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# Maintenance of Operation Theatre Quality as a Preventive Measure of Surgical Site Infections: A Systematic Review

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## Abstract

**Introduction:** Surgical Site Infections (SSIs) represent index of healthcare system and are third most commonly reported nosocomial infection. SSIs are responsible for high morbidity and mortality ratio and account round about 1/4 of hospital acquired infections which produce adverse impacts on patients. Moreover, they increase patient stay in hospital resultantly responsible for economical loss of patient and family.

**Objective:** The aim of present review is to assemble already known information regarding incidence of SSIs, pathological as well as microbiological risk factors and mitigation strategies (pre-operative, intraoperative and postoperative) for patients posted for any surgery in hospital. Additionally, importance of SSIs related preventive measures and prophylactic antibiotic therapy for better healthcare is also highlighted.

**Methodology:** Several research, review articles, clinical reports and survey-based reports were searched by using different databases to gather the information regarding SSIs. Moreover, 10 published records were thorough discussed to understand importance of operation theater quality in management of SSIs.

**Results:** Data obtained showed that implementation of pre, intra and postoperative strategies can cut down mortality rate associated with SSIs around the world. Moreover, surveillance of SSIs risk factors and decline in them may also decrease nosocomial infections.

**Conclusion:** SSIs surveillance is a well-established and comprehensive approach to reduce incidence of SSIs. Along with, maintenance of operation theater quality is hallmark for reduction in SSIs. However, further studies are still required to improve standards for periodic surveillance and management of hospital acquired infections.

**Keywords: SSIs; Operation Theater; Pre-operative; Nosocomial infection; Surveillance programs**

## Introduction

Operating care has become an integral measure of global health care with approximately 234 million procedures per year. The World Bank reported that an estimated 11% of entire disease burden were associated with operating procedure [1]. Studies on incidence of in-hospital adverse effects have shown that 1 in 10 patients admitted to hospital have faced nosocomial infection. Among all on these, majority of in-hospital events are linked to surgical incisions and administration of medications [2]. Surgical Site Infections (SSIs) represent major health care complications and account for 38% of hospital associated infections. SSIs usually occur within one month of procedure execution or maximum in 1 year in patients who has received implants [3]. SSIs are responsible for high morbidity and mortality ratio as SSI patients remain 2 to 11 times more expected to die than non-SSI patients therefore they poses a significant clinical concern globally. Moreover, surgical site infected patients stay in hospital for around seven to ten additional days which resultantly drop economic conditions of patients [4]. One research report has been exhibited that *Staphylococcus aureus* associated surgical site infected patients faced higher probability of medical complications, increased post-operative medical stay and related hospital expenses [5].

### Surgical site infections

SSIs are termed as contaminations happening in duration of one month after a surgery (or within duration of 1 year in case of an in-dwelling implant) and affecting incisional area or deep tissues under operative site. These contaminations could be deep or superficial incisional infections

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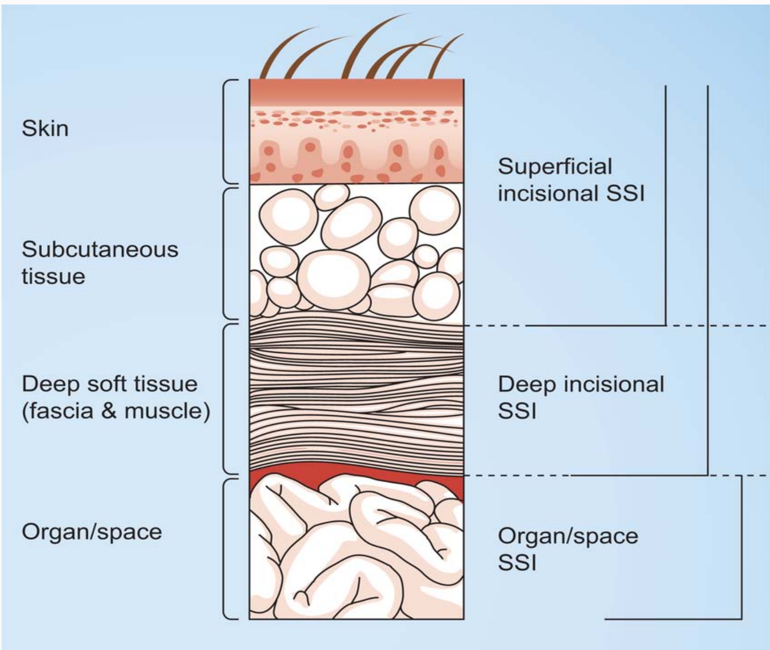


**Figure 1:** Surgical Site Infections (SSIs) classification according to Centers for Disease Control National Nosocomial Infections Surveillance (CDC NNIS) system [6].

and generally involve body organs or body spaces (Figure 1). In particular, superficial diseases that affect skin only can be SSIs, for instance, operative wound pathogens mainly involve surface tissues, organs, or soft masses [6]. Extreme SSIs account for about half of all SSIs in deep incisions or organ gaps [7]. The degree of degradation at medical site during operation time determines risk of infection at operative wound. Four major types of injuries are categorized as 1) clean wounds, an uninfected operational wound in which no inflammation is observed and alimentary, respiratory, genital, or uninfected urinary tract is not accessed; 2) operative incisional wounds that accompany blunt trauma; 3) clean -contaminated wounds, a surgical wound in which gastrointestinal, respiratory, genital, or urinary tracts are entered under sterile environments and without unusual contamination; and 4) contaminated wounds including open, fresh or accidental wounds. In addition, procedures with major disruptions in following sterile technique or gross leakage from GIT tract and those incisions in which non-purulent, acute inflammation is encountered), dirty-infected wounds (Existing traumatic wounds containing devitalized tissue which hasn't healed, as well as those with a pathological infection or lacerated viscera) according to existence and level of contagion [6,8,9]. In these four categories, rates of infection have been reported in several research base articles (Figure 1). For treatment of wounds, before providing prophylactic antibiotics to patients, rates of infections were ≥ 1% to 2% for clean wounds, 6% to 9% for clean-contaminated wounds, 13% to 20% for contaminated wounds and 40% for dirty or toxic wounds. The use of antibiotic prophylaxis has significantly reduced this hazard particularly with surgical treatments at higher risk of diabetes and intestinal pathologies [10,11]. There is no difference in variety and distribution of disease-derived bacteria over last decade but a major shift in microbiology of SSIs has proved presence of pathogens that are resistant to antibiotic therapy [12].

## Etiology of SSIs

**Microorganisms presenting as source of SSI:** In most of SSIs, pathogens are acquired from endogenous flora of patients. *Staphylococcus aureus* is constantly principal source of nosocomial or hospital acquired infections and frequency of Methicillin-Resistant *Staphylococcus aureus* (MRSA) strains is rising continuously. MRSA now accounts for nearly 2/3 of *S. aureus* infections attained in some Intensive Care Units (ICUs). Hospitalizations for MRSA infections has raised further than double in last years and now it has become prominent cause of SSIs in numerous community and educational hospitals [3]. This expansion may reflect cumulative number of immunocompromised or surgically ill patients and prevalent use of broad-spectrum antibiotic drugs. Likewise, microorganisms can originate from pre-operative infectious sites other than operative region, predominantly in patients undergoing insertion of an implant or other prosthesis. *S. aureus*, Coagulase-Negative Staphylococci (CoNS), *Enterococcus* spp. and *Escherichia coli* are most commonly encountered organisms, though microorganisms isolated are dependent on type of performed procedure [6,13] (Table 1).

Rarely, pathogenic microorganisms are originated from an exogenous source like Operating Theatre (OT) environment, surgical personnel or employees [14], and total tools including instruments as well as materials used during a surgery [13,15]. Giacometti et al. [16] studied 676 patients of surgery with signs and symptoms suggestive of wound infections, who presented over course of six years. Findings showed bacterial pathogens in 614 victims and most of them were aerobic bacteria (*S. aureus, P. aeruginosa, E. coli, S. epidermidis* and *Enterococcus faecalis*) with percentages of 28.2, 25.2, 7.8, 7.1 and 5.6 respectively [16].

## Risk factors for SSIs

The chances of developing SSI differ considerably depending on procedure type and specific clinical characteristics of individual undertaking surgery [14]. Different studies have identified both internal (related to patient i.e. dehydration, older age, co-existing disease and diabetes) as well as external (related to procedure i.e. length of procedure, working ethics of surgeon, stability of pre-


**Figure 2:** Strategies for Surgical Site Infections (SSIs) prevention.

operative skin preparation, adequacy of antimicrobial prophylaxis and addition of foreign objects) factors responsible for SSIs [15]. A research conducted by Dominioni et al. [17] has shown that serum albumin accumulation, older age and predisposing points associated with patients were also important risk factors [17] (Table 2). Moreover, rate of surgical infections is highly affected by standard of operation theater as well [11].

## Methodology

Numerous numbers of research and review articles have been analyzed for acquisition of information about surgical site infections and their remedial measures. Different databases have been investigated to find out the information about respective topic. Keywords used were "surgical site infection", surgical site prevention", "operation theater infections", risk factors responsible for SSIs", Strategies to reduce SSIs", "SSIs related complications", "Etiology of SSIs", "intra-operative SSIs", "post-surgical site infections", "exposure time for surgical site treatment", "nosocomial infection types" and so on. It was a qualitative type review so no specific software was used for data analysis. Articles having supposititious and un-authentic information regarding SSIs were excluded from the review process.

## Results and Discussion

For the avoidance of surgical site infections, few strategies are adopted including preoperative, intra-operative and post-operative strategies. The summary is given in Figure 2.

### Pre-operative strategies

For pre-operative preparation of skin, most commonly used agents are alcohol-containing products, iodophors, and chlorhexidine gluconate. According to FDA, alcohol is well-established agent having active constituents including ethyl alcohol ($C_2H_5OH$) 60% to 95% or isopropyl alcohol 50% to 91.3% by volume [18]. Alcohol remains most effective, readily available, inexpensive, rapidly acting agent and has bactericidal, fungicidal and virucidal activity, but spores can show resistance [19]. The technique for application of antiseptic is in concentric circle, starting from area of supposed incisional site to periphery [20]. According to Center for Disease Control (CDC) guidelines maintenance of "hand hygiene" including trimming of nails, use of proper antiseptic agent for scrubbing and drying can help to reduce pathogen transfer from medical workers to patients [15]. For removing hairs, shaving of surgical site causes a significant increase in SSI (5.6%) as compared to other hair removal agents (0.6%). Shaving causes microscopic traumas in skin that later act as a center for replication of bacteria [21].

OT workers may have interactions during medical procedures with individual skin and/or mucous membranes and there is a chance of sharp injury leads towards chronic infections. Sharp wounds placed employees at threat of exposure to blood-borne diseases as well [22]. Proper educational programmers and policies must be developed among health sector personals in order to limit chances of pathogen transfer to patients which in turn decreases hospital acquired infections among post-surgery patients [15]. Before surgery, administration of antimicrobial prophylaxis has been shown to significantly decrease severity of wound infections associated with surgical procedures. The usage of antibiotic drug prophylactically prior to surgery allows availability of appropriate concentration in tissue thus; reduce microbial concentration and occupancy at incisional site [23].

### Intra-operative strategies

SSIs may result from bacteria surviving on surgical tools or penetrating directly into operational site [24]. Ventilation and humidity in the OT are important factors to minimize chance of infection. In order to avoid getting potentially polluted air to reach surgical suite, Surgical Operation Room (SOR) must be hold on to positive pressures in comparison to the hallways outside the room [25]. As best practice, there must also be at least 15 air changes per hour (3 of fresh air). To stop development of molds and fungi, humidity should be conserved at a definite level [26]. The Ventilation health care facility suggests that the OT must be managed at 20ºC to 24ºC, with positive pressure and humidity of 20% to 60% [27]. Flash sterilization is a procedure designed for instant use of instruments (e.g., for reprocessing of an accidentally dropped instrument). However, it is not recommended for implants because of a viable risk of infection [28]. Various studies did not prefer this method as a routine sterilization for convenience, to save time and to minimize sterilization cycle factors (i.e., temperature and time) [29] (Table 2).

Environmental surfaces are hardly concerned for expansion of SSIs. When surfaces get visibly soiled during a procedure, a hospital disinfectant approved by Environmental Protection Agency (EPA) would be used before next procedure [30]. According to Occupational Safety and Health Administration (OSHA) requirement, environmental surfaces should be disinfected after interaction with infectious material or blood ("U.S. Department of Labor, Occupational

**Table 1:** Pathogens commonly linked with majorly performed surgical procedures [6].

| Type of surgery | Common Pathogens |
|---|---|
| Colorectal | Anaerobes ; Gram-negative bacilli |
| Implant or prosthesis | *Staphylococcus aureus*; Coagulase-negative *Staphylococci* |
| Appendectomy | Anaerobes ; Gram-negative bacilli |
| Gastro-duodenal | Streptococci; Oro-pharyngeal anaerobes; Gram-negative bacilli |
| Cardiac | Coagulase-negative staphylococci; *Staphylococcus aureus* |
| Ophthalmic | *S. aureus*; Coagulase-negative staphylococci; Streptococci; Gram-negative bacilli |
| Urological | Gram-negative bacilli |

**Table 2:** Endogenous and exogenous risk factors responsible for SSIs.

| Endogenous | Exogenous |
|---|---|
| High Age | Surgical scrub timings |
| Diabetes mellitus | Preoperative shaving and skin preparation |
| Nutritional status | Duration of operation |
| Obesity | Surgical drains |
| Smoking | Improper sterilization of surgical instruments |
| Colonization with micro-organisms | Foreign material at surgical site |
| Immunocompromised health status | Anti-microbial prophylaxis |
| Length of pre-operative hospital stay | Surgical technique used |

**Table 3:** Parameters for flash sterilization cycles [28].

| Gravity displacement | Minimum time for exposure | Temperature (ºC) |
|---|---|---|
| Non-porous items | 3 minutes | 132ºC |
| Non-porous and porous items | 10 minutes | 132ºC |
| **Pre vacuum** | **Minimum time for exposure** | **Temperature (ºC)** |
| Non-porous items | 3 minutes | 132ºC |
| Non-porous and porous items | 4 minutes | 132ºC |

Safety and Health Administration. Occupational exposure to blood borne pathogens; final rule (29 CFR Part 1910.1030). Federal Register 1991;56:64004-182"). After the end of night or day, a disinfectant approved from Environmental Protection Agency (EPA) is used on regular basis for wet-vacuuming of floor of operating room [31]. The tacky mats have not been played significant role in reduction of microorganism present on stretcher wheels or shoes. So, there is no need to use them for controlling infection [32].

Microbiological sampling and counting can regularly be used to determine condition of air in OTs, but the relationship between two approaches has rarely been tested. A study indicated that there is no need to substitute microbiological sampling with particle counting in conventionally ventilated operating theatres for routine assessment of pathogenic organisms [33]. Surgical attire is worn to minimize release of microbes into atmosphere of Operation Theater. Clean, freshly washed scrubs should be worn by each medical staff member just to prevent spread of possible pathogens to the wounds [34]. In addition, sterile drapes can also be used for the same purpose [35].

Strict obedience to codes of asepsis by scrubbed staff as well as by anesthesia personnel is base for controlling SSIs. Different surveys related to operation theater visits revealed that anesthesia personnel were involved as source of pathogen when placing intra-vascular devices, Endotracheal Tubes (ETT), and when administrating Intravenous (IV) drugs [36]. Improper implementation of aseptic-principles throughout performance is associated with outbreaks of post-operative infections. It is believed that risk of SSIs can be reduced through application of surgical technique in operation theatre [37]. Presence of some type of foreign body like suture material, an implant, or drain, might stimulate inflammation at surgical site and may enhance chance of SSIs [38]. Moreover, studies have been showed that risk of SSIs drop when closed suction drains are used instead of open drains [39] (Table 3).

## Post-operative strategies

After performing a surgery, the care of surgical site incision is mandatory depending upon the type of incision the patient had. There are three forms of incision sites including closed skin edges incision, open edges incision which is closed later and open incision site for healing purpose. Postoperative incision care in case of closed edges, the incision is covered with germ free bandage for up to 48 h [40]. In case of open edges incision, it must be packed with sterile dressing for minimizing the contamination of surgical site. When the incision site left open for healing purpose, it is also filled with germ free damped gauze and covered with bandage. The American College of Surgeons (ACS) and other authorities have suggested usage of germ-free gloves and tools while exchanging dressings of surgical incision [30,41].

Presently, patients are discharged momentarily even afore surgical incisions have restored. Physician will provide specific instructions about when and how to adjust it. After a few days, most wounds do not require taking off the gauze but wrapping of area and change dressing on regular basis by maintaining proper hand hygiene it may help to protect cut from infection and it may heal more quickly. The discharge planning intent is to sustain reliability

**Table 4:** Summary of previously published record on SSIs and their mitigation strategies.

| Aim | Methodology | Results | References |
|---|---|---|---|
| To see that behavioral and structural interventions would reduce intra-operative infection during knee and hip replacements. | Comparative study was performed to see the positive outcomes in operations done under controlled conditions. In group 1, behavioral measures were introduced and cultures were taken during operations using better use of plenum. In group 2, disciplinary measures, and installation of air-flow system with use of plenum was introduced. | Group 1 showed contamination in 34.3% and Group 2 showed in 8.6% of cases. Reduction of SSI in group 2 showed that combination of systemic and behavioral changes in an OR lessened the incidence of intra-op contamination which showed positive outcomes during post-operative period. | (Knobben, Van Horn, Van der Mei, & Busscher, 2006) |
| To see factors accountable for contamination and by using which strategies, rate of SSI can be decreased. | Charnley evaluated 5,800 surgical operations to observe factors responsible for causing intra-op contamination and shows a major risk to success of joint replacement. | When unidirectional airflow regimes with a high number of hourly air exchanges used and surgical staff wore special suits, the rate of SSI dropped noticeably from 7 to 0.5%. | (Charnley, 1972) |
| To evaluate risk factors and efficacy of prophylactic antibiotics for SSI among patients with uncomplicated open appendectomy. | A prospective cohort study was conducted in eight hospitals in Thailand by using the National Nosocomial Infection Surveillance (NNIS) system criteria to identify SSI associated with appendectomy. | Antibiotic prophylaxis was linked with decreased risk. A combined single dose of metronidazole and gentamicin administered preoperatively or intra operatively appears sufficient to decrease SSIs in patients with uncomplicated appendicitis. | (Kasatpibal et al., 2006). |
| To provide latest and modernized evidence-based recommendations for the prevention of SSI. | A targeted systematic review of the literature was conducted. A modified Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach was used to assess the quality of evidence and the strength of the resulting recommendation. | Public reporting of procedure, result, and other quality improvement measures is now needed for treating SSI. It has been estimated that approximately half of SSIs are preventable by application of evidence-based strategies. | (Berríos-Torres et al., 2017) |
| To summarize interventional studies performed in Sub-Saharan Africa that had attempted to reduce the risk of post-op SSI. | Searched Medline, Embase and Global Health databases for studies published between 1995 and 2010 without language restrictions and extracted data from full-text articles. | Proper use of antibiotic prophylaxis in surgery can dramatically reduce the risk of SSI and alcohol-based preparations may provide a low-cost alternative to traditional surgical hand-washing and skin preparation methods. | (Aiken, Karuri, Wanyoro, & Macleod, 2012). |
| To investigate the application of nasal de-contamination with topical formulations for prevention of SSI. | The literature from the years 2002 to 2012 was investigated. Websites of international and Greek organizations, scientific guidelines and databases (e.g., PUBMED) were searched for staphylococcus articles as well as articles for nasal decontamination and SSI. | Pre- operatively, nasal decontamination is used to avoid SSI in countries where staphylococcus is prevalent. | (Efstathiou & Papageorgiou, 2014). |
| To develop a consensus-based "Best Practice" Guideline (BPG), informed by both the available evidences and expert opinion. | A panel of 20 pediatric spine surgeons and three infectious disease specialists from North America was created, with each member chosen for their extensive expertise in the field of pediatric spine surgery. | This study presented a consensus-based Best Practice" Guideline (BPG) consisting of 14 recommendations for the prevention of SSIs after spine surgery in high-risk pediatric patients. | (Vitale et al., 2013) |
| To see how effective chlorhexidine and povidone-iodine were at preventing post-op SSI. | PUBMED, Web of Science, EMBASE, and CNKI were used to check for research on "skin antiseptic" and "SSI." There were 30 studies in total, with 29,006 participants. Revman 5.3 was used to analyze all of the results. | In the clean-contaminated surgery, chlorhexidine was superior to povidone-iodine in preventing postoperative SSI. | (Chen, Chen, Guo, & Xu, 2020). |
| To assess risk factors and to confirm existing SSI prevention strategies. | The prospective observational cohort study included 6,283 consecutive general surgery procedures monitored for evidence of SSI up to 1 year after surgery. By using multiple logistic regression analysis, the dataset was scrutinized for the impact of possible SSI risk factors, such as the timing of surgical antimicrobial prophylaxis (SAP), glove puncture, anemia and transfusion. | SAP should be directed between 74 and 30 mins before surgery and double gloving is recommended to prevent SSI. Anemia and transfusion do not rise the risk of SSI. | (Junker et al., 2012). |
| To identify the best antiseptic agent in terms of skin preparation for reducing SSI. | The incidence of SSI linked with pre-op skin antiseptic preparation was explored through these given databases: British Nursing Index, The Allied and Complementary Medicine Database, Cumulative Index to Nursing and Allied Health, PubMed, The Mohammed Abdullah Al Maqbali Cochrane Database of Systematic Reviews and MEDLINE. | Chlorhexidine with alcohol is the most effective in terms of reducing SSI. | (Maqbali, 2013). |

of restorative incision, let the patient to know almost signs and symptoms of infection and direct patient about whom to interact to account any issues [42]. Previous studies which have worked to identify the risk factors responsible for surgical site infections and strategies for preventing them are summarized below (Table 4).

Data obtained exhibited that an area where all contaminating factors and micro-environmental changes are kept under controlled supervision is considered as a safe operating unit. By giving thorough attention, this task can be done by proper management and frequent inspections, as well as by adequate ongoing employee training [43]. Indeed, OT is an extremely complex environment in which there are various risk factors, including not only infrastructure characteristics and its equipment but also the administration and actions of workers in healthcare system [44]. Design of OT is one of the most important parameters to maintain quality of procedure. In specific description, it is essential to separate clean and dirty areas and maintain organized and logical movement of patients from their entrance to exit. For execution of medical procedures and for preparation of equipment separate rooms should be allocated. In these rooms, it is essential to limit the level of movement and activities of people as both factors can manipulate microbial contents and therefore can influence possibility of infections. The size of storage area should be determined according to workload and types of materials need to be placed in it. Windows of Operating Room (OR) should have a surface that is easy to clean and free from collecting dust [45]. Design of operation room, furniture, floor finishing and its covering will influence cleaning condition of operation room. In order to assist infection control, surface of floor should be impermeable, easy to clean, anti-stain and suitable for moving equipment's of operating room [46].

## Conclusion

To summarize, surgical site infections can be avoided through implementation of well-planned pre-operative, intra-operative and post-operative strategies as well as by practicing infection management through execution of sterile technique while conducting procedures. It's important to remember that much of the morbidity and mortality ratio associated with SSIs can be reduced by modifying a variety of variables, including surgical environment, patient-related or procedure-related risk factors along with personnel behavior. Furthermore, SSIs surveillance is a well-documented and well-established method of reducing incidence of SSIs. Despite its usefulness, many hospitals continue to ignore this advice. The importance of good patient preparation, aseptic conditions and adherence to sterile surgical procedure are highlighted in the CDC guidelines for prevention of SSIs and antimicrobial prophylaxis is also guided in particular circumstances. Altogether, SSIs prevention necessitates a comprehensive approach and the contribution of all individuals involved, including those responsible for the design, layout, and management of operating rooms. However, further research into prevention strategies, as well as strict adherence to the implementation of established evidence-based methods to mitigate SSIs is still required to reduce infection even more.

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