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Surgical Site Infections: Prevention Strategies and Emerging Technologies – A Comprehensive Review

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Abstract
Surgical site infections (SSIs) are among the most common complications after surgery worldwide. They place a significant burden on healthcare systems. SSIs lead to higher patient illness, longer hospital stays, more readmissions, additional surgeries, and increased healthcare costs. Despite improvements in surgical methods and cleanliness practices, SSIs continue to be a challenge, especially in settings with limited resources. This review summarizes current evidence-based strategies to prevent SSIs and highlights new technologies aimed at lowering their occurrence. It focuses on antibiotic use, negative pressure wound therapy (NPWT), and antimicrobial-coated sutures. The review also discusses risk factors, prevention strategies, cost-effectiveness, and future directions. An approach that combines standard prevention methods with innovative technologies appears to be the most effective way to reduce SSI rates globally.

Keywords
Surgical site infection, antibiotic prophylaxis, negative pressure wound therapy, antimicrobial sutures, infection prevention, perioperative care

1. Introduction

Surgical site infections (SSIs) are infections that occur within 30 days after surgery or within one year if an implant is placed. These infections can be categorized into superficial incisional, deep incisional, and organ/space infections. SSIs account for a substantial share of infections acquired in hospitals worldwide. Their incidence varies by surgery type, patient population, and healthcare setting, ranging from 2% in clean procedures to over 20% in contaminated or emergency surgeries. In low- and middle-income countries, the burden is even greater due to fewer resources and inconsistent infection control practices. Besides the clinical impacts, SSIs significantly increase healthcare costs due to longer hospital stays, extra tests, antibiotic treatments, and additional surgeries. Given these issues, prevention is a crucial part of surgical care.

2. Risk Factors for Surgical Site Infections

Understanding risk factors is key to preventing SSIs. These factors generally fall into two categories: those related to patients and those related to procedures.

2.1 Patient-Related Factors

Diabetes is a major risk factor because it slows wound healing and weakens the immune system. Poor blood sugar control strongly links to higher SSI rates. Obesity affects healing through reduced blood flow and longer surgery times. Smoking hinders oxygen delivery and collagen production, delaying healing. Malnutrition and low albumin levels weaken the immune response, while immunosuppressive treatments or cancer increase the risk of infections. Older age and other health issues, like kidney failure, also raise the risk.

2.2 Procedure-Related Factors

Longer surgery times increase exposure to bacteria and cause more tissue damage. Emergency surgeries usually lack proper preoperative preparation and have a higher risk of contamination. The classification of wounds (clean, clean-contaminated, contaminated, dirty)

greatly affects the likelihood of SSIs. Poor clean techniques, insufficient sterilization of tools, and excessive handling of tissues also contribute to infections. The use of implants or prosthetic mesh further raises the risk.

Table1.Risk factors for surgical site infection

Patient related	**Procedure related**
Diabetes mellitus	Prolonged operative time
Obesity	Emergency surgery
Smoking	Contaminated wounds
Malnutrition	Poor aseptic technique
Immunosuppression	Implant/mesh use

3. Standard Prevention Strategies

3.1 Antibiotic Prophylaxis

Using antibiotics to prevent infections is one of the most efficient methods against SSIs. The timing of administration is crucial. Most guidelines suggest giving antibiotics within 60 minutes before a surgical incision. For antibiotics requiring longer infusion, such as vancomycin, administration can start 120 minutes before the incision. Cefazolin is commonly used for clean procedures because it effectively targets common skin bacteria. Clean-contaminated or colorectal surgeries may need additional coverage for anaerobic bacteria. Redosing is recommended during long surgeries or significant blood loss. Postoperative use of prophylactic antibiotics for more than 24 hours is generally not recommended. It does not reduce SSI rates and can lead to antibiotic resistance.

3.2 Preoperative Measures

Using chlorhexidine-alcohol solutions for skin preparation has shown better results than povidone-iodine in lowering bacterial presence. If hair removal is needed, it should be done with electric clippers right before surgery instead of razors, which can create microabrasions and raise infection risks. Optimizing health issues, especially controlling blood sugar tightly, can greatly lower SSI rates. Keeping patients warm helps improve tissue oxygen levels and immune function. Showering with antiseptic agents before surgery may further cut down on bacteria.

3.3 Intraoperative Measures

Intraoperative strategies include strictly following sterile techniques, performing proper hand washing, and maintaining discipline in the operating room. Ensuring enough oxygen during anesthesia helps tissue blood flow and immune response. Reducing surgery time and avoiding unnecessary trauma to tissues are vital. Proper control of bleeding and rinsing wounds may also lower bacterial contamination.

4. Emerging Technologies in SSI Prevention

4.1 Negative Pressure Wound Therapy (NPWT)

Negative pressure wound therapy applies controlled sub-atmospheric pressure to closed surgical wounds. This approach removes excess fluid, reduces swelling, improves blood flow, and decreases bacterial presence. Closed-incision NPWT has shown good results in high-risk groups, such as obese patients or those undergoing colorectal or abdominal surgeries. Studies suggest it reduces SSI rates compared to standard dressings. However, costs and availability of devices are important concerns, especially in resource-limited settings.

Table 2. Comparison of NPWT vs Standard Dressing

Parameter	**NPWT**	**Standard Dressing**
SSI reduction	Lower in high risk patient	Baseline
Cost	Higher upfront cost	Lower cost
Edema control	Yes	Limited
Bacterial load	Reduced	Variable

4.2 Antimicrobial-Coated Sutures

Antimicrobial-coated sutures, often containing triclosan, stop bacteria from sticking to and multiplying on the suture material. Bacterial biofilm on sutures is known to contribute to SSIs. Multiple reviews have shown a small but statistically significant reduction in SSI rates with the use of antimicrobial sutures, especially in clean-contaminated surgeries. Although these sutures are slightly more expensive than regular sutures, fewer readmissions and complications may balance out the extra costs.

Table 3.Antimicrobial vs Conventional Sutures

Feature	**Antimicrobial suture**	**Conventional suture**
Bacterial colonisation	Reduced	Higher
SSI rate	Modest reduction	Baseline
Cost	Slightly higher	Lower
Best Indication	Clean- contaminated surgery	Clean surgery

4.3 Advanced Dressings and Innovations

Silver-based antimicrobial dressings release ions that kill bacteria. Smart dressings, capable of detecting early infection markers like pH changes or inflammatory signals, are being researched. Advanced irrigation systems using pulsatile lavage may lessen bacterial loads. Tools based on artificial intelligence that predict patient risk are emerging to help clinicians tailor preventive strategies.

5. Multimodal Prevention Bundles

Evidence indicates that using multiple preventive strategies together yields better results than applying isolated methods alone. Surgical safety checklists, standard protocols for antibiotic timing, blood sugar management plans, and monitoring wounds after surgery collectively lower SSI rates. Implementing these prevention bundles needs collaboration among surgeons, anesthesiologists, nursing staff, and infection control teams.

6. Cost-Effectiveness Considerations

Though new technologies like NPWT and antimicrobial sutures have higher upfront costs, preventing SSIs can lead to significant savings overall. Shorter hospital stays, fewer additional surgeries, and reduced antibiotic use contribute to economic gains. Cost-effectiveness analyses are especially vital in developing nations where healthcare resources are limited.

7. Challenges and Future Directions

Ongoing challenges include antibiotic resistance, inconsistent following of guidelines, and limited access to new technologies in rural areas. Future research should focus on large multicenter randomized controlled trials that evaluate long-term outcomes and cost impacts. Personalized infection prevention plans based on patient risk and artificial intelligence could be the next step in managing SSIs.

8. Conclusion

Surgical site infections continue to be a significant global challenge in healthcare, despite progress in perioperative care. A thorough, evidence-based method that combines standard preventive strategies with new technologies like NPWT and antimicrobial-coated sutures shows promise. Strict adherence to infection control protocols, teamwork across disciplines, and continuous research are crucial for further reducing SSI rates and improving patient outcomes.

References

1. Allegranzi B, Bischoff P, de Jonge S, et al. New WHO recommendations on preoperative measures for surgical site infection prevention: An evidence-based global perspective. Lancet Infect Dis. 2016;16:e276–e287.
2. 2602513_576199_108_111 pAnderson DJ, Podgorny K, Berríos-Torres SI, et al. Strategies to prevent surgical site infections in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol. 2014;35:605–627.
3. Astagneau P, Rioux C, Golliot F, Brücker G. Morbidity and mortality associated with surgical site infections. Am J Infect Control. 2009;37:674–681.
4. Badia JM, Casey AL, Petrosillo N, et al. Impact of surgical site infection on healthcare costs and patient outcomes: A systematic review in six European countries. World J Surg. 2017;41:2852–2861.
5. Ban KA, Minei JP, Laronga C, et al. American College of Surgeons and Surgical Infection Society: Surgical site infection guidelines, 2016 update. J Am Coll Surg. 2017;224:59–74.
6. Berríos-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for Disease Control and Prevention guideline for the prevention of surgical site infection, 2017. JAMA Surg. 2017;152:784–791.
7. Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013;70:195–283.
8. Darouiche RO, Wall MJ Jr, Itani KM, et al. Chlorhexidine–alcohol versus povidone–iodine for surgical-site antisepsis. N Engl J Med. 2010;362:18–26.
9. de Jonge SW, Atema JJ, Solomkin JS, Boermeester MA. Effect of postoperative continuation of antibiotic prophylaxis on surgical site infection: A systematic review and meta-analysis. Br J Surg. 2017;104:e118–e133.
10. GlobalSurg Collaborative. Surgical site infection after gastrointestinal surgery in high-, middle-, and low-income countries: A prospective, international, multicentre cohort study. Lancet Infect Dis. 2018;18:516–525.
11. Hyldig N, Vinter CA, Kruse M, et al. Prophylactic incisional negative pressure wound therapy reduces the risk of surgical site infection after caesarean section in obese women: A pragmatic randomized clinical trial. BMJ. 2019;365:l2198.
12. Leaper D, Edmiston CE Jr, Holy CE. Antimicrobial sutures and prevention of surgical site infection: A systematic review and meta-analysis. Int Wound J. 2017;14:134–143.
13. Norman G, Goh EL, Dumville JC, et al. Negative pressure wound therapy for surgical wounds healing by primary closure. Cochrane Database Syst Rev. 2020;CD009261.
14. Tuuli MG, Liu J, Stout MJ, et al. Effect of prophylactic negative pressure wound therapy vs standard wound dressing on surgical site infection in obese women after cesarean delivery: A randomized clinical trial. JAMA. 2020;323:1180–1189.
15. World Health Organization. Global Guidelines for the Prevention of Surgical Site Infection. Geneva: WHO; 2016.