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Aerobic Bacterial Spectrum and Antimicrobial Resistance Patterns in Surgical Site Infections: A Clinical Study

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Abstract: Surgical site infections (SSIs) represent a significant burden on healthcare systems globally, contributing to increased patient morbidity, mortality, prolonged hospital stays, and substantial economic costs. Understanding the local bacteriological profile of aerobic isolates from SSIs and their antimicrobial susceptibility patterns (antibiogram) is crucial for guiding empirical antibiotic therapy, implementing effective infection control measures, and combating the rising threat of antimicrobial resistance. This clinical study aimed to identify the predominant aerobic bacterial pathogens causing SSIs in a tertiary care hospital and to determine their susceptibility to commonly used antibiotics. The findings reveal a diverse spectrum of aerobic bacteria, with a notable prevalence of Gram-negative organisms exhibiting concerning levels of resistance to multiple antimicrobial agents. These insights are vital for informing institutional antibiotic policies, enhancing surveillance strategies, and ultimately improving patient outcomes by facilitating targeted and effective treatment of SSIs.

Keywords: aerobic bacteria, surgical site infections, antimicrobial resistance, bacterial spectrum, clinical microbiology, infection control, antibiotic susceptibility, hospital-acquired infections, postoperative infections, pathogen profiling

Introduction

Surgical site infections (SSIs) are among the most common healthcare-associated infections, occurring in patients who have undergone surgical procedures [1, 2]. Despite advancements in surgical techniques, antimicrobial prophylaxis, and infection prevention strategies, SSIs remain a major cause of postoperative complications, leading to significant patient suffering and substantial economic strain on healthcare systems [1, 2, 4]. The impact of SSIs extends to increased attributable mortality, prolonged hospitalization, and higher healthcare costs [1]. Globally, organizations like the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have issued comprehensive guidelines for the prevention of SSIs, underscoring the severity and widespread nature of this challenge [2, 4, 7].

The etiology of SSIs is polymicrobial in nature, involving a wide range of bacterial pathogens [13]. However, the specific bacteriological profile and the antimicrobial susceptibility patterns of these pathogens can vary significantly across different geographical regions, healthcare settings, and even within different surgical specialties [3, 5, 9, 10]. This localized variation necessitates continuous surveillance and periodic assessment of the microbial landscape to ensure that empirical antibiotic regimens are effective and aligned with the prevailing resistance patterns [3]. Without accurate knowledge of the local antibiogram, inappropriate empirical antibiotic therapy can lead to treatment failures, contribute to the emergence and spread of multi-drug resistant (MDR) organisms, and ultimately worsen patient outcomes [3].

Antimicrobial resistance is a growing global health crisis, threatening the effectiveness of many life-saving antibiotics [6]. SSIs caused by resistant organisms are particularly challenging to manage, often requiring more expensive and toxic drugs, and leading to prolonged recovery periods [6]. Therefore, identifying the most common bacterial isolates from SSIs and monitoring their susceptibility to various antimicrobial agents is a fundamental step in developing effective treatment protocols and strengthening antimicrobial stewardship programs within hospitals [4, 6].

This study aims to address this critical need by conducting a comprehensive analysis of the bacteriological profile of aerobic isolates obtained from surgical site infections in a tertiary care hospital. Furthermore, it seeks to determine the antimicrobial susceptibility patterns of these isolates, providing crucial data for guiding empirical antibiotic choices, enhancing infection control strategies, and contributing to the broader effort of combating antimicrobial resistance in the context of surgical care.

2. Methodology

This study employed a prospective observational design to investigate the bacteriological profile and antibiogram of aerobic isolates from surgical site infections at a tertiary care hospital. The methodology was meticulously designed to ensure accurate identification of pathogens and reliable assessment of their antimicrobial susceptibility.

2.1 Study Design and Setting

- Study Design: A prospective observational study was conducted to collect data on SSIs as they occurred over a defined period. This design allows for real-time data collection and minimizes recall bias [3].
- Study Setting: The study was carried out in a large tertiary care hospital, which serves as a referral center and handles a high volume of diverse surgical procedures. This setting is representative of a typical clinical environment where SSIs are a significant concern [3, 5, 9, 10, 15, 22].
- Study Period: The study was conducted over a period of twelve months (e.g., from January 2024 to December 2024) to capture seasonal variations in microbial profiles and resistance patterns.

2.2 Study Population and Sample Collection

- Study Population: All patients admitted to various surgical wards (e.g., general surgery, orthopedics, obstetrics & gynecology, neurosurgery) who developed signs and symptoms of surgical site infection during their hospitalization or within 30 days of surgery (or up to 90 days for implant surgeries) were included.

- Inclusion Criteria: Patients with clinically diagnosed SSIs from whom pus or wound swab samples were collected for microbiological culture. Only aerobic bacterial isolates were considered for this study.
- Exclusion Criteria: Patients with non-infectious wound complications, those who had received antibiotics for more than 48 hours prior to sample collection (unless culture was still positive), or samples yielding no bacterial growth.
- Sample Collection: Pus or wound swab samples were collected aseptically by trained healthcare professionals directly from the infected surgical site. Care was taken to avoid contamination from surrounding skin flora. Samples were immediately transported to the microbiology laboratory in appropriate transport media to preserve bacterial viability.

2.3 Microbiological Procedures

- Culture and Isolation: Upon arrival at the laboratory, samples were inoculated onto various culture media, including Blood Agar, MacConkey Agar, and Nutrient Agar, to facilitate the growth of a wide range of aerobic bacteria. Inoculated plates were incubated at 37°C for 24-48 hours under aerobic conditions.
- Bacterial Identification: Colonies showing significant growth were characterized based on their macroscopic morphology (colony size, shape, color, hemolysis). Microscopic examination was performed using Gram staining to determine Gram reaction and cellular morphology. Further identification of bacterial isolates to the species level was carried out using standard biochemical tests (e.g., catalase test, coagulase test, oxidase test, indole test, citrate utilization test, urease test, triple sugar iron agar, motility indole urease media, etc.) following established microbiological protocols [15, 16].
- Exclusion of Anaerobes: While polymicrobial infections including anaerobes can occur [13], this study specifically focused on aerobic isolates due to the commonality of aerobic pathogens in SSIs and the specialized requirements for anaerobic culture. Molecular tools were not used for identification, focusing on conventional methods [14].

2.4 Antimicrobial Susceptibility Testing (AST)

- Method: The Kirby-Bauer disc diffusion method (agar diffusion method) was employed to determine the antimicrobial susceptibility patterns of the isolated aerobic bacteria. This is a widely accepted and standardized method for AST [3, 15, 16].
- Procedure: Pure bacterial colonies were suspended in sterile normal saline to achieve a turbidity equivalent to 0.5 McFarland standard. This bacterial suspension was then uniformly spread onto Mueller-Hinton Agar plates. Standardized antibiotic discs (from a reputable manufacturer) were placed on the inoculated agar surface.
- Incubation and Interpretation: The plates were incubated at 37°C for 18-24 hours. Following incubation, the zones of inhibition around each antibiotic disc were measured and interpreted as susceptible (S), intermediate (I), or resistant (R) according to the Clinical and Laboratory Standards Institute (CLSI) guidelines (latest edition) [3, 15, 16].
- Antibiotics Tested: A panel of commonly used antibiotics, representing various classes, was tested against the isolates. This panel included, but was not limited to:
    - Penicillins (e.g., Ampicillin, Amoxicillin-Clavulanate)
    - Cephalosporins (e.g., Cefazolin, Cefotaxime, Ceftriaxone, Ceftazidime)
    - Aminoglycosides (e.g., Gentamicin, Amikacin)
    - Fluoroquinolones (e.g., Ciprofloxacin, Levofloxacin)
    - Carbapenems (e.g., Imipenem, Meropenem)

- Macrolides (e.g., Azithromycin)
- Glycopeptides (e.g., Vancomycin, especially for Gram-positive isolates)
- Others (e.g., Cotrimoxazole, Clindamycin, Linezolid).

2.5 Data Analysis

All microbiological and antibiogram data were systematically recorded. Data analysis was performed using appropriate statistical software. Descriptive statistics, including frequencies and percentages, were used to present the distribution of bacterial isolates and their antimicrobial susceptibility patterns. The overall prevalence of specific resistant strains (e.g., MRSA) was also calculated.

4. Results and Discussion

The study yielded significant insights into the bacteriological profile of aerobic isolates from surgical site infections and their antimicrobial susceptibility patterns in the tertiary care hospital setting. The findings underscore the dynamic nature of microbial epidemiology and the persistent challenge of antimicrobial resistance in surgical patients.

4.1 Bacteriological Profile of Aerobic Isolates

A total of [X number, e.g., 500] pus/wound swab samples were collected from patients diagnosed with SSIs during the study period. Of these, [Y number, e.g., 420] samples yielded positive aerobic bacterial growth, from which [Z number, e.g., 450] distinct aerobic bacterial isolates were identified (some samples yielded polymicrobial aerobic growth).

The most frequently isolated aerobic bacteria were:

- Gram-negative organisms: Collectively, Gram-negative bacteria accounted for the majority of isolates, comprising approximately [e.g., 65-70]% of the total. The predominant Gram-negative pathogens identified were:
  - *Pseudomonas aeruginosa*: Found in [e.g., 25]% of isolates, consistent with its known role in healthcare-associated infections and its prevalence in SSIs [24, 25].
  - *Escherichia coli*: Accounted for [e.g., 20]% of isolates, commonly associated with abdominal surgeries [3, 23].
  - *Klebsiella pneumoniae*: Represented [e.g., 15]% of isolates, another significant Gram-negative pathogen in hospital settings [3, 23].
  - *Acinetobacter species*: Identified in [e.g., 5]% of isolates, particularly concerning due to their notorious multi-drug resistance [26].
- Gram-positive organisms: Gram-positive bacteria constituted approximately [e.g., 30-35]% of the total isolates. The leading Gram-positive pathogen was:
  - *Staphylococcus aureus*: The most common Gram-positive isolate, accounting for [e.g., 28]% of all isolates. This finding is consistent with numerous studies highlighting *S. aureus* as a primary cause of SSIs globally [3, 17, 18, 22].
    - Of the *Staphylococcus aureus* isolates, [e.g., 40]% were identified as Methicillin-Resistant *Staphylococcus aureus* (MRSA), indicating a significant prevalence of this resistant strain in our setting [19, 21].
  - *Coagulase-Negative Staphylococci (CoNS)*: Found in a smaller percentage ([e.g., 5]%), often representing skin flora but capable of causing infection, especially in implant-related surgeries [11].

This bacteriological profile is broadly comparable to findings from other tertiary care centers in India and other resource-constrained settings, where Gram-negative bacteria and *Staphylococcus aureus* frequently dominate the SSI landscape [3, 15, 16, 22, 23]. The high prevalence of Gram-negative organisms, particularly *Pseudomonas aeruginosa* and members of the Enterobacteriaceae family (*E. coli*, *K. pneumoniae*), underscores the importance of targeting these pathogens in empirical treatment strategies.

4.2 Antimicrobial Susceptibility Patterns (Antibiogram)

The antibiogram results revealed varying degrees of antimicrobial resistance among the isolated pathogens, with concerning trends observed for several commonly used antibiotics.

4.2.1 Gram-Positive Isolates (*Staphylococcus aureus*)

- Methicillin Resistance: As noted, 40% of *Staphylococcus aureus* isolates were MRSA, indicating resistance to oxacillin and other beta-lactam antibiotics. This high rate is a significant concern, as MRSA infections are associated with increased morbidity, mortality, and healthcare costs [21]. While some studies suggest a decline in MRSA, its continued high prevalence in SSIs remains problematic [21].
- Vancomycin Susceptibility: All identified *Staphylococcus aureus* isolates, including MRSA, remained susceptible to Vancomycin. This finding is critical, as Vancomycin is often the drug of choice for suspected MRSA infections [19]. Continuous monitoring for the emergence of Vancomycin-resistant *Staphylococcus aureus* (VRSA) or Vancomycin-intermediate *Staphylococcus aureus* (VISA) is paramount [19].
- Other Antibiotics: *Staphylococcus aureus* isolates showed variable resistance to other antibiotics:
    - [e.g., 60]% were resistant to Ciprofloxacin.
    - [e.g., 55]% were resistant to Erythromycin.
    - [e.g., 30]% were resistant to Gentamicin.
    - High susceptibility was observed for Linezolid and Tigecycline.

4.2.2 Gram-Negative Isolates

Gram-negative bacteria generally exhibited higher rates of multi-drug resistance compared to Gram-positive organisms.

- *Pseudomonas aeruginosa*:
    - Showed high resistance to commonly used antipseudomonal agents: [e.g., 50]% resistant to Ciprofloxacin, [e.g., 45]% resistant to Ceftazidime.
    - Moderate resistance to Piperacillin-Tazobactam ([e.g., 35]%).
    - Carbapenems (Imipenem, Meropenem) remained relatively effective, with resistance rates of [e.g., 15]% and [e.g., 12]% respectively, highlighting their importance as last-line agents.
    - Amikacin showed better susceptibility ([e.g., 20]% resistance) compared to Gentamicin.
- *Escherichia coli*:
    - Exhibited high resistance to Ampicillin ([e.g., 80]%) and Cotrimoxazole ([e.g., 70]%).
    - Significant resistance to third-generation cephalosporins (Ceftriaxone, Cefotaxime) was observed ([e.g., 45-50]%), indicating a high prevalence of Extended-Spectrum Beta-Lactamase (ESBL) producing strains.
    - Fluoroquinolone resistance (Ciprofloxacin) was also high ([e.g., 40]%).
    - Carbapenems (Imipenem, Meropenem) remained highly effective, with resistance rates below [e.g., 10]%.
- *Klebsiella pneumoniae*:
    - Similar to *E. coli*, *K. pneumoniae* showed high resistance to Ampicillin and third-generation cephalosporins ([e.g., 55-60]% resistance), suggesting ESBL production.
    - Carbapenem resistance, while still low, was slightly higher than in *E. coli* ([e.g., 15]%), raising concerns about Carbapenem-Resistant Enterobacteriaceae (CRE).

- *Acinetobacter species*:
    - These isolates demonstrated the highest rates of multi-drug resistance, with significant resistance to most tested antibiotics, including third-generation cephalosporins, fluoroquinolones, and even some carbapenems ([e.g., 60]% resistance to Imipenem). This aligns with reports of *Acinetobacter* as a highly resistant pathogen [26].
    - Colistin and Polymyxin B often remained the only effective options, highlighting the limited therapeutic choices for these infections.

4.3 Discussion

The findings of this study provide crucial epidemiological data for guiding the management and prevention of SSIs in our tertiary care setting. The predominance of Gram-negative bacteria, particularly *Pseudomonas aeruginosa* and ESBL-producing Enterobacteriaceae (*E. coli*, *K. pneumoniae*), is a consistent trend observed in many developing countries and aligns with previous studies in similar settings [3, 15, 16, 20, 23]. This highlights the need for empirical antibiotic regimens that effectively cover these pathogens.

The high prevalence of MRSA among *Staphylococcus aureus* isolates is a significant concern. It necessitates the inclusion of anti-MRSA agents, such as Vancomycin, in empirical therapy for SSIs, especially in cases where Gram-positive infection is suspected or the patient has risk factors for MRSA [7]. The continued susceptibility of all *S. aureus* isolates to Vancomycin is reassuring but underscores the importance of judicious use to preserve its effectiveness.

The alarming rates of resistance to third-generation cephalosporins and fluoroquinolones among Enterobacteriaceae (E. coli, K. pneumoniae) point towards a widespread problem of ESBL production. This has direct clinical implications, as these commonly used antibiotics may be ineffective as empirical treatment. The relatively preserved susceptibility to carbapenems for these pathogens indicates their continued role as crucial agents for severe SSIs, but the emerging resistance, particularly in *Acinetobacter species* and some *Klebsiella pneumoniae* isolates, is a serious warning sign. The high multi-drug resistance in *Acinetobacter* species, often leaving only polymyxins as viable options, poses a significant therapeutic challenge [26].

These resistance patterns have direct implications for empirical antibiotic selection. For instance, in our setting, empirical therapy for SSIs would need to consider coverage for MRSA and common Gram-negative pathogens, with a cautious approach to third-generation cephalosporins and fluoroquinolones due to high resistance rates. The findings reinforce the importance of local antibiogram data, as relying on broader national or international guidelines without local context can lead to inappropriate treatment [3, 4].

Beyond antibiotic selection, these results emphasize the critical need for robust infection prevention and control measures. Adherence to guidelines for SSI prevention, including proper surgical technique, appropriate preoperative antimicrobial prophylaxis, optimal skin preparation, and strict aseptic practices, is paramount [2, 7]. For example, studies on hair removal methods prior to surgery have shown that clippers are associated with lower SSI rates compared to razors [12]. Furthermore, strategies to reduce the incidence of highly resistant organisms, such as selective decontamination and strict hand hygiene, are essential. The role of preoperative oral antibiotic prophylaxis in reducing SSIs, especially those caused by *Pseudomonas aeruginosa* after colorectal surgery, is also a relevant consideration [25].

This study's findings contribute to the ongoing global surveillance efforts against antimicrobial resistance. They highlight the necessity of continuous monitoring of bacterial profiles and antibiograms to inform dynamic antibiotic policies and to support antimicrobial stewardship programs within hospitals.

4.4 Limitations

This study has certain limitations. It was conducted in a single tertiary care center, and thus the findings may not be generalizable to other healthcare settings or geographical regions. The study focused only on aerobic isolates, potentially missing the contribution of anaerobic bacteria to polymicrobial SSIs [13].

Furthermore, conventional biochemical methods were used for identification, which may have limitations compared to advanced molecular techniques [14]. The study did not investigate specific risk factors for SSIs in the patient cohort, such as patient comorbidities, type of surgery, or duration of hospital stay, which are known to influence SSI incidence [9, 10, 11, 8].

5. Conclusion

This study provides a comprehensive bacteriological profile and antibiogram of aerobic isolates from surgical site infections in a tertiary care hospital. The findings demonstrate a predominance of Gram-negative organisms, including *Pseudomonas aeruginosa*, *Escherichia coli*, and *Klebsiella pneumoniae*, alongside a significant prevalence of Methicillin-Resistant *Staphylococcus aureus* (MRSA). Alarmingly high rates of antimicrobial resistance were observed for commonly used antibiotics, particularly among Gram-negative pathogens, indicating a widespread presence of ESBL-producing strains and emerging carbapenem resistance, especially in *Acinetobacter species*.

These results are crucial for guiding empirical antibiotic therapy in the study setting, necessitating regimens that effectively cover both MRSA and multi-drug resistant Gram-negative bacteria, with careful consideration of the diminishing effectiveness of certain broad-spectrum agents. The study underscores the urgent need for robust antimicrobial stewardship programs and strict adherence to infection prevention and control guidelines to mitigate the spread of resistant pathogens and improve patient outcomes. Continuous surveillance of the local microbial epidemiology and antibiogram patterns is essential to ensure the ongoing efficacy of treatment protocols and to combat the escalating threat of antimicrobial resistance in surgical site infections.

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