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BACTERIA, FUNGUS, VIRUS AND PARASITES CAUSING RISK FACTORS FOR SURGICAL SITE INFECTION

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Abstract

A surgical site infection (SSI) is an infection that occurs after surgery in the part of the body where the surgery took place. Surgical site infections can sometimes be superficial infections involving the skin only. The commonest of these include bacteria *Staphylococcus, Streptococcus*, and *Pseudomonas,* and fungal infections can range from mild to life-threatening. Parasites, *Acanthamoeba* enter a patient's body via skin cuts, contact-lens solution or inhalation, and *Toxoplasma gondii*, leishmaniasis, hydatidosis dissemination into other organs.

Key words: Bacteria, Fungus, Virus, Parasites, Surgical site infections

Introduction

Surgical wound infections are the second most common nosocomial infection. In one survey from Switzerland that excluded asymptomatic bacteriuria as the main cause of nosocomial infection, surgical site infections (SSIs) were actually the most frequent infection reported (Pitte *et al,* 1999). While usually localized to the incision site, surgical wound infections can also extend into adjacent deeper structures; thus, the term surgical wound infection has now been replaced with the more suitable name, surgical site infection (CDC, 1992).

Among surgical patients, SSIs are the most common type of nosocomial infection, accounting for 38% of nosocomial infections. It is estimated that SSIs develop in 2 to 5% of 16 million patients undergoing surgical procedures each year; one out of every 24 patients who have inpatient surgery in the United States has a postoperative SSI (Horan *et al,* 1992).

Impact: SSIs are associated with substantial morbidity and mortality (Vegas *et al,* 1993): 1- SSIs increase the post-operative length of hospital stay by 7 to 10 days, 2- Hospital charges increase by $2,000 to $4,500 in patients with SSI, & 3- Death is directly related to SSI in over 75 percent of patients with SSI who died in the post-operative period.

In one paired case-control study of SSIs following orthopedic procedures in both a community and a tertiary care teaching hospital, the occurrence of an SSI accounted for a median 14 day increased the total hospitalization, an approximate doubling in the rate of rehospitalization, and increased total costs of more than 300%. Cases and controls were matched by hospital, surgical procedure, NNIS risk index (see below), age within five years, date of surgery within one year, and operating surgeon (Whitehouse *et al.* 2002)

Another study found significantly increased costs associated with SSI diagnosed after discharge. Using patient questionnaires and administrative databases to assess impact during the first eight weeks following the discharge, the average total cost for patients with SSI diagnosed following discharge was $5,155 compared with $1,773 for those without SSI. Infected patients also utilized more healthcare resources, including the outpatient and emergency department visits, the radiology, laboratory, and home health aides were readmitted more frequently (Perencevich *et al,* 2003).

Definitions: The United States Centers for Disease Control and Prevention (CDC) has developed criteria for defining SSIs, which have become the national standard and are widely used by surveillance and surgical personnel (Martone *et al,* 1995). These criteria were define SSIs as infections related to the operative procedure that occurs at or near the surgical incision within 30 days of an operative procedure or within one year if an implant is left in place (Poulsen *et al,* 1994).

Clinical criteria used to define a SSI include any of the following: 1- A purulent exudate draining from a surgical site, 2- A positive fluid culture obtained from a surgical site that was closed primarily, 3- Surgeon's diagnosis of infection, & 4- A surgical site that requires reopening (Boyce *et al,* 1990).

The SSIs are classified as incisional or organ/space. Incisional SSIs are further divided into superficial (i.e., those involving only the skin or subcutaneous tissue) or deep (i.e., those involving deep soft tissues of an incision). An organ/space SSI may involve any part of the anatomy (other than the incision) that was opened or manipulated during the operative procedure as meningitis following an elective neurologic procedure or mediastinitis following coronary artery bypass surgery ((Abdelrahman *et al,* 2016). Although organ/ space SSIs account for only one-third of all SSIs were associated with 93% of deaths related to SSIs, the organ/ space SSIs are also vastly more costly than incisional SSIs (CDC, 1998a).

Epidemiology: Rates of SSIs for individual procedures vary widely depending upon the patient population, size of the hospital, experience of the surgeon, and methods used for surveillance. Nonteaching hospitals generally have the lowest rates of SSI compared to small (<500 beds) or large (>500 beds) teaching hospitals (4.6 vs. 6.4 & 8.2%, respectively). Several studies have noted an increased risk of SSI in patients with cancer who undergo surgical procedures (Hughes *et al,* 1983).

The type of procedure is also associated with different rates of SSIs. The highest rates occur after abdominal surgery (Guinan *et al,* 2003): small bowel surgery (5.3 to 10.6%), colon surgery (4.3 to 10.5%), the gastric surgery (2.8 to 12.3%), liver/pancreas surgery (2.8 to 10.2%), exploratory laparotomy (1.9 to 6.9%), and appendectomy (1.3 to 3.1%). High volume surgeries were associated with higher SSI rates and the commonest ones include (CDC, 1998b): Coronary bypass surgery (3.3 to 3.7%), cesarean section (3.4 to 4.4%), vascular surgery (1.3 to 5.2%), joint prosthesis (0.7 to 1.7%), and spinal fusion (1.3 to 3.1%), but eye surgery was associated with an extremely SSI low rate (0.14%). But, Seo *et al.* (2017) in Korea mentioned that although there were many postoperative febrile causes, surgical-site infection has always been considered as one of the major causes, but it should be excluded; as most spinal surgeons should be aware that postoperative fever can be common without a wound infection, despite its appearance during the late acute or subacute period.

Pathogenesis and Microbiology: The commonest pathogens causing SSIs are normal skin flora including the staphylococcal species, *Staphylococcus aureus* and coagulase negative staphylococci (CNS). When the surgical procedure involves opening a viscus, the pathogens causing SSIs reflect the endogenous flora of the viscus or nearby mucosal surface. Such infections are typically polymicrobial (Martone and Nicholas, 2001). Emori and Gaynes (1993) in USA reported that microorganisms species isolated from surgical site infections have remained relatively stable over recent decades. But, Ghawaby and Morsy (1976) in Egypt reported traumatic myiasis in an orthopedic hospitalized patient and Abosdera and Morsy (2013) reported oral cavity myiasis. Schaberg *et al.* (1991) in USA reported that SSIs% caused by antibiotic-resistant agents increased as methicillin-resistant *S. aureus* (MRSA), methicillin-resitant *S. epidermidis* (MRSE), & vancomycin-resistant enterococci. Lenz *et al.* (2008) in USA reported that the surgical-site infections remain a common complication, affecting some 5% of patients undergoing surgical procedures at time of surgery and sometimes present a major challenge after surgery with life-threatening septic illness, and that most SSIs were acquired. The commonest source was believed to be direct inoculation of endogenous patient flora at the time of the surgery. Kamel *et al.* (2011) in Canada reported that the surgical site infections (SSIs) were in patients' undergone thoracic and orthopaedic surgery, and in those undergone intra-abdominal procedures. SSIs were associated with increased morbidity and mortality in some patients after surgery, with prolonged hospital stay and increased costs. The topical antiseptics might be applied to patient as a preoperative skin preparation to reduce risk of SSIs, and the three main antiseptics are iodine or iodophor, ethanol and chlorhexidine gluconate.

Moreover, fungi, particularly *Candida albicans* were isolated from an increasing percentage of SSIs (Jarvis, 1995). This trend toward resistant organisms and Candida species probably is due to the widespread use of prophylactic and empiric antibiotics, increased severity of illness, and greater numbers of immunocompromised patients undergoing surgical procedures (Schaffner *et al,*1969). While most SSIs are due to normal endogenous flora, there are also exogenous sources of infection. These include contamination of the surgical site by flora from the operating room environment or personnel. Anal, vaginal, or nasopharyngeal carriage of Group A streptococci by operating room personnel has been implicated as a cause of several SSI outbreaks (Stamm *et al,* 1978). The carriage of gram-negative organisms on the hands showed to be greater among surgical personnel with artificial nails (Pottinger *et al*, 1989). Rarely, outbreaks or clusters of surgical site infections caused by unusual pathogens have been traced to contaminated dressings, bandages, irrigants, or disinfection solutions.

Risk factors: Whether a SSI occurs is dependent upon a complex interaction between many factors including: 1- Nature and number of organisms contaminating the surgical site, 2- Health of the patient, & 3- Skill and technique of the surgeon. Rahman *et al.* (2019) in Bangladesh reported that clinical examination alone and/or together with different diagnostic methods could reduce the number of negative laparotomies and associated morbidities. Single surgeon must closely monitor a patient of penetrating abdominal injury and take vital decisions from the time of admission until discharge.

The wound classification: A widely accepted wound classification system was developed over 35 years ago. This wound classification scheme, developed by the National Academy of Sciences and the National Research Council, was based upon the degree of expected microbial contamination during surgery (Altemeier *et al,* 1984). It stratified wounds as clean, clean-contaminated, contaminated, or dirty using the following definitions: 1- Clean wounds were defined as uninfected operative wounds in which no inflammation was encountered and the wound was closed primarily. By definition, a viscus (respiratory, alimentary, genital, or urinary tract) was not entered during a clean procedure, 2- Clean-contaminated wounds were defined as operative wounds in which a viscus was entered under controlled conditions and without unusual contamination, 3- Contaminated wounds included open, fresh accidental wounds, operations with major breaks in sterile technique or gross spillage from a viscus. Wounds in which acute, purulent inflammation was encountered also included in this category & 4- Dirty wounds were defined as old traumatic wounds with retained devitalized tissue, foreign bodies, or fecal contamination or wounds involved existing clinical infection or perforated viscus.

Several studies found a moderate correlation between the wound classification and the SSI rate. SSI rates according to wound class were (Cruse and Ford, 1980): a- Clean: 1.3 to 2.9, b- Clean-contaminated: 2.4 to 7.7, c- Contaminated: 6.4 to 15.2, & d- Dirty: 7.1 to 40.0.

While widely using of this classification scheme turned out to be a poor predictor of overall risk of SSI. Other factors, such as the operative technique, length of surgery, and health of the surgical patient, were as important as wound classification in predicting infectious risks for SSI (Olson *et al,* 1984).

Other defined risk factors: Several other patient-related characteristics have consistently been identified as risk factors for SSI in well-designed studies (Anderson *et al,* 2008), these risk factors include: 1- Diabetes, 2- Obesity, 3- Cigarette smoking, 4- Systemic corticosteroids or treatment with other immunosuppressive drugs, 5- Malnutrition, 6- Preoperative nasal carriage or colonization at other sites with S. *aureus*, 6- Presence of a remote focus of infection, 7- Preoperative hospitalization aeration, & 8- Preoperative severity of illness of the patient

Many of these patient-related factors cannot be altered preoperatively. The extremes of age of infants and older individuals were identified as a risk factor for SSI (Kluytmans, 1997). However, a prospective cohort study of 144,485 consecutive surgical adult patients found that increasing age independently predicted an increased risk of SSI only until age 65 years; risk increasing 1.1% per year between 17 and 65 years. In contrast, at ages ≥65 years, increasing age independently predicted a decreased risk of SSI, risk decreased 1.2% for each additional year (Kaye *et al,* 2005). They hypothesized that the decreased risk of SSI in patients ≥65 years may be a selection bias (more healthy elderly patients undergo surgery compared to frail elderly) and/or due to a "hardy survivor" effect (persons who survive to older ages may have a genetic make-up that enables them to better withstand threats to health than some middle-aged persons).

Several factors related to surgical environment and practices during procedure are also defined to be significant risks for SSIs: 1- Preoperative hair removal (particularly shaving), 2- Inordinate personnel traffic during an operation, 3- Excessive use of electrosurgical cautery units, 4- Presence of a prosthesis or other foreign body, 5- Prolonged duration of surgery, degree of tissue trauma, & 6- Need for blood transfusion.

Owens and Stoessel (2008) in USA reported that surgical site infections (SSIs) are defined as infections occurring up to 30 days after surgery (or up to one year after surgery in patients receiving implants) and affecting either the incision or deep tissue at the operation site. They added that despite improvements in prevention, SSIs remain a significant clinical problem as they were associated with substantial mortality and morbidity up to 20%, (originate from patient's endogenous flora) depended on the surgical procedure, surveillance criteria used, and the quality of data collection. Dohmen (2008) in Germany reported that the commonest ones were *S. aureus*, coagulase-negative staphylococci, *Enterococcus* spp. and *Escherichia coli*, which might be antibiotic resistant. Besides, Kaur *et al.* (2007) in USA reported a case of amebic keratitis with unusually rapid clinical progression after corneal trauma in a patient one year after successful laser in situ keratomileusis (LASIK) surgery. Also, Bron *et al.* (2007) in Netherlands reported a 27-year-old male patient with disseminated sacral hydatidosis, which progressed and not controlled with multiple decompression procedures and continuance of anti-helminthic therapy. Kim (2014) in South Korea reported that infectious complications are major causes of morbidity and mortality after liver transplantation, despite recent advances in the transplant field. They added that bacteria, fungi, viruses and toxoplasmaosis caused infection before and after transplantation. They concluded that patients with more than 12 hours of cumulative surgical time had a higher rate of severe infections ($P < 0.001$), particularly fungus ($P < 0.001$), bacteria ($P < 0.01$) and protozoa ($P < 0.05$).

NNIS risk index: Haley published a statistical model using four risk factors that had better predictive value than models based on the simple wound classification system (Haley *et al,* 1985). These four independent risk factors included: 1- Presence of three or more underlying diagnoses, 2- Wound classification, 3- An operation involving the abdomen, & 4- An operative procedure lasting longer than 2hrs.

The National Nosocomial Infections Surveillance System (NNIS) surgical patient risk index, now called the National Healthcare Safety Network (NHSN) risk index, was developed in 1990. This risk index score was a simplified and better predictor of SSI rates than Haley's model. The risk index stratified patients undergoing surgery into four risk index groups by assigning each of the following a value of one, if present: 1- An American Society of Anesthesiologists (ASA) preoperative assessment score of 3, 4, or 5, 2- A surgical wound classified as either contaminated or dirty, & 3- An operation lasting over T hours, where T depends upon the operative procedure being performed. The SSI rates of different strata were 1.5 for risk index 1= zero points, 2.9 for index 2= one point, 6.8 for index 3 = points & 13 for index 4= 3points (Culver *et al,* 1991). Russo and Spelman (2002) in Australia reported that to have a new, simple, and practical risk index for patients undergoing coronary artery bypass graft (CABG) surgery, to develop a preoperative risk index was predictive of surgical-site infection, and to compare the new risk indices with the National Nosocomial Infections Surveillance (NNIS) System risk index. They found that potential risk factor data were complete for 2,345 patients were 199 SSIs. The obesity, peripheral or cerebrovascular disease, insulin-dependent diabetes mellitus, and a procedure lasting longer than 5hrs were identified as independent risk factors for SSI. With the use of a different combination of these risk factors, two risk indices were constructed and compared using the Goodman-Kruskal nonparametric correlation coefficient (G). Kisk-index B had the highest G value (0.3405; CI95, 0.2245 to 0.4565), compared with the NNIS System risk index G value (0.3142; CI95, 0.1462 to 0.4822). G value for risk index A, constructed from preoperative variables only, was 0.3299 (CI9, 0.2039 to 0.4559).

Reanalysis of the Study on the Efficacy of Nosocomial Infection Control (SENIC) conducted by the CDC in the light of the NNIS risk index found that ASA score was more predictive than age or number of underlying diagnoses and determined operative procedure length (T) was more predicative than an arbitrary 2hrs cutoff point (Hughes, 1988)

Minimally-invasive procedures and laparoscopically-assisted surgery: These procedures are used by general surgeons for multiple intra-abdominal operations including gastric fundoplication, inguinal hernia repair, and colorectal resection. Perceived benefits include the less patient discomfort, shorter hospital stays, and more rapid return to work. Additional benefits included lower rates of SSIs. With regard to cholecystectomy and colon surgery, the SSI rate was significantly lower when the procedure was done laparoscopically within each NNIS risk index category. However, for appendectomy and gastric surgery, use of a laparoscope affected SSI rates only when no other risk factors were present (Gaynes *et al,* 2001). Müller (2010) in Germany concluded that the use of SRC neither reduces inpatient postoperative complications nor the severity of complications. They added that the calculations of the SRC rely on a 30-day postoperative follow-up. Poor sensitivity and medium specificity of the SRC showed that the SRC could not make accurate predictions in a short follow-up time averaging 6 days. They concluded that alternatively as recorded complication rate was low, in an environment of already highly implemented risk management tools, reductions in complications were not easily achieved.

Conclusion and Recommendations

• Among surgical patients, surgical site infections (SSIs) are the commonest nosocomial infection type associated with substantial morbidity and mortality. SSIs are infections related to operative procedure that occurs at or near surgical incision within 30 days of an operative procedure or within one year if an implant is left in place.

• Rates of SSIs for individual procedures vary widely depending upon patient population, hospital size, surgeon experience, and methods used for surveillance. Non-teaching hospitals have the lowest rates of SSI compared to teaching ones. Surgery type is also associated with different rates of SSIs, with the highest rates after abdominal surgery.

• Most SSIs are acquired at the surgery time. The commonest source was believed to be direct inoculation of the endogenous patient flora at surgery. For clean the procedures, the most common pathogens causing SSIs are normal skin flora as staphylococcal species, *Staphylococcus aureus* and coagulase negative staphylococci. When surgical procedure involves opening a viscus, pathogens causing SSIs reflect the endogenous flora of viscus or nearby mucosal surface. Such infections are typically polymicrobial.

• Microorganisms isolated from surgical site infections remained relatively stable over recent decades, but the percentage of SSIs that are caused by anti-biotic-resistant pathogens increased (as methicillin-resistant *S. aureus,* methicillin-resistant *S. epidermidis,* vancomycin-resistant enterococci). Also, fungi, mainly *Candida albicans*, were isolated from an increasing SSIs%. Besides, zoonotic parasites particularly self-healing ones as toxoplasmosis, visceral leishmaniasis, as well as liver amaebiasis, malaria with or without HIV increased the SSIs particularly in life-threatening liver transplantations.

• Whether a SSI depends upon a complex interaction between numerous factors including, nature and number of organisms contaminating surgical site, health of patient, and skill and surgical technique.

• A wound classification system developed based upon expected microbial contamination degree during surgery. It stratifies wounds as clean, clean-contaminated, contaminated, or dirty. Although widely used, this classification scheme is a poor predictor of overall risk of SSI. Other factors, such as the operative technique, length of surgery, and health of the patient, were as important as wound classification in predicting infectious risks for SSI.

• Patient-related risk factors for SSI include diabetes, obesity, smoking, systemic corticosteroids or treatment with other immunosuppressive drugs, malnutrition, preoperative nasal carriage or colonization at other sites with *S. aureus*, a remote infective focus, pre-operative hospitalization duration, and preoperative severity of patient's illness.

• The National Nosocomial Infections Surveillance System (NNIS) surgical patient risk index (later renamed the National Healthcare Safety Network [NHSN] risk index) stratifies patients undergoing surgery into four risk index groups are useful to predict infection risk in surgical patients.

• Laparoscopic approaches for certain types of surgeries (as cholecystectomy, colon surgery) are associated with lower rates of SSIs than open surgeries.

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Explanation of figures

Fig. 1: *Straphylococcus aureus* in histopathological sections.
Fig. 2: Chronic *Pseudomonas* in lung histopathological sections.
Fig. 3: Acute fungal infestation in lung histopathological section.
Fig. 4: *Candida albicans* in small intestine histopathological section.
Fig. 5: Cutaneous leishmaniasis necrosis disseminated dysplasia at basal layer
Fig. 6: Human hepatic hydatidosis histopathological section.
Fig. 7: *Toxoplasma gondii* disseminated in human lung histological section.
Fig. 8: *Acanthamoeba* species affecting human CNS.