

OVERVIEW ON SURGICAL SITE INFECTIONS: COMPREHENSIVE REVIEW

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Surgical site infections (SSIs) represent a foremost public health argue, aiding to increased morbidity, mortality, and healthcare budget wide-reaching. They stand as a prominent category within the area of healthcare-associated infections, emerging within a duration of 30 days following a surgical technique at the precise site or anatomical region where the surgery widened. This article presents a comprehensive review of the epidemiology, categorization, Global Incidence, risk factors, microbiological aspects, treatment moods, and prevention approaches for SSIs, based on modern research and evidence-based practice protocols. Vast literature review was overseen, synthesizing existing studies on this title. Inclusion criteria encompassed peer-reviewed articles as well as American and European guidelines focusing on the epidemiology, threat factors, microbiology, treatment, and prevention of SSIs. These findings emphasize the significance of preventive measures, such as appropriate preoperative interventions, strict aseptic techniques, and proper antibiotic prophylaxis, in bring down SSI incidence and improving patient and population outcomes.

Keywords: Global incidence, prevention, source of infection.

I. INTRODUCTION

A Surgical Site Infection (SSI) is an infection that occurs after surgery in the area where the surgery took place. It typically develops within four weeks of the practice or, in cases involving implants, up to one year afterward. SSIs is a principal cause of morbidity and mortality in current health care. SSIs remain a significant concern in universal healthcare, mainly in the Middle East and North Africa (MENA) region, where they

represent a notable proportion of hospital-acquired infections (HAI)¹. Several factors contribute to the incidence of SSIs in the MENA region. Hospitals in some areas have challenges such as limited access to sterile equipment, crowded facilities, and inadequate staff training on infection prevention protocols. Furthermore, cultural practices and economical state also play a role in varying standards of hygiene, which can directly impact patient outcomes. Associated with patients without surgical site infections, those with them remain

in the hospital approximately 7 to 11 days longer. Study involving 177 706 postsurgical patients reported that 78% were readmitted because of the infection². Most surgical site infections can be prevented if suitable strategies are applied. These infections are typically caused when bacteria from the patient's endogenous flora are inoculated into the surgical site at the time of surgery. Development of an infection depends on various factors such as the health of the patient's immune system, presence of foreign material, degree of bacterial wound contamination, and use of antibacterial prophylaxis³. The current review provides updates to the epidemiology and diagnosis of SSIs with particular emphasis on risk factors, evidence-based prevention strategies, and surveillance.

II. Epidemiology

SSIs harmfully impact on both physical and mental health of the patient. However, variability existed between length of hospital stay (LOS) reported in studies in the same country as well for the same surgical specialty^{3&4} as in figure 1.

Additional of (LOS) associated with surgical site infection (SSI) versus no incidence. LOS in hospital (days) reported in patients that developed an SSI, compared with who uninfected patients^{5&6}. The discussed health problem is in low- and middle-income countries (LMICs), the most common healthcare-associated infections (HAIs) and in high-income countries, the second most common, contributing significantly to postoperative morbidity, mortality, and healthcare costs. Prolonged postoperative antibiotics did not reduce surgical-site infection, but pervasive use was associated

with a longer length of hospital stay, in resource-limited healthcare systems. With the growing threat of antimicrobial resistance, surgical initiatives to implement antimicrobial stewardship programmes in low- and middle-income countries are critical⁷.

Other studies indicate that SSI has a considerable cost impact for hospital providers through increased length of stay, readmission and the costs of antibiotics⁸.

1. Global incidence

The mutual global frequency of SSIs across all surgical types is approximately 2.5%, however, this varies by procedure, region, and surveillance definitions. According to (WHO), the incidence of SSI in low- and middle-income countries can reach up to 11.8%, compared to 2–5% in high-income countries⁹. A 2023 global meta-analysis estimated the following average SSI incidence rates: Africa: 7.2%, Southeast Asia: 6.5%, Eastern Mediterranean (MENA): 5.6% and Europe & Americas: <3%¹⁰ (Fig. 2).

An organized review and meta-analysis included a total of 43 studies conducted on 798 712 patients (ranging from 105 to 633 990 study participants). Among of them, 5 were reported in China, 3 in the USA, 3 in Ethiopia, 2 in Switzerland, 2 in Benin, 2 in Germany, 2 in Iran, 2 in Poland and 2 in Italy,. One in each of France, Turkey, Saudi Arabia, Ghana, Nigeria, Argentina, Rwanda, South Africa, Cuba, Thailand, Albania, Malawi, Tunisia, Nepal, Herzegovina, Australia, India, Tanzania, Georgia, and Cameroon¹¹.

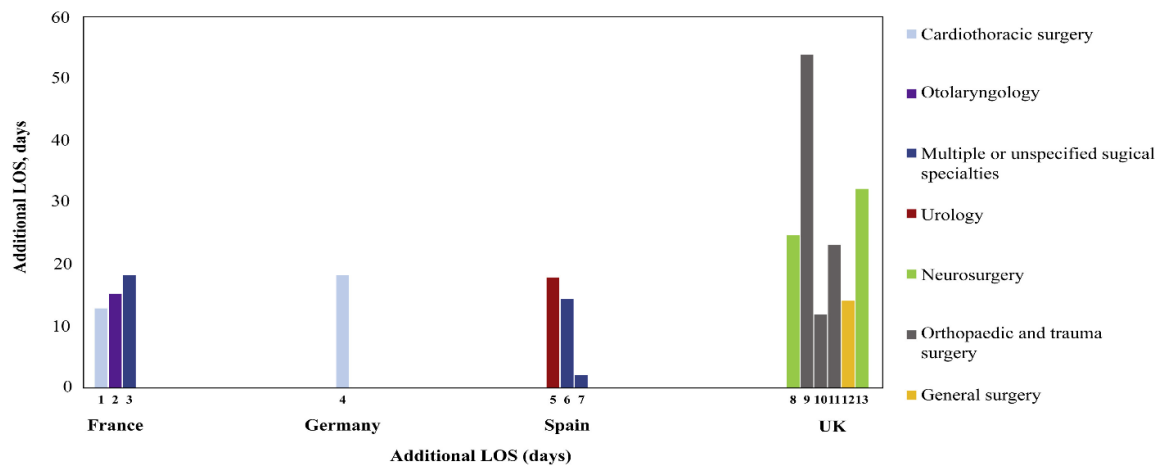


Fig. 1: Additional (LOS) associated with surgical site infection (SSI) versus no SSI⁴.

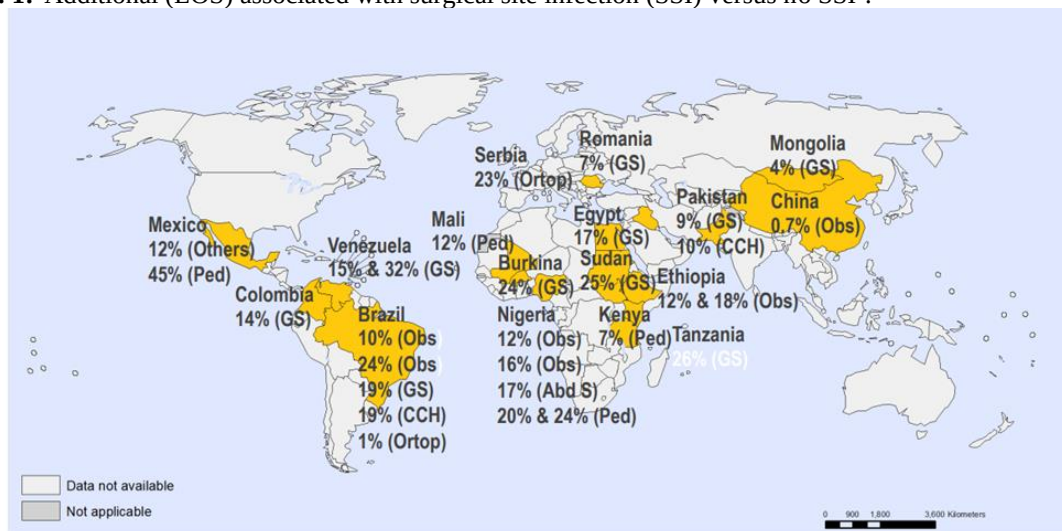


Fig. 2: SSI frequency in specific countries (2010-2014)¹².

Among these studies, Tanzania reported the highest incidence of SSI, which accounted for 26.0%. while China reported the lowest incidence of SSI for 0.2%, followed by another study conducted in China and France, which accounted for 0.22% and 0.3%, respectively¹⁰.

2. Incidence by surgery type

Caesarean section SSIs are particularly high in LMICs, with rates ranging from 5% to 20%. Colorectal surgeries and procedures involving implants or contaminated fields also show increased risk, with rates often exceeding 10%¹³.

A study results about post caesarean section (CS), 180 eligible studies (207 datasets) involving 2,188,242 participants from 58 countries were included in this review. The pooled global incidence of post-CS SSIs was 5.63% [95% confidence interval (CI) 5.18–6.11%]. The highest and lowest incidence rates

for post-CS SSIs were estimated for the African (11.91%, 95% CI 9.67–14.34%) and North American (3.87%, 95% CI 3.02–4.83%) regions, respectively. The incidence was significantly higher in countries with lower income and human development index levels. The pooled incidence estimates have increased steadily over time, with the highest incidence rate during the coronavirus disease 2019 pandemic (2019–2023). *Staphylococcus aureus* and *Escherichia coli* were the most prevalent pathogens. Several risk factors were identified¹⁴.

Among 3,663 study participants, 134 (3.66%) episodes of SSI were identified. The incidence rate of SSI decreased from 5.9 infections per 100 procedures in 2015 to 3.1 infections per 100 procedures in 2018 (incidence rate ratio, 0.52; 95% CI, 0.28–0.94). The SSI rates were 1.88, 4.15, 6.27 and 11.58 per 100 operations for the National Nosocomial

Infections Surveillance system (NNIS) risk index categories of 0, 1, and 2 or 3, respectively. *Escherichia coli* (54/134, 40.3%) and *Klebsiella pneumoniae* (10/134, 7.5%) were the most frequently isolated microorganisms. A high prevalence of antibiotic resistance were observed in our study, with rates of extended spectrum beta-lactamase-producing or carbapenem-resistant *Escherichia coli* and *Klebsiella pneumonia* of 50.0% (27/54) and 30.0% (3/10) respectively. Preoperative hospital stay ≥ 48 h (OR = 2.28, 95% CI: 1.03-5.02, $p = 0.042$) and contaminated or dirty wound (OR = 3.38, 95% CI: 1.88-6.06, $p = 4.50 \times 10^{-5}$) were significantly associated with increasing risk of SSI after CRS. Noticeably, the relatively high rates of multidrug-resistant pathogens causing SSI after CRS should be alert, while more studies with large population are needed due to the small number of isolates identified in this survey¹⁵.

3. Trends over time

In high-income countries, SSI incidence has remained relatively stable due to standardized protocols and surveillance. In LMICs, rates remain higher but are underreported due to inadequate surveillance systems and variability in postoperative follow-up¹.

4. SSI in Egypt and the MENA region

A 5-year retrospective study in Egypt at a tertiary hospital reported an SSI incidence of 9.1% after cesarean deliveries¹⁶. Also, a study at Mansoura University Hospital found the rates of SSI is 8.4% in general surgery procedures¹⁷. Contributing factors in the MENA region include limited infection control resources, overcrowded facilities, inconsistent antimicrobial stewardship, and inadequate surveillance systems¹⁷.

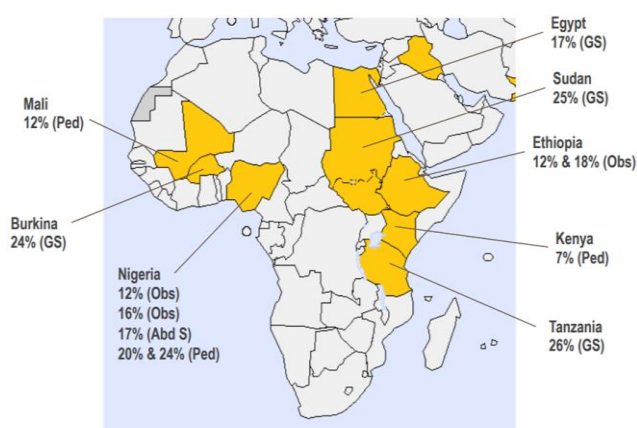


Fig. 3: SSI frequency in specific African countries¹².

5. Burden and impact

SSIs are linked with: Increased length of stay (average 7–11 additional days), Higher hospital readmission rates (up to 78% of post-surgical readmissions), Elevated treatment costs, including prolonged antibiotic therapy and potential reoperations, Increased mortality, particularly in deep and organ/space infections¹⁸.

Intervals in SSI surveillance in LMIC are due to insufficient data from many countries, inconsistent use of definitions and surveillance methodologies and limited data about antimicrobial resistance.

III. Types of SSIs

(SSIs) are classified by the Centres for Disease Control and Prevention (CDC) into three major categories according to the depth and tissue involved. This classification system allows clinicians to differentiate between superficial and more severe infections, guiding both surveillance and treatment protocols¹⁹.

1. Superficial incisional type

- **Definition:** Involves only the skin and subcutaneous tissue of the incision.
- **Clinical signs:**
 - Purulent drainage from the superficial incision.
 - Isolation of organisms from an aseptically obtained culture of fluid or tissue.
 - Careful reopening of the incision by the surgeon due to signs of infection.
 - Pain, localized swelling, redness, or heat.
- **Time frame:** Happens within one month post-operation without implant insertion.

2. Deep incisional category

- **Definition:** Involves deep soft tissues such as the fascia and muscle layers.
- **Clinical signs:**
 - Purulent drainage from the deep incision.
 - A deep incision that dehisces spontaneously or is deliberately opened by a surgeon due to infection.
 - Signs such as fever ($>38^{\circ}\text{C}$), localized pain, or tenderness.
 - Abscess formation or detection by direct examination, reoperation, or imaging.
- **Time frame:** Occurs within four weeks post-surgery, or within one year if an implant is in place and the infection is related to the operation.

3. Organ/Space kind

- **Definition:** Involves any part of the anatomy (organs or spaces), other than the incision,

that was opened or manipulated during the surgical procedure.

- **Clinical signs:**
 - Purulent drainage from a drain placed into the organ/space.
 - Organisms isolated from fluid or tissue from the organ/space.
 - Abscess or other evidence of infection found during direct examination, histopathology, or imaging.
- **Time frame:** Within four weeks (no implant) or up to 1 year (with implant) if infection is linked to the operation.

These categories are essential in epidemiological surveillance, quality control, and clinical outcome improvement initiatives.

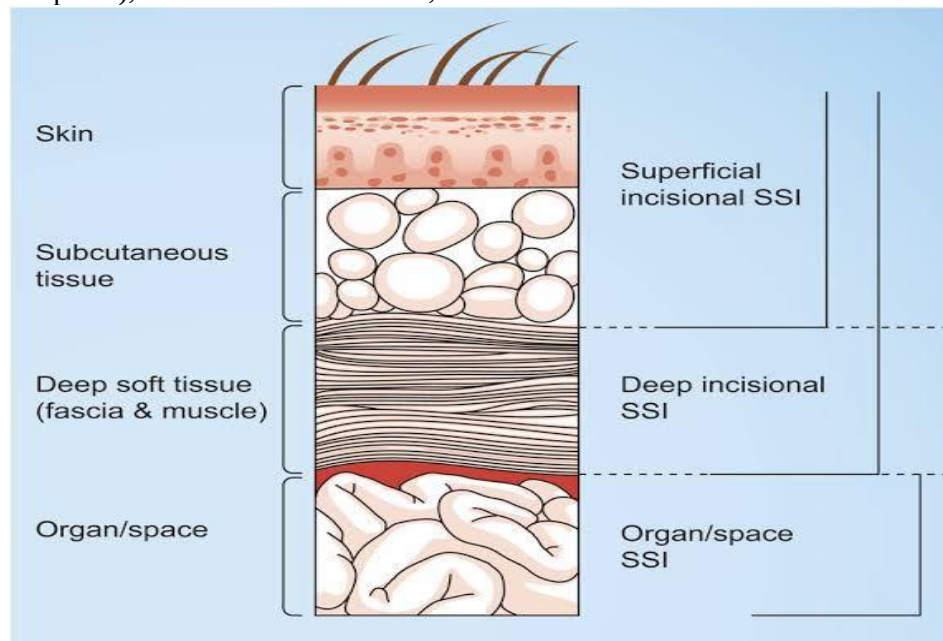


Fig. 4: Types of (SSIs)²⁰.

Worldwide SSI distribution

Global trends show that superficial incisional SSIs consistently account for over 50% of all SSIs. A Japanese tertiary hospital study reported: Overall SSI incidence of 4.8%, with superficial SSI at 3.4% and deep/organ-space comprising the remainder²¹. Studies across Africa, the Middle East, and high-income countries show superficial SSI rates ranging from 67% to over 90% (e.g., obstetric procedures: 67–93% superficial)^{22&23} as summarized in table 1²⁴.

Table 1: Worldwide SSI Distribution²⁴.

Region/Study	Superficial SSI	Deep Incisional SSI	Organ/Space SSI
Egypt	47.1%	28%	24.9%
Global average	> 50%	~20–30%	~10–20%
Africa/MENA	67–93%	≤ 30%	≤ 20%

Surgical site infections are persistent and preventable health care-associated infections. There is increasing demand for evidence-based interventions for the prevention of SSI. The last

version of the CDC Guideline for Prevention of Surgical Site Infection was published in 1999. While the guideline was evidence informed, most recommendations were based on expert opinion, in the era before evidence-based guideline methods. CDC updated that version of the guideline using GRADE as the evidence-based method that provides the foundation of the recommendations in this guideline. These new and updated recommendations are not only useful for health care professionals but also can be used as a resource for professional societies or organizations to develop more detailed implementation guidance or to identify future research priorities. The paucity of robust evidence across the entire guideline created challenges in formulating recommendations for the prevention of SSI. Nonetheless, the

thoroughness and transparency achieved using a systematic review and the GRADE approach to address clinical questions of interest to stakeholders are critical to the validity of the clinical recommendations.

The number of unresolved issues in this guideline reveals substantial gaps that warrant future research. A select list of these unresolved issues may be prioritized to formulate a research agenda to advance the field. Adequately powered, well-designed studies that assess the effect of specific interventions on the incidence of SSI are needed to address these evidence gaps. Subsequent revisions to this guideline will be guided by new research and technological advancements for preventing SSIs²⁵.

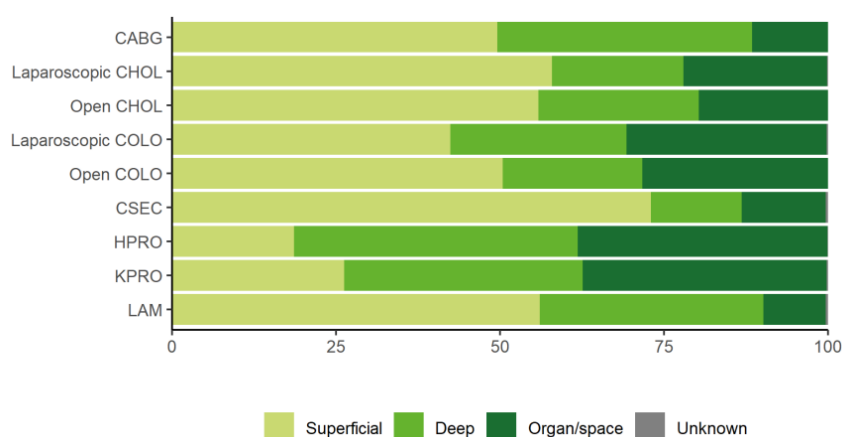


Fig. 5: Classification according to surgical procedure, EU/EEA, 2018-2020²¹.

Reports from Lithuania, Austria, Estonia, France, Norway, Germany, Hungary, Italy, Malta, the Netherlands, Portugal, Finland and Slovakia. LAM: laminectomy Source, CABG: coronary artery bypass graft, CHOL: cholecystectomy, CSEC: caesarean section, COLO: colon surgery HPRO: hip prosthesis surgery, KPRO: knee prosthesis surgery: Note: The Netherlands reported all combined deep and organ/space SSIs as deep SSIs.

Classification of SSI in Egypt

A 5-year retrospective study at a tertiary Egyptian hospital (post-caesarean section) analysed 828 SSI cases: Superficial incisional SSI: 47.1%, Deep incisional SSI: 28%, Organ/space SSI: 24.9%¹⁶.

IV. Risk factors

1. Patient-related factors

Older adults and neonates are at higher risk, increased adipose tissue may compromise wound healing, Poor glycemic control increases susceptibility to infections, impairs blood flow and immune response, weakens the immune system and delays healing, conditions or treatments (e.g., chemotherapy, HIV, or corticosteroids) reduce infection resistance and cardiovascular or respiratory diseases¹².

2. Surgery-related factors

Prolonged procedures increase exposure to potential pathogens, clean-contaminated or contaminated procedures carry higher risks (e.g., colorectal surgery), poor technique or tissue trauma increases infection risk and implants or prostheses can harbor bacteria²⁶.

3. Environmental and procedural factors

Contamination from unsterile equipment or personnel, Inadequate cleansing or shaving

may introduce pathogens., Failure to use appropriate antibiotics or improper timing/dosing and Poor wound care or failure to recognize early signs of infection²⁶.

4. Microbial factors

The microbiological profile of the surgical site infections is influenced by the patient flora in surgical site, environmental contamination, and hospital practices. Microbial factors play a pivotal role in the pathogenesis, severity, and treatment outcomes of SSIs⁶.

4.1. Common pathogens²⁶

- ***Staphylococcus aureus***: The most frequently isolated pathogen in SSIs, particularly in procedures involving the skin, orthopedic, and cardiovascular surgeries. Both methicillin-sensitive (MSSA) and methicillin-resistant strains (MRSA) are implicated.
- **Coagulase-negative *Staphylococci* (CoNS)**: Often associated with implanted medical devices and prostheses due to biofilm formation.
- ***Escherichia coli***: Common in gastrointestinal, urological, and gynecologic surgeries. Extended-spectrum β -lactamase (ESBL)-producing strains complicate therapy.
- ***Enterococcus species***: Found especially in abdominal and colorectal surgeries; includes vancomycin-resistant *Enterococci* (VRE) in nosocomial settings.
- ***Pseudomonas aeruginosa***: Frequently isolated in burns and immunocompromised patients; notable for its resistance profile.
- ***Klebsiella pneumoniae***: A major pathogen in abdominal surgeries, especially when multidrug-resistant.
- **Anaerobes (e.g., *Bacteroides fragilis*)**: Common in contaminated surgeries, especially colorectal or intra-abdominal procedures.
- **Fungi (e.g., *Candida spp.*)**: Rare but may be seen in immunocompromised patients or following broad-spectrum antibiotics.

4.2. Multidrug resistance²⁷

The emergence of multidrug-resistant organisms (MDROs) significantly complicates the management of SSIs. Factors contributing to resistance include inappropriate antibiotic

prophylaxis, prolonged hospital stays, and invasive devices.

- **MRSA** is associated with prolonged hospitalization, increased mortality, and higher costs²⁸.
- **ESBL-producing Enterobacteriaceae** are now common in abdominal and urogenital procedures²⁹.
- **Carbapenem-resistant organisms (CROs)**, such as carbapenem-resistant *K. pneumoniae*, pose a growing threat³⁰.
- **Biofilm formation**: Many SSI-causing pathogens form biofilms, particularly on implanted materials (e.g., orthopedic hardware, catheters). This protective matrix enhances resistance to antibiotics and host immune defenses³¹.

V. Pathophysiology

Surgical site infections (SSIs) result from the complex interplay between microbial contamination of the surgical wound and host defence mechanisms. Their development hinges on three primary factors: bacterial inoculum, local tissue conditions, and host immune response³².

1. Source of pathogens

The majority of SSIs (approximately 70–95%) are caused by microorganisms from the patient's own endogenous flora, introduced into the surgical site at the time of incision. The remaining cases stem from exogenous contamination¹¹.

The nature of the surgical procedure often predicts the type of pathogen: Clean surgeries (e.g., orthopedic, cardiac) → Gram-positive cocci like *Staphylococcus aureus* and *Streptococcus spp.* Or Contaminated surgeries (e.g., gastrointestinal) → Gram-negative bacilli and anaerobes like *E. coli*, *Enterococcus spp.*, and *Bacteroides fragilis*³³.

The **bacterial inoculum** refers to both the **number** and **pathogenic potential** of microorganisms introduced into the wound.

- Even **100 colony-forming units (CFU)** of *Staphylococcus aureus* can result in infection under ideal conditions for bacterial survival.
- High-risk pathogens like *S. aureus*, *Pseudomonas aeruginosa*, and *Enterococcus faecalis* are equipped with **virulence factors** (e.g., toxins, adhesion proteins, immune evasion strategies).

- **Polymicrobial infections**, especially in colorectal or trauma surgery, increase SSI risk and severity.
- The presence of **multidrug-resistant organisms (MDROs)** like MRSA and ESBL-producing *E. coli* makes eradication more difficult and often results in worse outcomes³⁴.

2. Local tissue conditions (wound environment and surgical technique)¹⁷

Local wound environment plays a decisive role in whether inoculated bacteria are cleared or persist.

Key factors include:

- Tissue perfusion and oxygenation: Hypoxic tissue diminishes neutrophil oxidative killing and delays healing.
- Surgical technique: Excessive cautery, rough tissue handling, and large dead spaces impair healing and immune function.
- Foreign bodies or implants: These serve as surfaces for biofilm formation, which protects bacteria from antibiotics and phagocytosis.
- Hematomas, seromas, or necrotic debris act as nutrient-rich reservoirs for microbial proliferation.
- Use of drains or catheters may inadvertently increase contamination¹⁶.

3. Host response

The host's immune system mounts both innate and adaptive responses to eliminate invading pathogens. Factors such as malnutrition, diabetes mellitus, advanced age, smoking, and immunosuppression (e.g., corticosteroids, HIV, cancer) impair leukocyte recruitment, phagocytosis, and cytokine signaling—raising infection risk. Neutrophils are the first responders, releasing reactive oxygen species (ROS) and proteases to kill pathogens. Inflammatory cytokines like IL-1, IL-6, and TNF- α amplify the response but also contribute to tissue damage if uncontrolled³³.

Risk-enhancing conditions include³⁴:

- **Diabetes mellitus:** Impairs leukocyte function, chemotaxis, and cytokine signaling.
- **Immunosuppressive therapies:** Corticosteroids, chemotherapy, and transplant regimens reduce the inflammatory response.

- **Malnutrition or hypoalbuminemia:** Weakens epithelial barriers and delays collagen deposition.
- **Obesity:** Adipose tissue is poorly vascularized, limiting immune cell access.
- **Smoking:** Impairs vasodilation, tissue oxygenation, and immune response.
- **Age extremes:** Neonates and elderly patients have underdeveloped or declining immune responses³³.

4. Role of biofilm formation

Many pathogens involved in SSIs – especially *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, and *Enterococcus spp.* – form biofilms on surgical implants or necrotic tissue. Biofilms are protective matrices that shield bacteria from antibiotics and immune attacks, promoting chronic and recurrent infections³⁴.

5. Local tissue factors

The surgical wound environment also dictates infection risk: Poor tissue perfusion, necrosis, or hematoma impairs immune cell migration. Hypothermia and hypoxia at the wound site reduce oxidative burst and macrophage function³⁴.

Collectively, these factors influence the colonization–infection threshold and determine whether microbial presence will be eliminated, tolerated, or lead to infection.

VI. Prevention strategies

According to American College of Surgeons and Surgical Infection Society, preventive measurements could be summarized in prehospital and hospital interventions as mentioned in Guidelines³⁴.

VII. Conclusion

Surgical site infections continue to represent a main global challenge in both high-income and low-income countries, accounting for a substantial quantity of healthcare-related infections (HAIs). They are allied with increased patient morbidity and mortality, prolonged hospital stays, higher rates of hospital readmission, and significant economic burdens for both patients and healthcare systems. In resource-limited settings, these infections aggravate existing gaps in surgical safety and infection control infrastructure, further worsening outcomes.

Despite the preventable nature of most SSIs, their persistence underscores the need for rigorous adherence to standardized preventive strategies. With the rise of multidrug-resistant organisms and increasing complexity of surgical procedures, there is a growing urgency to integrate both traditional infection control measures and modern innovations, such as biofilm-disrupting agents, advanced wound dressings, and diagnostic biomarkers. Ultimately, the effective management of SSIs relies on a multidisciplinary approach that combines early diagnosis, prompt surgical intervention (e.g., debridement or drainage), and appropriate, targeted antimicrobial therapy. Continuous research, robust public health policies, and global collaboration are critical to address the burden of SSIs and improving surgical outcomes worldwide.

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نظرة عامة على عدوى مكان الجراحة: بحث مرجعي شامل

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تُمثل عدوى موقع الجراحة (SSIs) قضية رئيسية في مجال الصحة العامة، إذ تُسهم في زيادة معدلات الاعتلال والوفيات، وتُفاقم عجز ميزانية الرعاية الصحية. وتُمثل هذه العدوى فئة بارزة في مجال العدوى المرتبطة بالرعاية الصحية، حيث تظهر خلال 30 يومًا من إجراء عملية جراحية في

الموقع أو المنطقة التشريحية التي توسعت فيها الجراحة. تُقدم هذه المقالة مراجعةً شاملةً لعلم الأوبئة ، والتصنيف ، ومعدلات الإصابة العالمية ، وعوامل الخطر ، والجوانب الميكروبيولوجية ، وأنماط العلاج ، وأساليب الوقاية من عدوى موقع الجراحة ، استنادًا إلى الأبحاث الحديثة وبروتوكولات الممارسة القائمة على الأدلة. وقد أشرف على مراجعة واسعة للأدبيات ، مع تجميع الدراسات الحالية حول هذا الموضوع. وشملت معايير الإدراج مقالاتٍ مُراجعة من قِبل أقران ، بالإضافة إلى إرشادات أمريكية وأوروبية تُركز على علم الأوبئة ، وعوامل الخطر ، وعلم الأحياء الدقيقة ، وعلاج عدوى موقع الجراحة ، والوقاية منها. وتؤكد هذه النتائج على أهمية التدابير الوقائية ، مثل التدخلات الجراحية المناسبة قبل الجراحة ، والتقنيات المعقمة الصارمة ، والوقاية بالمضادات الحيوية المناسبة ، في خفض حالات الإصابة بالتهابات موقع الجراحة وتحسين نتائج المرضى والسكان.