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Original Article

Microbiology Section

Impact of Surgical Antimicrobial Prophylaxis Protocol Implementation on Surgical Site Infection Rates and Microbial Epidemiology: A Prospective Observational Study

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ABSTRACT

Introduction: Surgical Site Infections (SSIs) are a leading cause of postoperative morbidity, contributing to prolonged hospital stays and increased healthcare costs. Institutional strategies, including surveillance and adherence to Surgical Antimicrobial Prophylaxis (SAP) guidelines, remain essential in combating SSIs.

Aim: To determine the distribution, microbial profile, and antimicrobial resistance patterns of SSIs, and to assess adherence to SAP protocols in a tertiary care teaching hospital.

Materials and Methods: This prospective observational study was conducted at Mahatma Gandhi Medical College and Research Institute, Puducherry India, from January 2022 to December 2024. As this was a prospective, period-based surveillance study, all eligible SSI cases detected during the study period were included. The parameters assessed were SSI incidence, clinical classification of infections, patient demographics, microbial distribution, antimicrobial resistance patterns, and SAP adherence indicators. SSI surveillance followed the Centres for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) criteria with 30- or 90-day follow-up. SAP adherence was monitored across eight surgical departments.

Results: A total of 15,650 clean and clean-contaminated surgeries were performed, among which 125 patients developed SSIs. Females constituted 82 (65.6%) of SSI cases, with the 31-50 years age group most affected, 56 (44.8%). The overall SSI rate was 125 (0.79%), with the highest burden observed in post-Lower Segment Caesarean Section (LSCS) cases, 82 (65.6%). Gram-negative organisms predominated 88 (70.4%), primarily *Escherichia coli* and *Klebsiella pneumoniae.* Resistance to third-generation cephalosporins was notably high at 61 (71.8%).

Conclusion: The present study showed that SSIs in this tertiary care setting were largely associated with Gram-negative organisms, many of which exhibited multidrug resistance. An important observation was the higher proportion of SSIs among post-LSCS cases, suggesting that obstetric surgeries may represent a vulnerable group within the overall SSI burden. Strengthening perioperative infection control measures, ensuring appropriate postoperative antibiotic discontinuation, and reinforcing patient education and follow-up may support sustained reduction in SSI.

Keywords: Antimicrobial stewardship, Drug resistance, Healthcare-associated infections, Infection control

INTRODUCTION

The SSIs continue to represent a significant proportion of healthcare-associated infections worldwide and remain an important cause of postoperative morbidity. They are associated with prolonged hospital stay, increased healthcare costs, and added burden on both patients and healthcare systems. The World Health Organisation (WHO) and CDC have consistently identified SSIs as one of the most frequent healthcare-associated infections, particularly in low- and middle-income countries, where limitations in resources and infection prevention infrastructure persist [1,2]. Despite advances in surgical techniques, sterilisation methods, and perioperative care, SSIs remain a persistent challenge in routine clinical practice [3].

The development of SSIs is influenced by multiple factors, including patient-related characteristics, type and duration of surgery, wound classification, and perioperative practices. Institutional factors such as adherence to infection prevention protocols and antimicrobial policies also play a critical role [4]. In recent years, several studies from India and other South Asian countries have reported a shift in the microbial aetiology of SSIs, with Gram-negative organisms increasingly identified as predominant pathogens. This pattern is consistent with findings reported by Deka S et al., who documented a predominance of Gram-negative organisms among SSI isolates in a tertiary care hospital setting in India [5-7]. This trend is concerning, as many of these organisms exhibit resistance to commonly used antimicrobials, thereby limiting treatment options and complicating postoperative management.

The SAP is a well-established and evidence-based intervention for SSI prevention. International guidelines, including those issued by the CDC-NHSN and the WHO, emphasise appropriate antibiotic selection, administration within the recommended time frame prior to incision, and discontinuation within 24 hours after surgery for most procedures [2,8]. When implemented correctly, SAP has been shown to significantly reduce SSI risk. However, inappropriate practices, particularly prolonged postoperative antibiotic use, have not demonstrated additional benefit and may contribute to antimicrobial resistance, adverse drug events, and unnecessary healthcare expenditure [9,10].

In the Indian healthcare setting, adherence to SAP guidelines is inconsistent. Multiple studies from tertiary care hospitals have demonstrated considerable variation across surgical specialties, with frequent non compliance related to inappropriate timing and unnecessarily prolonged duration of prophylactic antibiotic use [11-13]. Concerns regarding postoperative infections, lack of standardised institutional protocols, and limited audit mechanisms

often contribute to continued antibiotic overuse. At the same time, data from the Indian Council of Medical Research (ICMR) antimicrobial resistance surveillance network indicate a rising prevalence of multidrug-resistant organisms in healthcare-associated infections, including SSIs [14]. These findings highlight the importance of strengthening antimicrobial stewardship initiatives within surgical settings.

Active SSI surveillance, when combined with systematic monitoring of SAP adherence, provides an opportunity to assess the effectiveness of infection prevention strategies and identify areas for improvement [15]. However, many published studies from Indian settings have assessed SSI rates, antimicrobial resistance profiles, or antibiotic prophylaxis practices separately, and few have evaluated these components together over an extended period across multiple departments, highlighting a lack of comprehensive longitudinal surveillance that integrates SSI outcomes, microbial epidemiology, and SAP compliance in tertiary care teaching hospitals [16,17].

The rationale for this study was to generate institution-specific data that can support targeted infection prevention and antimicrobial stewardship strategies. Local epidemiological data are essential for guiding empirical therapy and refining prophylactic protocols in accordance with prevailing resistance patterns. Regular assessment of SAP adherence also facilitates identification of practice gaps and supports evidence-based quality improvement initiatives [18].

The novelty of this study lies in its prospective design spanning three years, integrating active SSI surveillance with structured SAP monitoring across multiple surgical departments. By examining SSI trends alongside antimicrobial prophylaxis practices and microbial epidemiology, this study provides a comprehensive overview of SSI dynamics within a real-world tertiary care setting and contributes valuable evidence to ongoing national efforts aimed at reducing SSI burden and addressing antimicrobial resistance.

This study aimed to evaluate the impact of SAP protocol implementation on SSI rates and associated microbial epidemiology in a tertiary care teaching hospital. The primary objective of the study was to assess the incidence and distribution of SSIs and evaluate adherence to SAP protocols among clean and clean-contaminated surgeries in a tertiary care hospital, and the secondary objectives were to analyse the microbial profile and antimicrobial susceptibility patterns of SSI isolates, to assess department-wise trends in SAP adherence over the study period, and to evaluate temporal changes in SSI rates following SAP protocol implementation.

MATERIALS AND METHODS

A prospective observational study was conducted at Mahatma Gandhi Medical College and Research Institute, Puducherry, India. This study was conducted from January 2022 to December 2024 by recruiting all patients who had undergone clean and clean-contaminated surgeries. The study received approval from the Institutional Research and Ethics Committee of Mahatma Gandhi Medical College and Research Institute: MGMCRI/2022/IRC/96/04/IHEC/38

As this was a prospective, period-based SSI surveillance study, the sample size was determined by complete enumeration, wherein all eligible clean and clean-contaminated surgeries performed during the three-year study period and all SSI cases identified among them were included. Formal sample size calculation was not performed, in accordance with CDC-NHSN recommendations for SSI surveillance studies, which advocate inclusion of all cases occurring within the defined surveillance period [2].

Inclusion criteria: Surgical patients of all ages and genders with culture-positive SSIs and clinically suspected SSI during the study period were included in the study.

Exclusion criteria: Postoperative patients who underwent primary surgical procedures outside this hospital were excluded from the study. SSI surveillance was conducted in accordance with the criteria established by the CDC NHSN guidelines. The SSIs were classified as superficial incisional, deep incisional, or organ/space infections, based on the NHSN criteria [2].

Study Procedure

Following daily ward rounds by Infection Control Nurses (ICNs) in all postoperative surgical wards and Surgical Intensive Care Units (SICU), postoperative patients who had undergone clean or clean-contaminated surgical procedures and presented with any signs or symptoms suggestive of SSI were further monitored. Appropriate clinical samples were collected and sent for culture and sensitivity testing. All culture-positive and surgeon-suspected SSI patients were included for further analysis. Data for SSI epidemiology were retrieved from the Microbiology laboratory portal in real time. Demographic data, clinical findings, laboratory reports and details of SAP were recorded in SSI surveillance forms (in-house drafted) by Infection Prevention and Control team members (IPC) as extracted. Information on the type of surgery, organism isolated, and antimicrobial susceptibility (as per Clinical and Laboratory Standards Institute (CLSI) guidelines [19] were extracted.

Clean and clean-contaminated surgical patients with implant and non implant procedures were monitored for 90- and 30-day surveillance periods. Postoperative follow-up was conducted as per NHSN recommendations, with patients undergoing non implant procedures followed for 30 days and those undergoing implant-associated procedures followed for 90 days, to ensure detection of late-onset SSIs related to implanted material, respectively [2]. Incidence of SSI data was captured from medical records, registration desk, surgical ward log book, nursing registers, Microbiology sample receiving register, daily inpatient and outpatient follow-up records, OPD dressing room register, and by daily postoperative ward rounds by IPC team members. In addition, during postoperative care discharge, each patient and their attenders were informed about the surveillance period and follow-up calls. They were also educated about personal hygiene, hand washing and surgical wound care. In case of any evidence of fever, redness, oedema, or discharge at the operated site, they were advised to report back to the institute as early as possible for further management.

SAP monitoring was carried out among all clean and clean-contaminated surgeries across eight surgical departments: General Surgery, Obstetrics & Gynaecology (OBG), Orthopaedics, Ear, Nose, and Throat (ENT), Neurosurgery, Oral and Maxillofacial Surgery (OMFS), Cardiothoracic and Vascular Surgery (CTVS) and Urology. Monitoring focused on three key compliance indicators: Appropriate SAP given (correct choice of antibiotic), appropriate SAP administered within 60 minutes before surgical incision was made (optimal timing) and discontinuation of antimicrobial agents 24 hours after surgery (adherence to recommended duration).

STATISTICAL ANALYSIS

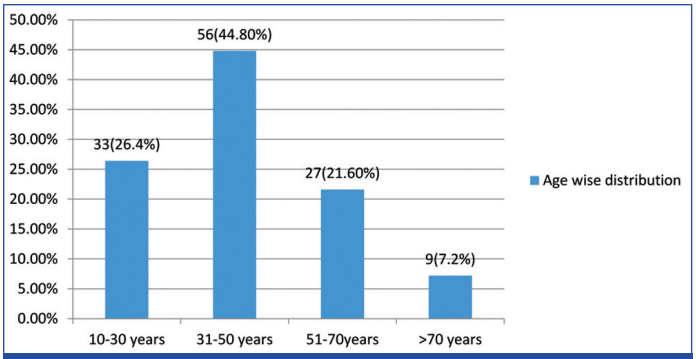
Data were entered and analysed using Statistical Package for the Social Sciences (SPSS) software version 23.0 (IBM Corp., Armonk, NY, USA). Categorical variables were summarised as frequencies and percentages n (%).

RESULTS

A total of 15,650 clean and clean-contaminated surgeries were performed, of which 125 patients developed SSI, giving an overall SSI rate of 125 (0.79%). The annual SSI rates were 35/6,062 (0.57%) in 2022, 47/4,737 (0.99%) in 2023, and 43/4,851 (0.88%) in 2024.

The 31-50 years age group was found to be the most commonly affected population at high risk of developing SSI in this study [Table/Fig-1].

Of the 125 patients who developed SSI, females constituted the majority, accounting for 82 cases (65.6%), while males comprised



[Table/Fig-1]: Distribution of SSI patients based on age (n=125).

43 cases (34.4%), indicating a higher burden of SSI among female patients.

Patients from the obstetrics department accounted for the highest proportion of SSI cases, 82/125 (65.6%) [Table/Fig-2].

Type of surgery	n (%)
Orthopaedic	18 (14.4)
Gastrointestinal	14 (11.2)
Obstetric	82 (65.6)
Neurosurgical	4 (3.2)
Others	7 (5.6)

[Table/Fig-2]: Distribution of Surgical Site Infections (SSI) by type of surgery (n=125).

The incidence of deep incisional SSI was more highest, followed by superficial and organ/space-occupying SSI infections [Table/Fig-3].

Type of SSI	n (%)
Superficial incisional SSI	51 (40.8)
Deep incisional SSI	72 (57.6)
Organ/space SSI	2 (1.6)

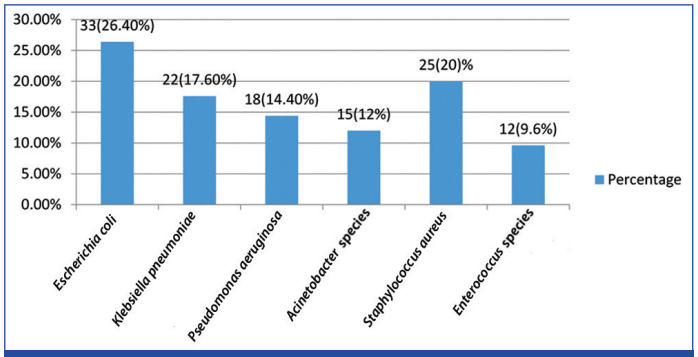
[Table/Fig-3]: Classification of Surgical Site Infections (SSI) (n=125).

Out of 11,400 non implant surgeries done over this study period, the majority 98 (0.85%) developed SSI. Patients with implant surgeries showed reduction 27 (0.63%) in developing SSI from a total of 4250 surgeries done [Table/Fig-4].

		2022	2023	2024
1	Total number of SSI	35	47	43
2	Rate of SSI	35/6062 (0.57%)	47/4737 (0.99%)	43/4851 (0.88%)
	a. Implant SSI	13 (1.36%)	10 (0.63%)	4 (0.23%)
	b. Non implant SSI	22 (0.43%)	37 (1%)	39 (1.2%)
	Superficial SSI	19 (54%)	6 (13%)	26 (60.4%)
	Deep SSI	15 (43%)	41 (87%)	16 (37.2%)
	Organ space-occupying SSI	1 (3%)	0	1 (2.32%)
3	Total number of clean and clean-contaminated surgeries SSI done	6062	4737	4851
	Implant surgeries	16% (953)	34% (1587)	35% (1710)
	Non-implant surgeries	84% (5109)	66% (3150)	65% (3141)

[Table/Fig-4]: Trends in Surgical Site Infections (SSI) and surgical volume (2022–2024).

Gram-negative organisms predominated, accounting for 88 (70.4%) of the total isolates. *Escherichia coli* was the most frequently isolated pathogen, 33 (26.4%), followed by *Klebsiella pneumoniae* 22 (17.6%), *Pseudomonas aeruginosa* 18 (14.4%), and *Acinetobacter species* 15 (12.0%). *Staphylococcus aureus* accounted for 25 (20.0%) isolates, of which Methicillin-Resistant *S. aureus* (MRSA) constituted 10 (40.0%), contributing to 10 (8.0%) of overall SSI cases. *Enterococcus* species were isolated in 12 (9.6%) cases. High resistance to third-generation cephalosporins was observed among Gram-negative isolates 61 (69.3%), while carbapenem resistance was detected in 10 (11.8%). No vancomycin resistance was observed among *Staphylococcus aureus* or *Enterococcus faecalis* isolates [Table/Fig-5].



[Table/Fig-5]: Microbial isolates from SSI.

The monitoring of SAP adherence demonstrated a notable improvement across several departments from 2022 to 2024. For the parameter "appropriate SAP given," most departments showed progressive increases in compliance. General Surgery improved from 85.0% (854/1,005) in 2022 to 99.0% (567/573) in 2024. Obstetrics and Gynaecology (OBG) achieved 99.0% compliance (1,649/1,666) in 2024. Orthopaedics showed an improvement to 97.0% (513/529), while ENT and Neurosurgery achieved 100% compliance by 2024 (262/262 and 112/112, respectively). Departments with lower baseline compliance in 2022, such as CTVS {54.0% (178/330)} and urology {67.0% (374/558)}, demonstrated substantial improvement, reaching 90.0% (112/124) and 99.0% (253/256) compliance, respectively, by 2024 [Table/Fig-6].

DISCUSSION

The present study observed an overall SSI rate of (0.79%) among clean and clean-contaminated surgeries, with no marked fluctuation across the three-year surveillance period. This rate was lower than that reported in several Indian studies, where SSI incidence has ranged from approximately 3-10%, depending on surgical specialty, case mix, and institutional practices. For instance, Deka S et al., reported higher SSI rates in a tertiary care hospital and demonstrated considerable inter-institutional variability, underscoring the influence of local infection control practices and microbial epidemiology on SSI burden [6]. Similarly, Kownhar H et al., reported a higher SSI burden in centres without structured surveillance mechanisms, underscoring the role of systematic monitoring in infection prevention [5]. The comparatively lower SSI rate in the present study is likely attributable to active surveillance, routine monitoring by infection control personnel, and consistent adherence to standardised perioperative protocols, findings that are in line with earlier reports demonstrating the effectiveness of surveillance-driven infection control programs [15].

An important finding of this study was the predominance of SSIs following obstetric surgeries, particularly post-LSCS procedures, which constituted the majority of SSI cases in the cohort. This observation was consistent with reports from Indian tertiary care hospitals demonstrating that high-volume surgical services contribute substantially to the overall SSI burden, reflecting institutional case mix and infection control practices [6,11]. Rehan HS et al., also highlighted variability in infection prevention and antimicrobial prophylaxis practices in obstetric units, which may influence SSI occurrence even in procedures categorised as clean or clean-contaminated [11]. Microbiological analysis in the present

Surgical Antimicrobial Prophylaxis (SAP)monitoring among clean and clean contaminated surgeries							
January to December	2022		2023		2024		2022, 2023, 2024
Surgical departments under surveillance	Appropriate SAP given	Discontinuation of antimicrobial agents 24 hours after surgery	Appropriate SAP given	Discontinuation of antimicrobial agents 24 hours after surgery	Appropriate SAP given	Discontinuation of antimicrobial agents 24 hours after surgery	Appropriate SAP administered within 60 minutes before surgical incision made
General surgery	854/1005 (85.0)	733/1005 (73.0)	635/722 (88.0)	563/722 (78.0)	567/573 (99.0)	555/573 (97.0)	2300/2300 (100)
OBG	824/886 (93.0)	522/886 (59.0)	1414/1428 (99.0)	1172/1428 (82.0)	1649/1666 (99.0)	1167/1666 (70.0)	3980/3980 (100)
Ortho	627/774 (81.0)	595/774 (77.0)	532/560 (95.0)	481/560 (86.0)	513/529 (97.0)	514/529 (97.0)	1863/1863 (100)
ENT	282/288 (98.0)	201/288 (70.0)	383/387 (99.0)	321/387 (83.0)	262/262 (100)	212/262 (81.0)	937/937 (100)
Neuro surgery	102/102 (100)	102/102 (100)	100/100 (100)	100/100 (100)	112/112 (100)	112/112 (100)	314/314 (100)
OMFS	62/74 (84.0)	36/74 (48.0)	42/58 (72.0)	40/58 (68.0)	75/79 (95.0)	59/79 (74.0)	211/211 (100)
CTVS	178/330 (54.0)	194/330 (59.0)	85/163 (52.0)	65/163 (40.0)	112/124 (90.0)	95/124 (77.0)	617/617 (100)
Urology	374/558 (67.0)	318/558 (57.0)	314/324 (97.0)	171/324 (53.0)	253/256 (99.0)	171/256 (67.0)	1138/1138 (100)

[Table/Fig-6]: Surgical Antimicrobial Prophylaxis (SAP) monitoring among clean and clean-contaminated surgeries by department (2022-2024).
SAP: Surgical antimicrobial prophylaxis; OBG: Obstetrics and gynaecology; ENT: Ear, Nose and Throat; OMFS: Oral and maxillofacial surgery; CTVS: Cardiothoracic and vascular surgery Values are expressed as n/N (%), where n represents the number of cases meeting the specified SAP parameter and N represents the total number of eligible clean and clean-contaminated surgeries for that department and year. Ophthalmic cases were included for SSI analysis under clean/clean-contaminated procedures but excluded from SAP adherence monitoring due to use of topical rather than systemic antimicrobial prophylaxis

study demonstrated a predominance of Gram-negative organisms, with *Escherichia coli* and *Klebsiella pneumoniae* being the most frequently isolated pathogens. This finding was in agreement with observations from Indian tertiary care hospitals, where Deka S et al., reported a similar predominance of Gram-negative organisms among SSI isolates [6]. The high resistance observed to third-generation cephalosporins, along with the presence of carbapenem resistance among Gram-negative isolates, reflects broader national antimicrobial resistance trends documented by the Indian Council of Medical Research (ICMR) surveillance network [14]. These findings highlight the growing challenge of antimicrobial resistance in surgical infections and reinforce the importance of local microbiological surveillance to guide empirical therapy and periodically reassess prophylactic antibiotic policies, as emphasised in previous literature [10,18].

When implant and non implant surgeries were compared, the present study found lower SSI rates in implant-associated procedures, with a declining trend over the study period. Similar observations have been reported in surveillance-based studies, where improved outcomes in implant surgeries were linked to stringent aseptic techniques and structured follow-up protocols [15,17]. The application of extended surveillance periods of 90 days for implant-related procedures, in accordance with CDC-NHSN recommendations, facilitates early detection and management of late-onset infections [2,4]. In contrast, the relatively higher SSI rates observed in non implant surgeries underscore the need for sustained attention to perioperative infection prevention measures, even in procedures traditionally considered to carry a lower infection risk.

Assessment of SAP adherence in the present study demonstrated progressive improvement across most departments, particularly with respect to appropriate antibiotic selection and timely administration. Similar findings have been reported from Indian tertiary care hospitals, where implementation of institutional SAP protocols and audit mechanisms resulted in improved compliance with recommended prophylactic practices [12,13]. However, variability persisted in relation to the timely discontinuation of postoperative antibiotics, a concern also highlighted in Indian studies evaluating adherence to SAP guidelines [12]. These findings point to the continued need for comprehensive antimicrobial stewardship efforts, including regular audit and feedback, clinician education, and multidisciplinary collaboration, in line with established stewardship recommendations [18-20]. Although the present study did not assess individual patient-level risk factors, the consistently higher proportion of post-LSCS SSIs highlights the need for focused preventive strategies in obstetric settings, including strict compliance with SAP protocols and reinforcement of perioperative aseptic practices. Future studies evaluating targeted stewardship interventions and their effect on SSI outcomes may further strengthen infection prevention practices in tertiary care hospitals.

Limitation(s)

This study had certain limitations. It was a single-centre study, which may limit the generalisability of the findings to other institutions. Furthermore, the resistance mechanisms of the isolated organisms were not molecularly characterised, which could provide deeper insights into the epidemiology of multidrug-resistant strains.

CONCLUSION(S)

This three-year prospective analysis reveals a predominant microbial pattern in SSIs driven by multidrug-resistant Gram-negative bacilli, with concerning levels of resistance to third-generation cephalosporins and carbapenems. Simultaneously, the study demonstrates substantial improvement in institutional adherence to SAP protocols, especially concerning timely administration and appropriate antibiotic selection. While improved SAP likely contributed to a reduction in high-impact implant-related SSIs, the fluctuating overall SSI rates highlight the complex interplay between evolving antimicrobial resistance and infection control efforts. To effectively mitigate the burden of SSIs in tertiary care settings, continuous surveillance of microbial epidemiology, tailored antibiotic policies based on local antibiograms, strict adherence to surgical asepsis, and a reinforced focus on comprehensive antibiotic stewardship programs, including optimised postoperative discontinuation, are essential.

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