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Incidence Rate and Risk Factors of Surgical Site Infections: A Microbiological Perspective in a Tertiary Care Hospital

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Abstract: Surgical Site Infections (SSIs) account for 20% of healthcare-associated infections (HAIs), contributing to significant morbidity, mortality, and increased healthcare costs, with global incidence rates reaching up to one-third of surgical patients. This study analyzes the incidence of SSIs, associated risk factors, and microbial profile in a tertiary care hospital in North India from January 2023 to October 2024. A cross-sectional observational study was conducted on 3,463 surgeries, with SSIs diagnosed with CDC guidelines and categorized as superficial, deep, or organ/space infections. Patient risk factors, surgical variables, and microbiological findings were analyzed using active and post-discharge surveillance. The overall SSI rate was 1.1 per 100 surgeries (39 cases), with malignancy-related surgeries exhibiting the highest incidence (5.4%). Major risk factors included advanced age, ASA grade ≥3, BMI >25 kg/m², prolonged surgical duration (>4 hours), and elevated postoperative blood glucose levels, while 25.64% of cases showed a significant breach in antibiotic prophylaxis timing. Microbiological analysis identified *Klebsiella* spp. as the predominant bacterial isolate (48.7%). Despite advancements in surgical and infection control practices, SSIs remain a concern, emphasizing the need for continuous surveillance, timely interventions, and strict adherence to prophylactic protocols to mitigate risk and improve patient outcomes.

Keywords: HAI, SSI, North India, Risk Factors, Surveillance.

1.Introduction

Surgical Site Infections (SSIs) are a major contributor to healthcare-associated infections (HAIs), accounting for approximately 20% of all HAIs [1]. SSI significantly impact patient morbidity, mortality, and healthcare costs. Globally, conditions requiring surgical intervention contribute to an estimated 11% of disability-adjusted life-years (DALYs) [2]. With an annual surgical volume of approximately 234 million procedures, SSIs affect up to one-third of surgical patients, with the highest incidence occurring after abdominal surgeries. These infections increase the risk of mortality by 2 to 11 times, with 75% of SSI-related deaths directly linked to the infection[3]. The incidence of Surgical Site Infections (SSIs) varies significantly depending on the type of procedure, surgical specialty, and patient conditions, ranging from 0.1% to 50%. In India, the reported SSI rate is between 4.1 and 11.0 per 100 surgeries [3]. Patients who develop SSIs often face extended hospital stays, with an average increase of 7 to 11 days, and have a 2- to 11-fold higher risk of mortality compared to those without SSIs. Additionally, SSIs contribute to 20% of unplanned surgical readmissions [3]. The risk of developing Surgical Site Infections (SSIs) is influenced by both patient-related and procedure-related factors, as well as the characteristics of the infecting organism. Patient-related risk factors include advanced age, poor nutritional status, pre-existing infections, comorbidities, excessive alcohol consumption, intravenous drug use, chronic liver disease, and chronic renal failure. Procedure-related factors, such as poor surgical technique, prolonged surgery duration, inadequate preoperative preparation, and improper sterilization of instruments, also play a significant role [4]. Furthermore, the virulence and invasiveness of the pathogen, the physiological condition of the wound tissue, and the patient's immune response are critical determinants of infection risk [5]. The etiological agents causing SSIs depend on the surgical procedure and the source of infection. Endogenous sources, such as the patient's own flora, include *Staphylococcus aureus*, coagulase-negative staphylococci, and mucosal organisms from the gastrointestinal, respiratory, or genitourinary tracts. Common endogenous organisms include aerobic Gram-negative bacilli (e.g., *Klebsiella*, *Escherichia coli*, *Enterobacter*), Gram-positive cocci (e.g., *Enterococcus*), and anaerobes. Exogenous sources, such as contact with operating room personnel, instruments, or the environment, commonly involve *Staphylococcus aureus* and Gram-negative bacilli (e.g., *Pseudomonas* and *Acinetobacter* species) [3]. Studies have identified *Staphylococcus aureus* as the most common pathogen associated with Surgical Site Infections (SSIs), with one study reporting a prevalence of 50.4%, followed by *Escherichia coli* (23.02%), *Pseudomonas aeruginosa* (7.9%), and *Citrobacter species* (7.9%)[6]. Another study analyzing 494 bacterial isolates found *Staphylococcus aureus* (31%), *E. coli* (20.7%), and *Klebsiella pneumoniae* (9.8%) as the predominant organisms [7]. SSI surveillance and feedback of data to surgeons are critical components of infection control strategies, with studies demonstrating a 32–50% reduction in SSI rates through such programs [8]. Preventing SSIs requires a multidisciplinary approach involving surgeons, nurses, anaesthetists, and infection preventionists. Despite advances in infection control and surgical practices, SSIs remain a significant challenge, even in hospitals with modern facilities. This study aims to analyze surgical site infections in terms of their incidence, the most common bacterial isolates, pre-surgical prophylaxis, and factors such as the duration of surgery.

2. Methods to Identify Surgical Site Infections (SSI)

The CDC defines an SSI as an infection related to a surgical procedure that occurs near the surgical site within 30 days following surgery (or up to 90 days if an implant is involved). Incisional SSIs are further divided into those involving only the skin and subcutaneous tissues (superficial incisional SSI) and those affecting the deeper soft tissues of the incision (deep incisional SSI). Organ/space infections include abscesses, anastomotic leaks in intra-abdominal operations, and implant-associated infections. A retrospective cross-sectional study was conducted at a tertiary care hospital from January 2023 to October 2024, including all surgeries meeting CDC surveillance criteria to analyze SSI incidence and associated risk factors. To ensure comprehensive detection of SSIs, the following systematic methods were employed during the surveillance period:

2.1. Active Patient-Based Surveillance

- **Concurrent Monitoring:**
  - Patients were actively monitored during their hospital stay for any signs or symptoms indicative of SSI.
  - Health records and operative data were reviewed in real time.
- **Post-Discharge Follow-Up:**
  - Patients discharged from the hospital were tracked throughout the surveillance period (30 or 90 days, depending on the type of surgery).
  - Follow-up was conducted via outpatient visits, phone calls, or electronic communication.

2.2. Data Sources for SSI Identification

- **Medical Records Review:**
  - Admission, readmission, emergency department (ED), and operating room (OR) logs.
  - Surgical clinic patient records were reviewed for signs of SSI.
- **Patient Charts and Consultant Notes:**
  - Detailed documentation was analyzed for:
    - Redness, swelling, or discharge at the surgical site.
    - Fever or localized pain at the surgical site.
    - Wound dehiscence or other abnormal findings.
- **Laboratory Reports:**
  - Microbiological culture and sensitivity test results from samples taken from suspected infected sites.
  - Evidence of raised inflammatory markers (e.g., WBC count, C-reactive protein) supporting an infection diagnosis.
- **Imaging Studies:**
  - Radiological evidence of fluid collections, abscess formation, or implant-related infections.
  - Diagnostic imaging such as ultrasound, CT scans, or MRIs.
- **Diagnostic Tests:**
  - Analysis of fluid from drains for infectious organisms.
  - Identification of leaks or abscesses through anastomotic integrity tests.

2.3. Post-Operative Monitoring

- **Wound Inspections:**
  - Regular physical examinations of the surgical site during hospital stays and outpatient dressing visits.
  - Monitored signs included erythema, induration, purulent drainage, and tenderness at the incision site.

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- **Feedback from Healthcare Providers:**
  - Input from surgeons, nurses, and other healthcare professionals on suspected SSI cases.
  - Structured communication during multidisciplinary rounds.

2.4. Surveillance Timeline

- **Surveillance Period:**
  - 30 days: For most surgical procedures.
  - 90 days: For surgeries involving implants or prosthetic materials.
- **Date of Event (DOE):**
  - Defined as the first documented occurrence of any criterion meeting the SSI definition during the surveillance period.

2.5. Classification of SSI

Once a potential infection was identified, it was classified into one of the following categories:

1. **Superficial Incisional SSI:** Involvement of the skin or subcutaneous tissue.
2. **Deep Incisional SSI:** Involvement of deeper soft tissues at the incision site.
3. **Organ/Space SSI:** Infection affecting organs or spaces opened or manipulated during surgery.

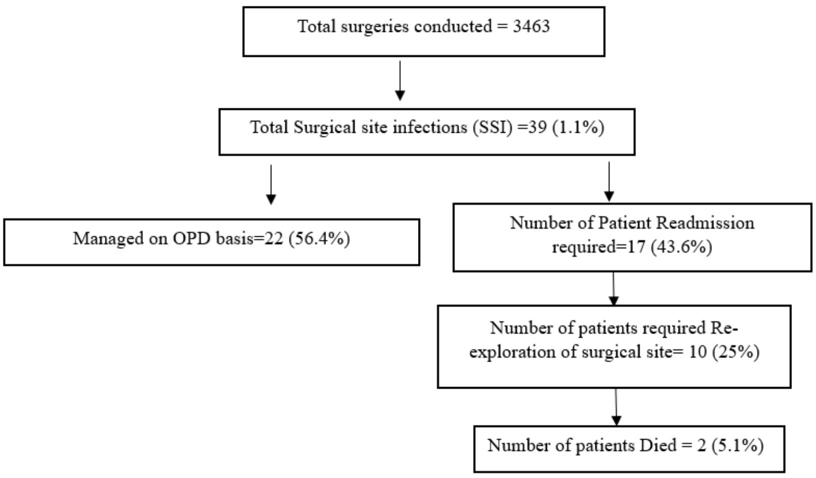
2.6. SSI Rate Calculation

$$\text{SSI Rate per 100 surgeries} = \left(\frac{\text{SSI Cases}}{\text{Total Surgeries}}\right) \times 100$$

The SSI rate was calculated using the formula:

3. Results

From January 2023 to October 2024, a total of 3,463 surgeries were performed at the institute, with 39 cases of Surgical Site Infections (SSIs) identified based on CDC criteria, yielding an SSI rate of 1.1 per 100 surgeries. Most patients (22 cases, 56%) were managed on an outpatient basis, while the remaining 17 cases (44%) required readmission. Re-exploration of the surgical site was necessary in 10 patients (25%), and the mortality rate among SSI-detected patients was 5% (Flow Chart 1).



Flow Chart 1: Showing the SSI management and outcome of the SSI

The distribution of SSI cases by department specialization showed the highest incidence in malignancy-related surgeries (5.40%), followed by Pediatric Surgery (4.00%), Neurosurgery (1.97%), General Surgery (1.65%), Cardiac Surgery (0.87%), Vascular Surgery (0.82%), Plastic and Orthopedic Surgery (0.39% each), and the lowest in Gynecological Surgery (0.20%) (Table 1).

Table 1. Classification of SSI according to the Department and type of surgery

Department	Total No. of patient detected with SSI	Total number of surgeries done in specific specialty	Percentage (%)	Site of surgery	No. of patient detected with SSI
Oncology surgery	8	148	5.40	Pancreas	3
				Colon	3
				Gall bladder	1
				Buccal mucosa	1
Paediatric surgery	3	75	4.00	Urogenital (external genital organ)	2
				Gastrointestinal (small intestine and colon)	1
Neurosurgery	3	152	1.97	Spinal with implant	2
				Cranial	1
General surgery	8	483	1.65	Cholecystectomy	2
				Exploratory laparotomy	2
				open appendectomy	1
				Hernioplasty	3
Cardiac Surgery	12	1364	0.87	Triple Vessel Disease	6
				Triple vessel disease and cardiac valve	4
				congenital heart disease	2
vascular surgery	2	243	0.82	Peripheral arterial disease	2
plastic surgery	1	252	0.39	Amputation lower limb	1
Gynaecology	1	493	0.20	Transabdominal hysterectomy	1
Orthopaedics surgery	1	253	0.39	lower limb with implant	1

Among the 39 SSI cases, 80% were superficial, and 21% were deep. Identified risk factors included female gender (54%), age >50 years, prior SSI (87%), diabetes (32%), hypertension (26%), malignancy (24%), previous surgery (12%), radiotherapy (6%), BMI >25 kg/m² (62%), ASA grade >3 (90%), postoperative blood sugar >120 mg/dL (56%), PATOS cases (21%), class 1 surgical wounds (51%), postoperative stay >5 days (52%), surgery duration >2 hours (75%), elective surgery (87%), care bundle breaches (38%), antibiotic timing issues (26%), and implant use (8%). The most common surgery duration was 4–6 hours (36%) (Table 2).

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Table 2- Showing Risk factors

Variables	Classification	No. of patients (percentage)
Age (in Years)	0-20	6 (15%)
	21-40	3 (8%)
	41-60	16 (41%)
	61-80	11 (28%)
	>80	3 (8%)
Gender	Male	18 (46%)
	Female	21 (54%)
Bmi (kg/m2)	<16	3(8%)
	16-17	3(8%)
	17-18.5	1(3%)
	18.5-25	8(24%)
	25-30	12(31%)
	30-35	8(24%)
	35-40	2(6%)
	>40	2(6%)
Smoking	-	Nil
Previous history	Diabetes mellitus type 2	11 (32%)
	Hypertension	9(26%)
	previous surgery/ invasive procedure	4 (12%)
	radiotherapy	2 (6%)
	diagnosed malignancy	8 (24%)
ASA	1	1 (3%)
	2	3 (8%)
	3, 3E	24 (62%)
	4, 4e	11 (28%)
Pre-operative Sugar levels	<=120	16 (41%)
mg/dl	>120	16 (41%)
	Not done	7 (18%)
Post operative sugar levels	<=120	8 (21%)
mg/dl	>120	11 (28%)
	>200	11 (28%)
	Not done	2 (5%)
PATOS	Yes	8 (21%)
	No	31 (79%)
Class of Surgical wound	class 1	20 (51%)

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	class 2	6 (15%)
	class3	6 (15%)
	class 4	7 (18%)
Environmental factors		
preoperative stay	Days	
	<= 3	31 (79%)
	4-6	6 (15%)
	7-9	1 (3%)
	10-12	1 (3%)
post operative stay	<= 5	19 (49%)
	6-10	10 (26%)
	11-15	5 (13%)
	16-20	3 (8%)
	21-25	2 (5%)
duration of surgery	<2 hrs	10 (26%)
	2-4 hrs	7 (18%)
	4-6 hrs	14 (36%)
	6-8 hrs	8 (21%)
Type of surgery	Emergency	5 (13%)
	Elective	34 (87%)
breech in policy	SSI bundles missed	15 (38%)
	antibiotic not given within specified time frame	10 (26%)
Implants used	Yes	3 (8%)
	No	36 (92%)

The majority of SSIs (39%) were detected within the first 5 days post-surgery. However, 44% occurred after 5 days, and 18% extended beyond 30 days. The earliest detection was at 2 days (13%), while the latest occurred at 65 days (5%) (Table 3).

Table 3- Distribution of cases according to the Detection of SSI and day of event (DOE)

Days	Number of patients detected SSI	Percentage (%)
<= 5	15	38
5-10	9	23
10-15	2	5
15-20	1	3
20-25	2	5
25-30	3	8
>30	7	18

All 39 SSI cases were diagnosed per CDC guidelines. Of these, 35 had microbiological confirmation, while 4 (10.3%) were diagnosed clinically. Gram-negative bacilli were predominant 31(88.5%), with *Klebsiella spp.* being the most common 19(49%), followed by *Escherichia coli* 5(13%), *Pseudomonas spp.* 3(8%), *Enterobacter spp.* (5%), and *Acinetobacter spp.* (3%). Gram-positive bacteria accounted for 11.4%, with

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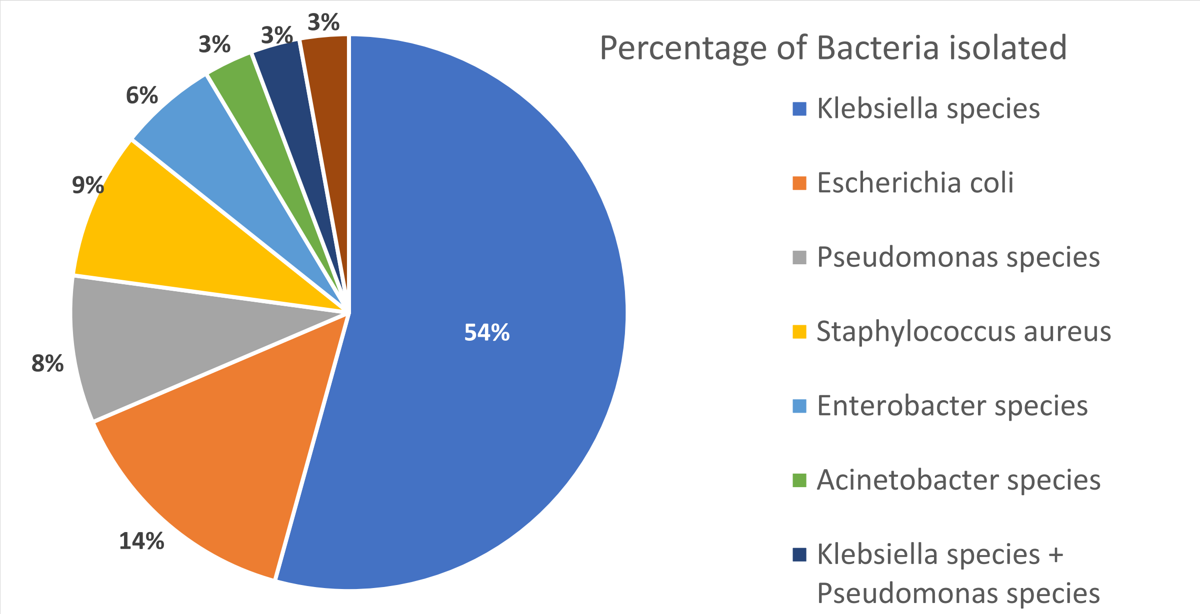
Staphylococcus aureus 3(8%). Mixed infections were found in 2 cases: *Klebsiella spp.* with *Staphylococcus aureus* and *Klebsiella spp.* with *Pseudomonas spp.*. (Pie Diagram 1)



4. Discussion

At a tertiary care hospital in North India, 3,463 surgeries were performed, with 39 SSI cases detected, resulting in an SSI rate of 1.1 per 100 surgical procedures. According to a WHO report, SSI rates in low- and middle-income countries range from 1.2 to 23.6 per 100 surgical procedures, which aligns with our findings[9]. Additionally, a multicentric study by the ICMR reported a cumulative SSI rate of 5.2%, higher than our observed rate[10]. Other studies have also reported higher SSI rates of 2.5%, 7%, and 15%[11–14]. When analyzing SSI rates by surgical department, the highest incidence was observed in oncology surgery (5.4%). A study on major oncology surgeries involving the upper gastric and pancreatic regions reported an SSI rate of 18.6%, significantly higher than our study. In contrast, a study on breast surgery reported an SSI rate of 2.1%, comparable to our findings [15-16].

In our study, the SSI rate for pediatric surgery was 4.0%, similar to another study that reported a rate of 3.6% in neonatal surgeries. However, SSI rates were higher in infants and children, at 11.9% and 6.3% in colorectal surgeries, respectively [17-18]. According to Salahuddin et al., the SSI rate for general surgery ranges from 2% to 17.8%, while our study found a slightly lower rate [18]. For neurosurgery, our study observed an SSI rate of 1.7%, comparable to the reported 2% in other studies [20]. However, some neurosurgical procedures have reported an SSI rate of 4.3% within three months post-surgery, with craniotomy cases showing a rate of 5.14%, higher than our findings [21].

In cardiac surgery, our study found an SSI rate of 0.9%, aligning with the findings of Sahu et al. (0.56%) [22]. Orthopedic SSI rates vary widely, from 0.8% to 71% [23]. Additionally, plastic surgery reported an SSI rate of 3.0%, while gynecological hysterectomy had a rate of 1.6%, slightly higher than our findings [24-25]. Variations in SSI rates may be attributed to differences in study populations, associated risks, the nature of surgical procedures involving different anatomical sites, and infection control practices. In our study, the majority of surgeries were elective (34 cases, 87%), while only 5 cases (12%) were emergency procedures. This contrasts with studies by Narayan et al., Pathak et al., and Youba et al., which reported a higher association between emergency procedures and increased SSI rates [12,26-27]

Most SSIs in our study were superficial (31 cases, 80%). Deep infections were observed in 8 cases (21%), requiring readmission, re-exploration, and, in some instances, negative pressure wound therapy (VAC dressing) for recovery, similar to studies by Pathak et al. and Alkaaki et al. [12,28].

The study identified common risk factors for SSI, including female gender, age 41–60 years (mean ± SD: 51 ± 21 years), and BMI ≥ 25. The mean preoperative hospital stay was 2.5 ± 2 days, while the mean postoperative stay was 7.5 ± 6 days. Longer surgery durations (mean ± SD: 4 ± 2 hours), ASA grade ≥3, and postoperative glucose levels >120 mg/dL were significant risk factors. Additionally, 38.5% of staff failed to adhere to the SSI maintenance bundle, and 25.64% of patients received antibiotics outside the recommended 1-hour window. Most wounds were classified as class 1 (51.2%), followed by class 4 (17.9%). Preoperative blood glucose analysis was inconclusive due to data limitations. Several studies (Pathak et al., Narayan et al., Youba et al.) have identified similar risk factors for SSI, including female gender, advanced age, obesity, and subcutaneous tissue thickness (measured via MRI) as a potentially more significant predictor of SSI than BMI alone. Other contributing factors include diabetes, smoking, ASA scores greater than 2, low socioeconomic status, emergency surgeries, and prolonged operative durations (≥2 hours). Longer surgeries increase the risk of bacterial contamination due to extended microbial exposure, tissue trauma, and blood loss, leading to tissue hypoxia. Additional risk factors reported in the literature include preoperative hospital stays exceeding 24 hours, contaminated or dirty wound classifications, elevated fasting blood glucose levels, inappropriate antibiotic prophylaxis timing, and intraoperative blood transfusions, all consistent with our findings. Despite the aforementioned risk factors, most SSIs in our study were associated with class 1 surgical wounds (20 cases, 51.2%), followed by class 4 wounds (7 cases, 17.9%). This may be attributed to the fact that most surgeries performed at our institute are cardiac procedures, and a significant proportion of detected SSIs were from non-GI surgeries, which generally have lower infection rates compared to GI surgeries.

Notably, none of the patients in our study were smokers. This could be due to the predominance of female patients and the influence of religious and socioeconomic factors. A study by Nayan et al. reported a higher incidence of SSI in male patients, which may be due to differences in comorbidities, lifestyle factors such as smoking and obesity, variations in immune responses between genders, or differences in surgical techniques and postoperative care practices. Additionally, a five-year analysis by Fahad et al. on orthopedic surgeries found that SSIs were more common in younger patients and those classified as ASA grade 1. This trend may be explained by the fact that many of these patients were treated for trauma, which frequently involves preoperatively infected soft tissue [29].

In our study, 35 culture samples showed Gram-negative bacilli (GNB) as the predominant bacterial isolates, accounting for 31 cases (88.5%). Among these, *Klebsiella* spp. was the most frequently identified pathogen (19 cases, 48.7%). A similar bacterial profile was observed in an ICMR multicentric study [10]. A study by Kochhal N. et al. also reported *Klebsiella pneumoniae* (33.33%) and *Escherichia coli* (33.33%) as the most common isolates, followed by *Staphylococcus aureus* (16.67%) and *Pseudomonas aeruginosa* (16.67%) [30]. Similarly, findings by Worku et al. indicated a predominance of Gram-negative bacteria over Gram-positive bacteria. However, in their study, *Staphylococcus aureus* (31%) was the most commonly isolated pathogen, followed by *Escherichia coli* (20.7%) and *Klebsiella pneumoniae* (9.8%). Overall, Gram-negative bacteria accounted for 57.9% (286/752) of isolates, while Gram-positive bacteria comprised 42.1% (208/752) [7].

5. Limitations

This study has both strengths and limitations. A key limitation is its focus solely on infected patients, without a comparative analysis of the full cohort of 3,463 surgical cases. As a single-center study, its findings may not be widely generalizable due to variations in surgical techniques, infection control measures, and institutional practices. Additionally, while microbiological profiling was conducted, antibiotic resistance patterns were not analyzed, which limits the ability to assess antimicrobial resistance trends. However, the study's strengths include its setting up in a tertiary care hospital, making the findings relevant to similar healthcare environments. The large sample size enhances the reliability of the results, and the comprehensive evaluation of risk factors, surgical variables, and microbiological profiles provides valuable insights into SSI determinants. These findings contribute to the understanding of SSI risks and can guide future preventive strategies.

6. Conclusions

Surgical Site Infection (SSI) is a multifactorial complication influenced by patient-related risk factors, the surgical environment (including ICU exposure), staff adherence to protocols, and surgical techniques. The findings of this study highlight the importance of strict adherence to infection prevention measures, including timely antibiotic prophylaxis, optimized perioperative care, and continuous postoperative surveillance. To enhance infection control strategies, strengthening antimicrobial stewardship programs and incorporating antibiotic resistance profiling in future studies will be crucial. Given the single-center nature of this study, multicentric research is recommended to improve the generalizability of findings. Developing hospital-specific interventions tailored to patient demographics and surgical practices will be essential in minimizing SSI incidence and improving overall surgical outcomes.

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10. Ethic Committee Approval- Not required as the study is done retrospectively.

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