (79.2)
Amikacin	18 (75.0)
Meropenem	21 (87.5)
Linezolid*	9 (100.0)
Vancomycin*	9 (100.0)

***Percentage calculated among Gram-positive isolates.**

Risk Factors Associated with SSI: Diabetes mellitus, operative duration exceeding three hours, emergency surgery, obesity, and smoking were significantly associated with SSI. The strongest statistical association was observed between diabetes and prolonged surgery.

Table 8: Risk Factors Associated with Surgical Site Infection

Variable	SSI Present n (%)	SSI Absent n (%)	P value
Diabetes mellitus	12 (50.0)	18 (23.7)	0.018*
Surgery >3 hours	11 (45.8)	15 (19.7)	0.014*
Emergency surgery	13 (54.2)	22 (28.9)	0.029*
Obesity	10 (41.7)	14 (18.4)	0.031*
Smoking	9 (37.5)	19 (25.0)	0.041*

***Statistically significant (P < 0.05).**

Compliance with SSI Prevention Measures: Skin antisepsis and sterile dressing techniques were found to be highly compliant with preventive practices assessed (94% and 92% respectively). Prophylactic anti-biotics were administered at an appropriate time in 86% of patients and compliance with perioperative glycemic control was somewhat less (78%).

Table 9: Compliance with SSI Prevention Measures

Prevention Measure	Compliant n (%)
Appropriate antibiotic prophylaxis	86 (86.0)
Hair removal using clippers	82 (82.0)
Skin preparation	94 (94.0)
Hand hygiene	90 (90.0)
Sterile dressing	92 (92.0)
Glycemic control	78 (78.0)

The overall results showed that specifically about 25% of patients who had undergone an operation experienced a SSI. Staphylococcus aureus continued to be the most common pathogen, and diabetes mellitus, long operative time, emergency surgery, obesity and smoking were important risk factors for SSI. While compliance with most of the infection prevention practices was good, optimising glycemic control and antibiotic prophylaxis at the right time could result in further reduction in the incidence of postoperative wound infections.

Discussion

SSI Prevalence: The current study revealed the overall prevalence of SSI was 24% among the postoperative patients of PMCH. This result is comparable with recent studies conducted in India reporting SSI rates of 15% to 28% in tertiary care hospitals, indicating the continued burden of postoperative infections in developing healthcare settings.

Other international studies have found lower rates of SSI (2%-10%) reflecting improved infrastructure, standardised infection control measures, and good surveillance. The relatively increased prevalence observed in the present study could be due to the larger proportion of emergency surgeries, the high volume of patients admitted and the presence of multiple comorbidities among the admitted patients.

Distribution of Pathogens: The most common pathogen in SSIs was found to be Staphylococcus aureus, which is in agreement with Indian as well as international literature. As it is a common inhabitant of the skin and surgical wounds, it is still the primary source of postoperative wound infections. There was also a significant number of infections caused by gram-negative bacteria such as Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa and Acinetobacter baumannii, most of which occurred after abdominal surgeries and contaminated surgeries [13]. Despite its lower percentage, the occurrence of MRSA is clinically significant as it limits treatment options and poses a risk of extended hospital stays.

Antibiotic Resistance: Antimicrobial susceptibility pattern showed high sensitivity of the bacterial isolates to meropenem and piperacillin–tazobactam for Gram negative bacteria and high activity of linezolid and vancomycin against gram positive bacteria including MRSA [14]. By contrast, ceftriaxone had an intermediate susceptibility indicating a rise in resistance to third-generation cephalosporins.

These results align with recent publications that have noted an increasing antimicrobial resistance problem with the emergence of healthcare-associated pathogens. The rise in multidrug-resistant organisms highlight the need for regular culture and susceptibility testing and the need for antimicrobial stewardship to help ensure the right antibiotic is being used, and, reduce the unnecessary use of broad-spectrum antibiotics.

Risk Factors: The present study revealed that diabetes mellitus, obesity, smoking, emergency surgery and duration of operation were significant risk factors for SSI. Diabetes lowers immune function and slows the healing process while obesity compromises tissue perfusion and increases technical difficulty during surgery [15].

Smoking decreases tissue oxygenation and thus compromises postoperative recovery. In emergency procedures, there may be a short period of time to prepare patients; lengthy procedures result in longer exposure to microorganisms and handling of tissues. This study corroborates earlier studies showing that these variables are independent predictors for postoperative wound infection.

Prevention Strategies: This study revealed high adherence to the three recommendations of skin antisepsis, sterile dressing of the wound and hand hygiene, but identified low adherence to the other recommendations, which were timely antibiotic prophylaxis and perioperative glycemic control.

International guidelines from the World Health Organization (WHO) and the CDC focus on evidence-based practice during the entire peri-operative period, such as the use of appropriate antibiotics, good aseptics, hand hygiene, normothermia and standardized postoperative wound care. Implementation of these infection prevention bundles can significantly decrease SSI incidence and enhance surgical outcomes if they are consistently implemented.

Strengths and Limitations: This study's strengths include its prospective observational design, microbiological confirmation of infections (culture

and antimicrobial susceptibility testing), and comprehensive evaluation of perioperative infection prevention practices.

There are some limitations of the study, however. It was performed in a single tertiary care center and relatively small number of patients (100), and the follow-up period was short, which may restrict the applicability of results. In addition, molecular resistance characterization was not conducted which limited detailed resistance mechanism analysis.

Conclusion

Overall prevalence of SSI was 24% in present study with Staphylococcus aureus being the most common isolated pathogen followed by important gram-negative bacteria in the postoperative patients of PMCH, Patna. High meropenem, piperacillin–tazobactam, linezolid, and vancomycin susceptibility was observed and reduced susceptibility to ceftriaxone suggested development of antimicrobial resistance. Significant risk factors for SSI were diabetes mellitus, obesity, smoking, emergency surgery and longer operative time. Optimizing infection prevention bundles, providing timely antibiotic prophylaxis, managing glycaemia and implementing strict aseptic techniques, along with ongoing post-operative SSI surveillance and antimicrobial stewardship, are all key components to minimize the risk of post-operative infections and optimize patient outcomes.

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