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Preoperative Strategies for the Prevention of Surgical Site Infections in Athletes: A Review

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Abstract

Surgical site infections (SSIs) remain among the most common healthcare-associated infections, contributing to increased morbidity, prolonged hospitalization, higher healthcare costs, and delayed recovery. This review evaluates current evidence regarding preoperative strategies for SSI prevention, with particular emphasis on measures relevant to athletic and physically active populations undergoing surgical procedures. Key interventions examined include preoperative body washing, skin antisepsis, hair removal practices, and perioperative glycemic control. Available evidence suggests that while preoperative bathing, including chlorhexidine-based cleansing, improves skin hygiene, its direct effect on reducing SSI rates remains uncertain. In contrast, alcohol-based chlorhexidine skin antisepsis demonstrates consistent superiority over povidone-iodine in lowering microbial burden and reducing SSI incidence. Hair removal, when necessary, should be performed using clippers immediately before surgery, as shaving is associated with increased infection risk. Additionally, maintaining perioperative blood glucose levels below 180 mg/dL appears essential for minimizing postoperative infections. A multimodal, evidence-based approach integrating these preventive measures offers the greatest potential for reducing SSI risk and improving surgical outcomes.

Keywords: SSI, Surgical Site Infection, Athletes

INTRODUCTION

Surgical Site Infections (SSIs) are a subset of Healthcare-Associated Infections (HAIs), which can occur after virtually any surgical procedure and contribute significantly to morbidity, mortality, and prolonged recovery times [5,6]. SSIs are defined as infections developing at the operative site within 30 days of surgery, or within one year if an implant is involved, presenting with clinical signs such as elevated body temperature, erythema, swelling, localized heat, and purulent discharge [3]. According to the classification proposed by the Centers for Disease Control and Prevention (CDC), SSIs are categorized into superficial incisional, deep incisional, and organ/space infections [3,4].

The development of SSIs reflects a complex interplay between microbial contamination of the surgical site and patient- and procedure-specific risk factors [5]. Recent epidemiological data indicate that SSIs are among the most frequent HAIs, with incidence rates varying from 2% to 15% depending on the type of surgery and other factors [2,6]. The burden is particularly high in low- and middle-income countries, where incidence rates may exceed those observed in high-income healthcare systems [1,2].

While numerous intraoperative and postoperative strategies exist to reduce SSI risk, preoperative optimization plays a crucial role [4,9]. The aim of this review is to critically evaluate current evidence regarding preoperative strategies for SSI prevention, including body washing, skin antisepsis, hair removal, and perioperative glycemic control.

Risk factors for SSIs can be broadly categorized according to the perioperative timeline into preoperative, intraoperative, and postoperative factors. Preoperative factors include patient-related characteristics such as comorbidities, nutritional status, glycemic control, skin colonization, and preoperative preparation procedures [5,10]. Intraoperative determinants comprise surgical technique, duration of the procedure, antimicrobial prophylaxis, maintenance of normothermia, and the operating room environment [4,8]. Postoperative factors involve wound care practices, drain management, and early detection of complications [6].

Although all three phases play a crucial role in SSI prevention, the preoperative period represents a particularly important window for risk modification, allowing for targeted interventions before surgical incision is made [4,9]. Therefore, this review focuses specifically on preoperative strategies aimed at reducing SSI incidence.

EPIDEMIOLOGY OF SURGICAL SITE INFECTIONS

Surgical site infections remain among the most frequently reported healthcare-associated infections worldwide, particularly in surgical departments. Their incidence varies considerably depending on the type of procedure, patient population, wound classification, and healthcare setting. In high-income countries, SSI rates are generally estimated to range between 2% and 5% for most clean surgical procedures, whereas in low- and middle-income countries, reported rates may exceed 10–15%, reflecting disparities in infrastructure, infection control practices, and access to perioperative optimization [1,2,5].

The risk of SSI is strongly influenced by procedure-related factors, with higher incidence observed in colorectal, vascular, and emergency surgeries compared to clean elective procedures. Moreover, patients with significant comorbidities, such as diabetes mellitus or obesity, demonstrate consistently elevated SSI rates [7].

Importantly, SSIs are associated with substantial clinical and economic burden. They represent one of the leading causes of unplanned readmissions following surgery and are linked to prolonged hospital stays, increased need for antibiotic therapy, reoperations, and intensive care admissions. Mortality rates are significantly higher among patients who develop deep or organ/space infections compared to those without postoperative infectious complications [9].

Despite advances in surgical techniques and antimicrobial prophylaxis, global surveillance data indicate that the overall burden of SSIs remains substantial [1,2,5]. This underscores the need for effective preventive strategies throughout the perioperative continuum. Among the different phases of surgical care, the preoperative period represents a particularly important window for intervention, as it allows for identification and modification of risk factors prior to incision [10].

Accordingly, the following sections review current evidence regarding selected preoperative strategies aimed at reducing SSI incidence, including preoperative body washing, skin antisepsis, hair removal practices, and perioperative glycemic control.

Preoperative Body Washing

Rationale and Importance

Preoperative body washing is widely recommended as a component of surgical preparation, aiming to reduce the microbial burden on patient skin prior to incision and thereby potentially lowering the incidence of surgical site infections (SSIs). The rationale for this practice stems from the fact that the skin is a major reservoir of endogenous bacteria capable of contaminating the surgical wound during surgery. Surgical sites can become colonized by bacteria from the patient's own skin, which may subsequently lead to infection if other risk factors are present. Consequently, many clinical protocols recommend preoperative washing using either plain soap or antiseptic agents to reduce the bacterial load and improve overall perioperative hygiene [10,11].

Practical Preoperative Washing Protocol

In clinical practice, the following structured approach is commonly recommended for preoperative body washing:

Shower or full-body bath**:** Patients should take a shower or full-body bath either the evening before or on the day of surgery, using soap (plain or antiseptic) or another suitable cleansing agent.

Thorough cleansing: Emphasis should be placed on thoroughly washing all areas of the body, especially those included in the surgical field, while maintaining overall skin hygiene.

Use of antiseptics (if applicable): When antiseptic agents such as chlorhexidine gluconate (CHG) are used, they should be applied according to manufacturer instructions and left on the skin for the recommended contact time (typically 1–2 minutes) before rinsing, to maximize reduction of skin microbial flora.

Post-wash precautions: After bathing, patients should use clean towels and wear fresh clothing to avoid recontamination of the skin prior to entering the operating room.

This protocol is designed to reduce skin bacterial load and improve perioperative hygiene. While the evidence regarding its direct effect on SSI rates is mixed, preoperative body washing is considered a low-risk intervention and is generally implemented as part of a broader multimodal infection prevention strategy [5].

Evidence from Clinical Trials and Meta-Analyses

The most frequently studied antiseptic agent in this context is CHG, typically in a 4% aqueous solution. Multiple systematic reviews and meta-analyses have evaluated the effectiveness of preoperative bathing with CHG compared to non-antiseptic soap, placebo, or no washing. A Cochrane systematic review analyzing data from numerous randomized controlled trials reported no clear evidence that preoperative whole-body bathing with CHG significantly reduces SSI incidence compared to other wash products or no washing, although some individual studies indicated a reduction in bacterial skin flora following CHG use. The pooled relative risk (RR) for SSI when comparing CHG bathing to placebo was 0.91 (95% CI 0.80–1.04), demonstrating no statistically significant benefit [12].

Similarly, comparisons between CHG and plain soap did not consistently demonstrate a significant difference in SSI outcomes. However, in specific surgical populations, one larger randomized trial found a significant reduction in SSI rates with CHG bathing compared to no washing, suggesting that the benefit may be context-specific. More recent meta-analyses, incorporating broader datasets from 16 controlled trials involving nearly 18,000 patients, confirmed that preoperative CHG bathing does not significantly reduce overall SSI rates compared with soap, placebo, or no bath (RR 0.90; 95% CI 0.77–1.05) [13].

National guideline reviews often conclude that while preoperative bathing can improve general skin cleanliness, the current evidence is insufficient to recommend CHG bathing specifically for SSI prevention beyond standard preparation protocols. Despite the lack of strong evidence for a direct effect on SSI incidence, preoperative bathing remains widely practiced due to its low cost, low risk, and potential contribution to improved perioperative hygiene. Expert consensus statements frequently consider preoperative skin cleansing a reasonable component of a multimodal SSI prevention bundle, particularly in patients with additional risk factors for infection [11,14].

Limitations and Considerations

Variability in study designs, differences in surgical populations, inconsistent definitions of SSI outcomes, and heterogeneous timing and frequency of bathing protocols all contribute to uncertainty in the literature. The impact of CHG may also depend on the type of surgery, baseline skin colonization, and concurrent infection prevention measures. Consequently, high-quality randomized trials with standardized protocols are needed to better define the role of preoperative body washing in SSI prevention.

Summary and Transition

In summary, preoperative body washing, particularly with antiseptics such as CHG, is a low-risk and widely implemented intervention. Although current evidence does not conclusively demonstrate a significant reduction in SSI rates, this practice is generally regarded as a supportive element within broader perioperative infection control strategies rather than a standalone preventive measure. Building on the principles of preoperative cleansing, the choice and application of antiseptic agents directly to the surgical site represents another critical component of SSI prevention, which will be discussed in the following section on Skin Antisepsis.

Preoperative Skin Antisepsis

Rationale and Clinical Importance

Preoperative skin antisepsis refers to the application of chemical antiseptic agents directly to the surgical site immediately prior to incision, with the goal of substantially reducing the load of resident and transient microbes on the skin. Unlike body washing, which affects the skin over the entire body, skin antisepsis targets the specific operative field at the point of incision, where microbial contamination poses the greatest risk of leading to surgical site infections (SSIs). Effective skin antisepsis is considered a cornerstone of SSI prevention and is recommended by multiple international guidelines as a critical step in surgical preparation. It is based on evidence that reduction of skin flora at the incision site can diminish the likelihood of endogenous contamination during surgery. The main antiseptic agents used in preoperative skin preparation include chlorhexidine gluconate (CHG), povidone-iodine (PVI), and combinations thereof, often formulated with alcohol to enhance antimicrobial activity [5,6].

Evidence from Randomized Trials and Meta-Analyses

A substantial body of clinical evidence supports the superiority of CHG-based antiseptics over povidone-iodine for preoperative skin antisepsis. Multiple meta-analyses comparing chlorhexidine formulations (often in alcohol) with povidone-iodine have consistently found a lower incidence of SSIs associated with CHG use. One large systematic review and meta-analysis including more than 29,000 participants showed that chlorhexidine was significantly more effective than povidone-iodine in preventing postoperative SSIs (risk ratio [RR] 0.65; 95% confidence interval [CI] 0.55–0.77), with particular benefits seen in both clean and clean-contaminated surgery types [15]. Similarly, other aggregated analyses have demonstrated an overall reduction in SSI incidence (RR around 0.70–0.73), suggesting a consistent advantage of CHG over PVI in diverse surgical populations [16].

In orthopedic surgery specifically, meta-analytic data have confirmed the ability of alcoholic CHG to more effectively reduce positive skin cultures than PVI, serving as a surrogate marker for potential SSI risk [17]. However, it is important to acknowledge that not all studies uniformly show significant reductions in clinical SSIs with CHG for every surgical type. For example, in cesarean section populations, some meta-analyses did not find statistically significant differences in overall SSI rates between CHG- and PVI-based skin preparation [18]. Nonetheless, larger and more recent network meta-analyses incorporating extensive randomized data continue to support the superiority of CHG in reducing overall SSI incidence, particularly in clean-contaminated procedures, and in lowering superficial incisional SSI risk [19].

Antiseptic Agents and Formulations

Preoperative skin antisepsis typically involves the use of antiseptic agents in combination with alcohol, which enhances microbial kill and persistence on the skin. Alcohol has rapid bactericidal effects but does not provide residual activity; combining it with CHG imparts both immediate microbial reduction and sustained suppression of regrowth [15,16]. CHG formulations commonly range from 0.5% to 4% in alcohol, with several studies indicating that even lower concentrations can be effective when adequately applied [15].

Povidone-iodine, although effective against a broad spectrum of organisms, tends to have lower residual activity and, in many comparative trials, is associated with higher SSI rates compared to CHG. Despite this, PVI remains an acceptable alternative, especially in resource-limited settings or in patients with CHG allergy [16]. Emerging combination strategies using both CHG and PVI aim to exploit potential synergistic effects on bacterial reduction, although high-quality evidence on SSI outcomes with combination regimens remains limited [19].

Guideline Recommendations and Practice Considerations

International clinical practice guidelines generally recommend the use of effective skin antiseptics immediately prior to incision but differ in details regarding preferred agents. NICE guidelines indicate moderate-quality evidence that CHG is associated with lower SSI incidence than PVI, and that CHG in alcohol has a high probability of being associated with the lowest SSI risk among commonly used preparations [6]. Guideline evidence tables from AORN and other professional organizations reflect that some individual studies do not find significant differences among antiseptic agents, but overall consensus favors alcohol-based CHG as a first-line antiseptic for most surgical contexts, with alternatives considered when CHG is contraindicated (e.g., allergy or iodine sensitivity) [20].

Limitations of the Evidence and Future Directions

Despite the generally positive evidence for CHG-based skin antisepsis, heterogeneity across studies remains a challenge. Variations in study design, surgical populations, antiseptic concentrations, application techniques, and SSI definitions contribute to inconsistency in observed effects. Some analyses highlight low or very low quality evidence in specific subgroups, underscoring the need for additional high-quality, adequately powered randomized trials to define optimal antiseptic regimens for various procedures [6].

Summary and Transition

In summary, preoperative skin antisepsis is a well-established component of SSI prevention, with strong evidence supporting the use of alcohol-based CHG as the preferred antiseptic agent in many surgical contexts due to its superior reduction of skin bacterial flora and lower associated SSI rates compared with PVI. While not universally conclusive for all types of surgery, current evidence and guideline recommendations favor CHG-based preparation as a key perioperative strategy. Building on these principles, the subsequent section will examine hair removal practices, another modifiable preoperative factor associated with variations in SSI risk.

Preoperative Hair Removal Practices

Rationale and Clinical Importance

Preoperative hair removal at the surgical site has traditionally been performed to improve visualization of the operative field, facilitate surgical draping, and reduce contamination risk. However, hair removal can itself be a risk factor for surgical site infections (SSIs) if performed improperly, as it may cause micro-abrasions or cuts in the skin that serve as entry points for bacteria [5,6].

Current guidelines emphasize that hair should only be removed when absolutely necessary, and if removal is indicated, the method, timing, and technique are critical determinants of SSI risk. The primary goal is to balance the need for a clear surgical field with minimizing trauma to the skin. Hair removal is considered a modifiable preoperative risk factor and is particularly relevant in procedures where hair at the incision site could interfere with wound closure, draping, or sterility [20].

Methods of Hair Removal

Three main methods are commonly used:

Shaving with a razor

Traditional method involving removal of hair at the skin surface.

Associated with higher risk of micro-abrasions and subsequent SSI if performed immediately before surgery or with improper technique [21].

Meta-analyses indicate that razor shaving significantly increases SSI risk compared to clipping [22].

Clipping with electric or manual clippers

Hair is trimmed close to the skin without cutting it completely, minimizing microtrauma.

Considered the preferred method for surgical hair removal by WHO, CDC, and NICE guidelines [5,6,33].

Evidence demonstrates a lower incidence of SSIs compared with razor shaving while achieving adequate visualization of the operative field [21,22].

Depilatory creams (chemical removal)

Use of topical agents to dissolve hair.

Generally safe in terms of skin trauma but may cause allergic reactions or chemical burns in sensitive patients [23].

Evidence on SSI prevention is limited, and these are not routinely recommended in most guidelines.

Timing of Hair Removal

The timing of hair removal is critical in influencing SSI risk:

Immediate preoperative removal (within 2 hours before incision) is associated with lower SSI rates compared to removal the night before surgery. Early removal allows bacteria more time to colonize micro-abrasions and increase infection risk [21,22].

Clipping immediately prior to surgery is therefore preferred to minimize skin trauma and bacterial regrowth.

Evidence from Randomized Trials and Meta-Analyses

Multiple studies and meta-analyses have compared methods and timing of hair removal.

A systematic review of 18 randomized controlled trials involving over 10,000 patients found that razor shaving increased SSI risk by nearly 50% compared with clipping (RR 1.48; 95% CI 1.25–1.74) [22].

Clipping immediately before surgery was associated with significantly lower SSI rates compared to shaving the night before.

Chemical depilatories showed no clear benefit over clipping in preventing SSI but had a slightly higher incidence of skin irritation [23].

Overall, these data support clipping immediately preoperatively as the safest and most effective practice for hair removal when necessary [5,6,20].

Guideline Recommendations

International guidelines converge on several key points:

• Hair removal should be limited to cases where hair interferes with the procedure; unnecessary removal is discouraged [5,6].

• Clipping is preferred over shaving due to lower risk of skin trauma and SSIs [5,20,22].

• Removal should occur as close to the time of surgery as possible, ideally in the preoperative holding area [20].

• Depilatory creams may be used in special circumstances but are generally not recommended as routine practice [23].

Practical Protocol for Hair Removal

• Assess whether hair removal is necessary; avoid routine shaving.

• If removal is needed, use electric or manual clippers with disposable heads.

• Perform hair removal in the preoperative area, immediately before surgery.

• Avoid razors and minimize mechanical trauma to the skin.

• Ensure sterile handling of clippers and disposal of single-use components.

• If chemical depilatories are used, perform a patch test to prevent allergic reactions.

This structured approach minimizes the risk of micro-abrasions and subsequent SSI while ensuring a clear operative field.

Limitations and Areas for Future Research

Most studies focus on elective procedures; data in emergency surgeries are more limited.

Research on depilatory creams and newer hair removal technologies is sparse.

Future studies should evaluate patient-centered outcomes, cost-effectiveness, and integration of hair removal practices into multimodal SSI prevention bundles.

Summary and Transition

Hair removal is a potentially modifiable preoperative factor that influences SSI risk. Evidence supports clipping immediately prior to surgery as the safest approach, while shaving and unnecessary hair removal increase infection risk. Implementing standardized protocols for hair removal complements other preoperative strategies such as body washing and skin antisepsis. The next section will focus on perioperative glycemic control, another critical modifiable preoperative factor in SSI prevention.

Perioperative Glycemic Control

Rationale and Clinical Importance

Perioperative glycemic control is increasingly recognized as an important component of surgical site infection (SSI) prevention. Hyperglycemia, whether related to pre-existing diabetes mellitus or stress-induced metabolic responses to surgery, has been consistently associated with an increased risk of postoperative infectious complications. Elevated blood glucose levels impair several aspects of host immune function, including neutrophil chemotaxis, phagocytosis, and microbial killing, while also promoting a pro-inflammatory environment and impairing wound healing. Consequently, poor glycemic control may facilitate bacterial proliferation and compromise tissue recovery following surgical procedures [24,25].

The association between hyperglycemia and SSI risk has been demonstrated in both diabetic and non-diabetic surgical patients. Importantly, perioperative hyperglycemia appears to be an independent risk factor for infection, regardless of diabetes status. Therefore, optimization of blood glucose levels before and during the perioperative period has become a key target within multimodal SSI prevention strategies [26].

Evidence from Clinical Studies and Meta-Analyses

A substantial body of evidence supports the relationship between perioperative hyperglycemia and increased SSI incidence. Numerous observational studies have demonstrated that postoperative blood glucose levels exceeding 180 mg/dL (10 mmol/L) are associated with significantly higher rates of wound infections, prolonged hospitalization, and adverse surgical outcomes [25].

In cardiac surgery, one of the most extensively studied surgical populations, intensive glycemic management protocols have been associated with reductions in deep sternal wound infections and overall postoperative morbidity. Similar findings have been reported in orthopedic, vascular, colorectal, and general surgical procedures, where elevated perioperative glucose levels correlate with increased SSI rates [27,28].

Meta-analyses evaluating perioperative glycemic control strategies have generally shown that maintaining blood glucose within moderate target ranges reduces the risk of postoperative infections compared with poorly controlled hyperglycemia. However, evidence does not consistently support very strict glycemic targets because intensive insulin therapy may increase the risk of hypoglycemia, which itself is associated with adverse clinical outcomes. As a result, current evidence favors balanced glucose management rather than aggressive normalization of blood glucose concentrations [29,30].

Preoperative Assessment and Optimization

Effective perioperative glycemic management begins during the preoperative period. Patients with known diabetes should undergo assessment of long-term glycemic control, commonly through measurement of glycated hemoglobin (HbA1c). Elevated HbA1c levels have been associated with higher SSI rates and poorer postoperative outcomes in several studies [31].

Preoperative optimization may include adjustment of antidiabetic medications, dietary counseling, and coordination with endocrinology specialists when necessary. Elective procedures may occasionally be postponed in patients with severely uncontrolled diabetes to allow improvement of metabolic control before surgery. In addition, screening for previously undiagnosed diabetes or stress hyperglycemia may be beneficial in high-risk patient populations [32].

Guideline Recommendations and Target Glucose Levels

International guidelines consistently recommend maintaining adequate perioperative glycemic control to reduce SSI risk. The World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and various surgical societies advocate monitoring blood glucose levels in both diabetic and non-diabetic patients undergoing major surgery [5,33].

Most contemporary guidelines recommend maintaining perioperative blood glucose concentrations below 180 mg/dL (10 mmol/L) while avoiding hypoglycemia. Target ranges of approximately 110–180 mg/dL (6.1–10 mmol/L) are commonly suggested for hospitalized surgical patients. Insulin therapy remains the primary method of achieving glycemic control when necessary, particularly in major surgical procedures requiring intensive monitoring [32,33].

Conclusion

Surgical site infections remain one of the most common and clinically significant healthcare-associated infections, contributing substantially to patient morbidity, prolonged hospitalization, increased healthcare costs, and postoperative mortality [1,9,33]. Despite advances in surgical techniques, anesthesia, and antimicrobial prophylaxis, SSIs continue to represent a major challenge for healthcare systems worldwide.

The evidence reviewed in this paper highlights the importance of preoperative optimization as a fundamental component of SSI prevention. Although individual interventions vary in the strength of supporting evidence, several modifiable risk factors can be addressed before surgery to reduce the likelihood of postoperative infection. Preoperative body washing contributes to overall skin hygiene and may support broader infection prevention efforts [10–14], while preoperative skin antisepsis—particularly with alcohol-based chlorhexidine formulations—has demonstrated consistent effectiveness in reducing microbial contamination and SSI risk [15–19]. Similarly, avoidance of unnecessary hair removal and the use of clipping instead of shaving minimize skin trauma and lower the risk of postoperative wound infection [20–23]. Furthermore, adequate perioperative glycemic control plays a critical role in optimizing immune function and wound healing, with hyperglycemia consistently identified as an independent risk factor for SSI development [24–33].

Importantly, no single intervention is sufficient to eliminate SSI risk. Rather, the greatest benefit appears to arise from the implementation of evidence-based multimodal prevention bundles that combine patient optimization, standardized perioperative protocols, and adherence to infection prevention guidelines [5,6,33]. Future research should continue to refine these strategies and identify procedure-specific approaches that maximize patient safety while remaining practical and cost-effective.

In conclusion, preoperative preventive measures represent a valuable opportunity to reduce the burden of surgical site infections. Consistent application of evidence-based practices before surgery should remain a priority for healthcare professionals seeking to improve surgical outcomes and enhance the quality of patient care [5,33].

Disclosure:

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