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PREVENTION OF SURGICAL SITE INFECTIONS IN MODERN SURGERY

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Abstract

Surgical site infections remain one of the most clinically significant complications of operative treatment, affecting patient safety, hospital workload, antimicrobial use, and healthcare costs worldwide. Despite progress in aseptic surgery, anesthesia, perioperative monitoring, minimally invasive techniques, and antimicrobial prophylaxis, surgical site infections continue to occur in both high-income and low- and middle-income healthcare systems. The aim of this article is to analyze the current evidence on the burden, risk factors, prevention strategies, and clinical importance of surgical site infections in modern surgical practice. The article was prepared using an analytical literature-based approach, drawing on international guidelines, PubMed-indexed studies, World Health Organization recommendations, and surgical infection prevention principles. The findings show that surgical site infection is not caused by a single factor but by the interaction of patient-related, procedure-related, microbial, environmental, and system-level determinants. Effective prevention requires a structured perioperative bundle that includes preoperative risk assessment, rational antibiotic prophylaxis, skin antisepsis, maintenance of normothermia and glycemic control, strict operating room discipline, safe surgical technique, and postoperative wound surveillance. Modern developments such as antimicrobial stewardship, electronic surveillance, artificial intelligence-assisted risk prediction, and minimally invasive surgery may further reduce infection rates when integrated into quality improvement programs. In conclusion, surgical site infection prevention must be treated as a continuous multidisciplinary process rather than a single technical action. Strengthening

evidence-based surgical safety protocols is especially important for countries modernizing their healthcare systems and expanding access to safe surgery.

Keywords

surgical site infection, surgery, infection prevention, antibiotic prophylaxis, perioperative care, wound infection, patient safety, antimicrobial resistance.

Introduction

Surgery is one of the central pillars of modern medicine. It is essential for the treatment of trauma, acute abdominal emergencies, tumors, congenital anomalies, obstetric complications, cardiovascular diseases, and many other conditions that cannot be managed adequately by conservative therapy alone. Global surgical care has expanded significantly during the last decades, but the increase in operative volume has also highlighted the importance of surgical safety. Among postoperative complications, surgical site infection is one of the most frequent and preventable problems.

A surgical site infection is commonly defined as an infection that occurs in the area of the surgical incision or deep operative field after a surgical procedure. Depending on the anatomical depth and clinical presentation, it may be classified as superficial incisional, deep incisional, or organ/space infection. Superficial infections involve the skin and subcutaneous tissue, while deep infections involve fascia and muscle. Organ/space infections are often more severe because they affect deeper anatomical structures manipulated during surgery, such as the peritoneal cavity, joint space, mediastinum, or intra-abdominal organs.

The clinical relevance of surgical site infection is high because it may prolong hospitalization, delay wound healing, increase the need for additional antibiotics, require repeated surgical intervention, and raise the risk of sepsis or death in vulnerable patients. In addition, these infections increase the economic burden for hospitals and families. In low-resource settings, delayed diagnosis, limited microbiological testing, overcrowding, and inconsistent access to quality surgical supplies may intensify the consequences.

Surgical site infection is also strongly connected with antimicrobial resistance. When postoperative wound infections occur, broad-spectrum antibiotics are often used empirically, sometimes without culture confirmation. This practice may contribute to the selection of resistant bacteria, including methicillin-resistant Staphylococcus aureus, extended-spectrum beta-lactamase-producing Enterobacterales, and other multidrug-resistant organisms. Therefore, prevention of surgical site infection is not only a surgical priority but also a public health strategy.

The World Health Organization has emphasized that surgical site infections are preventable through evidence-based measures applied before, during, and after surgery. The WHO global guidelines include recommendations related to surgical antibiotic prophylaxis, preoperative preparation, hand hygiene, operating room discipline, wound protection, maintenance of physiological homeostasis, and postoperative care. Similarly, modern surgical quality improvement programs recommend bundle-based prevention rather than isolated interventions.

In Uzbekistan and other developing healthcare systems, the modernization of surgical services requires special attention to infection prevention and control. The development of clinical guidelines, improvement of hospital epidemiology, rational antibiotic use, staff training, and digital monitoring systems can help reduce avoidable postoperative complications. For this reason, surgical site infection prevention is a relevant topic for clinical practice, medical education, public health planning, and scientific research.

The aim of this article is to evaluate surgical site infection prevention from an evidence-based perspective and to describe practical strategies that may improve postoperative outcomes in modern surgery.

Materials and Methods

This article was prepared as a narrative literature-based scientific review following the IMRAD structure. The methodological approach included the analysis of international guidelines, systematic reviews, clinical recommendations, and recent scientific publications related to surgical site infection prevention.

The main information sources included World Health Organization documents on surgical site infection prevention, PubMed-indexed reviews and meta-analyses, Centers for Disease Control and Prevention recommendations, surgical safety literature, and publications on global surgery. Particular attention was given to studies describing the epidemiology of surgical site infections, perioperative antibiotic prophylaxis, risk factors, infection prevention bundles, antimicrobial stewardship, and new technologies in surgical care.

The inclusion criteria for the literature analysis were as follows: publications focusing on surgical site infections, perioperative infection prevention, surgical quality improvement, antibiotic prophylaxis, global surgical safety, or postoperative wound complications. Preference was given to recent systematic reviews, guideline documents, and high-quality clinical articles. Older but foundational sources were included when they provided essential definitions or widely accepted principles.

The exclusion criteria included non-surgical infections, isolated case reports without generalizable conclusions, publications without clear clinical relevance,

and non-evidence-based recommendations. The collected information was analyzed thematically. The main categories were epidemiology, patient-related risk factors, procedure-related risk factors, microbiology, prevention before surgery, intraoperative prevention, postoperative surveillance, and future innovations.

Because this article is a review and does not involve direct patient data, ethical approval was not required. However, the article follows the ethical principles of academic writing by using evidence-based interpretation and avoiding unsupported claims.

Results

The reviewed literature shows that surgical site infection is a multifactorial complication. It develops when microbial contamination, impaired host defense, tissue trauma, and inadequate perioperative control overlap. The probability of infection depends on bacterial load, virulence of microorganisms, wound class, duration of surgery, patient comorbidities, surgical technique, and quality of infection prevention measures.

One of the most important findings is that surgical site infection remains common despite the availability of modern prevention methods. Global studies show variable infection rates between regions, hospitals, and surgical specialties. Clean operations usually have a lower infection risk, while clean-contaminated, contaminated, and dirty procedures carry progressively higher risk. Abdominal surgery, colorectal surgery, emergency surgery, trauma surgery, vascular procedures, and operations involving implants are particularly important because infection in these areas may lead to severe consequences.

Patient-related risk factors include diabetes mellitus, obesity, malnutrition, smoking, anemia, immune suppression, advanced age, chronic kidney disease, poor skin condition, and colonization with pathogenic bacteria. Diabetes is clinically important because perioperative hyperglycemia impairs leukocyte function, reduces tissue oxygenation, and delays collagen synthesis. Obesity increases technical difficulty, prolongs operative time, and reduces tissue perfusion in adipose layers. Smoking causes vasoconstriction and decreases oxygen delivery to healing tissue. Malnutrition weakens immune response and delays wound repair.

Procedure-related risk factors include long operative duration, excessive tissue manipulation, poor hemostasis, inadequate sterilization, improper antibiotic timing, hypothermia, blood loss, foreign material implantation, and breaks in aseptic technique. The operating room environment is also relevant. Door openings, crowding, poor ventilation discipline, and improper instrument handling may increase contamination risk. Although sterile technique is a traditional

principle of surgery, modern evidence shows that it must be integrated into a broader infection prevention system.

The microbiology of surgical site infection depends on the type of operation. In clean surgery, skin flora such as Staphylococcus aureus and coagulase-negative staphylococci are common. In abdominal and colorectal surgery, Gram-negative bacteria and anaerobes are more frequent. In healthcare environments with high antibiotic pressure, resistant organisms may be encountered. Microbiological culture is important for targeted treatment, especially in deep or organ/space infections.

Preoperative prevention begins with risk identification. Patients should be assessed for diabetes, obesity, smoking, nutritional status, immune suppression, anemia, and active infection. Elective surgery should ideally be delayed when uncontrolled infection or severe metabolic imbalance is present. Preoperative bathing may reduce skin colonization, although its direct effect on infection rates differs across studies. Hair removal should not be performed routinely; if necessary, clipping is preferred over shaving because shaving may cause microtrauma.

Antibiotic prophylaxis is one of the strongest evidence-based measures in surgical infection prevention. The antibiotic should be selected according to the expected microbial flora, type of procedure, local resistance patterns, and patient allergy status. The key principle is correct timing: prophylactic antibiotics should reach effective tissue concentration before incision. Prolonged postoperative antibiotic use without indication is not recommended because it does not improve prevention in most clean and clean-contaminated operations and may increase resistance, adverse effects, and cost.

Intraoperative prevention includes strict surgical hand preparation, appropriate skin antisepsis, maintenance of sterile fields, gentle tissue handling, adequate hemostasis, avoidance of dead space, removal of devitalized tissue, and careful closure. Normothermia is important because hypothermia reduces immune function and tissue oxygenation. Oxygenation, fluid balance, and blood glucose control are also relevant. In selected high-risk operations, wound protectors, antimicrobial sutures, and negative pressure wound therapy may be considered.

Postoperative prevention depends on wound care, early recognition of infection, patient education, and surveillance. A wound should be assessed for redness, warmth, swelling, pain, discharge, separation, fever, or systemic symptoms. Patients discharged early after surgery must receive clear instructions about wound hygiene and warning signs. Surveillance is essential because many infections appear after discharge. Hospitals with active SSI monitoring systems can

identify trends, compare departments, and implement targeted quality improvement.

Modern studies increasingly support the use of prevention bundles. A bundle is a group of evidence-based actions performed together with high compliance. For example, a colorectal surgery bundle may include antibiotic prophylaxis, mechanical bowel preparation with oral antibiotics when indicated, normothermia, glycemic control, wound protection, and standardized closure. The advantage of a bundle is that it changes surgical culture from individual habit to systematic practice.

Emerging technologies may strengthen prevention. Electronic medical records can remind clinicians about antibiotic timing and redosing. Artificial intelligence models may help predict high-risk patients based on comorbidities, laboratory values, procedure type, and operative data. Surgical video analysis and digital operating room systems may improve training and procedural quality. However, these innovations must be validated clinically and should not replace basic infection prevention principles.

Discussion

The prevention of surgical site infection requires a shift from a narrow "wound problem" concept to a broader perioperative safety model. The infection begins not only at the moment bacteria enter the wound but also when patient physiology, surgical trauma, microbial contamination, and system failures converge. Therefore, responsibility belongs not only to the surgeon but also to anesthesiologists, nurses, infection control specialists, microbiologists, pharmacists, hospital managers, and patients.

One of the most important practical problems is inconsistent compliance with guidelines. Many hospitals have protocols, but real-world adherence may be incomplete. Antibiotics may be given too early, too late, or continued unnecessarily. Hair may still be removed by shaving. Operating room traffic may remain uncontrolled. Wound surveillance may be weak after discharge. These gaps show that written guidelines alone are insufficient; hospitals need audit, feedback, staff training, checklists, and leadership support.

Antibiotic prophylaxis deserves special attention. In surgical practice, there is sometimes a belief that longer antibiotic administration provides stronger protection. However, evidence-based guidelines generally support short prophylaxis when appropriate and discourage unnecessary continuation. The goal is to prevent infection while minimizing antimicrobial resistance. This balance is especially important in countries where antibiotics are easily accessible and self-medication is common.

Another important issue is patient optimization. Surgeons often focus on technical success, but preoperative correction of modifiable risk factors may be equally important. Smoking cessation, glycemic control, anemia management, nutritional support, and treatment of remote infections may reduce complications. In emergency surgery, there is less time for optimization, but rapid assessment and structured perioperative management remain valuable.

The role of minimally invasive surgery is also relevant. Laparoscopic and robotic approaches may reduce incision size, tissue trauma, pain, and wound complications in selected procedures. However, minimally invasive surgery does not eliminate infection risk. Trocar-site infection, intra-abdominal abscess, and contamination during specimen extraction may still occur. Therefore, surgical technology must be combined with infection prevention discipline.

For low- and middle-income countries, SSI prevention has additional importance because complications may consume limited hospital resources. A preventable infection may lead to longer bed occupancy, additional antibiotics, repeated surgery, and financial stress for patients. Therefore, investment in sterilization systems, microbiology laboratories, antibiotic stewardship, nursing education, and digital surveillance can produce significant clinical and economic benefits.

In Uzbekistan, the development of modern surgical care should include national adaptation of international recommendations. Local protocols should consider available resources, bacterial resistance patterns, hospital infrastructure, and training needs. Integration of Ministry of Health clinical guidelines, WHO infection prevention principles, and institutional quality indicators may improve surgical outcomes. Medical universities should also teach SSI prevention as a practical surgical competency rather than a theoretical topic only.

Future research should focus on local SSI rates, microbiological profiles, antibiotic resistance, compliance with prophylaxis protocols, and cost-effectiveness of prevention bundles. Without local data, hospitals may underestimate the problem or apply generic solutions that do not fully match their clinical environment. Multicenter studies, electronic registries, and cooperation between surgeons and epidemiologists are needed.

Conclusion

Surgical site infection remains a major challenge in modern surgery, but a large proportion of these infections can be prevented through evidence-based perioperative care. The most effective approach is not a single intervention but a coordinated prevention bundle that includes patient optimization, correct antibiotic

prophylaxis, aseptic technique, physiological stability during surgery, careful wound management, and active surveillance.

The prevention of SSI is clinically important because it reduces morbidity, mortality risk, hospital stay, repeated operations, antibiotic use, and healthcare costs. It is also strategically important in the fight against antimicrobial resistance. For surgical departments, SSI prevention should be a measurable indicator of quality and patient safety.

Modern surgery is moving toward safer, more individualized, and technology-supported care. However, the foundation remains the same: disciplined asepsis, rational antibiotics, skilled surgical technique, and continuous monitoring. Strengthening these principles in every hospital can improve postoperative outcomes and protect patients from avoidable harm.

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