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Research Article

Bacterial Profile and Antimicrobial Resistance Patterns among Patients with Surgical Site Infections: A Prospective Study

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ABSTRACT
Background: Surgical site infections (SSIs) represent a major subgroup of healthcare-associated infections that escalate postoperative morbidity, extend hospital stays, and increase financial burdens. Understanding local microbiological profiles and antibiotic resistance trends is crucial for informing targeted empirical therapy and antimicrobial stewardship. Objective: To isolate and characterize bacterial pathogens from surgical site wound specimens, evaluate their antimicrobial susceptibility profiles, and determine the prevalence of multidrug-resistant (MDR) strains among hospitalized surgical patients.
Methods: A prospective hospital-based observational study was conducted over a 12-month period at Khaja Bandanawaz University, Gulbarga, Karnataka, India. A total of 100 clinical surgical site specimens (pus aspirates and wound swabs) were collected from eligible post-operative patients showing clinical evidence of SSI. Standard laboratory procedures, including direct microscopy, selective culture, and phenotypic biochemical assays, were utilized for bacterial identification. Antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion technique on Mueller–Hinton agar in accordance with Clinical and Laboratory Standards Institute (CLSI) guidelines.
Results: Among 100 analyzed specimens, 92 (92.0%) yielded positive bacterial cultures, giving a total of 102 bacterial isolates (82 monomicrobial and 10 polymicrobial infections). Gram-negative bacteria predominated, comprising 59.8% (n=61) of the total isolates, whereas Gram-positive bacteria accounted for 40.2% (n=41). The leading pathogens were Escherichia coli (22.5%, n=23), Staphylococcus aureus (20.6%, n=21), Klebsiella pneumoniae (14.7%, n=15), Pseudomonas aeruginosa (11.8%, n=12), and Acinetobacter baumannii (9.8%, n=10). Among S. aureus isolates, 33.3% (n=7/21) were methicillin-resistant S. aureus (MRSA); notably, all Gram-positive isolates remained fully susceptible (100%) to vancomycin and linezolid. Gram-negative bacilli demonstrated severe resistance to ampicillin (88.5%), ceftriaxone (68.9%), and ciprofloxacin (63.9%), but maintained substantial susceptibility to amikacin (73.8%), piperacillin-tazobactam (70.5%), and meropenem (80.3%). Multidrug resistance was observed in 37.3% (n=38/102) of all isolates, with Gram-negative organisms demonstrating higher MDR rates (41.0%) than Gram-positive organisms (31.7%).
Conclusion: Gram-negative pathogens dominate the microbiological spectrum of SSIs in our institution, with high levels of resistance to routinely prescribed first- and second-line antibiotics. Continuous microbiological surveillance, institutional antibiograms, and structured antimicrobial stewardship programs are vital to optimize empirical therapy and control the spread of multi-resistant bacterial pathogens.

Keywords: Surgical Site Infections, Antimicrobial Resistance, Methicillin-Resistant Staphylococcus Aureus, Multidrug Resistance, Bacterial Profile, Hospital Infection Control.

INTRODUCTION

Surgical site infections (SSIs) represent one of the most common and challenging categories of healthcare-associated infections (HAIs) worldwide [1,2]. Defined as infections occurring within 30 days of an operative procedure (or up to 90 days if an implant is left in place), SSIs involve the incisional tissue, deeper soft tissues, or organs and body spaces manipulated during surgery [1]. Despite

substantial advances in sterile techniques, operating room ventilation, perioperative antibiotic prophylaxis, and infection control standards, SSIs continue to impose a severe burden on healthcare systems. They lead to prolonged hospital stays, increased postoperative morbidity, repeated surgical interventions, substantial economic expenditures, and elevated patient mortality [1,3].

The pathogenesis of SSI involves a complex interplay between host susceptibility factors, surgical parameters, and environmental microbial contamination [2]. Key patient-related risk factors include advanced age, poor nutritional status, uncontrolled diabetes mellitus, obesity, anemia, and concurrent systemic comorbidities [2,4]. Surgical determinants include the duration and complexity of the procedure, wound contamination classification (clean, clean-contaminated, contaminated, dirty), emergency vs. elective settings, and adherence to surgical asepsis [3,4]. Surgical site pathogens originate either from the patient's endogenous skin or mucosal flora or via exogenous acquisition from contaminated operating room air, instruments, or healthcare personnel [1,2].

Microbiologically, SSIs encompass a diverse range of bacterial pathogens [3]. Common causative microorganisms include Gram-positive cocci such as Staphylococcus aureus and coagulase-negative staphylococci (CoNS), alongside Gram-negative bacilli including Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Acinetobacter baumannii, and Proteus species [3,4]. However, the institutional distribution of SSI pathogens varies considerably across geographical regions, surgical specialties, and hospital environments [3,4]. Consequently, local epidemiological data are mandatory for clinical management.

In recent years, the escalation of antimicrobial resistance (AMR) has critically impaired the effective management of SSIs [5,6]. The emergence and global dissemination of multidrug-resistant (MDR) organisms—such as methicillin resistant Staphylococcus aureus (MRSA), extended-spectrum β-lactamase (ESBL)-producing Enterobacterales, and carbapenem-resistant Gram-negative bacilli—have restricted therapeutic options and increased empirical treatment failures [5,6]. Routine antimicrobial susceptibility testing (AST) is therefore crucial for directing pathogen-specific therapy, reducing selection pressure, and guiding local empirical treatment protocols [7].

In alignment with World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) guidelines, institutional surveillance of SSI pathogens and their resistance patterns provides essential evidence for hospital infection control and antimicrobial stewardship [1,2,8]. Therefore, this prospective study was conducted to identify the bacterial spectrum and evaluate antimicrobial resistance patterns among patients with SSIs at Khaja Bandanawaz University, Gulbarga, Karnataka, India.

MATERIALS AND METHODS

Study Design and Setting: A prospective observational hospital-based study was conducted over a period of 12 months in the Department of Microbiology in collaboration with the Department of Surgery at Khaja Bandanawaz University, Gulbarga, Karnataka, India. The study aimed to prospectively evaluate the microbiological etiology and resistance profiles of bacterial isolates obtained from patients clinically diagnosed with surgical site infections.

Study Population and Sample Size: The study population comprised 100 consecutive non-duplicate surgical patients who developed clinical evidence of SSI during their postoperative care at Khaja Bandanawaz University, Gulbarga, Karnataka, India. For each participant, a single representative clinical wound specimen was collected for microbiological processing.

Inclusion and Exclusion Criteria:

Inclusion Criteria:

- Patients who had undergone a surgical procedure at Khaja Bandanawaz University, Gulbarga, Karnataka, India during the study period.
- Patients presenting with clinical signs and symptoms of SSI, defined by localized purulent discharge, wound dehiscence, erythema, localized swelling, heat, pain, or fever, in accordance with standard diagnostic guidelines [2,4].
- Patients from whom an adequate clinical sample (pus aspirate or wound swab) could be collected.
- Patients or legally authorized representatives who provided written informed consent.

Exclusion Criteria:

- Infections present or incubating at the surgical site prior to the index operative procedure.
- Inadequately collected or improperly transported clinical specimens.
- Duplicate or repeat samples obtained from the same infection episode.
- Patients refusing consent or possessing incomplete clinical documentation.

Clinical Data Collection

Demographic characteristics (age, sex) and clinical details—including type of surgical procedure (elective vs. emergency), underlying comorbidities (diabetes mellitus, hypertension, obesity, anemia), prior antibiotic exposure, and local wound manifestations—were recorded using a pre-tested structured data collection tool.

Specimen Collection and Laboratory Processing

Clinical specimens were obtained prior to the administration of new empirical antibiotic doses whenever clinically achievable. Exudates or deep pus aspirates were collected using sterile syringes. When aspirates were unobtainable, superficial debris was cleared with sterile saline, and specimens were taken from the active wound edge using two sterile cotton swabs. Specimens were transported immediately to the microbiology laboratory in sterile transport media for processing. Gram-stained smears were examined directly under microscopic magnification to evaluate inflammatory cell counts and preliminary bacterial morphology. Specimens were inoculated onto 5% Sheep Blood Agar and MacConkey Agar plates (HiMedia Laboratories, Mumbai, India) and incubated aerobically at 35°C–37°C for 18–24 hours. Colony morphology, hemolytic activity, and lactose fermentation characteristics were documented.

Identification of Bacterial Isolates

Bacterial isolates were identified to the species level using standard microbiological methods, including catalase, coagulase (slide and tube tests), oxidase, indole, methyl red, Voges–Proskauer, citrate utilization, urease production, motility testing, and triple sugar iron (TSI) biochemical reaction profiles.

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion method on Mueller–Hinton agar according to Clinical and Laboratory Standards Institute (CLSI) guidelines [7]. Bacterial inocula were standardized to a 0.5 McFarland turbidity standard. Commercial antibiotic disks (HiMedia) were applied, and zone diameters were measured after 16–18 hours of incubation at 35°C–37°C.

Antibiotics tested for Gram-positive isolates included amoxicillin-clavulanate (30 µg), erythromycin (15 µg), ciprofloxacin (5 µg), gentamicin (10 µg), amikacin (30 µg), clindamycin (2 µg), linezolid (30 µg), and vancomycin (30 µg). Methicillin resistance in S. aureus was detected using a cefoxitin disk (30 µg). For Gram-negative isolates, the panel included ampicillin (10 µg), amoxicillin-clavulanate (30 µg), ceftriaxone (30 µg), ceftazidime (30 µg), ciprofloxacin (5 µg), gentamicin (10 µg), amikacin (30 µg), piperacillin-tazobactam (100/10 µg), and meropenem (10 µg).

Results were categorized as susceptible, intermediate, or resistant based on CLSI interpretive criteria [7]. Quality control was maintained using reference strains: Escherichia coli ATCC 25922 and Staphylococcus aureus ATCC 25923.

Assessment of Multidrug Resistance (MDR)

Multidrug resistance (MDR) was defined as acquired non-susceptibility to at least one agent in three or more antimicrobial categories, per international consensus definitions [5].

Statistical Analysis

Data were compiled in Microsoft Excel and analyzed using IBM SPSS Statistics Version 26.0. Continuous variables were expressed as mean ± standard deviation (SD). Categorical parameters were presented as frequencies and percentages. Categorical associations were evaluated using the Pearson Chi-square test or Fisher's exact test. A p value < 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee of Khaja Bandanawaz University, Gulbarga, Karnataka, India.

Informed consent was secured from all participants. Patient confidentiality was strictly preserved throughout the investigation.

RESULTS

Patient Demographics and Clinical Characteristics

A total of 100 surgical site infection cases were evaluated. The mean age of the study cohort was 46.2 ± 16.8 years (range: 18–82 years). The most prevalent age bracket was 41–50 years (24.0%), followed by 31–40 years (20.0%) and 51–60 years (20.0%). Males predominated in the study population, accounting for 61.0% (n=61), while females constituted 39.0% (n=39) (Table 1).

Table 1. Age and Sex Distribution of Study Participants (N = 100)

Variable	Category	Number of Patients (n)	Percentage (%)
Age Group (years)	18–30	17	17.0
	31–40	20	20.0
	41–50	24	24.0
	51–60	20	20.0
	> 60	19	19.0
Sex	Male	61	61.0
	Female	39	39.0
Total	--	**100**	**100.0**

Regarding surgical intervention, 63.0% (n=63) of patients underwent elective surgical procedures, whereas 37.0% (n=37) had undergone emergency surgery. Underlying clinical comorbidities were identified in 52.0% of patients. Diabetes mellitus was the most frequent comorbidity (23.0%), followed by hypertension (19.0%), anemia (16.0%), and obesity (12.0%) (Table 2).

Table 2. Clinical Characteristics and Surgical Context of Patients (N = 100)

Clinical Characteristic	Patient Count (n)	Percentage (%)
Elective Surgery	63	63.0
Emergency Surgery	37	37.0
Diabetes Mellitus	23	23.0
Hypertension	19	19.0
Anemia	16	16.0
Obesity	12	12.0
No Documented Comorbidity	48	48.0

3.2 Culture Positivity and Infection Types Of the 100 wound specimens processed, 92 (92.0%) showed significant bacterial growth on culture media, while 8 (8.0%) exhibited no growth. Monomicrobial growth was documented in 82 (89.1%) culture-positive specimens, while 10 (10.9%) exhibited polymicrobial growth, yielding a total of 102 non-duplicate bacterial isolates (Table 3).

Table 3. Microbiological Culture Positivity and Growth Characteristics

Culture Parameter	Number (n)	Proportion (%)
Culture Positive Specimens	92	92.0
Culture Negative Specimens	8	8.0
Monomicrobial Infections	82	89.1*
Polymicrobial Infections	10	10.9*
Total Recovered Bacterial Isolates	**102**	**100.0**

** Percentage calculated among culture-positive specimens (n = 92).*

3.3 Distribution of Bacterial Pathogens Gram-negative bacilli were the predominant causative agents, accounting for 59.8% (n=61) of total bacterial isolates, whereas Gram-positive cocci comprised 40.2% (n=41). Escherichia coli was the single most frequently isolated bacterial species (22.5%, n=23), followed closely by Staphylococcus aureus (20.6%, n=21), Klebsiella pneumoniae (14.7%, n=15), Pseudomonas aeruginosa (11.8%, n=12), and Acinetobacter baumannii (9.8%, n=10) (Table 4 and Figure 1).

Table 4. Taxonomic Distribution of Bacterial Isolates (N = 102)

Bacterial Pathogen	Gram Reaction	Number of Isolates (n)	Relative Frequency (%)
Escherichia coli	Gram-Negative	23	22.5
Staphylococcus aureus	Gram-Positive	21	20.6
Klebsiella pneumoniae	Gram-Negative	15	14.7
Pseudomonas aeruginosa	Gram-Negative	12	11.8
Acinetobacter baumannii	Gram-Negative	10	9.8
Coagulase-Negative *Staphylococcus* (CoNS)	Gram-Positive	8	7.8
Proteus mirabilis	Gram-Negative	7	6.9
Enterobacter spp.	Gram-Negative	4	3.9
Enterococcus spp.	Gram-Positive	2	2.0
Total Isolates	—	**102**	**100.0**

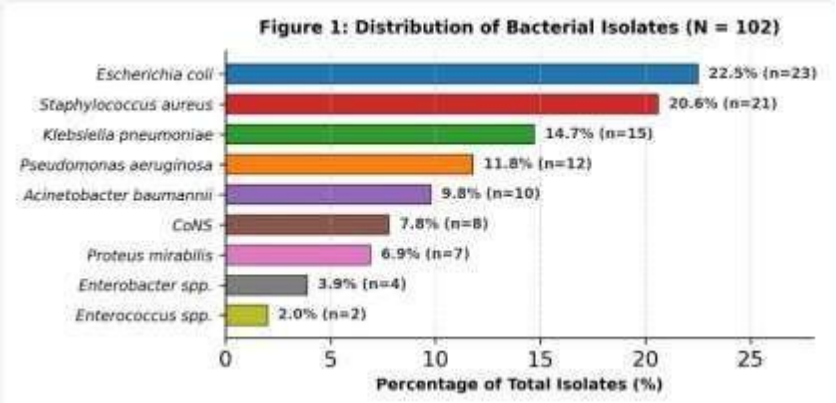

Figure 1. Relative frequency of isolated bacterial pathogens from surgical site infections (N = 102). Gram-negative species combined constituted 59.8% of isolates, led by Escherichia coli (22.5%), while Staphylococcus aureus was the predominant Gram positive organism (20.6%).

3.4 Antimicrobial Susceptibility Profile of Gram-Positive Isolates Among Gram-positive isolates, S. aureus (n=21) displayed complete sensitivity (100.0%) to vancomycin and linezolid, followed by high susceptibility to amikacin (81.0%, n=17) and gentamicin (66.7%, n=14). Elevated resistance levels were observed against erythromycin (66.7%, n=14), amoxicillin-clavulanate (61.9%, n=13), and ciprofloxacin (57.1%, n=12) (Table 5).

Table 5. Antimicrobial Susceptibility Pattern of Staphylococcus aureus Isolates (n = 21)

Antimicrobial Agent	Susceptible Count n (%)	Resistant Count n (%)
Amoxicillin-clavulanate	8 (38.1)	13 (61.9)
Erythromycin	7 (33.3)	14 (66.7)
Ciprofloxacin	9 (42.9)	12 (57.1)
Gentamicin	14 (66.7)	7 (33.3)
Amikacin	17 (81.0)	4 (19.0)
Clindamycin	12 (57.1)	9 (42.9)
Linezolid	21 (100.0)	0 (0.0)
Vancomycin	21 (100.0)	0 (0.0)

Phenotypic screening for methicillin resistance revealed that 33.3% (n=7/21) of S. aureus isolates were MRSA, whereas 66.7% (n=14/21) were methicillin-sensitive S. aureus (MSSA) (Table 6).

Table 6. Prevalence of MRSA and MSSA Phenotypes among S. aureus Isolates

Staphylococcal Phenotype	Isolate Count (n)	Proportion (%)
Methicillin-Sensitive *S. aureus* (MSSA)	14	66.7
Methicillin-Resistant *S. aureus* (MRSA)	7	33.3
Total *S. aureus*	**21**	**100.0**

3.5 Antimicrobial Resistance among Gram-Negative Isolates Gram-negative isolates (n=61) exhibited high rates of resistance to first-line agents: ampicillin (88.5%), ceftriaxone (68.9%), ciprofloxacin (63.9%), amoxicillin-clavulanate (63.9%), ceftazidime (62.3%), and gentamicin (54.1%). In contrast, higher sensitivity was retained for meropenem (80.3% susceptible), amikacin (73.8% susceptible), and piperacillin-tazobactam (70.5% susceptible) (Table 7 and Figure 2).

Table 7. Overall Antimicrobial Resistance Profile of Gram-Negative Isolates (n = 61)

Antimicrobial Agent	Resistant Count n (%)	Susceptible Count n (%)
Ampicillin	54 (88.5)	7 (11.5)
Ceftriaxone	42 (68.9)	19 (31.1)
Amoxicillin-clavulanate	39 (63.9)	22 (36.1)
Ciprofloxacin	39 (63.9)	22 (36.1)
Ceftazidime	38 (62.3)	23 (37.7)
Gentamicin	33 (54.1)	28 (45.9)
Piperacillin-tazobactam	18 (29.5)	43 (70.5)
Amikacin	16 (26.2)	45 (73.8)
Meropenem	12 (19.7)	49 (80.3)

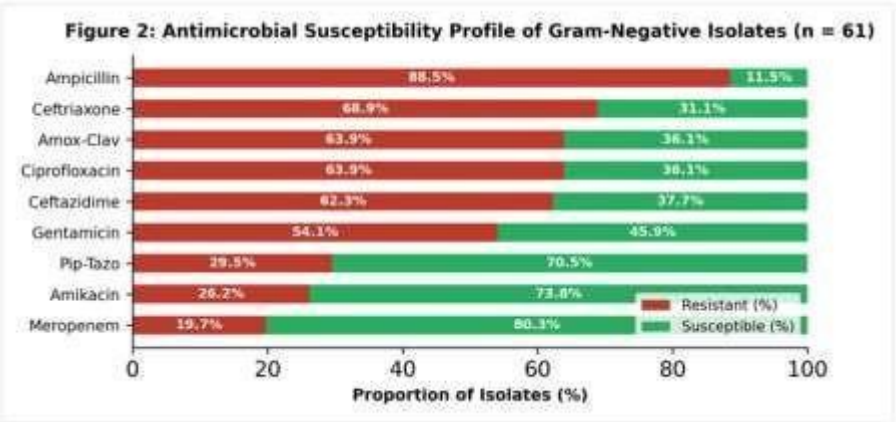

Figure 2. Antimicrobial susceptibility and resistance percentages among Gram-negative isolates (n = 61). High resistance was recorded for ampicillin and 3rd-generation cephalosporins, whereas carbapenems (meropenem) and aminoglycosides (amikacin) retained favorable activity.

3.6 Prevalence of Multidrug Resistance (MDR) Overall, 37.3% (n=38/102) of all bacterial isolates were categorized as multidrug-resistant (MDR). The frequency of MDR was higher among Gram-negative bacilli (41.0%, n=25/61) than Gram-positive cocci (31.7%, n=13/41) (Table 8).

Table 8. Distribution of Multidrug-Resistant (MDR) Bacterial Isolates

Pathogen Group	Total Isolates (N)	MDR Isolates (n)	MDR Prevalence (%)
Gram-Positive Organisms	41	13	31.7
Gram-Negative Organisms	61	25	41.0
Total Isolates	**102**	**38**	**37.3**

3.7 Association between Surgery Type and Culture Positivity 41.0 37.3 Patients undergoing emergency surgical procedures demonstrated higher culture positivity rates (97.3%, n=36/37) compared to those undergoing elective surgeries (88.9%, n=56/63). However, this numerical difference did not achieve statistical significance in our cohort ($\chi^2 = 2.45$, $p = 0.118$). 4.

DISCUSSION

Surgical site infections continue to pose a formidable challenge to surgical teams, clinical microbiologists, and hospital administrators [1,3]. In this prospective hospital-based investigation at Khaja Bandanawaz University, Gulbarga, Karnataka, India, we observed a culture positivity rate of 92.0% among 100 suspected SSI wound specimens. This rate aligns closely with findings from other regional studies across India, such as reports by Gautam et al. (96.4%) and Sharma et al. (92.3%) [4,5]. High culture yields reflect appropriate clinical diagnostic criteria and proper specimen handling techniques.

In our study, Gram-negative organisms predominated, accounting for 59.8% of all isolates, whereas Gram-positive organisms comprised 40.2%. This shift toward Gram-negative dominance in SSIs reflects wider regional trends reported in India and tertiary medical centers across South Asia [3-5]. Escherichia coli was the single most common isolate (22.5%), followed by Staphylococcus aureus (20.6%), Klebsiella pneumoniae (14.7%), Pseudomonas aeruginosa (11.8%), and Acinetobacter baumannii (9.8%). The frequent isolation of Enterobacterales like E. coli and K. pneumoniae is often linked to endogenous contamination during abdominal, gastrointestinal, or pelvic surgeries [1,3]. Conversely, non-fermenting Gram-negative bacilli such as P. aeruginosa and A. baumannii point toward environmental or nosocomial acquisition in postoperative wards and intensive care units [5,6].

Among Gram-positive isolates, S. aureus remains a principal pathogen in surgical wound breakdown [2,4]. In our study, 33.3% of S. aureus isolates were identified as MRSA. The prevalence of MRSA in SSIs varies widely in Indian literature, ranging from 20% to over 45% depending on hospital size and infection prevention practices [4,5]. MRSA colonization or infection is linked to higher treatment costs and prolonged hospitalization [2,6]. Encouragingly, all Gram-positive isolates in our series were 100% susceptible to vancomycin and linezolid, confirming their reliability as reserve options for severe MRSA infections [6,7].

Antimicrobial susceptibility testing of Gram-negative isolates revealed high resistance to standard first-line therapies, including ampicillin (88.5%), ceftriaxone (68.9%), ciprofloxacin (63.9%), and ceftazidime (62.3%). These findings reflect widespread selective pressure caused by empirical misuse of β-lactams and fluoroquinolones [5,6,8]. Conversely, amikacin (73.8% sensitive), piperacillin-tazobactam (70.5% sensitive), and meropenem (80.3% sensitive) retained strong bactericidal activity against Gram-negative pathogens. These findings reinforce the importance of reserving broad-spectrum carbapenems and β-lactamase inhibitor combinations for severe or refractory cases [6,7].

The overall MDR prevalence of 37.3% in our study underlines the growing threat of resistant hospital-acquired infections [5,8]. Gram-negative isolates demonstrated higher MDR rates (41.0%) than Gram-positive cocci (31.7%), emphasizing the urgent need for robust surveillance, antibiotic stewardship programs, and adherence to WHO multimodal infection prevention guidelines [1,8,9].

Strengths and Limitations

Strengths: This study provides valuable prospective data on SSI microbiology and resistance profiles in an underserved region of Karnataka. Adherence to standard CLSI diagnostic protocols ensures data reliability to inform local empirical antibiotic guidelines.

Limitations: First, the sample size was limited to 100 patients at a single medical center. Second, molecular resistance profiling (e.g., PCR detection of mecA or blaCTX-M genes) was unavailable due to resource limitations.

Third, detailed surgical risk factors (e.g., operative duration, NNIS risk index) were not systematically analyzed.

CONCLUSION

Surgical site infections at Khaja Bandanawaz University, Gulbarga, Karnataka, India are predominantly caused by Gram-negative bacilli, led by Escherichia coli, alongside Staphylococcus aureus. High resistance to first-line β-lactams and fluoroquinolones, combined with a 37.3% MDR prevalence and a 33.3% MRSA rate, underscores the need for routine culture-guided antimicrobial therapy. Institutional antibiograms, active AMR surveillance, and rigorous infection control practices are essential to optimize patient outcomes and preserve antibiotic efficacy.

Declarations

Ethical Approval: Approved by the Institutional Ethics Committee of Khaja Bandanawaz University, Gulbarga, Karnataka, India

Consent to Participate: Written informed consent was obtained from all patients. Conflict of Interest: The authors declare no competing financial or personal interests.

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