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SURGICAL SITE INFECTION (SSI): EVIDENCE-BASED PREVENTION STRATEGIES AND POSTOPERATIVE WOUND CARE – A LITERATURE REVIEW

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ABSTRACT

Background: Surgical site infection (SSI) is among the most prevalent postoperative complications and remains a significant cause of increased morbidity, prolonged hospital stay, unplanned re-interventions, excessive antimicrobial consumption, and substantial economic burden to healthcare systems. Although improvements in operative techniques, aseptic precautions, perioperative antimicrobial prophylaxis, and standardization of perioperative practices have reduced infection rates, SSIs continue to occur across all wound classes, including clean, clean-contaminated, contaminated, and dirty procedures. Contemporary evidence increasingly supports the implementation of comprehensive prevention bundles and structured postoperative wound care protocols to minimize SSI incidence and improve clinical outcomes. **Objective:** To critically review current evidence regarding the definition, classification, etiopathogenesis, risk factors, microbiological profile, and prevention strategies for SSI, with particular emphasis on evidence-based perioperative prevention bundles and postoperative wound care principles. **Methods:** A narrative review was undertaken using standard surgical literature and infection control resources, including clinical guidelines and peer-reviewed publications related to SSI. The review incorporated key domains such as SSI definitions and classification (superficial incisional, deep incisional, and organ/space SSI), patient- and procedure-related risk

determinants, causative microorganisms with antimicrobial resistance patterns, and evidence-based preventive measures spanning the preoperative, intraoperative, and postoperative phases. Additionally, approaches to early diagnosis and structured postoperative wound management were synthesized to present a clinically applicable framework for SSI reduction. **Results:** The occurrence of SSI is multifactorial and influenced by host-related variables such as diabetes mellitus, obesity, anemia, malnutrition, smoking, and immunosuppression, as well as operative and environmental factors including prolonged operative duration, excessive tissue trauma, presence of foreign bodies or drains, perioperative hypothermia, suboptimal glycemic control, and breaches in sterile technique. The predominant pathogens implicated in SSI include Staphylococcus aureus (including methicillin-resistant strains) and gram-negative bacilli, with variation based on the operative site and degree of contamination. Evidence supports the effectiveness of prevention bundles comprising preoperative patient optimization, appropriate skin antisepsis, correctly timed antimicrobial prophylaxis, maintenance of normothermia and adequate oxygenation, strict adherence to asepsis, and standardized postoperative wound care protocols. Prompt recognition and management—including clinical wound evaluation, microbiological sampling, culture-guided antimicrobial therapy, and surgical interventions such as drainage or debridement when indicated—are essential to prevent progression to deep or organ/space infections. **Conclusion:** Surgical site infection continues to represent a major challenge in postoperative care. Implementation of evidence-based perioperative prevention bundles, supported by standardized postoperative wound care practices and early detection strategies, remains fundamental for effective SSI control. Strengthening adherence to infection prevention protocols and optimizing modifiable risk factors may significantly improve surgical outcomes and reduce SSI-related complications.

KEYWORDS: Surgical site infection; SSI; postoperative wound care; infection prevention; antimicrobial prophylaxis; prevention bundle; asepsis; antimicrobial resistance.

INTRODUCTION

Surgical site infection remains one of the most frequent postoperative complications and continues to contribute significantly to morbidity, prolonged hospitalization, readmissions, re-interventions, increased antimicrobial use, and healthcare costs. Despite improvements in aseptic practices, operative techniques, sterilization standards, and perioperative antimicrobial prophylaxis, surgical site infections persist across all wound classes, including

clean, clean-contaminated, contaminated, and dirty surgeries.

The development of surgical site infection is multifactorial and results from an interplay between microbial contamination, local tissue factors, host immunity, and procedure-related variables. Important determinants include diabetes mellitus, obesity, anemia, malnutrition, smoking, immunosuppression, prolonged operative time, excessive tissue handling, hematoma formation, foreign bodies or drains, perioperative hypothermia, poor glycemic control, and breaches in sterile technique. The microbiological spectrum varies with surgical site and degree of contamination; however, Staphylococcus aureus (including methicillin-resistant strains) remains a common organism, while gram-negative bacilli and enteric organisms are frequently implicated in clean-contaminated and contaminated procedures.

In recent years, emphasis has shifted towards evidence-based surgical site infection prevention bundles that integrate multiple coordinated interventions across the preoperative, intraoperative, and postoperative periods. Standardized postoperative wound care and early recognition of infection are equally important to prevent progression to deep incisional or organ/space surgical site infection. Given the continuing burden of surgical site infection and the growing concern of antimicrobial resistance, a consolidated review of evidence-based prevention strategies and postoperative wound care practices is clinically relevant.[1,4]

AIM

To review evidence-based prevention strategies and postoperative wound care practices for surgical site infection, and to discuss supportive Ayurvedic modalities relevant to wound management.

OBJECTIVES

1. To summarize the definition, classification, burden, etiopathogenesis, and major risk factors of surgical site infection.
2. To review the microbiological profile of surgical site infection, with emphasis on antimicrobial resistance.
3. To describe evidence-based perioperative prevention strategies, including surgical site infection prevention bundles.
4. To outline key principles of postoperative wound care and early management of surgical site infection.

5. To present a brief correlation with Ayurvedic wound-care concepts (Vrana/Dushta Vrana) and supportive modalities (Rakshoghna karma, Dhupana, and Vrana shodhana–ropana) as adjuncts in postoperative wound care.

MATERIALS AND METHODS

This review was conducted as a narrative literature review. Relevant information on surgical site infection was collected from standard surgical textbooks, infection control guidelines, and peer-reviewed articles .Classical Ayurvedic literature related to Vrana/Dushta Vrana and supportive wound-care modalities was also referred for conceptual correlation. Key search terms included "surgical site infection," "infection prevention bundle," "antimicrobial prophylaxis," "postoperative wound care," and Ayurveda-related terms such as "vrana," "dushta vrana," "rakshoghna," and "dhupana."

Definition and Classification of Surgical Site Infections

Definition

Surgical site infection is defined as an infection occurring at or near the surgical incision (or within the operative field) following an operative procedure.[2] Standard surveillance definitions categorize surgical site infection based on the depth of tissue involvement and emphasize that the reported category should reflect the deepest level of infection identified.

Classification[2,3]

The Centers for Disease Control and Prevention (CDC), through the National Healthcare Safety Network (NHSN), classifies surgical site infection into three principal categories:

a) Superficial incisional surgical site infection:

- Involves skin and subcutaneous tissue of the incision.
- Presents with local features such as pain/tenderness, localized swelling, redness, or discharge.

b) Deep incisional surgical site infection

- Involves deep soft tissues (e.g., fascial and muscle layers).
- May be associated with spontaneous dehiscence, abscess formation, or systemic signs.

c) Organ/space surgical site infection

- Involves any anatomical part of the body other than the incision, that was opened or manipulated during the operative procedure (e.g., intra-abdominal abscess after abdominal surgery).

Pathogenesis of Surgical Site Infection

Surgical site infection develops when microbial contamination of a surgical wound exceeds the host's local and systemic defense mechanisms. The occurrence of surgical site infection is multifactorial, involving interactions between microbial factors, host-related factors, and procedure/environment-related determinants. The risk is not limited to contaminated surgeries; it is also observed following clean and clean-contaminated procedures, particularly in the presence of comorbidities and modifiable perioperative risk factors.[1]

Sources of microbial contamination

Microbial contamination leading to surgical site infection can occur from:

a) Endogenous sources

These originate from the patient's own flora:

- Skin commensals (commonly Staphylococcus aureus)
- Gastrointestinal flora in abdominal/colorectal surgery
- Genitourinary flora in urologic or gynecologic surgeries

b) Exogenous sources

These include contamination from:

- Surgical team members
- Operation theatre environment and air quality
- Surgical instruments and materials
- Breaches in aseptic protocols

Mechanism of infection development

The development of surgical site infection is typically explained by the following sequence:

- Inoculation/contamination of wound during incision or intraoperative handling
- Adherence of microbes to tissues and foreign materials (e.g., sutures, drains, implants)
- Local proliferation supported by favorable conditions such as tissue trauma, devitalized tissue, hematoma, and poor perfusion

- Failure of host defenses due to systemic factors (diabetes, malnutrition, immunosuppression) and local wound environment

Clinical infection presenting as superficial incisional infection, deep incisional infection, or organ/space infection.

Role of tissue factors and surgical technique[3]

- Several local wound conditions increase susceptibility to surgical site infection:
- Devitalized tissue due to excessive dissection or trauma
- Hematoma/seroma, which can serve as medium for microbial growth
- Poor tissue oxygenation, impaired local perfusion
- Foreign bodies (sutures, drains, implants), which lower the inoculum threshold required for infection.

Biofilm and persistent infection[2]

Biofilm formation is increasingly recognized in surgical infections, particularly when foreign materials (implants, sutures, prostheses) are present. Biofilms protect bacteria from host immunity and reduce antimicrobial penetration, contributing to chronic infection, persistent discharge, and delayed wound healing.

Host immune response and systemic contributors[3]

Host-related factors such as hyperglycemia/diabetes, anemia, hypoalbuminemia, obesity, smoking, and immunosuppression reduce wound healing capacity and impair immune clearance of bacteria. These factors increase susceptibility to surgical site infection even in surgeries performed under appropriate aseptic precautions.

Procedure-related Risk Factors

Operative and technical factors are major determinants of wound contamination and tissue viability.

Important procedure-related risk factors include

- Prolonged duration of surgery
- Excessive tissue trauma / devitalized tissue
- Inadequate hemostasis leading to hematoma/seroma
- Presence of foreign material (sutures, drains, prosthesis/implants)

- Emergency procedures (limited optimization time)
- Type of surgery and wound classification

1. Clean wound
2. Clean-contaminated wound
3. Contaminated wound
4. Dirty/infected wound

Environmental and System-related Risk Factors

These factors relate to infection control practices and OT discipline.

Common environment/system risk factors include

- Breaks in aseptic technique
- Inadequate sterilization/disinfection practices
- High OT traffic and crowding
- Poor compliance with hand hygiene protocols

Microbology of sugical site infection

Understanding the microbiological profile of surgical site infection is essential for selecting appropriate prophylactic antibiotics, guiding empirical therapy when infection is suspected, and supporting antibiotic stewardship. The causative organisms of surgical site infection vary depending on the type of procedure, wound classification, anatomical site, and patient-related risk factors.[1,4]

Common causative organisms

Across many surgical procedures, surgical site infection is most frequently caused by:

a) Gram-positive organisms

- Staphylococcus aureus (including methicillin-resistant Staphylococcus aureus [MRSA])
- Coagulase-negative staphylococci (especially when implants/prostheses are used)

b) Gram-negative organisms

More commonly implicated in clean-contaminated and contaminated surgeries:

- Escherichia coli
- Klebsiella spp.
- Pseudomonas aeruginosa
- Enterobacter spp.

c) Anaerobic organisms

Especially relevant in colorectal and pelvic surgeries:

Influence of surgical site and wound class

- Clean surgeries: mainly skin flora (e.g., Staphylococcus aureus)
- Clean-contaminated surgeries: mixed flora (gram-positive + gram-negative)
- Contaminated/dirty surgeries: polymicrobial organisms, including anaerobes and resistant gram-negative bacilli

Antimicrobial resistance (AMR) and its relevance

Antimicrobial resistance is a critical concern in surgical infections, especially due to:

- Widespread prophylactic antibiotic use
- Inappropriate postoperative antibiotic continuation
- Empirical therapy without culture guidance
- Hospital-acquired resistant organisms
- Resistant organisms relevant to surgical site infection include:

a. MRSA
b. Extended-spectrum beta-lactamase (ESBL) producing gram-negative bacilli
c. Multidrug-resistant Pseudomonas and other hospital-acquired pathogens.

Evidence-Based Prevention Strategies for Surgical Site Infection[1]

Prevention of surgical site infection requires a multimodal bundle approach implemented across the perioperative period. Contemporary guidelines emphasize that isolated measures are insufficient; rather, coordinated interventions before, during, and after surgery significantly reduce the incidence of surgical site infection. The World Health Organization (WHO) has published evidence-based recommendations for prevention of surgical site infection, which form the basis of modern bundle protocols.

Preoperative Prevention Strategies

Preoperative optimization aims to reduce microbial burden, strengthen host defense, and minimize contamination at the time of incision.

Patient optimization

- Optimization of comorbidities (e.g., diabetes control)
- Correction of anemia and nutritional deficiencies where feasible

- Smoking cessation counseling (when time permits)

Preoperative bathing

- Preoperative bathing or showering is recommended to reduce skin microbial load prior to surgery.

Hair removal

- If hair removal is required, it should be done using clippers rather than razors to reduce microabrasions and infection risk.

Surgical antibiotic prophylaxis

- Appropriate perioperative antimicrobial prophylaxis is a core element of prevention:
- Selection should follow institutional protocols and surgical type
- Administration should occur within the recommended time window prior to incision

Skin preparation

- Preoperative skin antisepsis using effective antiseptic agents is recommended to reduce incision site microbial contamination.

Intraoperative Prevention Strategies

- Intraoperative measures focus on maintaining asepsis, preserving tissue viability, and minimizing conditions that promote bacterial growth.

Strict aseptic technique

- Appropriate surgical hand preparation ,sterile gowns, gloves, drapes
- Operation theatre discipline (minimize unnecessary movement and personnel)

Maintenance of normothermia

- Maintaining normal body temperature is recommended to support tissue perfusion and immune function during surgery.

Adequate oxygenation

- Ensuring appropriate perioperative oxygenation is recommended as impaired tissue oxygenation predisposes to infection.

Glycemic control

- Perioperative hyperglycemia increases infection risk; therefore, glycemic control is recommended during major surgeries and in high-risk patients.

Gentle tissue handling and hemostasis

- Excessive tissue trauma and hematoma formation increase infection risk. Minimizing tissue injury and ensuring proper hemostasis are important surgical principles aligned with infection prevention.

Postoperative Prevention Strategies

- Postoperative strategies focus on protecting the healing wound and early identification of infection.

Standardized wound care

- Appropriate dressing care
- Maintenance of clean wound environment
- Patient counseling regarding wound hygiene

Avoid unnecessary continuation of antibiotics

- Continuation of prophylactic antibiotics beyond the recommended period is discouraged, as it contributes to antimicrobial resistance without clear benefit in many surgeries.

Early detection and follow-up

- Early recognition of local signs (pain, redness, discharge) and systemic signs (fever) allows timely intervention and prevention of deep or organ/space infection.

Ayurvedic Concepts Relevant to Surgical Site Infection and Postoperative Wound Care

In Shalya Tantra, postoperative wound complications can be broadly correlated with the concepts of *Vrana (*wound) and *Dushta Vrana* (infected/non-healing wound). A wound that shows features such as excessive pain, swelling, foul smell, discharge of pus, discoloration, delayed healing, or recurrent breakdown may be interpreted in Ayurvedic terms as *Dushta Vrana,* requiring systematic wound care and protection from contamination. *Sushruta Samhita* gives detailed descriptions of wound assessment and emphasizes the need for appropriate local and systemic measures to promote healing and prevent complications.

Vrana and its clinical importance

Ayurveda considers Vrana not merely as a local cut/injury but as a dynamic pathological state involving: tissue disruption (*dhatu kshaya* at local level), inflammation/swelling (*shotha),* pain (*vedana)* and need for protection and proper care (*raksha).*[5]

Postoperative wounds require careful *Bandhana (*dressing/bandaging) and *Vrana pariksha* (wound assessment) in order to prevent contamination and support proper healing.

Dushta Vrana[6]

Classical characteristics of Dushta Vrana described by Sushruta include:

- *Ati-ruja (*severe pain),
- *Ati-shotha* (excessive swelling),
- *Puya srava (*purulent discharge),
- *Dourgandhya* (foul smell),
- *Vaivarnya* (discoloration),
- *Chirakari* (delayed healing)

These features show strong clinical similarity to surgical site infection presentations such as erythema, tenderness, warmth, purulent discharge, wound gaping and delayed healing.

Rakshoghna concept[6]

In Ayurvedic surgical care, Raksha (protection) is a key perioperative principle. The term Rakshoghna is used in classical texts for measures/dravyas aimed at controlling external contamination and preventing wound complications. These measures can be interpreted as an early infection-control principle focusing on:

- Cleanliness,
- Avoidance of contamination,
- Environmental purification,
- Wound protection.

Shalya Tantra emphasizes two major wound management approaches

A**) Vrana Shodhana**

This includes measures aimed at:

- Cleaning wound bed,
- Removal of slough/necrotic tissue,

- Reducing discharge and foul smell,
- Preparing the wound for healing.

B) Vrana Ropana

This aims at:

- Promotion of granulation and epithelialization,
- Reduction in inflammation,
- Minimizing delayed healing.

Sushruta describes structured Vrana chikitsa strategies supporting these principles in chronic and complicated wounds.

Dhupana

Dhupana is described in Ayurvedic texts as a measure for environmental purification and protective care in susceptible settings (wounds, post-procedure rooms, etc.). While modern sterile practice uses validated disinfection and sterilization protocols, Dhupana can be discussed in the review as a traditional supportive environmental hygiene measure, conceptually comparable to environmental decontamination approaches.

Bandhana

Sushruta gives importance to Bandhana methods depending upon wound site and exudate. This is relevant in the context of postoperative wound care as proper dressing selection and wound protection significantly reduce contamination and mechanical trauma, thereby supporting uncomplicated healing.

DISCUSSION

In contemporary surgical practice, surgical site infection develops when microbial contamination of the operative wound, together with local tissue factors such as tissue trauma, devitalized tissue, hematoma/seroma, poor perfusion, and foreign bodies, exceeds the patient's host defence mechanisms. The risk is further increased by systemic conditions such as diabetes mellitus, malnutrition, anemia, and immunosuppression. Clinically, surgical site infection presents with wound pain, erythema, induration, purulent discharge, wound dehiscence, and delayed healing.

These manifestations demonstrate close conceptual similarity to the Ayurvedic entity *Dushta Vrana* described in Shalya Tantra. *Dushta Vran*a is characterized by lakshanas such as Ati-

ruja, Ati-shotha, Puya-srava, Dourgandhya, Vaivarnya and Chirakari nature of the wound. Thus, the clinical spectrum of infected or non-healing postoperative wounds may be interpreted within the Dushta Vrana framework.

Prevention of surgical site infection in modern surgery is based on evidence-based perioperative bundles aimed at reducing microbial load and optimizing healing conditions. These include skin antisepsis, strict aseptic technique, timely antimicrobial prophylaxis, maintenance of normothermia, perioperative glycemic control, and standardized postoperative wound care. Conceptually, these preventive principles correlate with the Ayurvedic approach of Vrana Raksha and Rakshoghna measures, which emphasize wound protection and prevention of Vrana Dushti.

Similarly, modern management prioritizes early recognition and source control through drainage of pus/collections, debridement of devitalized tissue, and culture-guided antimicrobial therapy. This approach can be correlated with the Shalya Tantra principle of *Vrana Shodhana* as an essential prerequisite for healing, followed by *Vrana Ropana* to promote tissue repair and restoration.

In addition, standardized postoperative dressing protocols in modern surgery correspond to Bandhana in Ayurveda, wherein the wound is protected, exudate (Kleda) is controlled, and healing is supported by minimizing repeated contamination and mechanical trauma. While modern infection control practices remain indispensable and non-substitutable, the Ayurvedic concepts of *Vrana, Dushta Vrana, Raksha, Shodhana, and Ropan*a provide a structured supportive perspective for postoperative wound surveillance and care.

CONCLUSION

Surgical site infection continues to be a major postoperative complication despite improvements in surgical techniques, sterilization standards, perioperative antibiotic prophylaxis, and infection control practices. The development of surgical site infection is multifactorial, influenced by host-related factors, surgical and procedural determinants, and institutional/environmental variables. Evidence supports the effectiveness of bundled preventive strategies implemented across the preoperative, intraoperative, and postoperative phases, along with standardized postoperative wound care protocols and early recognition of infection signs.

From a Shalya Tantra perspective, the clinical features of infected postoperative wounds show conceptual resemblance to *Dushta Vrana*, and the principles of *Vrana Raksha, Rakshoghna, Vrana Shodhana, Vrana Ropana, and Bandhana* provide a structured supportive framework for wound protection, monitoring, and local wound care. However, these measures should be considered adjunctive and should not substitute evidence-based modern infection prevention and management protocols.

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