CHAPTER 16
Surgical Site Infection

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Introduction

Infection is the clinical manifestation of the inflammatory reaction incited by invasion and proliferation of microorganisms.[1] Despite modern surgical techniques and the use of antibiotic prophylaxis, surgical site infection (SSI) is one of the most common complications encountered in surgery. SSI places a significant burden on both the patient and health system,[2] especially in Africa where resources are limited. SSI occurs in up to 40% of surgical procedures, delaying recovery by one week on average and often resulting in the need for further surgical procedures.[3] It is still a major limiting factor in advancing the horizons of surgery in spite of the progress made in its control. SSI is thus a major cause of morbidity, prolonged hospital stay, and increased health costs.[4]

Demographics

Although a large number of reports on SSI are available in adult literature,[5–8] reports for children are few, and most are from developed countries with an overall incidence of 2.5–20%.[4,9–13] In most of Africa, incidence data are not available, but one hospital-based prospective report suggests an incidence of 23.6%.[14]

Classification

SSIs are defined as infections occurring within 30 days of the procedure and involving the operative area. Where implants have been placed, this time period is extended to 1 year if the infection appears to relate to the procedure.[3]

A system of classification for operative wounds that is based on the degree of microbial contamination was developed by the US National Research Council (NRC) group in 1964.[15] Four wound classes with an increasing risk of SSIs were described: clean, clean-contaminated, contaminated, and dirty (Table 16.1). The simplicity of this system of classification has resulted in its widespread use to predict the rate of infection after surgery.

The term used by the Centers for Disease Control and Prevention (CDC) for infections associated with surgical procedures was changed from surgical wound infection to surgical site infection by the Surgical Wound Infection Task Force in 1992.[16] Infections are classified by the depth of the tissue involved: superficial incisional (skin and subcutaneous tissue), deep incisional (deep soft tissue–muscle and fascia), and organ space[16] (any part of the anatomy opened or manipulated during the procedure other than the incision).

Table 16.1: Classification of operative wounds based on degree of microbial contamination.

Classification	Criteria
Clean	Elective, nonemergency, nontraumatic case, primarily closed; no acute inflammation; no break in aseptic technique; respiratory, gastrointestinal, biliary, and genitourinary tracts not entered.
Clean-contaminated	Urgent or emergency case that is otherwise clean; elective opening of respiratory, gastrointestinal, biliary, or genitourinary tract with minimal spillage (e.g., appendectomy) not encountering infected urine or bile; minor aseptic technique break.
Contaminated	Nonpurulent inflammation; gross spillage from gastrointestinal tract; entry into biliary or genitourinary tract in the presence of infected bile or urine; major break in aseptic technique; penetrating trauma <4 hours old; chronic open wounds to be grafted or covered.
Dirty	Purulent inflammation (e.g., abscess); preoperative perforation of respiratory, gastrointestinal, biliary, or genitourinary tract; penetrating trauma >4 hours old.

Source: B'ernard F, Grandon J, Postoperative wound infections: the influence of ultraviolet irradiation of the operating room and of various other factors. Ann Surg 1964; 160(Supp 1).

Superficial Incisional SSI

A superficial incisional infection occurs within 30 days after the operation. It involves only the skin or subcutaneous tissue of the incision. At least *one* of the following is present:

- purulent drainage, with or without laboratory confirmation, from the superficial incision;
- organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision;
- at least one of the following signs or symptoms of infection: pain or tenderness, localised swelling, redness, or heat *and* superficial incisions deliberately opened by the surgeon, *unless* the incision is culture-negative; or
- diagnosis of superficial incisional SSI by the surgeon or attending physician.

Deep Incisional SSI

A deep incisional SSI occurs within 30 days after the operation if no implant is left in place, or within 1 year if an implant is present. It involves the deep soft tissues (e.g., fascial and muscle layers) of the incision. At least *one* of the following is present:

- purulent drainage from the deep incision but not from the organ space component of the surgical site;
- a deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38°C), localised pain, or tenderness, unless the site is culture-negative;
- an abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination; or
- diagnosis of a deep incisional SSI by the surgeon or attending physician.

Organ Space SSI

An organ space SSI occurs within 30 days after the operation if no implant is left in place, or within 1 year if an implant is present. It involves any part of the anatomy (e.g., organs or spaces), other than the incision, that was opened or manipulated during an operation. At least *one* of the following is present:

- purulent drainage from a drain that is placed through a stab wound into the organ or space;
- organisms are isolated from an aseptically obtained culture of fluid or tissue in the organ or space;
- an abscess or other evidence of infection involving the organ space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination; or
- diagnosis of an organ space SSI by a surgeon or attending physician.

Risk Assessment

Attempts have been made to derive a clinically useful index that will encompass the major factors influencing wound infection rate and thus predict a patient's risk of developing wound infection in the postoperative period. A multivariate index combining patient susceptibility and wound contamination was developed and tested during the CDC Study on the Efficacy of Nosocomial Infection Control (SENIC).[17] This index involves the following four risk factors:

1. an operation that involves the abdomen;
2. an operation lasting longer than 2 hours;
3. an operation classified as either contaminated, dirty, or infected; and
4. a patient having three or more discharge diagnoses.

Each of these equally weighted factors contributes a point when present, so the risk index values range from 0 to 4. By using these factors, the SENIC index predicted SSI risk twice as well as the traditional wound classification scheme alone. Because this index included discharge diagnoses, some modification and a prospective evaluation of the index became necessary before it could be recommended for clinical use. A further modification of this index was therefore developed. This is the National Nosocomial Infection Surveillance (NNIS) index.[18] The NNIS risk index is operation-specific and applied to prospectively collected surveillance data. The index values range from 0 to 3 points and are defined by three independent and equally weighted variables. One point is scored for each of the following when present:

1. a patient having an American Society of Anesthesiologists (ASA) preoperative score of 3, 4, or 5;
2. an operation classified as either contaminated or dirty; and
3. an operation lasting more than *T* hours, where *T* depends on the operation being performed (*T* approximates the 50th percentile of the duration of a procedure and varies from 1 hour for an appendectomy to 7 hours in organ transplant surgery).

The ASA class replaced discharge diagnoses of the SENIC risk index as a surrogate for the patient's underlying severity of illness (host susceptibility). It has the advantage of being readily available in the chart during the patient's hospital stay. Unlike SENIC's constant 2-hour cut point for the duration of the operation, the operation-specific cut points used in the NNIS risk index increase its discriminatory power. Although their long-term usefulness in predicting postoperative wound infection is still being evaluated, preliminary reports have been validating the usefulness of these indices in adult patients. There is a need to validate these indices in paediatric patients before general acceptance.

In a report on 322 sub-Saharan African children undergoing operation, the SSI rate was 14.3% in clean incisions, 19.3% in clean-contaminated incisions, 27.3% in contaminated incisions, and 60% in dirty incisions. The degree of incisional contamination and a duration of surgery ≥2 hours were important risk factors that were significantly associated with SSI.[14]

In addition to the above general factors, there are important individual patient risk factors that may also affect the incidence of wound infection, such as body mass index (BMI), age, human immunodeficiency virus (HIV), and immune deficiency states.

Pathophysiology

SSI arises secondary to exogenous or endogenous bacterial contamination at the time of the operative procedure. Bacterial proliferation results in tissue reaction and outpouring of inflammatory cells, leading to tissue destruction and pus formation. The presence of local factors such as necrosis, haematoma, and dead space provide bacteria with a milieu for growth, and the presence of other foreign bodies inhibits local tissue resistance.[7] Microorganisms may contain or produce toxins and other substances that increase their ability to invade a host, produce damage within the host, or survive on or in host tissue. Many gram-negative bacteria produce an endotoxin that stimulates cytokine production. The cytokines can trigger a systemic inflammatory response syndrome that sometimes leads to multiple system organ failure.[19]

Patient factors that may possibly increase the risk of an SSI include coincident remote site infections or colonisation, diabetes, systemic steroid use, obesity (>20% ideal body weight), and poor nutritional status.

Clinical Presentation

Nonspecific clinical signs mimicking infection frequently occur in the postoperative period, making the diagnosis difficult. These signs include wound erythema and induration secondary to lymphatic and venous obstruction, fever, and leucocytosis. Most SSIs present from 3 to 14 days postoperatively.

Gram-positive SSIs tend to arise early (3 to 6 days) and are characterised by prominent local signs and symptoms. The wound is indurated, erythematous, and tender. Drainage is purulent and generous. Systemic signs are usually mild and include low-grade fever and irritability.[1] Group A streptococcus SSI typically presents dramatically 24 to 48 hours postoperatively with spreading cellulitis with distinct margins and lymphangitis. Drainage is scant and serous in nature. Systemic signs are prominent with high-grade fever and toxaemia.[1]

Gram-negative SSI tends to arise later, 7 to 14 days postoperatively, and thus could present after discharge from hospital. Local signs are less pronounced. Systemic signs are, however, often more prominent, with high-grade fever and tachycardia. Wound drainage, if present, is sero-purulent and may be foul smelling.

Local Features of SSI

Common local features of SSI include:

- pain and tenderness beyond what is expected for the nature of the surgery, and despite adequate analgesia;
- swelling, induration, and warmth;
- shiny, erythematous skin; and
- purulent discharge.

Systemic Features of SSI

Common systemic features of SSI include:

- pyrexia (≥37.8°C);
- leucocytosis;
- tachycardia;
- tachypnoea;
- vomiting; and
- refusal to feed/anorexia (particularly in neonates and infants).

Complications

If uncontrolled, SSI may progress to life-threatening complications. The severity of each complication depends in large part on the infecting pathogen, the site of infection, the nature of surgery, and the underlying host factors. Due to the frequently delayed presentation of several conditions, and the high prevalence of SSI, complications occur often in sub-Saharan Africa.

Commonly encountered early complications are necrotising fasciitis, wound dehiscence, metastatic abscesses, and septicaemia and organ failure. Delayed or long-term complications include incisional hernia and ugly and/or deforming scars.

Investigations

Although the diagnosis of most surgical site infection is clinical, further investigation may be necessary for planning of treatment and follow-up. Any of the following investigations may be relevant:

1. Any discharge from the wound should be cultured to establish the microbiological profile and organism antibiotic sensitivity of the infection. Tissue biopsy and culture may be helpful in situations where culture of discharge proves contaminated or unable to provide a reliable yield. The culture should involve both aerobic and anaerobic culture.

2. Ultrasonography may be required if subcutaneous or organ space collection is suspected; however, if used too early, this modality may give false positives, as fluid may just be postoperative serous collections rather than pus. It is also useful in monitoring treatment.

3. A computed tomography (CT) scan is rarely necessary but may be helpful in organ space infection, specifically where multiple relook laparotomies and bowel gas distort any ultrasound view or when ultrasonography does not provide conclusive information.

4. A complete blood count will determine whether leucocytosis and neutrophilia are evident, especially when the infection becomes systemic.

5. In persistent/uncontrollable situations, efforts should be made to identify any underlying predisposing factors such as HIV infection, diabetes mellitus, foreign bodies, or anastomotic breakdown and fistula formation.

Management

Specific Treatment

The definitive treatment of SSI is adequate pus drainage. The entire wound must be opened by suture removal for effective drainage. In incisional SSI, the wound is packed with moist gauze or commercial cavity dressing until granulation has appeared. Dressing with native honey has been proven efficient in Africa.[14,20] Depending on circumstances, secondary suture of granulating clean wounds may be possible. Vacuum-assisted dressings have been clinically proven to encourage granulation tissue and wound closure, and in the African setting, the use of wall suction on low pressure suction is perfectly acceptable to achieve adequate vacuum-assisted closure (VAC) dressing.

Even though percutaneous ultrasound-guided drainage may be possible in organ space collections, surgical drainage is often required to remove all collected pus and any dead tissue or slough, and to irrigate the cavity.

General Measures

In most instances, local wound care, as detailed above, may be enough to control the infection. However, if there are systemic features or the infection is not controlled by local measures, then empiric systemic antibiotics, altered when sensitivities become available, should be given. Failure of response within 48–72 hours may suggest underlying deeper abscess requiring drainage or wound exploration for gangrenous complications.[1]

Prevention

Risks

The risk of developing a surgical wound infection is largely determined by three factors:

1. the amount and type of microbial contamination of the wound;
2. the condition of the wound at the end of the operation (largely determined by surgical technique and disease processes encountered during the operation); and
3. host susceptibility, that is, the patient's intrinsic ability to deal with microbial contamination.

These factors interact in a complex manner to result in SSI.[21] Measures intended to prevent surgical wound infections are directed at these. The preoperative hospital stay should be kept as short as possible. Any host factors likely to predispose to SSI, including nutritional issues, medications such as steroids, diabetic control, and remote infections should be properly controlled before embarking on surgery.

Prophylactic Antibiotics

Prophylactic antibiotics are those administered to patients before contamination has occurred. Their role is to minimise postoperative infection in clean or clean-contaminated wounds. The choice and use of prophylactic antibiotics should be guided by the knowledge of site-specific flora (both patient and hospital environment), as well as the nature of the intended surgery, the antibiotic spectrum of cover, toxicity, and pharmacokinetics, with the aim being the highest tissue levels at the time of maximum contamination. If no hollow viscus or mucosal barrier is violated, antibiotics generally need to cover only gram-positive organisms, whereas breach of the gastrointestinal, genitourinary, biliary, and aerodigestive tracts should cover both skin flora and site-specific aerobic and anaerobic organisms, if needed.

Antibiotics should be given parenterally. The first dose should be given not more than 2 hours before the skin incision and is frequently given at the time of anaesthetic induction. Infection risk is higher in procedures lasting more than 2 hours, so antibiotic repetition may be required. It must be emphasized that prophylactic antibiotics should not be a substitute for adherence to strict asepsis in the operating room and meticulous surgical technique.

Operating Environment

The operating team should adhere to a tested scrub protocol using reliable antiseptics. The surgical site should be prepared by using potent and reliable antiseptics appropriate to the site. Every effort should be made to avoid breaking aseptic techniques during the entire procedure.

Most infections are acquired in the operating room, so good surgical practices are crucial to their prevention. Excellent surgical technique is widely believed to reduce the risk of SSI. This includes maintaining effective haemostasis while preserving adequate blood supply, preventing hypothermia, gently handling tissues, avoiding inadvertent entries into a hollow viscus, removing devitalised tissues, using suture material appropriately, eradicating dead space, and appropriately managing the postoperative incision.[21]

Surveillance

The development of an SSI surveillance programme within each unit or hospital is essential for recognition and reduction of surgical wound infections.[22–24] Further research is needed to determine the most practical and sensitive method for general use. Inpatient surveillance must include bedside examination and total chart review, which has a 90% sensitivity,[23] and microbiology report review (sensitivity 33–65%).[24] One infection control nurse for a total of 250 beds, together with an organised surveillance system, can reduce hospital infection rates by up to 32%.[22]

As surgical services improve and move toward ambulatory and day case surgery, 20–72% of surgical wound infections will present clinically only after discharge,[3] so a system of follow-up for case finding and reporting is mandatory in the outpatient population as well. This may include developing communication lines to local clinics or specific outpatient reviews within 2 weeks of discharge.

It is only by monitoring, reporting, and analyzing SSI incidence that procedure- or surgeon-specific trends can be determined and prevention methods put in place.

Table 16.2: Evidence-based research.

Title	Pediatric wound infections: a prospective multicenter study
Authors	Horwitz JR, Chwals WJ, Doski JJ, Suescun EA, Cheu HW, Lally KP
Institution	University of Texas-Houston Medical School and Herman Children's Hospital, Houston, Texas, USA; Wilford Hall USAF Medical Center, San Antonio, Texas, USA; Bownman Gray School of Medicine, Winston-Salem, North Carolina, USA
Reference	Annals of Surgery 1998; 227:553–558
Problem	To identify risk factors associated with the development of wound infection in children.
Comparison	Comparing children who developed wound infection and those who did not.
Outcome/ effect	The overall incidence of wound infection was 4.4%. The amount of wound contamination ($p = 0.006$) and duration of operation ($p = 0.03$) were found to be significantly associated with a postoperative wound infection. There were no significant differences in age, gender, ASA preoperative assessment score, length of preoperative stay, and use of perioperative antibiotics.
Historical significance/ comments	This report of a large series of surgical site infection in children with a multicentre approach provides a useful practice guide, although there is the possibility of differences in patient selection and case mix with this approach. The authors recommend prospective surveillance of wound infection in children with feedback to clinicians to reduce the cost of health care associated with wound infection.

Evidence-Based Research

At present, there are no randomised control trials on surgical site infection in children. Tables 16.2 and 16.3, which present analyses of paediatric wound infections, are based on reports of large prospective studies on incidence and risk factors of SSIs.

Table 16.3: Evidence-based research.

Title	Surgical site infection in children: prospective analysis of the burden and risk factors in a sub-Saharan African setting
Authors	Ameh EA, Mshelbwala PM, Nasir AA, Lukong CS, Jabo BA, Anumah MA, Nmadu PT
Institution	Division of Pediatric Surgery, Department of Surgery, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria
Reference	Surgical Infections (Larchmt) 2009; 10(2):105-9
Problem	There is a lack of data regarding the prevalence and risk factors of surgical site infection in children in Africa. The problem is to determine the burden and risk factors for SSI in children in a major teaching hospital in sub-Saharan Africa.
Comparison	Comparing children who developed wound infection and those who did not.
Outcome/ effect	The overall rate of SSI was 23.6%. The SSI rate was 14.3% in clean incisions, 19.3% in clean-contaminated incisions, 27.3% in contaminated incisions, and 60% in dirty incisions ($p < 0.05$). The infection rate was 25.8% in emergency procedures and 20.8% in elective procedures ($p < 0.05$). The infection rate was 31% in operations lasting 2 hours or more and 17.3% in operations lasting less than 2 hours ($p < 0.05$).
Historical significance/ comments	This is the first prospective report of SSI in children in sub-Saharan Africa. The burden of SSI is high in the setting. The authors attributed this to the lack of definite infection surveillance/control programmes and the tropical climate. The degree of incisional contamination and a long duration of surgery (≥2 hours) are important risk factors. The report draws attention to the lack of hospital infection control and antibiotic guidelines, and has prompted a proactive approach to these issues.

Key Summary Points

1. Surgical site infections are a major cause of morbidity and increased costs in health care.
2. A multitude of risk factors influence the development of SSIs, and awareness of these will help to promote effective preventive strategies.
3. The degree of wound contamination and duration of surgery are proven risk factors.
4. Surveillance systems that monitor rates of wound infection and provide feedback to clinicians have been shown to contribute to quality improvement and help to prevent and control infection.
5. Antibiotic prophylaxis is not an alternative to maintenance of asepsis.
6. SSIs in children are related more to perioperative factors than to the patients' overall physiologic status.
7. Rigorous adherence to the principles of asepsis by all scrubbed personnel is the foundation of surgical site infection prevention.

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