# SURGICAL SITE INFECTION

## PREVENTION AND MANAGEMENT ACROSS HEALTH-CARE SECTORS

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# Contents


**1. Introduction** 4
*Aims, objectives and scope of document* 4
*Structure and content* 4

**2. Methodology and terminology** 5

**3. Epidemiology of surgical site infection** 6
*Surgical site infection: background* 6
*Signs and symptoms of SSI* 7
*Source of microorganisms related to SSI* 10
*Type of surgery and risk of SSI* 10
*Adjusting rates of SSI for variation in case-mix* 12
*Patient-related factors and the risk of SSI* 12
*Involving patients with diagnostics* 13
*Conclusion* 13

**4. Principles of surgical wound management** 14
*Wound healing process* 15
*Primary and secondary healing* 15
*Principles of surgical wound closure* 16
*Multidisciplinary team approach to surgical wound management* 22
*Conclusion* 23

**5. Perioperative practice to prevent surgical site infection** 25
*Preoperative phase* 25
*Intraoperative phase* 27
*Postoperative phase* 31
*Conclusion* 37

**6. Principles of postoperative care** 38
*How to dress the wound in the outpatient setting* 38
*How to dress the wound in the home care setting* 40

**7. Wound assessment and diagnostics** 43
*Early signs of infection* 43
*General assessment of a patient* 43
*Vascular assessment* 43
*Sampling techniques* 44
*Lab procedures* 44
*Conclusion* 45

**8. Treatment of SSI** 46
*Non-surgical treatment* 46
*Antibiotic coverage* 46
*Systemic antibiotic therapy* 47
*Topical antibiotic therapy* 48
*Impact of oxygen* 49
*Conclusion* 50

**9. Conclusion** 51

**10. Future perspectives** 52
*Prevention and risk assessment* 52
*Treatment* 52
*Diagnostics* 52

**11. References** 53

**Appendix** 60
*Appendix 1: GRADE recommendation explanation* 60
*Appendix 2: Microbiological assessment for surgical site infection, investigation of the swabs* 61
*Appendix 3: A protocol for the prevention of surgical site infection* 64
*Appendix 4: Patient's Guide – frequently asked questions about SSI* 67

**Glossary** 68
*Definitions* 68
*Abbreviations* 68

# 1. Introduction

## Aims, objectives and scope of document

Surgical site infection (SSI) is an unfortunate postoperative complication that affects many surgical patients worldwide and treatment of this type of wound is most likely to occur following discharge from the acute care setting. While there are several guidelines for preventing and managing SSIs in hospitals there is an absence of guidelines for the optimum postoperative management in the home care setting. Furthermore, a set of recommendations on this topic covering primary and community health professionals remains absent from clinical resources.

The overall aim of this document is to:

- Highlight present knowledge regarding prevention and management of SSI in the primary and community health-care sectors
- Present a set of recommendations to guide clinical practice in the community setting for maximum patient healing outcomes following surgery.

More specifically, the main objectives of the document are to:

- Describe the incidence and prevalence of SSI, based on published information and data available from SSI-registries
- Present the principles of management of surgical wounds as well as the available modern techniques for prevention and treatment of SSIs across sectors
- Provide a summary of evidence-based clinical perioperative practice recommendations to prevent surgical site infections.

## Structure and content

This document is presented in ten chapters. Chapter 1 is the introduction to the document and describes the aim and objectives of the work. Chapter 2 presents the methodology and terminology used in the document. Chapter 3 describes the epidemiology of SSI. Chapter 4 discusses principles of the management of surgical wounds. Chapter 5 presents a summary of recommended practice during pre-, intra- and postoperative phases. Chapter 6 discusses principles of postoperative care and Chapter 7 presents contemporary methods of wound assessment and discusses diagnosis of infection. Chapter 8 reports on current treatments for clinical management of SSI. Chapter 9 summarises the main conclusions of the document, with Chapter 10 providing a brief look at new developments, highlighting areas that require further research.

# 2. Methodology and terminology

This document originates from a growing interest by many EWMA stakeholders, in the clinical management and prevention of SSI in hospital and following hospital discharge and their management in the community setting.

On the basis of a literature search search conducted by the document authors and the EWMA secretariat, as well as input from key EWMA stakeholders, a short description of the document aim, objectives and scope was developed during the first quarter of 2017. This basic document outline was then used over the next six months to identify the specialists, who constitute the author group.

The expert group was established to produce the most recent evidence-based consensus document for health-care workers across all health-care sectors, hospitals, primary and community care. The group consists of representatives from the EWMA council, Wounds Australia and the Infection Prevention Society (IPS). The Association for the Advancement of Wound Care (AAWC) contributed to the development of the document.

Each author has taken responsibility for the development of each individual chapter, with each author conducting relevant searches to investigate the literature. The opinions expressed in this document have been reached by consensus of the author group based upon professional, clinical and research expertise, as well as the experience of their peers. The clinical guidance provided in the document is based on critical analysis and synthesis of published guidelines, literature reviews and evidence-based recommendations as well as consensus driven expert opinion.

Where relevant, throughout the document, the GRADE classification for levels of evidence was applied to assess the level of evidence relevant to literature reviewed. The GRADE classification system is available in Appendix 1. There is a plethora of therapies and clinical approaches in the prevention and management of SSI and it was essential to grade the levels of evidence for relevancy in the clinical setting.

# 3. Epidemiology of surgical site infection

KEY POINTS

- Surgical site infection (SSI) is the third most commonly reported healthcare-associated infection (HCAI) and results in significant patient morbidity and mortality
- The risk of SSI is influenced by a number of intrinsic and extrinsic factors, particularly the number of microorganisms present at or introduced into the incision
- The risk of SSI increases with the age of the patient; other important risk factors are severe underlying illness and obesity
- Measuring and reporting rates of SSI in surveillance systems is an important strategy for determining prevalence of SSI and measuring the impact of prevention measures

## Surgical site infection: background

SSIs can be 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.[1,2] This definition is primarily used for surveillance and reporting purposes. The clinical definition includes signs and symptoms of infection confirmed by the presence of typical clinical signs of infection, such as redness, swelling and exudate — see *Chapter 7*. For surveillance purposes, the definition must be more accurate and univocal.[3] As an example of an algorithm taking this into account, we refer to the CDC SSI surveillance protocol.[4]

SSIs affect up to one-third of patients who have undergone a surgical procedure.[5] The incidence rate of SSIs vary from 2–15% depending on multiple factors, including the type of operation.[6] In the most recent prevalence survey conducted by the European Centre for Disease Surveillance and Control, SSIs accounted for 18% of healthcare-associated infections (HCAI).[7,8] The incidence of SSIs varies depending on multiple factors, including the type of operation[6] and is likely to be underestimated given that approximately 50% of SSIs become evident after discharge.[3] Surveillance following hospital discharge is important to accurately determine the prevalence and incidence of this postoperative complication. SSIs impair not only the patient's quality of life (QoL) but also have a negative economic impact. They increase length of time a patient stays in the hospital and incur considerable extra health-care costs.[9] According to Leaper et al. additional costs attributable to SSI of between £814 and £6626 have been reported, depending on the type of surgery and the severity of the infection.[10] Other studies have reported subsequent costs associated with clinical

**Clinical definition of SSI:** Infectious process present at the site of surgery. Clinical signs and symptoms of infection include heat, redness, swelling, elevated body temperature and purulent exudate from the wound or the drain.

**CDC reporting definition for surgical site infection surveillance:** 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. According to the range of affected tissues SSI can be superficial, deep or organ/space.[3]

management in the acute care setting, in the US costs exceed US$1.6 billion annually,[11] Australia AU$268 million annually[12] and UK £930 million annually.[13] In addition, up to 60% of SSIs have been estimated to be preventable and their risk can be minimised by applying best practice in the perioperative period.[14,15]

The main factors affecting the occurrence of SSI are pre-existing health status of the patient, type of surgery and postoperative management in the acute care setting and following discharge.

### Pathogenesis of surgical site infection

A surgical procedure exposes sterile body tissues. Microorganisms introduced during the procedure can multiply in the wound after it has been closed and subsequently cause an SSI. However, the accurate diagnosis of SSI is difficult to detect as it may take several weeks to develop and therefore many infections may not become apparent until after the patient has been discharged from hospital.[16,17] Only those patients with more severe SSI are likely to be readmitted to hospital, accounting for one-third of patients who present with an HCAI on admission.[18] SSI is the most common HCAI among patients who are admitted to hospital for a surgical procedure and in this group the prevalence of SSI is at least 5%.[19]

The morbidity and mortality associated with SSI is considerable. A key indicator of the adverse effect is the impact on length of hospital stay. Studies suggest that an SSI, regardless of whether it was superficial or more severe, doubles the length of postoperative hospital stay.[20–23] Other studies have confirmed the effect of SSI on length of hospital stay and also demonstrated the significant increase in costs associated with additional hospital stay and treatment.[9] In economic terms, the additional bed-days associated with the treatment of patients with SSI reflect 'opportunity costs' as they could be used to treat more patients.[24] A case control study of patients undergoing proximal femoral fracture repair found, that when repeat admissions to hospital, re-operations and other treatments are taken into account, severe SSI can quadruple the costs of care and decrease the QoL of affected patients.[25]

SSI also has an important impact on mortality. Coello et al.[20] found a significant increase in in-hospital mortality associated with deep or organ-space SSI for three major categories of surgery: hip prosthesis, odds ratio (OR) 2.5; 95% confidence interval (CI) 1.3 to 4.5, large bowel surgery OR 1.8; 95%CL 1.1 to 3.2 and vascular surgery OR 6.8; 95%CL 3.0 to 15.4. Astagneau et al. found a case fatality rate of 4.5% in patients who developed an SSI and 38% of these deaths being directly attributable to the infection.[26]

## Signs and symptoms of SSI

SSI can affect the superficial cutaneous layer (superficial SSI), the fascial layers (deep SSI) or nearby organs and other sites such as joints or abdomen manipulated during the procedure (organ/space SSI) (Fig 2).

Clinical signs and symptoms of SSI at the site of an incision include purulent drainage, pain or tenderness, localised swelling, redness or heat (Table 1 and Fig 3–5). They usually become apparent by the end of the first week after surgery. Superficial infection come through local infection signs given below. SSI can also manifest as a cellulitis of soft tissue at the place of surgery or wound abscess. In the case of deep and organ/space SSIs the local signs of infection can be less expressed and the first clinical signs can be purulent drainage from the wound, unexplainable fewer, pathological patient's blood test results—high C-reactive protein (CRP), BSR: blood sedimentation rate (BSR) and pro-calcitonin level, high leukocyte accounts—or uncommon systemic

## Table 1. Clinical signs and symptoms of surgical site infection (SSI)[29–31]

| Superficial SSI symptoms | Deep SSI symptoms | Organ/space SSI symptoms* |
|---|---|---|
| Increased pain and tenderness at the site of surgery | Increased pain at the site of surgery | |
| Localised swelling and induration | Spreading induration and swelling of the place of incision | |
| Localised heat and redness of the wound | Erythema and heat of the surgical site | |
| Purulent drainage | Purulent drainage from the incision | Purulent drainage from a drain placed through the skin into the organ or body space |
| Cellulitis limited to the wound and adjacent soft tissues | Spreading cellulitis at the site of surgery | |
| Evident superficial wound abscess | Evident deep wound abscess or fasciitis | Organ or body space abscess diagnosed by radiological or histopathological examination |
| | Separation of the edges of incision exposing the deeper tissues | Evidence of infection involving the organ or body space seen on direct examination during surgery |
| | Unexpected postoperative fever accompanied by increasing wound pain and/or wound dehiscence | Postoperative fever |
| | Pathological blood test findings (elevated CRP, WBC counts, erythrocyte sedimentation rates, pro-calcitonin) | Positive result of blood cultures, deep tissue biopsies, surgical sampling or pathological blood test findings (see deep SSI column) |

*Involve any part of the anatomy other than the incision opened or manipulated during surgery; CRP— C-reactive protein; WBC—white blood count

inflammatory response of the body. Dehiscence of the incision, if site is tender or if the patient has a fever, may also indicate the presence of infection if microorganisms are also isolated.[27] According to Sandy-Hodgetts et al. dehiscence may be attributable to non-microbial causes such as obesity or pre-existing chronic disease states in some cases.[28] In diagnostics of deep-seated and organ-affecting SSIs it is necessary to carry out full clinical assessment of the patient and the place of surgery, plain X-rays and further imaging (e.g. MRI scan, CT scan, ultra-sound), blood cultures (particularly in acute cases), organ, bone and/or soft tissue biopsies and/or surgical sampling.

Almost half of SSIs reported in the European Centres for Disease Prevention and Control (ECDC) surveillance system are superficial, 30% deep, and 20% organ/space.[17] However, the distribution of infection type depends on the type of surgery and the nature of the surveillance system. The proportion of deep and organ/space SSI is likely to be higher if the surveillance is primarily focused on the postoperative hospital stay and/or patients readmitted with infection. In procedures associated with a very short postoperative stay e.g. caesarean section, the majority of SSI are only detected after the patient has been discharged from hospital.[16]

The signs of infection can progress within the time to become more evident and more extensive (Fig 1).

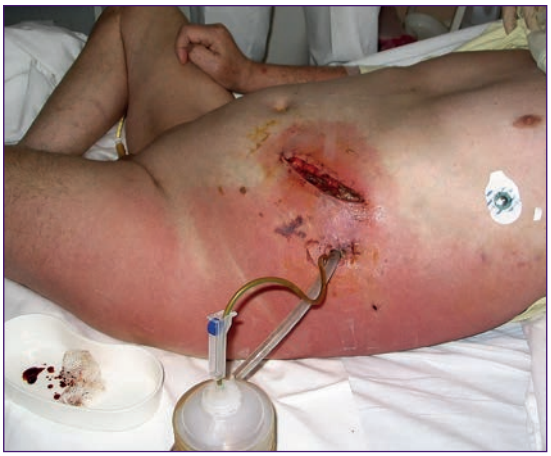

Fig 1. Deep surgical site infection (SSI) following lumbar sympathectomy

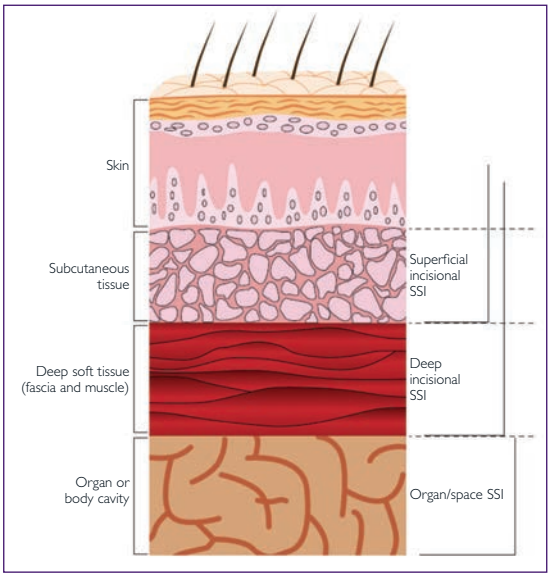


Fig 2. Types of surgical site infection, adapted from Horan et al[32]

Since skin is normally colonised by microorganisms, often microbiological evidence alone, is not a reliable indicator of SSI. However, in the presence of clinical signs and symptoms of infection, the results of wound cultures are helpful in indicating the likely causative pathogen (see Appendix 2 for microbiological investigation of swabs). Microorganisms cultured from aseptically aspirated fluid or tissue, or an abscess or other

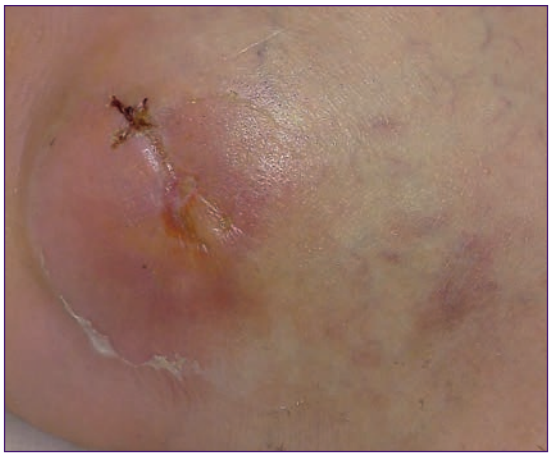

Fig 3. Example of superficial surgical site infection, infected incision

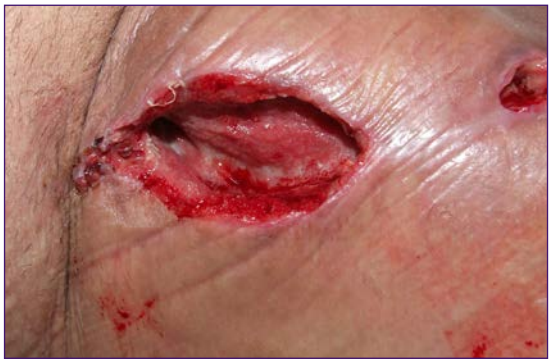

Fig 4. Example of deep surgical site infection: infected incision after femoral artery endarterectomy

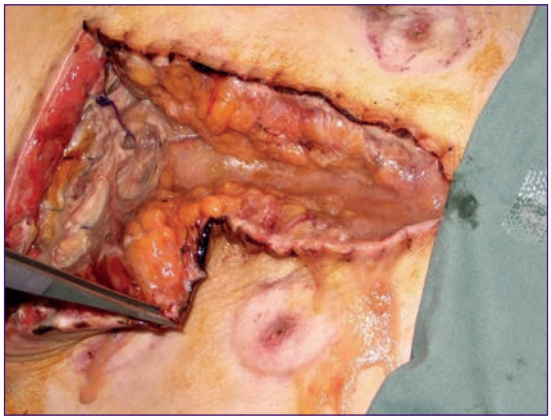

Fig 5. Organ/space surgical site infection in patient after colectomy with stercoraceous and purulent discharge from the wound. The wound was opened by the surgeon to release the pus and evaluate the range of infection

evidence of infection found by histopathological or radiological examination provide an accurate assessment of associated pathogenic activity indicative of SSI.[27] The clinical signs or symptoms of SSI can take days or weeks to become apparent. This can be as long as one year when foreign material such as a prosthetic joint or sternal wire, are left in the tissues.

## Source of microorganisms related to SSI

The microorganisms associated with SSI can be derived from sites on the patient that are colonised, such as the skin, mucous membranes or hollow viscera (endogenous). However, microorganisms may also originate from an exogenous source including operating personnel, the operating room environment and instruments and equipment used during the procedure (Fig 6). Occasionally, a distant source of infection can act as a source of microorganisms at a surgical site by attaching to prosthesis or other implant in a biofilm formation.[33]

The risk of SSI may be influenced by an array of factors that increase the risk of endogenous contamination, for example procedures that involve parts of the body with a dense flora such as the bowel. It is also affected by factors that increase the risk of exogenous contamination, such as exposure of tissues during prolonged or major operations and inadequate aseptic procedures. Intrinsic factors that affect the efficacy of the general immune response, such as diabetes, malnutrition, immunosuppressive therapy or the local immune response, such as foreign bodies, damaged tissue, haematoma, are also important in determining risk of SSI occurrences.

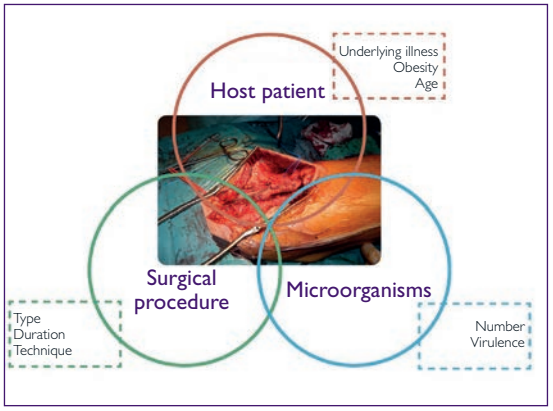


Fig 6. Factors that contribute to the risk of SSI

## Type of surgery and risk of SSI

The number of organisms present in the wound following a surgical procedure are strongly influenced by the site of the body involved.[34] Procedures on normally sterile tissues, such as bones or joints, are less likely to be contaminated by bacteria than those involving the colon where large numbers of bacteria are normally present.[34] The rates of SSI associated with surgery on sterile sites are therefore very low (>2%), compared with the rates SSI associated with surgery on contaminated sites, which may >10%.[35] Minimally invasive procedures, where the operation is performed via an endoscope, are associated with

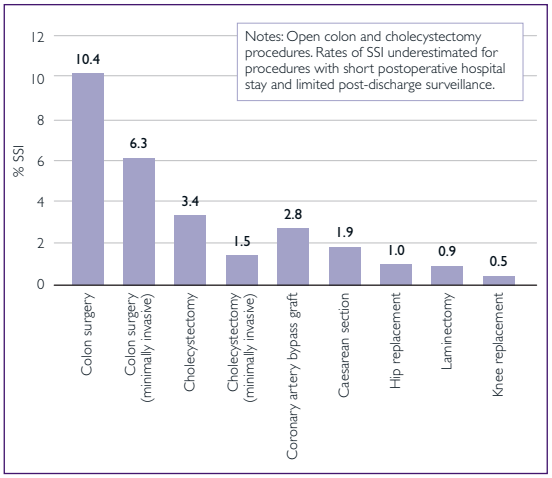


Fig 7. Cumulative incidence of SSI by category of procedure from European countries participating in surgical site infection surveillance. Adapted from ECDC. Annual epidemiological report for 2016, Stockholm; 2018 ECDC[17]

## Table 2. Class of surgery

| Class of surgery | Description |
|---|---|
| **Clean wounds** | Uninfected operative wounds in which inflammation is not encountered, and the respiratory, gastrointestinal, genital, urinary tracts or the oropharynx are not entered, and there is no break in aseptic technique. In addition, clean wounds must be primarily closed and, if there is drainage, this must be closed. Includes operative wounds that follow non-penetrating trauma, e.g. fractured neck of femur, providing they meet these criteria |
| **Clean-contaminated wounds** | Operative wounds in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination, providing that there is no evidence of infection or a major break in aseptic technique. Note: procedures that do not enter one of these body tracts cannot be clean contaminated e.g. orthopaedic procedures |
| **Contaminated wounds** | Operations on fresh, open traumatic wounds; or operations where there is a major break in aseptic technique; or operations in which there is gross spillage from the gastrointestinal tract; or acute inflammation without pus is encountered |
| **Dirty or infected wounds** | Operations in which acute inflammation with pus is encountered, or in which perforated viscera are found; operations on traumatic wounds, which have retained devitalised tissue, foreign bodies or faecal contamination, or where the operation on the traumatic wound has been delayed. Operations included in this class are those in which the organisms causing postoperative infection are likely to have been present in the operative field before surgery |

CDC/NHSN surveillance definitions for specific types of infections[34]

lower rates of SSI as a smaller amount of tissue is exposed during the procedure.[17] Fig 7 shows the variation in risk of SSI attributable to different operative procedures from data captured by the European Centres for Disease Prevention and Control surveillance system.[17]

A standard approach to classifying wounds according to the degree of microbial contamination likely to be present in the operative site has been described and is widely used to both predict the risk of SSI and enable comparisons in risk between different types of surgical procedure (Table 2). The classification takes account of both the site of the procedure and events that occur before or during the operation that may affect the level of contamination.[34] Type of surgical procedure classification (Table 2), is an important factor to consider when interpreting and appraising research evidence related to SSI.[34]

Operations on sites where infection is already present, referred to as 'dirty or infected' wounds, for example a gangrenous appendix, are at particular high risk of infection because of the number of microorganisms present at the site of incision.[34]

### Box 1, National Healthcare Safety Network (CDC) Surgical Site Infection Risk Index

Each operation is scored by the presence or absence of three risk factors at the time of surgery:

1. American Society of Anaesthesiologists' (ASA) preoperative assessment score of 3 or more (this indicates the patient has a severe underlying systematic disease)
2. Operation is classified as contaminated or dirty
3. Operation lasts for more than a specific period of time ('T hours'), where T is the 75th percentile of the duration of surgery and depends on the surgical procedure being performed (e.g. hip replacement T time=2 hours)

Each of the risk factors described above contributes one point to the risk index score, which ranges from 0 (none of the risk factors present) to 3 (all of the risk factors present).

Source: Public Health England (2013) Protocol for the Surveillance of Surgical Site Infection.[36]

## Adjusting rates of SSI for variation in case-mix

The type of surgery classification system remains an important, simple guide to the risk of SSI for different procedures. However, more sophisticated models that use a combination of intrinsic and extrinsic factors related to both patient and the operation are widely used to more reliably compare the risk of SSI for the same procedures over time and between institutions. The most widely used of these risk adjustment frameworks was developed for the national HCAI surveillance systems in the US and has been widely adopted by surveillance systems around the world (Box 1).[35]

More recently, a logistic regression analysis has been applied to a large dataset of surgical procedures captured for the National Healthcare Safety Network (NHSN) surveillance systems in the US, in order to develop specific risk models for different categories of procedure.[37] These specific models predict the risk of SSI more accurately but are still only able to account for about 60% of the variation in rates of SSI.[37] This suggests that other unknown factors influence the risk, including the infection control procedures applied during the procedure.

## Patient-related factors and the risk of SSI

Factors intrinsic to the patient undergoing surgery may influence the risk that they subsequently develop an SSI, either as a result of extending the length and complexity of the surgery or by diminishing the efficacy of the immune response. A prolonged duration of the operation is recognised as a strong predictor of risk of SSI for many types of procedure.[37,38] The American Society of Anaesthesiologists' (ASA) score is a measure of underlying illness but increasing ASA score is strongly associated with risk of SSI. Many factors included in more complex risk adjustment models are related to underlying illness in the patients undergoing surgery e.g. diabetes, obesity etc. Furthermore, the type and size of hospital and type of anaesthesia play a role.[37]

Poor vascularisation of adipose tissue combined with increased complexity of surgery may increase the risk of SSI in patients with a body mass index of 35kg/m² or more.[36] Studies have identified obesity as a risk factor for SSI in cardiac, spinal and obstetric surgery and estimates suggest it increases the risk by more than three-fold.[39,40] In patients with diabetes, damage to peripheral vasculature and an impaired immune response associated with high blood glucose levels, is shown to be associated with the doubling of the risk of SSI compared with patients without diabetes.[41,42]

Age is also an important independent predictor of SSI risk, with many studies demonstrating that the risk of SSI steadily increases with age across different types of surgery.[22,36,40] Adjustment for a range of risk factors for SSI following hip replacement demonstrated age as an independent risk factor and found that patients over 75 years were more than 1.5 times more likely to develop SSI than those under 65 years.[43]

The literature demonstrates that there are differences in characteristics and independent predictors for patients developing SSI in the hospital versus after discharge.[44–46] Wiseman et al. shows that SSIs occurring after discharge are predominantly associated with a patient's comorbidity burdens such as diabetes, smoking, hypertension, coronary artery disease (CAD), and chronic obstructive pulmonary disease (COPD), whereas patients who develop a SSI in the hospital are largely associated with perioperative factors.[47]

Table 3 summarises the important patient- and

procedure-related factors that influence the risk of SSI.

## Involving patients with diagnostics

During the initial process of consideration/assessment of any patient's suitability for surgery, it is important for all health professionals to be aware of an appropriate validated risk assessment tool that has been used that helps identify a patient's potential risk of SSI (e.g. the Surgical Site Infection Risk Score (SSIRS).[48] Especially in patient groups that have been previously reported to be more prone to SSIs, such as those having orthopaedic, colorectal or gynaecological surgery; or any patient having a surgical procedure who also has a diagnosis of cancer. Furthermore, for all patients undergoing surgery, it may also be helpful for health professionals to incorporate an appropriate validated Health Related Quality of Life (HRQoL) assessment score/tool as part of the patients initial assessment process, as this can help the clinician identify in particular social factors that may increase a patient risk of SSI.

Before surgery; health professionals and patients should be encouraged to discuss issues such as the patients social habits (such as smoking); their recent travel history; their current methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE) status (if known) or the need for screening if not and their current medical conditions (especially in relation to diabetes and cardiopulmonary conditions); as part of a holistic assessment process, so that modifiable issues such as a patient's diets, smoking and exercise habits may be addressed in advance of planned surgery.

**Table 3. Summary of key factors that predict the risk of surgical site infection. The effect of individual factors varies by type of surgery**

| Intrinsic (patient–related) factors | Extrinsic (procedure–related) factors |
|---|---|
| Age | Duration of procedure |
| Gender | Minimally invasive technique |
| Severe underlying illness (e.g. ASA score >3) | Skill of surgeon/surgical team |
| Diabetes mellitus | Performed as an emergency |
| Body mass index | Type of hospital *(may reflect volume of procedure and/or specialist expertise)* |
| Procedure due to trauma | |
| Wound classification *(level of microbial contamination at site of procedure)* | |

Based on analysis by Mu et al. 2011 and review by WHO, 2016.[37]

Why? There is a growing body of evidence that indicates that if these issues are addressed in a timely manner, the outcomes of surgery are improved and the risk of the patient suffering from an SSI are minimised.[20,34,42,87,88]

## Conclusion

SSIs are a common HCAI associated with considerable morbidity and mortality and additional health-care costs. The risk of SSI depends on a combination of intrinsic and extrinsic factors, related to the type of operation and patient. While it may be difficult to change the intrinsic and extrinsic risk of SSI in patients, practices and processes aimed at reducing overall risk are essential to ensure the lowest possible rates of SSI.[49] Early and fast diagnosing of SSI is essential in both inpatient and outpatient setting.

# 4. Principles of surgical wound management

## KEY POINTS

- Excellent surgical technique is considered to be a foundation of undisturbed healing process
- The choice of closure material is influenced by the type and placement of the wound, available materials, physician expertise and preferences, patient age and health
- Physiological process of wound healing comprises four phases – inflammation, proliferation, epithelialisation and remodelling. Inflammation is an integral part even of an undisturbed healing process
- Primary intention wound healing is usually achieved in uncomplicated surgical wound closure. Spontaneously and intentionally opened surgical incisions can be closed by secondary intention or delayed primary intention healing
- There are a number of intrinsic and extrinsic factors that affect wound healing after surgery
- Patients should be given clear and consistent advice about postoperatively wound management
- The information should be given written and orally not only to patients but also to community nurses and general practitioners

An estimated 234.2 million surgeries are conducted annually worldwide.[50] While most surgeries today are considered relatively safe with some element of risk, from time to time postoperative complications occur, which have considerable impact on the patient, their family and the wider health care system. The resources to manage surgical wound complications often include; surgical readmissions, extended home nursing visits or primary care visits for the clinical management of the wound complication. The more serious consequences include increased morbidity and mortality rates.[51,52]

Surgical procedures involve creating an opening of the skin (wound) of which the opposed margins are joined together for healing to take place by using staples, stitches, glue, referred to as healing by primary intention. Wound dressings applied over the incision site may provide protection from the external environment, physical support and act to absorb exudate. Chapter 5 goes into more detail of the different types of dressings and their characteristics often used in wound management for surgical wounds. While dressings are one part of the management of surgical wounds, there are a number of other intrinsic and extrinsic factors that may be related to the occurrence of wound complications after surgery (Fig 8). The clinical preoperative and postoperative management of the patient's wound includes an assessment of patient-related lifestyle factors and comorbidities, as these may contribute to delayed healing and postoperative complications such as SSI (Table 4).[54–74]

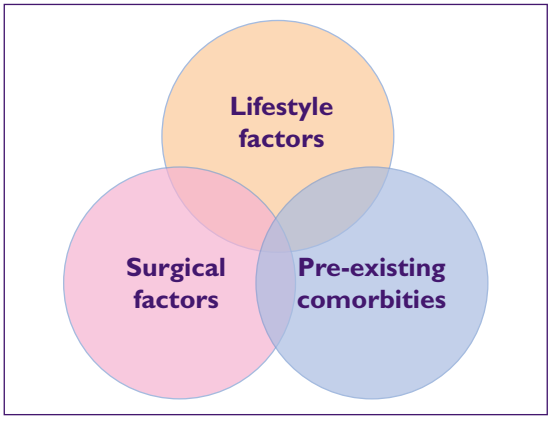




Fig 8. From Sandy-Hodgetts et al. Surgical wound dehiscence: a conceptual framework for patient assessment[53]

While a number of identified pre-existing comorbidities and lifestyle factors impact on the normal wound healing trajectory, there are a number of well-known factors in the peri and intraoperative period that impact on wound healing and may contribute to complications such as surgical site infection or wound dehiscence (Table 5).[35,75–90]

## Wound healing process

Physiological process of acute wound healing was described by Hunt et al.[91] as a cascade of four phases: inflammation, proliferation, epithelialisation and remodelling.

It is a general misconcepted, that inflammation is a symptom of infection, actually inflammation is the body's immune system response to harm and is essential for healing. Some traditional signs of infection can be viewed at the surgical site during the inflammative phase of healing, it is a temporary normal body response.

## Primary and secondary healing

Acute wounds are defined as disruptions in the integrity of the skin and underlying tissues that progress though the healing process in a timely and uneventful manner.

### Primary intention wound healing

Uncomplicated surgical wound healing is associated with primary intention healing. Wound margins have been sutured (brought close together with attention to tissue handling, proper use of surgical instruments, and then temporarily connected by stitches) by the surgeon and left to spontaneously heal (Fig 9). Wound edges are approximated and aligned immediately to ensure appropriate and timely healing occurs. The major activity in primary intention healing, is connective tissue deposition and epithelialisation. No granulation tissue is formed here. In non-complicated conditions of healing the blood capillaries from the wound margins can grow together. In some clinical situations (when primary suture is too risky or impossible) the wound can initially be left open. After a short period of time, when the edges are covered by granulation tissue, the edges are approximated with sutures by a surgeon. This technique is called delayed primary intention healing.

### Secondary intention healing

In some clinical situations, the surgeon is not able to close the wound through suturing and it has to be left opened, for example when the wound

**Table 4. Factors and conditions that may be associated with delayed healing**

| **Lifestyle factors** |
|---|
| Smoking |
| Nutrition |
| **Pre-existing patient-related factors** |
| Diabetes |
| Obesity |
| Depression |
| Chronic obstructive pulmonary disease |
| Peripheral arterial disease |
| Immunodeficiency (side effect of immunosuppressant use) |
| Adapted Sandy-Hodgetts et al. Surgical wound dehiscence: a conceptual framework for patient assessment[53] |

**Table 5. Intraoperative factors contributing to wound complications**

| **Intraoperative factors** |
|---|
| Procedural duration |
| Tissue oxygenation |
| Intraoperative body temperature |
| Class of surgery (clean, contaminated, dirty) |
| Method of closure |
| Surgeon's level of experience |
| Adapted Sandy-Hodgetts et al. Surgical wound dehiscence: a conceptual framework for patient assessment[53] |

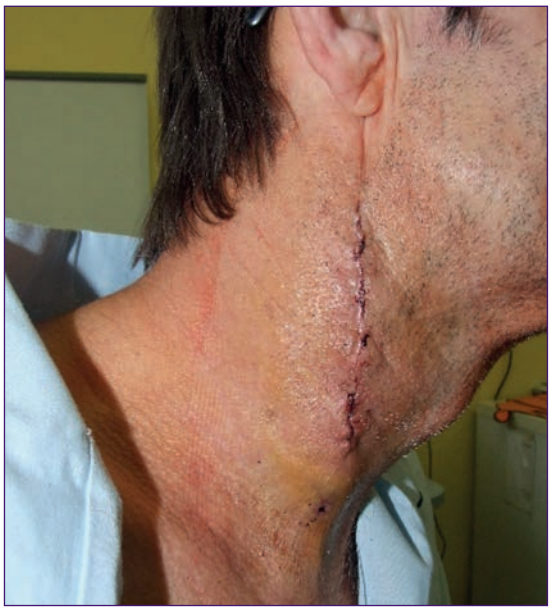

Fig 9. Uncomplicated surgical wound healing by primary intention (patient after carotic endartherectomy)`

edges cannot be approximated, non-viable wound margins are present, large amounts of tissue have been removed or destroyed. The wound extends through all layers of the skin (Fig 10). Full-thickness wound secondary intention healing principally occurs by granulation tissue filling in the tissue defect and subsequent contraction of the wound. The anatomic structure of the scar does not replicate the tissue replaced, so the scar tissue will not be equal in elasticity or tensile strength to the original tissue. Secondary intention wound healing involves a process that is divided into four orderly arranged overlapping phases of repair: inflammation, proliferation, epithelialisation and remodelling. This healing model is also associated with chronic wounds.

## Principles of surgical wound closure

The main goal of surgical closure and healing by primary intention is for complete healing of the incision to occur in a timely manner and without complication. Continual assessment of the surgical incision site must occur to ensure the treatment regime aligns with the management of the patient. The principles of surgical closure for primary intention are:[92]

1. Achieve haemostasis
2. Re-approximate opposed margins
3. Avoid tension on the incision site
4. Avoid local ischaemia of wound margins induced by improper suture technique
5. Re-establish functional soft tissue structural support
6. Elimination of dead space
7. Prevent contamination of the surgical site and possible infection
8. Prevent scarring

Adhering to these principles can reduce both the scarring or further postoperative complications at the incision site.

A considerable array of surgical closure materials are used to re-approximate margins and secure opposing wound margins which include;

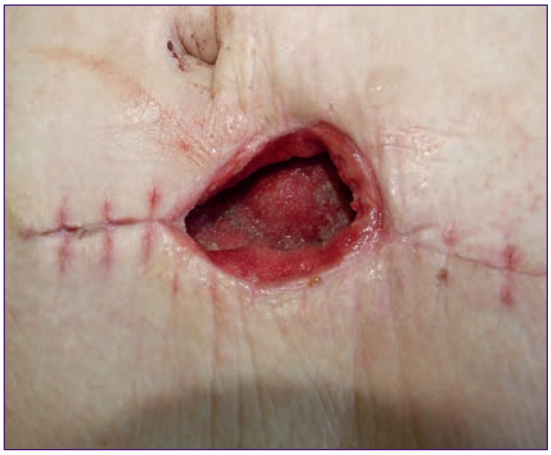

Fig 10. Incision after hernia surgery healing by secondary intention

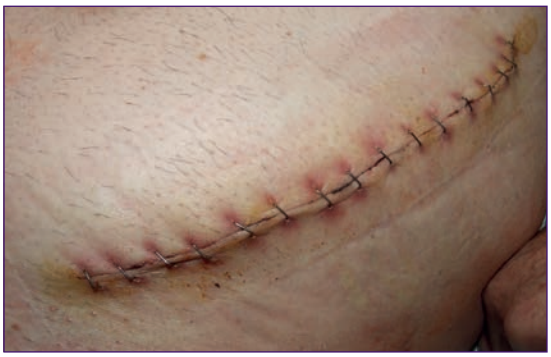

Fig 11. Wound closure by metal staples

- Atraumatic monofilament sutures
- Absorbable sutures
- Antibiotic-coated sutures
- Staples
- Clips
- Adhesive tapes
- Elastic sutures
- Tissue adhesives (i.e. glue).

Many factors are involved in the choice of skin closure material, including the type and place of the wound, available materials, physician expertise and preferences, and patient age and health.[93]

## Sutures

Modern surgical suture materials must meet a range of requirements to minimise trauma, sterility, inertness (minimal tissue reactivity) and durability. Sutures can be classified into absorbable or non-absorbable materials. Absorbable sutures are broken down by the body via enzymatic reactions or hydrolysis. The time in which this absorption takes place varies from several days to several months. Suture materials can be further sub-classified into monofilament or multifilament sutures. The surgical needle allows safe placement of the suture within the tissue and is made from stainless steel. Absorbable sutures are commonly used for deep tissues and tissues that heal rapidly. Non-absorbable sutures provide long term tissue support. Superficial wounds comprising skin are mostly sutured by monofilament removable non-absorbable suture fibres made from polypropylene or nylon. Sutures are considered a foreign body and may contribute to sustained inflammatory response, which may lead to an acute or chronic infection.[94]

## Tissue adhesives

Tissue adhesives offer the advantage of no needle-stick injury and no requirement to remove sutures later. Dumville et al. reported in a meta-analysis sutures were significantly better than tissue adhesives for minimising complications, but for SSI rates no evidence of differences was found.[95,96] In some cases, tissue adhesives may be quicker to apply than sutures. Although surgeons may consider the use of tissue adhesives as an alternative to other methods of surgical site closure in the operating theatre, considerations for the use of this type of closure include theatre time and patient-related factors that may impact healing.

## Staples

In specific clinical situations (wound margins with impaired microcirculation, extensive incisions, prolonged operations), surgeons may prefer staples to sutures for closing the wound (Fig 11).[97,98] Biancari et al. published a review[99] comparing rates of SSI, between the use of staples and sutures after saphenous vein graft harvesting for coronary artery bypass grafting (CABG). The review yielded limited evidence for the use of staples in this group in a reduction. However the authors highlighted a lack of large powered studies that are required to answer this question.

## Antimicrobial sutures and prosthetic devices

Antimicrobial sutures have been developed to minimise the risk of wound contamination originating during surgery causing infection in the incision. A suture resembles a prosthetic implant and its presence can therefore facilitate microbial

multiplication, and reduce the number of organisms required to produce a postoperative SSI.[100]

Antimicrobial sutures present an innovative approach to SSI incidence reduction supported by the evidence-based conclusions of many randomised controlled trials.[101] Triclosan is a phenolic antiseptic that has been used to impregnate or coat synthetic absorbable sutures such as polydioxanone, polyglactin and poliglecaprone. It has a broad spectrum of antibacterial (against Gram-positive and Gram-negative bacteria) and antifungal properties and a low toxicity.[102] The mechanisms of triclosan antimicrobial activity are multifactorial and its action is bacteriostatic or bactericidal, depending on concentration.[103] It has been published by Daoud et al. that the use of triclosan antimicrobial sutures reduces the incidence of SSI after clean, clean-contaminated, and contaminated surgery[104] (CEBM evidence level Ia). Sajid et al. meta-analysis concluded, that the use of antibacterial sutures for skin closure in surgical patients is effective in reducing the risk of surgical site infection and postoperative complications.[105,106] Thimour-Bergström et al. confirmed that leg-wound closure with triclosan-coated sutures in CABG patients reduces SSIs after open vein harvesting.[107,108] Leaper et al. reported from a meta-analysis that antimicrobial sutures may result in significant savings across various surgical wound types[109] due to reductions in SSI. The NICE guideline from 2019 concluded, that when using sutures, consider using antimicrobial triclosan-coated sutures, especially for paediatric surgery, to reduce the risk of SSI.[30]

## Surgical technique

Excellent surgical technique is considered a foundation for an effective healing process.[1] Surgical closure of the incision by precisely bringing together the wound edges promotes the healing by primary intention. It is the fastest and the most effective method of re-establishing surface integrity. Application of the principles of antisepsis (procedures to reduce contamination by microorganisms) and aseptic operating technique (the use of surgical practices that prevent contamination of the surgical site) are the necessary preconditions for uncomplicated wound healing.[110] Operation trauma minimisation is another challenge for a surgeon. The *physiological operating approach* has been published by Czech professor of plastic surgery František Burian in 1949.[95] It was based on careful manipulation with wound edges and organs, avoiding accidental injury and protecting healthy tissues, with the goal to shorten healing time, patient recovery and overall patient response. Other examples of excellent surgical technique include gentle handling of tissues, meticulous control of bleeding, maintenance of blood supply, prevention of tissue drying, removal of devitalised or contaminated tissues, avoidance of dead space, and the use of appropriate closure techniques.[111] Although there are no randomised controlled trials (RCT) confirming the usefulness of physiological operating approach, sterile, considerate and meticulous surgical technique is one condition of achieving good surgical results. Charoenkwan et al.[112] reported in a meta-analysis the effects of electrosurgery compared with scalpel for major abdominal incisions. It has shown no clear difference in wound infections, in mean blood loss, or difference in incision time between the scalpel and electrosurgery (low-certainty evidence). Conventional features of the surgeon's skills and work at the operating room, precise haemostasis and prevention of desiccation of exposed tissues are supplemented by new wound closure suture techniques by primary intention. However, there is still little evidence to suggest greater efficacy of one closure technique in comparison to the others.

## Wound irrigation

Surgical wound irrigation is an intraoperative technique, which may reduce the rate of SSIs

through removal of dead or damaged tissue, metabolic waste and wound exudate. Irrigation can be undertaken before wound closure or postoperatively. Results of previously published RCT[113] indicated possible association between intraoperative application of povidone iodine and reduction in surgical-site infections. Subsequent meta-analysis of intraoperative povidone-iodine application to prevent surgical-site infection published in 2010[114] reported statistically significant reductions in SSIs observed with povidone iodine treatment compared with no treatment (RR 0.58, 95% CI 0.40 to 0.83; 15 RCTs; $I^2$=54%). Povidone-iodine was also associated with significant reductions in surgical-site infections applied by irrigation. No significant between-group differences in SSIs were observed for spray, abdominal surgery, before wound closure, trials in which all patients received antibiotics or for superficial infection (p=0.003). The effectiveness of wound irrigation and intra-cavity lavage on prevention of SSI has been reassessed in a 2017 Cochrane database review[115] including 59 published studies with 14,738 participants. The authors concluded, that the evidence base for intra-cavity lavage and wound irrigation is generally of low certainty. Antibacterial washing solutions may reduce infection rates compared with non-antibacterial solutions, compared with other methods of irrigation (RR 0.57, 95% CI 0.44 to 0.75; $I^2$=53%; 30 studies, 5141 participants). There may be also fewer SSIs when a solution of povidone iodine is used compared with an alternative antiseptic.[115]

## Usage of topical antibiotics

Much regional and geographical variation exists in the use of topical antibiotics, and in resistance rates of pathogens to these agents. Avoiding antibiotics (as opposed to antiseptics) topically for treating wound infections may be advised as there is limited evidence of their effectiveness and they often select for resistant colonising bacteria.[116] In addition, topical treatment may cause periwound skin irritation, rash, eczema or impairment of wound healing.[116]

The routine usage of topical antibiotics for prevention of wound infection has been reported to contribute to the spread of antibiotic resistance.[117] In spite of this knowledge, some clinicians use antibiotics topically to prevent SSI,[118] which also contrasts with the conclusions of a Review of the Clinical Effectiveness and Guidelines: Topical Antibiotics for Infection Prevention published in 2017.[119] Here, two systematic reviews showed that in surgical patients, no statistically significant differences were observed in SSI rates with mupirocin compared with placebo, no intervention or no antibiotic; only one systematic review showed that in surgical patients, there was a statistically significant reduction in SSI with bacitracin compared with no antibiotic. A Cochrane review[106] concluded, that topical antibiotics may reduce the risk of SSI in people with surgical wounds healing by primary intention relative to no topical antibiotic and relative to antiseptics. The World Health Organization (WHO) Global Guideline on the prevention of surgical site infection[120] reports a strong recommendation with moderate quality evidence that mupirocin ointment with or without chlorhexidine gluconate body wash for the prevention of *Staphylococcus aureus* infection in nasal carriers undergoing surgery. Despite this, usage of topical antibiotics in wounds remains controversial. Topical antiseptic agents have to be preferred over topical antibiotic agents because they are broader in their spectrum of activity, practically unaffected by antimicrobial resistance and less likely to cause allergic reactions. The joint EWMA/BSAC position paper on antimicrobial stewardship in wound care from 2016 concludes that applying principles of AMS to the care of patients with wounds ensures the safest and most clinically effective therapy for infected wounds.[121]

## Closed incision negative pressure therapy

There is emerging literature on the role of closed incision negative pressure wound therapy (ciNPT) in SSI, where some reduction in the rate of SSI rate has been reported in selected surgical procedures.[122]

Negative pressure wound therapy (NPWT) is considered a standard mode of open wound treatment, but the evidence supporting the preventive usage of negative pressure therapy in closed surgical incisions is still sparse.[123] A number of systematic reviews have generated discourse on the clinical efficacy of ciNPT, currently there is a lack of evidence in support of its use due to poorly designed and underpowered studies, as well as those of a retrospective nature.[124–126] Sandy-Hodgetts et al.[126] reported conflicting results in the use of ciNPT for the reduction of wound dehiscence and seroma. Furthermore the authors concluded that given the small number of studies, mostly retrospective comparative cohort in design, no definitive conclusions can be reached as to the effectiveness of the use of NPWT in the prevention of surgical wound complications. Similarly, Webster et al.[127] reported in a Cochrane review that despite the addition of 25 trials, results are consistent with an earlier Cochrane review,[128] with the evidence judged to be of low or very low certainty for all outcomes. As a result, uncertainty remains regarding whether ciNPT compared with a standard dressing reduces or increases the incidence of important outcomes such as morbidity, dehiscence, seroma. The WHO Guidelines on the prevention of SSI graded the use of ciNPT as a conditional recommendation with low evidence to support this indication.[129]

When applying ciNPT, a polyurethane foam or gauze is placed over the length of the incision, secured with a protective occlusive tape and attached to a commercially available NPWT device set at between –75mmHg and –125mmHg, in a continuous suction (Fig 12).[122]

In 2015, Apelqvist et al. concluded that ciNPT is used in many different surgical disciplines. However, the present state of knowledge is that there is no rationale to apply ciNPT to all surgical incisions because the costs are too high in comparison with that of standard dressings.[108,124,125]

## Drains

Surgical drains are placed in the site of surgery at the end of the operation to remove fluids from a wound. They are tailored to manage collection of body fluids or other biological materials (blood, pus, gas, lymph, faeces, bile, urine, etc.) and to take them away from the skin. They are important from diagnostic (to early characterise action of the fluid), therapeutic and preventive reasons acting against development of so-called dead space collections. Dead space is defined as a space remaining in tissues as a result of failure of proper closure of

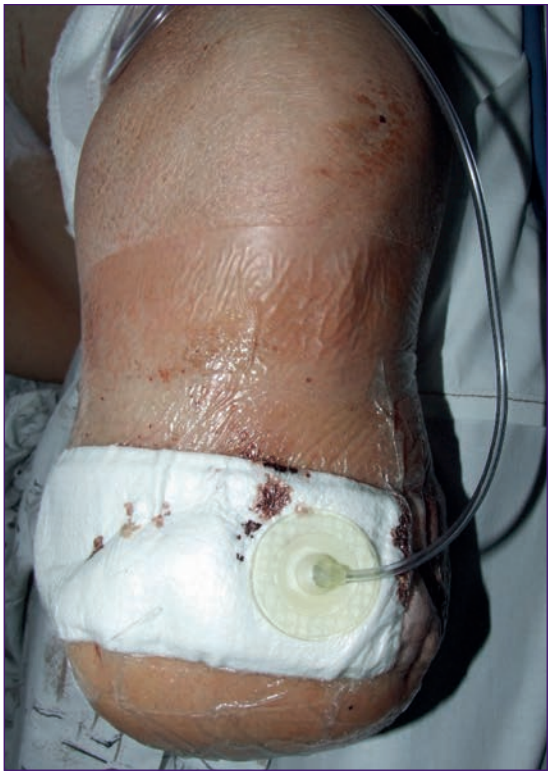

Fig 12. Closed incision negative pressure therapy device

surgical wound, permitting accumulation of blood or serum.[130] Fluid collection within the wound may disrupt the normal healing trajectory leading to complications e.g. preventing wound margins from close contact, slowing down tissue reparation and creating a suitable area for micro-organisms to multiply.

On the contrary, drains can hinder a patient's recovery by acting as an 'anchor', limiting mobility after surgery and the drain itself may allow infection into the wound by retrograde passage of bacteria through drain tubes or drain exit site. Medical drains can be classified according to their composition (silicone, rubber, latex, antiseptic dressing straps), shape (flat, round, half-round, T-type, pigtail drain), purpose and function (active/suctioning, passive; open/closed).

## Management of the insertion site

The site where the drain enters the surface of the skin should be kept clean and sterile and be covered an appropriate dressing. It is important to observe the skin around the drain for signs of possible infection. Drains should be removed when the drainage tubing becomes obstructed or further clinical assessment determines drains are no longer required. To reduce the risk of wound infection, drains should exit the skin away from the suture line. Early removal of the drain may decrease the risk of some complications, especially SSI.[131]

## Evidence regarding wound drainage

There is a paucity of evidence supporting the benefits of postoperative surgical wound drainage, although many surgeons simply follow their 'usual practice'.[132] When deciding whether to use a drain, surgeons consider a number of factors, including the patient's medical status (such as ongoing coagulopathy, antiplatelet medications), type of surgery (such as vascular operation, joint replacement), location of the surgery (such as neck, intracranial sites, other areas where complications are potentially life-threatening), extent of surgery (such as extensive tissue dissection, large wound area), and potential microbiological burden of the wound (such as traumatic wounds, obvious intraoperative contamination). In general, evidence regarding recommendations for routine use of drains after uncomplicated surgery is extremely limited or non-existent.

There is insufficient evidence from randomised trials to support the routine use of closed suction drainage in orthopaedic surgery[133] and there is also no evidence that drain insertion after plastic and reconstructive surgery of the breasts reduces complications.[134] A 2005 Cochrane database systematic review concluded that the potential benefits and harm associated with the use of wound drains in lower limb arterial surgery and caesarean sections remain uncertain.[132] Cochrane concluded the potential benefits and harms associated with the use of wound drains in lower limb arterial surgery and caesarean sections remain uncertain.[135] It concluded that drain insertion was associated with a reduced likelihood of seroma formation but did not affect the risk of infection, volume of fluid aspirated or risk of haematoma.

### Box 2. What is a wound navigator?

The patient navigator is a term originating from cancer and other high risk diseases.[138,139] In the 2014 EWMA Position Paper '*Managing wounds as a team*' Moore et al.[137] adapted the term to the field of wound management and coined the term 'wound navigator'.

It has been suggested that clinicians interested in establishing wound team services begin at the local level by assuming the role of the wound navigator. Interested clinicians could generate a list of local services, collaborate with identified services to develop referral mechanisms, aggregate assessment data collected by the services into a whole of system care plan, explore options for better use of existing remuneration schemes to fund identified patient need and collect outcomes data that supports the benefits of the wound team approach highlighted in the literature.[137]

Overall, the literature provides little evidence that surgical drains are beneficial. Drains are not a substitute for good surgical technique, and although they are often used, the potential benefits and harms should be carefully considered because their routine use does not seem to reduce the risk of surgical site infections. Nevertheless, drains may be of benefit in specific high-risk situations, such as obese patients or patients with contaminated wounds.[136]

## Multidisciplinary team approach to surgical wound management

A multidisciplinary team (MDT) approach is essential to successful surgical wound management not only in acute-care but also in community settings. These challenges include the contentious nature of sharing professional roles and expertise, planning and decision-making, while delivering quality patient care within complex contexts. Through this approach, patient-focused enhanced clinical outcomes can be achieved.[137]

The essential elements for an interdisciplinary wound care service are shown in Fig 13. This figure shows that the patient forms the focus of the wound care but relies on the expertise of the different disciplines.

The patient forms the focus of the care, but relies on the expertise of a wound navigator to organise wound care service via established referral mechanisms. The wound navigator and other health professionals either collaborate to explore beneficial remuneration and health care systems and/or lobby to meet the needs of the patient.[137]

**Table 6. Factors to improve home care management of surgical wounds**

| |
|---|
| Multidisciplinary approach |
| Consistency in care |
| Patient centred wound care plan with clear and well described guidance with appropriate management goals |
| Access to appropriate dressing resources and clinical expertise |
| Patient and carer education |
| Written and oral information |

**Table 7. Factors improving the outcomes across in-patient and out-patient settings**

| |
|---|
| Consistent communication and forwarding of medical reports |
| Clear responsibility roles |
| Education of patients and health care professionals |
| Working/functional national guidelines and standards comprising out- and inpatient sectors |

### Challenges related to home care

Reducing the duration of hospital stay presents a considerable problem to both the health care organisation and the patient. This means that the treatment of patients is transferred to the home care setting.[140] Once a patient is discharged, the first follow-up visit is usually scheduled 2 to 3 weeks after hospital discharge.[141] During this period, monitoring of the wound is reduced and this lack of monitoring is a concern, as the majority of patients do not have the experience or expertise to recognise early-stage wound infections.[142] Thus, patients often return to the hospital with an advanced wound infection that often requires a re-hospitalisation.[47] There are many factors improving the SSI prevention and treatment outcomes across in-patient and out-patient settings (Tables 6 and 7). A US study incorporating 346 hospitals identified SSI as the most common reason for readmission to hospital, accounting for 19.5% of overall readmissions.[143]

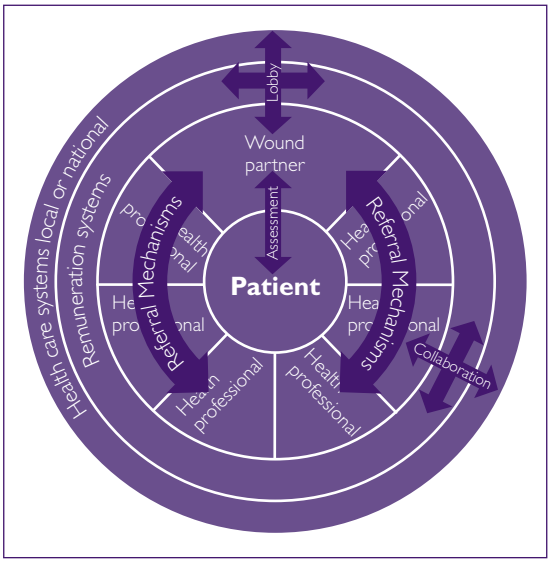


Fig 13. Essential elements in an interdisciplinary wound care service (First published in the 2014 EWMA document '*Managing wounds as a team*'.[137]

Literature suggests that readmissions might be reduced by ensuring better coordination of care with outpatient care teams, minimising fragmentation of post-discharge care, developing high-quality home care programmes, and improving the quality of education and discharge instructions given to patients.[144] A written and oral care-plan should be provided when discharging the patient.[145] In an RCT with burn patients, the intervention group (written information in addition to verbal information) had significantly higher knowledge scores overall than those in the control group (verbal information). The average knowledge scores for intervention group 0.79, standard deviation (SD) 0.15 and the average knowledge scores for the control group 0.73, SD 0.16, p=0.029. All patients and carers should be given clear and consistent advice regarding management of their wound postoperatively, they should be included in developing the plan of care, so care can be effectively managed at home. Any cultural, spiritual or socio-economic circumstances should be discussed that may affect postoperative management and plans of care developed to manage these. A MDT approach to the management of wounds is essential, ensuring that local guidance is adhered to and a coordinated approach to safe discharge with appropriate documentation, advice and dressings are given in a timely manner.[137]

The patient and carer should be advised how long the dressing can remain in place for and addressing that showering 48 hours postoperatively is acceptable.[40] Advice should be given to keep the dressing dry, if the dressing is to remain in place. If the wound has no signs of SSI, the dressing can be removed 48 hours postoperatively. Similarly, advice should be given as to how to recognise signs of a SSI (increased pain, tenderness around the wound area, inflammation, cellulitis or a collection of pus with systemic complications such as sepsis and feeling generally unwell) and contact numbers of which professional to contact if required. If an SSI is present, an interactive dressing that provides creation and maintenance of a local, warm, moist environment should be used and left in place for as long as indicated. There may be a need for antimicrobial dressings, which will be assessed in conjunction with the wound care team or medical staff. If an SSI is present the patient should be referred to the tissue viability team or other relevant health professional for advice. Patients and caregivers should be educated regarding hand hygiene procedures.

## Conclusion

The process of surgical wound closure itself is involved by many clinical factors acting at the time of operation. They can influence the range of contamination of the surgical site, duration of surgery, the extent of procedural tissue trauma, size of the dead space. Even though the surgeon is the main link in the chain, the operative phase gives an example of multidisciplinary

approach indispensability. Operation, carried out excellently gives the preconditions for good wound healing and fast patient recovery. Written and oral patient information is key to early identification of SSI and an appropriate pathway for the patient to follow in seeking help.

# 5. Perioperative practice to prevent surgical site infection

## KEY POINTS

- Before surgery, patients should shower (full body) with soap the night before and the day of the operation
- The incision site should be prepared with an alcohol-based antiseptic solution and hair removal should be avoided
- Antimicrobial prophylaxis should be administered only when indicated based on published clinical practice guidelines
- Normothermia should be maintained in all patients undergoing surgery
- Strategies to ensure glycaemic control should be in place
- Intraoperative factors such as tissue oxygenation, intraoperative warming and type of sutures may also influence the occurrence of SSI
- Measuring and reporting rates of SSI in surveillance systems is important practice for determining prevalence and incidence of SSI.

Postoperative complications arise as a result of a combination of risk factors; patient-related (age, obesity, underlying illness), quality of surgical procedure (duration, technique, type) as well as microorganisms involved (number, virulence). Interventions can be broadly delivered at three stages during the patient journey: preoperatively, intraoperatively and postoperatively. Table 8 provides a summary of the latest published SSI guidelines:

- SSIs: prevention and treatment, National Institute of Health and Clincal Excellence (NICE) 2008 (updated 2017)[40]
- Global Guidelines for the Prevention of Surgical Site Infection, WHO, 2016[5]
- Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, CDC, 2017[3]

## Preoperative phase

The preoperative phase is the 24 hours before the procedure and involves the admission of the patient and the preparation leading up to the perioperative phase.

### Nasal decolonisation

Recommended by WHO and NICE.[5,40]

*Staphylococcus aureus* is an important cause of SSI. It is commonly present as part of the normal flora of the skin and nose, with screening studies reporting carriage rates of around 20%.[146] An association between nasal carriage of *Staphylococcus aureus* and the development of SSI has been recognised.[147] Consequently, identification of nasal carriage before surgery and treatment of positives with a 5–day course of mupirocin and chlorhexidine soap has been associated with a significant reduction in rate of SSI caused by *Staphylococcus aureus*.[148] Decolonisation treatment preoperatively is recommended for all patients undergoing cardiothoracic and orthopaedic surgeries.[120] In patients undergoing other types of surgery, it is advisable to consider other factors including local rates of *Staphylococcus aureus* and MRSA, patient-related factors such as past

## Table 8. Summary of recommendations for the prevention of surgical site infections[3,5,40]

| Intervention | Recommendation | WHO[5] | CDC[3] | NICE[40] | NICE[245] |
|---|---|---|---|---|---|
| **Nasal decolonisation** | Consider nasal mupirocin in combination with a chlorhexidine body wash before procedures in which Staphylococcus aureus is a likely cause of a surgical site infection | ✔ | – | ✔ | |
| **Preoperative bathing** | Use soap solutions to clean the skin before surgery | ✔ | ✔ | ✔ | |
| **Hair removal** | Avoid the removal of hair from the site of incision; if essential use hair clippers | ✔ | – | ✔ | |
| **Preoperative warming** | Maintain peri-operative normothermia | ✔ | – | | ✔ |
| | Actively warm patients for 30 mins before start of anaesthesia. Temperature should be 36°C or above before transfer to theatre | | | | ✔ |
| | Patients' core temperature should be above 36°C or above before and during surgery and in the recovery area | | | | ✔ |
| **Surgical hand preparation** | Surgical hand preparation should be performed by scrubbing with either a suitable antimicrobial soap and water or using a suitable alcohol-based handrub before donning sterile gloves | ✔ | – | ✔ | |
| **Incision site skin disinfection** | Use an alcohol-based product to disinfect skin before incision | ✔ | ✔ | ✔ | |
| **Surgical antibiotic prophylaxis** | Where indicated, antibiotic prophylaxis should be given immediately before the surgical incision being made and not continued after completion of surgery | ✔ | ✔ | ✔ | |
| **Operating room ventilation** | Air should be filtered to remove contaminated particles and anaesthetic gases and flow from clean to less clean areas across the operating department[246] | ✔ | – | – | |
| **Operating room traffic** | Reduce operating room traffic to avoid possible contamination of the site of surgery[246,247] | – | – | – | |
| **Antimicrobial sutures** | Consider use of triclosan-impregnated sutures | ✔ | – | ✔ | |
| **Incise drapes** | The use of plastic adhesive drapes with or without antimicrobial properties is not necessary for the prevention of SSI | ✔ | ✔ | ✔ | |
| **Perioperative glycaemic control** | Implement perioperative glycaemic control in patients with and without diabetes | ✔ | ✔ | - | |
| **Perioperative oxygenation** | Maintain optimal oxygenation during surgery and in the recovery period to ensure adequate haemoglobin saturation. Adult patients should receive 80% fraction of inspired oxygen | ✔ | - | ✔ | |
| **Postoperative wound management** | Cover surgical incisions with an appropriate interactive dressing at the end of the operation. | ✔ | | ✔ | |
| **SSI surveillance** | Sustained surveillance and feedback of data on rates of SSI has been associated with reductions in rates of infection[248] | – | – | – | |

*Staphylococcus aureus* infection and colonisation by *Staphylococcus aureus* in sites other than the nose. While studies have yielded some reductions in using this approach, it is recommended a conservative approach be considered with the use of antibiotics.

### Preoperative bathing

Recommended by the WHO, the CDC and NICE,[3,5,40] bacteria may gain access to the surgical wound through several sources but the most common source is the patient's own skin.[2] Human skin is colonised by a large number of microorganisms known as 'resident' flora, which tend to live in the skin folds, sebaceous glands and hair follicles. The surfaces of the skin can also be contaminated with microorganisms from body excretions/secretions, dirt or from contact with contaminated surfaces or items (transient flora). While all these microorganisms are harmless on the surface of the skin, if they access a surgical incision they can cause a SSI. Cleansing of the skin before surgery is therefore required to remove as many microorganisms as possible from the skin surface.[149] Soap solutions are recommended to physically remove dirt and transient microorganisms from the surface of the skin. Patients should be encouraged to have a shower with soap. Reports by Dumville et al.,[150] WHO[5] and CDC[151] found that bathing with chlorhexidine soap does not significantly reduce SSI rates compared with bathing with plain soap.

### Hair removal

Recommended by WHO and NICE,[5,40] hair is no more heavily colonised with microbial flora than the skin and the criteria for hair removal at surgical site should be based on the need to view or access the operative site rather than to remove bacteria. If hair removal is essential, the best approach is to remove the minimum amount of hair, as near to the time of operation as possible.[5,40] A study has shown that shaving the skin before operation increases the risk of wound infection.[40] According to Tanner et al. bacteria multiply in micro abrasions caused by the razor on the skin surrounding the operative site and increase the risk of the incision becoming contaminated.[152] The longer the period between hair removal and the incision, the greater the risk of contamination. Where hair removal is essential, this should be done using hair clippers to minimise damage to the skin. Depilatory creams also do not abrade the skin but are less practical as they need to be left in place for several minutes and have the potential to cause allergic reactions.[5]

### Preoperative warming

Recommended by NICE,[149] hypothermia, defined as a core body temperature of less than 36.0ºC[149] is a common but preventable consequence of surgery. It can occur as a result of the suppression of the central mechanisms of temperature regulation due to global anaesthesia, and pharmacological relaxation of the muscles during surgery as well as the prolonged exposure of large surfaces of skin to cold temperatures in operating rooms and receiving large volumes of non-warmed fluids. Inadvertent perioperative hypothermia has been associated with clinical complications such as surgical site infection, wound-healing delay, increased bleeding or cardiovascular events. The NICE clinical guidelines on prevention of inadvertent hypothermia[149] recommend that all patients should be assessed within the hour before surgery for their risk of perioperative hypothermia and their temperature measured using a site that produces a direct measure or direct estimate of core temperature. All patients should be actively warmed on the ward/emergency department at least 30 minutes before induction of anaesthesia. If the patient's temperature is below 36ºC or they are at high risk of hypothermia, they should be warmed immediately. The patient's core temperature should be 36ºC or above before they are transferred to theatre.[149,153]

## Intraoperative phase

The second phase, known as the intraoperative phase, involves surgery.

### Surgical scrubbing

Recommended by WHO and NICE.[5,40] Surgical

hand antisepsis by all surgical teams is routinely carried out to remove transient microorganisms, inhibit the growth of resident microorganisms and maintain the lowest possible contamination of the surgical field, especially in the event of sterile glove puncture during the procedure. The SSI prevention guidelines[5] provide a strong recommendation that surgical hand preparation be performed either by scrubbing with a suitable antimicrobial soap and water or using an alcohol-based hand-rub licensed for surgical scrubbing, before donning sterile gloves.

A Cochrane review by Tanner et al.[154] assessed the effects of surgical hand antisepsis on preventing SSIs and also determined the effects of surgical hand antisepsis on the numbers of colony-forming units (CFUs) of bacteria on the hands of the surgical team. The review found no firm evidence that one type of hand antisepsis is better than another in reducing SSIs.[154]

Chlorhexidine gluconate scrubbing agents may reduce the number of CFUs on hands when compared with povidone iodine scrubs. However, the clinical relevance of this outcome is unclear. Alcohol hand rubs with additional antiseptic ingredients (such as chlorhexidine) may reduce CFUs compared with aqueous scrubs. Low-quality evidence indicates that there is a greater CFU reduction after a three-minute initial surgical scrub than two-minute scrub.[155] Findings on a longer initial scrub and subsequent scrub durations were not consistent. Tanner et al. also concluded that it is unclear whether nail picks and brushes used during scrubbing have an impact on the number of CFUs remaining on the hands.[154]

## Incision site skin disinfection

Recommended by WHO, CDC and NICE,[3,5,40] the aim of skin disinfection before incision is to apply antiseptic solutions to rapidly destroy skin microorganisms at the site of the incision and reduce the risk of contamination of the surgical site. Disinfection of the surgical site should occur as close to the time of surgery as possible and immediately before draping.[40]

The two main antiseptic agents used for preoperative skin preparation are chlorhexidine gluconate (CHG) and iodophors (povidone iodine; PI). Both CHG and PI are effective against a broad range of skin microorganisms and exert persistent activity that prevents regrowth for several hours after application.[156] They are available in either an aqueous or alcohol-based form. There is limited evidence to suggest that one agent is better than another. Products based on alcohol are probably more effective than aqueous products since alcohol is an antiseptic agent.[5] Evidence for differences in efficacy between PI and CHG is limited but tends to favour CHG.[157–159]

Most studies are too small to detect differences in rates of SSI,[160–162] measure only the change in skin colonisation or have focused on single types of operative procedure.[160,163–165] Alcohol-based solutions should be used where they are suitable for the particular site of incision as they include an additional, rapid-acting antiseptic agent that dries quickly. However, alcohol can damage mucous membranes (eyes, ears, genitalia) and aqueous solutions should be used for this type of surgery.

## Surgical antibiotic prophylaxis

Recommended by WHO, CDC and NICE,[3,5,40] the purpose of surgical antibiotic prophylaxis is to eliminate microorganisms introduced into the surgical wound during the procedure, which may subsequently multiply to cause SSI.[166] For many types of commonly performed surgery, there is consistent evidence that a single dose of antimicrobial with a long enough half-life to achieve activity throughout the operation is adequate.[167–172] A repeat dose is only indicated when there is excessive blood loss or if surgery is unexpectedly prolonged.

Administration of surgical prophylaxis should be timed to achieve the right levels of antibiotics in blood and tissue before bacterial contamination occurs during operation. The time taken for an antibiotic to reach an effective concentration in any particular tissue reflects its pharmacokinetic profile and the route of administration. Antibiotic prophylaxis administered too late or too early (more than 120 minutes before or after incision) reduces the efficacy of the antibiotic and may increase the risk of SSI.[173,174] A meta-analysis on the timing of preoperative surgical prophylaxis did not identify increased SSI risks if administration was within 120-minute timeframe before incision.[129,174] It is broadly recommended that the administration of the first dose of antibiotic is made within 60 minutes before the incision.[166]

Prophylaxis should be converted into a treatment regime when an existing infection is present in the wound at the time of surgery or significant contamination such as from bowel contents, occurs during the operation.[149]

## Intraoperative warming

Recommended by WHO, CDC and NICE.[3,5,40]
The NICE clinical guidelines on prevention of inadvertent hypothermia[149] state that induction of anaesthesia should not begin unless the patient's temperature is 36.0ºC or above (unless there is a need to expedite surgery). Patients having anaesthesia for longer than 30 minutes are at a higher risk of perioperative hypothermia and are to be warmed from induction of anaesthesia using forced air warming.[149] The patient's temperature should be measured and documented before induction of anaesthesia and then every 30 minutes until the end of surgery, using a site that produces a direct measure (pulmonary artery catheter, oesophagus and bladder) or direct estimate of core temperature (sublingual, axilla, rectal and zero heat flux). Devices using infrared technology to measure temperature are not recommended (tympanic, forehead, temporal).

## Forced air warming

Recommended by NICE.[149] A frequently used techniques to prevent inadvertent perioperative hypothermia is active body surface warming systems, which generate heat mechanically (heating of air, water or gels) that is transferred to the patient via skin contact. A Cochrane review assessing the effectiveness of preoperative and/or intraoperative active warming systems, to prevent perioperative complications from unintended hypothermia during surgery concluded that forced-air warming appeared to have a beneficial effect in reducing surgical site infection.[175]

## Fluid warming

Recommended by NICE.[149] If a patient requires a large volume of intravenous and/or irrigation fluids (500ml or more) and the temperature of these fluids is below core body temperature, they can cause significant heat loss. Warming intravenous and irrigation fluids to core body temperature or above might prevent some of this heat loss and subsequent hypothermia.

A recent review of clinical evidence found that warmed intravenous fluids kept the core temperature of study participants about half a degree warmer than that of participants given room temperature intravenous fluids.[176] The NICE guidelines[149] recommend that all irrigation fluids used intraoperatively should be warmed to a temperature of 38–40ºC in a thermostatically controlled cabinet.[149]

## Postoperative warming

Recommended by NICE.[149] NICE guidelines[40] recommend that the patient's temperature should be monitored and documented every 15 minutes in recovery. The patient should not be transferred to the ward, until their temperature is 36ºC or above.

## Operating room ventilation

Recommended by the CDC,[5] the ventilation systems used in operating theatres are useful to filter out airborne microorganisms, to prevent microorganisms from entering the theatre in the air supply from corridors or other parts of the hospital, and to dilute contaminated air in the room by replenishing with fresh filtered air.[177] Dust and textile particles, skin scales, airborne bacteria and other sources of microbial contamination within the surgical field all have the potential to cause SSI.

## Operating room traffic

In theatre, the main source of airborne bacteria is the staff entering and leaving the theatre and adjacent rooms, although power tools can also create aerosols from tissues.[177] The number of airborne microbial particles in an operating room is proportional to the number of humans present and their level of activity.[178] Each person has been estimated to emit approximately 1000 organisms per minute at rest, increasing to 50,000 per minute during activity as friction of clothing against the skin releases more squames.[179,180] These particles may settle on to instruments or gloved hands or into the wound itself and subsequently result in wound infection.[181,182]

## Laminar flow

Recommended by WHO.[5] Ultra-clean air systems (laminar flow) have been recommended to reduce the incidence of infection in prosthetic orthopaedic surgery, which are susceptible to infection even if only small numbers of bacteria are introduced into the wound. These 'laminar flow' systems direct parallel streams—a laminar flow of filtered air over the operating table—and use over 600 air changes per hour. Although early studies suggested laminar flow systems were associated with a reduction in wound infection rates, there is now an emerging body of evidence that suggests they may even increase the risk of infection, possibly due to disruption of air flow by personal and equipment and a reduction in wound tissue temperature. A meta-analysis by Bischoff et al.[179] showed no benefit for laminar airflow compared with conventional turbulent ventilation of the operating room in reducing the risk of SSIs in total hip and knee arthroplasties, and abdominal surgery. Indeed the WHO SSI guidelines[5] do not recommend laminar airflow as a preventive measure to reduce the risk of SSIs, stating these systems should not be installed in new operating rooms. This recommendation is however based on low to very low-level evidence.

## Incise drapes

Recommended by WHO, the CDC and NICE.[3,5,40] Adhesive plastic incise drapes, plain or impregnated with an antimicrobial agent (mostly an iodophor), are used on the patient's skin after surgical site preparation. The film adheres to the skin and the surgeon cuts through the drape and the skin. Such a drape is theoretically believed to represent a mechanical and/or microbial barrier to prevent the migration of microorganisms from the skin to the operative site.

However, some reports showed an increased recolonisation of the skin following antiseptic preparation underneath adhesive drapes compared to the use of no drapes. The WHO SSI guidelines (2016),[5] Cochrane review[183] and CDC (2017) SSI guidelines[3] found that the use of either non-antimicrobial-impregnated or antimicrobial-impregnated incise drapes is not necessary for the prevention of SSI.

## Impregnated sutures

Recommended by WHO and NICE,[5,40] surgical suture material is used to proximate wound edges and is thus in direct contact with the wound itself. To prevent microbial colonisation of the suture material in surgical incisions, sutures with antibacterial activity have been developed. The

WHO SSI prevention guidelines[5] recommend the use of triclosan-coated sutures for the purpose of reducing the risk of SSI, independent of the type of surgery and type of sutures (braided or monofilament). The meta-analysis was based on moderate-to-low quality evidence, examined triclosan-coated, absorbable sutures only and points out that many of the studies included had conflicts of interest.[101] There were no studies identified that investigated other antimicrobial agent coated sutures.

### Intraoperative administration of high oxygen concentrations

Recommended by WHO.[5] The SSI prevention guidelines recommends that adult patients undergoing general anaesthesia with endotracheal intubation for surgical procedures should receive 80% fraction of inspired oxygen intraoperatively and, if feasible, in the immediate postoperative period for 2–6 hours.

A meta-analysis suggested a beneficial effect of intraoperative administration of high oxygen concentrations during colorectal surgery.[184]

### Glucose control

Recommended by WHO and the CDC.[3,5] Blood glucose levels rise during and after surgery due to surgical stress.[185] Surgery causes a stress response that results in a release of catabolic hormones and the inhibition of insulin.[5] Several observational studies[186–189] showed that hyperglycaemia is associated with an increased risk of SSI and therefore an increased risk of morbidity, mortality and higher health care costs in both diabetic and non-diabetic patients and in different types of surgery.

Recently published guidelines seem to disagree on the level of glucose control required to reduce risk of SSI. The WHO[5] guidelines recommend that protocols for intensive perioperative blood glucose control should be used for both diabetic and non-diabetic adult patients undergoing surgical procedures. Centers for Disease Control (CDC) SSI prevention guidelines[3] highlight that moderate-quality evidence suggested no benefit of strict glucose control (80–100 mg/dl or 80–130 mg/dl) as compared with standard blood glucose target levels. A programme to enhance recovery after surgery is steadily in the implementation phase across the northern hemisphere. The enhanced recovery after surgery (ERAS) programme is a multimodal approach to reduce or modify the physiological and psychological effects of surgery. Initiated by Henrik Kehlet in the 1990s implementation of the ERAS protocol has been shown to reduce the occurrence of SSI and hospital length of stay in certain surgical populations; colorectal,[190] urological and orthopaedic surgery.[191,192] The key tenets of the ERAS protocol are underpinned by evidence-based practices and include perioperative counselling, preoperative nutrition (carbohydrate loading up to 2 hours preoperatively), standardised anaesthetic and analgesic regiments (epidural and non-opioid analgesia) and early mobilisation.[193] In some cases, implementation of the ERAS programme have resulted in 30% to 50% reductions in complications and reduced lengths of stay.[194] The key to success with the ERAS programme is a MDT approach to patient management which includes the surgical team, anaesthetist, ward staff, dieticians, patient and carer engagement.

## Postoperative phase

The postoperative phase is the period immediately following surgery. Application of antimicrobial dressings should be reserved only for specific surgical situation regarding high-risk patients undergoing high-risk procedures and only for a limited period of time.

### Wound dressings for the prevention of SSI and management of surgical wounds

Although there is no definitive evidence for the use of any particular type of modern interactive wound

## Table 9. Wound dressings for the management of surgical wounds (after NICE 2018[40] and WHO 2016)[5]

| Dressings category | Dressing characteristics | Wound characteristics / healing intention | Primary clinical indications | Phase of Management |
|---|---|---|---|---|
| **Advanced (Interactive)** | | | | |
| **Vapour-permeable films** | Vapour-permeable films are permeable to water vapour and oxygen, but not to water or microorganisms. They are normally transparent | • Superficial<br>• Minimal exudate*<br>• Primary intention | Facilitates the optimum healing environment (moist wound healing) and provides a barrier to bacteria/protects the incision site | • Intraoperative (In theatre)<br>• Postoperative<br>• In community/ home care settings |
| **Hydrocolloid dressing** | Hydrocolloid dressings vary significantly in their composition and physical properties. In general, they consist of a self-adhesive gel-forming mass applied to a carrier, such as a thin polyurethane film or a foam sheet. They contain colloidal particles, such as quar, karaya, gelatic, sodium carboxymethylcellulose, gelatin and pectin, in an adhesive mass usually made of polyisobutylene. In their intact state, hydrocolloids are virtually impermeable to water vapour. By trapping wound exudates, hydrocolloids create a moist environment that softens and lifts dry eschars. They favour also granulation tissue formation and re-epithelialisation | • Superficial<br>• Low exudate*<br>• Primary and secondary intention | Facilitates wound hydration and the optimum wound healing environment.<br>Promotes autolytic debridement and proteolytic digestion | Usually postoperative and in community/ home care settings |
| **Hydrogels or fibrous hydrocolloid dressing** | Hydrogels consist of 80–90% water and insoluble cross-linked polymers, such as polyethyleneoxide, polyvinyl pyrollidone, acrylamide or carboxymethylcellulos, with hydrophilic sites that interact with aqueous solutions, absorbing and retaining significant volumes of water | • Superficial or deep<br>• Low-to-moderate exudate*<br>• Secondary intention | Rehydration of tissues and some absorption of exudate.<br>Facilitates the optimum healing environment and protects the incision site. Some absorbency potential | • Intraoperative (occasionally)<br>• Postoperative<br>• In community/ home care settings |
| **Polyurethane matrix hydrocolloid dressing** | Polyurethane matrix hydrocolloid dressings consist of two layers: a polyurethane gel matrix and a waterproof polyurethane top film designed to act as a bacterial barrier | • Superficial or Deep<br>• Low to moderate exudate*<br>• Primary and secondary intention | Indicated for clean, granulating / sloughy or necrotic wounds.<br>Limited absorbency capacity - the amount of exudate that a hydrocolloid dressing can absorb will be dependent upon the MVTR (moisture vapour transfer rate) of the backing layer. | • Intraoperative<br>• Postoperative<br>• In community/ home care settings |

**Table 9. Wound dressings for the management of surgical wounds (after NICE 2018[40] and WHO 2016)[5] continued**

| Dressings category | Dressing characteristics | Wound characteristics/ healing intention | Primary clinical indications | Phase of management |
|---|---|---|---|---|
| **Alginates** | Manufactured from salts of alginic acid – source brown seaweed. On contact with wound exudate, ionic exchange occurs in the alginate and a hydrophilic gel formed.<br>The nature of this exchange is dependent upon the amount of guluronic (g) and mannuronic acid (m) used in manufacture.<br>The amount of g and m acid in the dressing also determines its ability to absorb exudate, retain its shape and how it will be removed from the wound – available in sheet/rope/cavity filler form | • Superficial or deep<br>• Low to moderate to high exudate*<br>• Secondary intention | Absorbency of exudate; maintains a moist wound surface and promotes the removal of cellular debris/slough from the wound surface (bed) | • Intraoperative (occasionally)<br>• Postoperative<br>• In community/ home care settings |
| **Polyurethane foams** | Made up of polyurethane and come in a variety of forms – simple foam sheets, film-backed foam sheets, polyurethane foam gels (hydro polymer) and cavity fillers (tube dressings).<br>One variety has additional additives, e.g. glycerine and a surfactant | • Superficial when used as a primary dressing<br>• Deep when used as a secondary dressing<br>• Low to moderate to high exudate*<br>• Usually secondary intention | Absorbency of exudate; maintains the optimum healing environment and can minimise the risk of trauma at the wound surface at the time of dressing change (dependent upon product chosen) | • Intraoperative<br>• Postoperative<br>• In community/ home care settings |
| **Bacteria and fungi binding dressings** | | | | |
| **Bacterial-binding dressing** (Dialkylcarbamoyl chloride [DACC] coated dressings ) | Dressings that facilitate the binding of microorganisms to the dressing as a result of the specific surface characteristics using the principles of hydrophobic interaction.<br>Common wound microorganisms, including MRSA, bind to the dressing surface from the wound bed and are removed at dressing change | • Superficial to deep<br>• Low to high exudate<br>• Primary and secondary intention | These dressings can be used both for infection prevention as well as well as for treating already infected surgical wounds.<br>No known mechanism of resistance development.<br>Suitable for prolonged duration of treatment. | • Intraoperative<br>• Postoperative<br>• In community/ home care settings |
| **Antimicrobial dressings** | Should not be used routinely for prophylaxis (i.e. to prevent infection). However, some antimicrobial products may contribute to the reduction of SSI risk in some surgical patients. Clinicians should make their decision to use any antimicrobial product prophylactically in view of their knowledge of the properties of the product being considered; the evidence available to support its proposed use and their own previous experience with the product/dressing. | | | |
| **Polyhexametylene biguanide** (PHMB) dressing | A commonly used antiseptic. It is used in a variety of products, including wound care dressings and wound cleansing solutions, perioperative cleansing products, contact lens cleansers and swimming pool cleaners | • Superficial or deep<br>• Moderate to high exudate*<br>• Secondary intention | Wound cleansing; wound bed preparation – the stimulation and influence of specific cells involved with the immune system and the management of wound infection in conjunction with appropriate systemic therapy | Usually postoperative and in community/ home care settings |

**Table 9. Wound dressings for the management of surgical wounds (after NICE 2018[40] and WHO 2016)[5] Continued**

| Dressings Category | Dressing Characteristics | Wound Characteristics / Healing intention | Primary Clinical Indications | Phase of Management |
|---|---|---|---|---|
| **Silver-impregnated dressing** | Silver provides extensive coverage against bacteria, fungi and viruses, including nosocomial pathogens and methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE), make it a valuable adjunct in the prevention and treatment of infection. Silver has both bactericidal effects via oxidation of the cell membrane and bacteriostatic effects by inhibiting bacterial replication through damage to DNA | Superficial or Deep<br>Moderate to High Exudate*<br>Secondary Intention | Wound cleansing; wound bed preparation – the stimulation and influence of specific cells involved with the immune system and the management of wound infection in conjunction with appropriate systemic therapy | Usually postoperative and in community/ home care settings |
| **Povidone Iodine impregnated dressings** | Iodine is an antiseptic that targets a broad spectrum of bacteria and other pathogens. It has been used successfully without complication for the management of many hard-to-heal wounds, however there is currently little evidence to support its use for the prevention and long term management of SSI. | • Superficial wounds<br>• Minimal exudate<br>• Secondary Intention | Iodine is an oxidizing agent, and its bactericidal activity involves the inorganic and essentially no development of resistance by microorganisms has been determined | Postoperative |
| **Advanced (Active)** | | | | |
| **Negative-pressure wound therapy (NPWT) dressings** | Primarily designed to prevent exudate collection while simultaneously preventing desiccation of the wound. | • Deep<br>• Low to Moderate to High Exudate*<br>• Secondary Intention | These dressings increase oxygen tension in the wound, improve blood flow to the wound bed, decrease bacterial count, increase granulation formation and minimise shear forces on the wound surface | • Intraoperative<br>• Postoperative<br>• In community /home care settings |
| **Basic wound contact layers** | | | | |
| **Absorbent dressing pads** | Absorbent materials are non-occlusive permeable dressings that allow the moisture to be absorbed to evaporate into the atmosphere. Many comprise of a soft viscose, polyester bonded pad that may or may not have external polyethylene contact layer.<br>'Superabsorbers' comprise of absorbent polymers (some of which expand on absorption of fluid) however this is a comparative not absolute term. | • Superficial<br>• Low exudate*<br>• Primary or Secondary Intention (when used as a secondary dressing)<br>• Superficial<br>• Low to moderate Exudate*<br>• Usually Secondary Intention (when used as a secondary dressing) | Additional absorbency of exudate over another primary dressing or a low adherent wound contact layer (see below) | Not generally recommended in theatre or the immediate post-operative phase. May be used as a secondary *dressing – occasionally* |

**Table 9. Wound dressings for the management of surgical wounds (after NICE 2018[40] and WHO 2016)[5] Continued**

| Dressings category | Dressing characteristics | Wound characteristics / healing intention | Primary clinical indications | Phase of Management |
|---|---|---|---|---|
| **Low-adherent wound contact layers (traditional)** | Low-adherent wound contact layers consist mainly of a fine mesh gauze impregnated with moisturizing, antibacterial or bactericidal compounds. They are either non-medicated (for example, paraffin gauze dressing) or medicated (for example, containing povidone iodine or chlorhexidine). As the dressing dries, fibrin from the wound bed causes temporary bonding of the dressing to the wound, thus permitting healing beneath it | • Superficial<br>• Low exudate*<br>• Usually primary Intention | These dressings are widely used, primarily as interface layers between the wound surface and a secondary absorbent dressing, usually made of cotton gauze, to prevent it from adhering to the wound surface and causing trauma upon removal | • Intraoperative (occasionally)<br>• Postoperative<br>• In community /home care settings |
| **Low adherent silicone wound contact layers** | | • Superficial but can be used to line a deep wound such as in combination with NPWT<br>• Usually low exudate* when dressing used for its prime clinical indication<br>• Usually primary but can be secondary when used in combination with NPWT | To minimise the risk of trauma at the wound surface and minimise the patients pain experience during dressing changes | • Intraoperative (occasionally)<br>• Postoperative<br>• In community/ home care settings |

***Exudate**: A generic term used to identify liquid produced from wounds[201 202]
Bates-Jensen[202 203] attempted to qualify the levels of exudate in relation to the terms often used by clinicians to describe the same
**Small (Low)**: wound tissues wet, moisture evenly distributed in wound, exudate affects 25% of dressing
**Moderate:** wound tissues saturated, drainage may or may not be evenly distributed in wound, exudate involves 25% to 75% of dressing
**Large (High):** wound tissues bathed in fluid, drainage freely expressed, may or may not be evenly distributed in wound, exudate involves 75% of dressing

dressing for the prevention of SSI,[128] NICE in the UK recommends covering surgical incisions with an appropriate interactive dressing at the end of the procedure.[40] The 2013 evidence update of the NICE guidelines agrees that no particular dressing type emerges as the most effective in reducing the risk of SSI, although silver nylon dressings may be more effective than gauze.[195] Furthermore in a recent Cochrane review there is limited evidence for the use of advanced wound dressings in the prevention of SSI. This is primarily due to a considerable lack of level one studies such as RCT's to determine comparative effectiveness of wound dressings in a controlled and systematic way.[150] Nonetheless, in clinical practice it is now generally accepted and reflected in various postoperative care plans (predetermined or developed further to assessment) or bundles that surgical dressings should be kept undisturbed for a minimum of 48 hours after surgery (longer if at all possible, up to 4 days) unless leakage occurs/associated symptomatology changes.[196,197] Further research

regarding dressing materials for the prevention of SSI is required, as there are still no specific level 1 evidence based guidelines regarding the type of surgical 'modern interactive' dressing to be used. However, given the available evidence (WHO, Nice guidelines), dressings are to be used based upon current clinical judgement, which may be guided by Table 9.

Most surgical wounds heal by primary intention and are covered with a dressing that acts as a protective barrier between the wound bed and the outside environment. A Cochrane review[150] sought to assess whether one type of dressing is better than any other in preventing surgical site infection. The authors reported a lack of evidence for the use of one dressing over another for prevention of SSIs. The NICE guidelines recommend covering surgical incisions with an appropriate interactive dressing at the end of the procedure.[26] A recent case control study of 834 participants who underwent either a total knee or hip arthroplasty yielded a statistically significant reduction between the intervention and control arms in SSI rate with use of silver nylon compared to standard dressing.[198] A literature review published in 2014 reported that silver-nylon dressings are associated with decreased SSI risk in small studies across several specialities, including colorectal surgery, neurosurgery, spinal surgery and some cardiac and orthopaedic procedures, although the authors recommend larger powered trials are required in these cohorts to determine the comparative effectiveness of silver-nylon dressing in the prevention of SSIs.[199] Results following a RCT of dialkylcarbamoyl chloride (DACC)-impregnated dressings compared with a control dressing, yielded evidence to suggest the use of DACC-dressings may assist in the prevention of SSI in caesarian-sections.[200,201] Furthermore, the WHO guidelines do not recommend using advanced dressings such as hydrocolloid, silver-containing dressings, polyhexamethylene biguanide (PHMB), over a standard dry absorbent dressing on primarily closed surgical wounds as an SSI prevention measure.[5] The WHO recommendation was based upon the low-level evidence and a limited number of level one studies available.

In Table 9 we describe the different dressing categories, their characteristics and healing intentions as well as their primary clinical indications and in which phase of management they could be considered. The following information should help you make your clinical decision.

## Surveillance

Surveillance is deined by the CDC's Guidelines for Evaluating Surveillance Systems as:

'*The ongoing and systematic collection, analysis, and interpretation of health data in the process of describing and monitoring a health event. This information is used for planning, implementing, and evaluating public health interventions and programmes. Surveillance data are used both to determine the need for public health action and to assess the effectiveness of programs.*'[151]

Surveillance of SSI is a key component of infection prevention and control programmes, as sustained surveillance has been shown to reduce rates of infection.[203] The risk of SSI should be monitored using standardised surveillance methodology to identify and investigate trends, guide identification of improvement actions and evaluate the effectiveness of these interventions. SSI surveillance is performed by reviewing microbiology reports and patient medical records, carrying out surgeon and/or patient surveys and screening for readmission and/or return to the operating room.[204] Feedback of SSI rates to surgeons and the surgical team is important to encourage ownership and active participation

for improvement of SSI rates.[205] Indeed, the European Council Recommendation on patient safety, including the prevention and control of health care-associated infections (2009/C 151/01), recommends 'performing the surveillance of the incidence of targeted infection types, using surveillance methods and indicators as recommended by ECDC and case definitions as agreed upon at Community level in accordance with the provisions of Decision No 2119/98/EC'.[206] However, it is acknowledged that SSI surveillance is challenging and requires expertise, time and resource dedication.[5]

Surveillance is an important subject not only in the acute care but also in the home care setting. The transition of the surgical care from the acute care to the home care setting poses special challenges that may increase the morbidity of post-discharge SSI.[207] At home, patients have the primary responsibility for problem recognition and wound care. A supervised wound assessment and patient-provider communication is missing. A comparative descriptive study of 76 patients with wounds showed that patients verbalised their concerns about going home with a wound as they have only minimal or ineffective discharge teaching.[208] This may result in a lack of knowledge and awareness about SSI and therefore they may miss an early infection.[209] Evidence suggests that a missing or an inadequate post-discharge communication may contribute to poorer outcomes resulting in hospital readmission.[141]

## Conclusion

Prevention of surgical site infections is complex and requires a multidisciplinary approach including patient and carer engagement. While published studies are contributing to the gradually growing evidence base for the use of dressings or ciNPT as a prophylactic measure in the prevention of SSI, further well designed and powered trials are required to determine the efficacy of dressings in the prevention of SSI. There is a considerable evidence base in the perioperative management of the patient, with standardised guidelines (WHO and NICE) for prevention of SSI during this phase of the patient's journey.

# 6. Principles of postoperative care

KEY POINTS

- Wounds should be covered with a protective dressing for at least 48 hours
- Wound dressings are only a part of the postoperative management of wound
- Postoperative management includes assessment of patient related lifestyle factors, comorbidities and risk of complications
- Use aseptic technique at all times
- Surgical wounds healing by secondary intention should be managed by health professionals with tissue viability expertise and dressed with appropriate dressings

Wound dressings are only one part of healing postoperative wounds and there are a number of other intrinsic and extrinsic factors that are related to wound healing after surgery (as described in Chapter 2). The clinical postoperative management of the patient's surgical wound must include an assessment of patient-related lifestyle factors and comorbidities, as these may contribute to delayed healing and postoperative complications such as surgical site infection.

The primary goals for acute wound management are to protect the approximated margins, minimise scar formation and allow the wound to heal as rapidly as possible without complications. Wound dressings applied on the wound play an important role in supporting healing. Appropriate dressing choice must meet wound requirements, which can vary according to the phase of the healing process.

For a detailed overview of wound dressings for prevention of SSI and management of surgical wounds see Table 9. Acute wound management approaches will vary due to the location and nature of the wound, therefore an evidence-based multidisciplinary approach provides the basis for wound healing (Table 3).

The primary principles for acute wound management include:

- Promote healing by primary intention
- Assess and reduce the risk of complications (infection, dehiscence, seroma, haematoma)
- Use aseptic technique at all times (Fig 14)
- Protect the incision site
- Promote patient recovery and wellbeing.

Regardless of procedure, all wounds must be kept as clean as possible to prevent the occurrence of surgical site infection. The NICE guidelines have made recommendations for the prevention of SSI in the postoperative phase.[40]

## How to dress the wound in the outpatient setting

In surgical wounds healing by primary intention, dressings act as semipermeable barrier to prevent bacterial contamination from the external environment. The main purpose of the use of a surgical dressing over an incisional wound, healing by primary intention, is to control any postoperative bleeding, absorb exudate, ease pain and provide protection for newly formed tissue.[30] Dressing change serves for examination of the

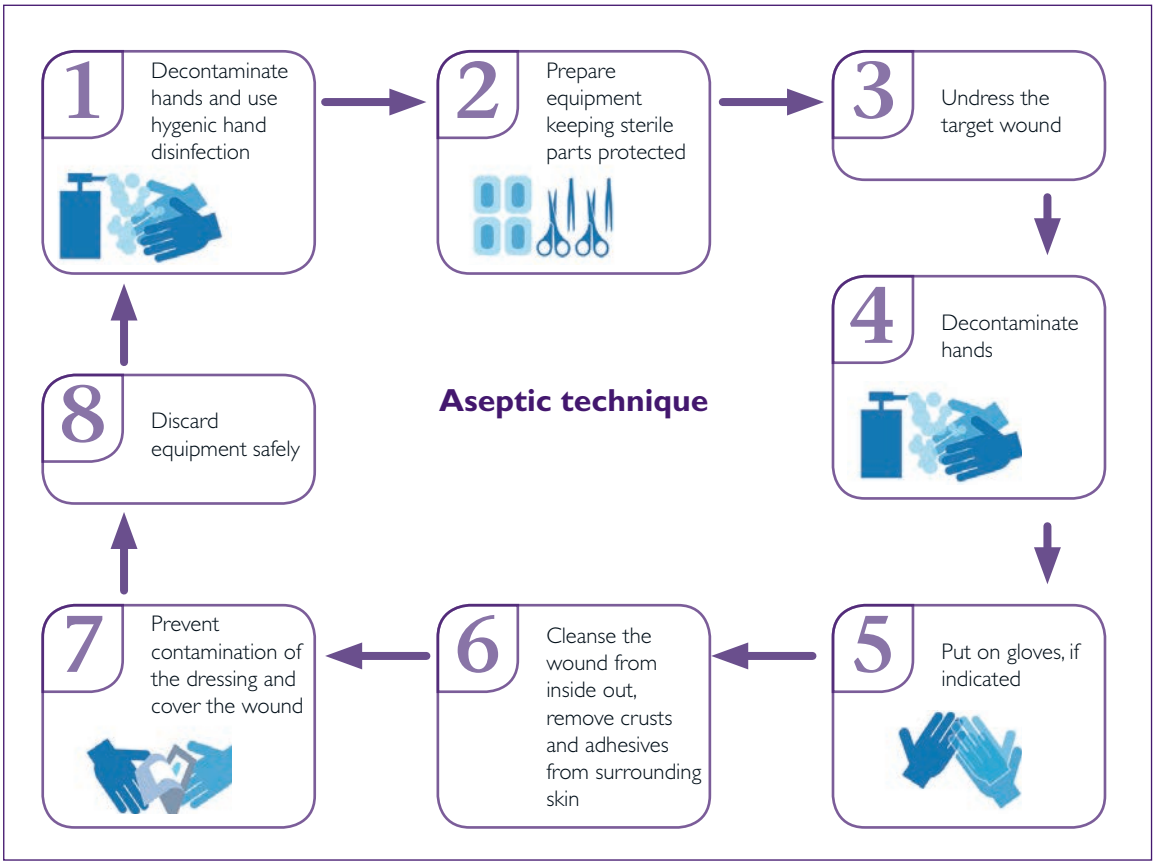


Fig 14. Aseptic technique (adapted from Wilson (2019), Infection Control in Clinical Practice, Elsevier Health Sciences)[210]

wound, lavage/cleansing, suture replacement, drains removal, drug application and exchange of dressings. If change of dressing is required in the first 48 hours of the postoperative phase the NICE SSI (2018) guideline update recommends using an aseptic technique (Fig 11).[40,210] This technique helps prevent contamination of the surgical wound by ensuring that only sterile objects and fluids come into the contact with the wound. Aseptic technique requires adequate hand hygiene, the use of appropriate personal protective equipment, preparation of the environment and maintenance of a sterile field at all times. Current NICE guidance (2018)[40] recommends to use sterile saline for wound cleansing up to 48 hours after surgery and to advise patients that they may shower safely 48 hours after surgery.[174] If the surgical wound has separated or has been surgically opened to drain exudate, tap water for wound cleansing may be used after 48 hours of surgery.[36] There is no need to use topical antimicrobial agents for surgical wounds that are healing by primary intention to reduce the risk of SSI.[211,212] Patients with sutured surgical wounds should be instructed to keep the wound clean and dry and to report any unusual changes in the wound area to their attending physician.

## How to dress the wound in the home care setting

Providing health care in the home care setting may present special challenges and health hazards such as infection control. To prevent infections and to offer the patient and her/his carer best practice wound care at home, the EWMA Home Care Document[140] suggests the following procedure:

- Use safe products (with minimal collateral effects)
- Employ simple-to-use products (to reduce risk of mistakes and anxiety from the informal carer or the patient)
- Use disposable products where possible (to reduce risk of transmission of infections from home care environment)
- Use products that reduce pain
- Use products that have a wide range of applications (i.e. not just very specialist products for difficult wounds but products that can be used daily on simple wounds and have, when necessary, the features required for the

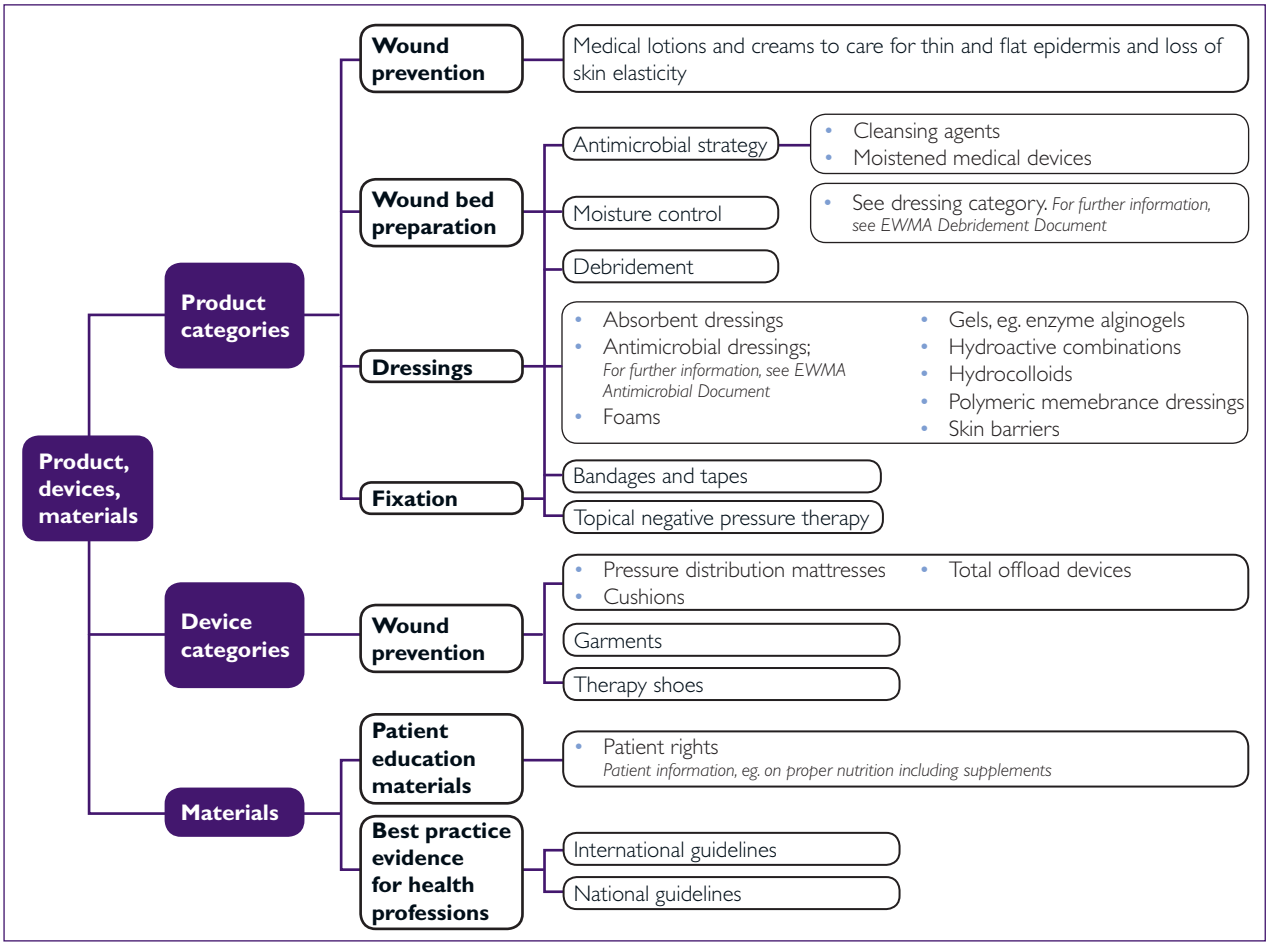


Fig 15. Recommendations for products, devices and materials available for home care wound care.[140]

treatment of more complex situations).

The following key points for health professionals when selecting a product in home care wound care should be followed (Fig 15):

- Wound dressings can be used through extended parts of the healing continuum
- Wound dressings should be non-adherent, and should eliminate or minimise need for wound bed cleaning
- Wound products are easy to use and access, especially if patient or informal carer takes part in wound management
- Wound products enable the lowest overall cost, including the cost of home care services and patient costs
- Wound products are eco-friendly.

In the home care setting, community health professionals as well as visitors may transmit germs to patients. The following recommendations for patients are adapted from the Australian Health and Medical Research Council (NHMRC).[213]

**Hand hygiene:**
- Use alcohol-based hand rub on a regular base.

**Personal protective equipment:**
- Use disposable gloves and plastic aprons.

**Cleaning:**
- Use detergent and water for general cleaning. Disinfectant is needed as well when infection is known or suspected
- Encourage a tidy environment for a patient's home environment.

**Managing spills:**
- Clean spills promptly, dispose of contaminated materials and perform hand hygiene.

**Clothing and personal hygiene:**
- Change clothing daily or when soiled. Wear short sleeves, or roll up sleeves above the elbows
- Remove clothing that is not washed daily (such as cardigans and jackets) during personal care activities, food preparation and cleaning activities; and ensure lanyards and mobile phones are secured
- Wear non-slip closed-in shoes to protect your feet against accidental injury/spillage during home visits
- Keep jewellery to a minimum and do not wear gel, acrylic or false fingernails
- Keep finger nails cleaned and trimmed.

**Food handling:**
- Perform hand hygiene before and after handling food
- Clean work areas with detergent and water and allow them to dry before preparing food
- Food should be consumed by the client shortly after preparation or covered and placed in the fridge.

**Multi-resistant organisms:**
- Use standard precautions (e.g. hand hygiene, gloves and gown if risk of blood or body fluid splash; goggles if high risk of splash to the eye).
- Place all disposable items in the home's general waste bin (except sharps, which require a specialised sharps container).

**Presence of pets:**
- Pets should be kept away when changing a dressing.

Most wounds should be covered with a protective, non-adherent dressing for at least 48 hours to ensure sufficient epithelialisation and to protect them from contamination (Fig 16).

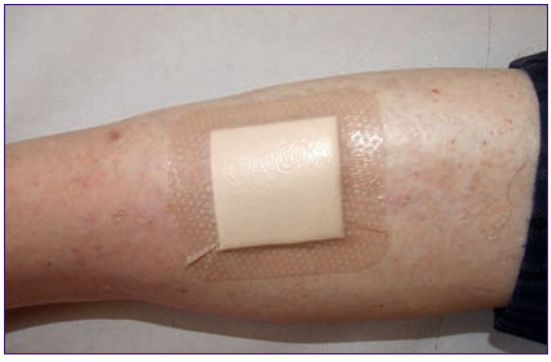

Fig 16. Wound dressing applied to the incision

Surgical wounds healing by secondary intention should be dressed appropriate with dressings based on moist wound healing principle (according to current wound needs), approved antiseptic solutions (lavage or as a poultice), NPWT techniques etc. Health professional with tissue viability expertise should be responsible for selection of the dressing and treatment method.[40]

# 7. Wound assessment and diagnostics

KEY POINTS

- Clinical signs of SSI include heat, redness, swelling, elevated body temperature and purulent exudate from the wound or the drain
- Early diagnostics of comorbidities and treatment of ischaemia can decrease the number of surgical site complications
- Important to sample for microbiological diagnostics
- Pus and biopsy samples enable the use of microscopy and additional diagnostic methods, including molecular tests

When possible, an interdisciplinary team of specialists should undertake the assessment and diagnosis of a possible SSI. These wound teams usually comprise clinicians (e.g. specialised nurses, physicians and surgeons), microbiologists, pharmacists, prosthetists/orthotists and others).[121] While the clinician will be responsible for the management of the patient, the microbiologist can play an important role in advising on whether to treat a wound with antibiotic (systemic) or antiseptic (topically) and, if so, on the systemic antibiotic treatment. Engagement of microbiologists can facilitate successful surgical wound infection management and assist in the control of antibiotic usage, potentially stemming the increase of antibiotic-resistant bacteria.[116]

## Early signs of infection

The use of diagnostic testing can provide the clinician with the appropriate level of information to enable an informed diagnosis, alongside clinical assessment. While the clinical signs and symptoms include heat, redness, swelling, elevated body temperature and exudate from the wound or the drain (Fig 3–5 and Table 1 presented in Chapter 3), sampling and testing of tissue and fluids enable early identification of pathogenic activity and determining the appropriate management regimes.[117]

Foreign bodies inserted such as implants must be monitored for early diagnosis and treatment of suspected biofilm activity on the implant.[214,215]

## General assessment of a patient

General assessment of a patient is often designed for detection of the most important risk factors and comorbidities related to SSIs. This often includes the patient's nutritional status, medication (such as glucocorticoids, anti-cancer drugs, anticoagulants), presence of diabetes mellitus and other metabolic illnesses, malignancies, peripheral arterial occlusive disease and serious infectious diseases in medical history.

## Vascular assessment

The main goal of vascular assessment is to diagnose impairments in the patient's macro- and microcirculation before planned surgery and to give priority to revascularisation. This approach has the potential to reduce the impact of untreated limb ischemia on tissue reparation and decrease the number of surgical site complications.

### Box 3. Z-swabbing[217]

The swab should be rotated between the fingers as the wound is swabbed from margin to margin in a 10-point, zigzag fashion

### Box 4. Levine method swab culture[218]

1. Cleanse wound with normal saline
2. Remove/debride nonviable tissue
3. Wait 2–5 minutes
4. If ulcer is dry, moisten swab with sterile normal saline
5. Culture the healthiest looking tissue in the wound bed
6. Do not culture exudate, pus, eschar or heavy fibrous tissue
7. **Rotate the end of the sterile alginate-tipped applicator over a 1cm$^2$ area for 5 seconds**
8. Apply sufficient pressure to swab to cause tissue fluid to be expressed
9. Use sterile technique to break tip of swab into collection device designed for quantitative cultures

Rest pain and claudication are the most important complaint when taking patient case history. During clinical examination, skin integrity and skin appendage changes, muscle hypotrophy, superficial skin temperature (compared with the opposite site of the limb) and palpation of arterial pulses are the main focuses. For assessing the severity of peripheral arterial occlusive disease the ankle brachial pressure index (ABPI) is measured or duplex ultrasonography (as the non-invasive examination) performed. Before revascularisation CT, X-ray or MRI angiography are performed to describe the patient's circulation system with present stenosis or arterial occlusions.

## Sampling techniques

Sampling in the case of suspected SSI is important, but also something which may not be readily accessible.[216] Several sampling methods are possible, providing different sample specimens. There is much discourse on the effectiveness of Z-swabbing or Levine (or even modified Levine) swabbing technique is mostly representative of bacterial load of the wound (Fig 17).[217,218] [217,218] Besides being the easiest method to obtain sample species, it is also the sample species which provides the most challenges on interpretation of clinical significance — there can be a high degree of colonisation by the skin microbiota, which leads to the question to what extent the bacteria are involved in the pathogenesis of the SSI. In addition, the surgical wound can be colonised with normally pathogenic bacteria, but since the sample technique is superficial, the presence of such a species is not necessarily involved in the aetiology of the SSI.

Sampling of wound secretion, pus, surgical biopsies or debridement, provide the possibility to improve the judgment of the relevance of the cultured bacteria by microscopy (Box 3–4, Fig 18).[217,218] Those samples are representative of the pathogens most likely to be causing the SSI.[217,219] Whether several biopsies are necessary or improve the diagnostics of SSI is unclear. However, for hard-to-heal wounds there is a marked difference in the distribution of the bacteria in the wound bed.[220] For deeper SSIs, including organ-associated SSIs, surgically acquired or aspirated material is required to provide best microbiological diagnosis. Finally, in the case of an implant-related SSI, removal of the foreign body and sending this to the clinical microbiological lab with adjacent tissue samples can provide relevant diagnostic information – especially if a new implant has to be inserted (Fig 19 and 20).[214] For more details regarding sampling techniques, see Appendix 2.

## Lab procedures

Lab procedures include the use of microscopy, culture-based methods or molecular techniques such as 16S polymerase chain reaction (PCR) and sequencing.

For pus or wound secretions, culturing under anaerobic conditions for 5–7 days, or sometimes longer is required. In addition, all cultured isolates

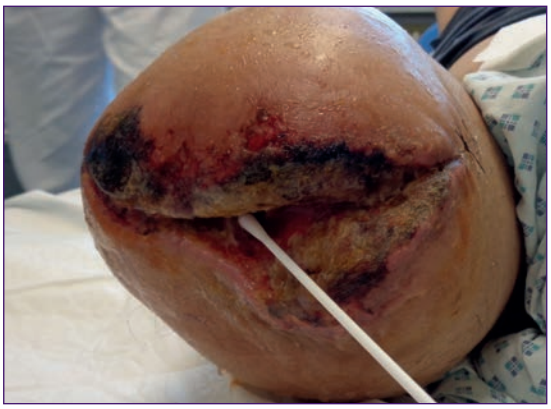

Fig 17. Levine method swab culture of the infected stump incision

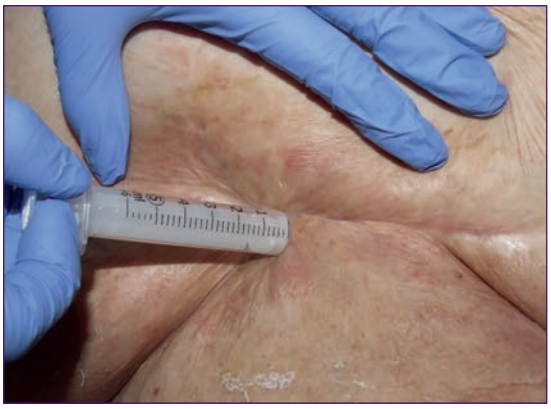

Fig 18. Pus collection syringe aided

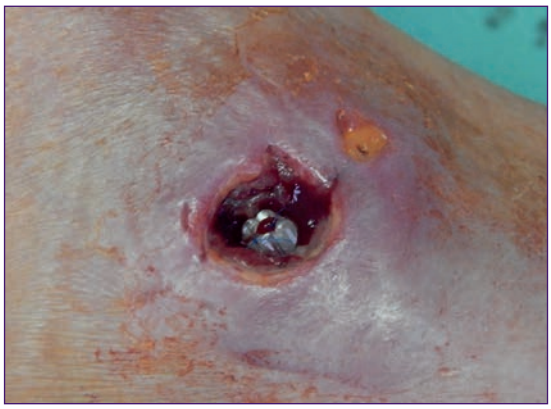

Figure 19. Infected vascular prosthesis before explantation

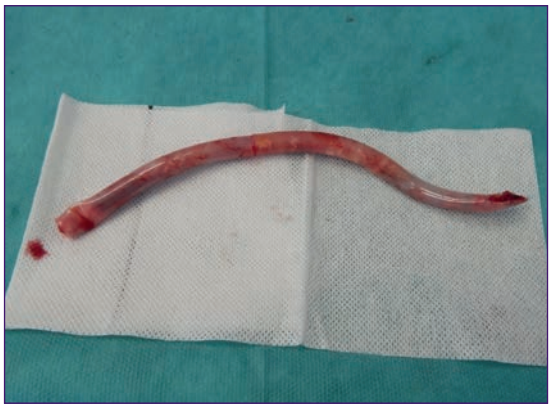

Fig 20. Infected vascular prosthesis after explantation

should be identified and have an antibiotic susceptibility testing performed. This should be supplemented with microscopy of a Gram-staining of slides from the material, to evaluate the presence of microbes in the material. Inflammation can also be estimated on the Gram-stained slide or can be supplemented with a Giemsa stained slide. If more exotic pathogens are suspected special staining can be performed including the acid-fast staining for mycobacteria (Appendix 2).

## Conclusion

Concurrent wound assessment allows early diagnosis of SSI. Untreated ischaemia is a significant risk factor of surgical site complications including infections. Detailed general assessment of a patient can detect the most important risk factors and comorbidities related to SSIs. Sampling and testing of tissue and fluids enable early identification of pathogenic activity and determining the appropriate management regimes.

# 8. Treatment of SSI

## KEY POINTS

**Non-surgical treatment**

- Results from microbiological investigations should inform the choice of antibiotic therapy
- Scoring of wound and patient clinical state should inform the choice of antibiotic
- Important to choose antibiotics with acceptable penetration to the target area
- Consider combination antibiotic therapy to prevent development of antibiotic resistance
- Consider impact of biofilm

**Surgical treatment**

- Surgical treatment can be a part of the SSI diagnosing procedure (e.g. release and drainage of pus)
- If indicated, surgical treatment should be done as soon as possible after diagnosing the infection
- The type and extent of surgical treatment depends on the range and seriousness of infection, type of previous surgery, presence of implants
- Non-surgical techniques should be considered as a part of complex treatment

Surgical treatment of SSI comprises procedures carried out immediately after diagnosis of SSI. Presence of fluid collection within the wound together with clinical signs and symptoms of infection are indications for review of the wound (depending on the extent of infection) and obtaining a swab or tissue samples for microbiological assessment. The type and extent of surgery required to manage the infection depends upon the extent of the infection, the presence or absence of prosthetic material and the patient's general health condition.

In superficial SSI wound margins separation and skin suture removal can be sufficient. Drain the wound using non-adherent antiseptic dressing straps, keep the skin opened and dress the wound with antiseptic dressings. Cleansing the wound by antiseptic lavage through the syringe may also be appropriate. Surgical debridement has an important role in the open wound management. Deep SSIs may require a more aggressive approach with careful revision of fascia and affected muscles, especially in cases of chronic limb ischaemia. Treatment of organ space SSI often requires admission into the acute care setting, targeted antibiotic treatment, drainage of the pus collection and complex management of the infection with the focus according to affected organ.

## Non-surgical treatment

Indications for antibiotic therapy to treat SSI include impaired wound healing, uncontrolled spreading of the wound infection to the adjacent skin and deeper layers, systemic signs of infection and systemic spreading of the infection to the blood stream. When antibiotic therapy is necessary to manage an SSI several things are important to consider in making the decision — microbiological results, the anatomical position of the SSI, previous antibiotic therapy, knowledge of local antibiotic resistance patterns, the clinical status of the patient and mode of administration of the antibiotic(s).

If there are no microbiological results to be guided by, obtaining a sample before use of antibiotic therapy is preferable if the condition of the patient allows for this.[223,224] The more septic the patient is the broader the spectrum has to be and the earlier the treatment has to be initiated;[223,225] also, refer to your local sepsis clinical pathway/guideline in the case of sepsis.

## Antibiotic coverage

Knowledge of local hospital or regional antibiotic resistance patterns is very important — especially

as there can be substantial differences between countries and regions in this respect. Surveys or reports on hospital, and even department situations are also helpful when using antibiotic therapy. Since the situation on antibiotic resistance is dynamic, such reports or surveys should be conducted by the local clinical microbiological department on a regular basis. Reports on outbreaks of specific microorganisms, including resistant pathogens, should also be taken into account.

Another aspect of antibiotic selection is the pathogens expected to be causing SSI in specific anatomical sites. There is a substantial diversity depending on the site of infection as well as the severity or depth of the SSI or the surgical procedure performed.[2,226] For procedures involving implanted or graft material, e.g. orthopaedic, cardiac, vascular or neurosurgery, as well as breast surgery, *Staphylococcus aureus* (which may be MRSA, especially in countries with high prevalence of resistant strains) or Coagulase negative staphylococci (CoNS) are the dominant bacteria identified.[227,228] However, Enterobacteriaceae cause a quarter of SSI in clean surgery and more than half in clean contaminated procedures, with evidence that they are increasing in importance as a cause of SSI.[226]

The picture is relatively different concerning abdominal surgery where Gram-negative bacteria *Enterobacteriaceae* and anaerobic bacteria are most frequently identified.[2] If the surgery is on the gastroduodenal tract, streptococci are also frequently present.[2]

Urogenital surgery most frequently involves Gram-negative bacteria, whereas obstetric and gynaecological surgery also often involves enterococci, haemolytic streptococci Group B and anaerobic bacteria.[2]

Comparable results have been reported from the Cardinal Health Outcomes Research Database,[216] which also indicates that polymicrobial SSI where more than one pathogen is present are frequent.[2,216]

The purpose is of course also to obtain a susceptibility testing of the identified pathogens to be able to optimise the antibiotic therapy best.

## Systemic antibiotic therapy

Systemic antibiotic therapy of SSI, either by the intravenous route or by oral administration is not only a matter of antibiotic coverage (ie. the antibiotic spectrum). A substantial challenge is the skin focus, further complicated by the compromised blood supply due to the surgical procedures *per se*. If necrosis is induced to microbial virulence, challenges obtaining sufficient antibiotic concentrations at the site of infection is even worse. It is highly important that the antibiotic actually reaches the infection-inducing bacteria in a sufficient concentration, and most antibiotics have relatively reduced penetration into the skin (Table 10).[229] Drugs with good bioavailability are preferred if the oral route is used. Most commonly used β-lactam antibiotics only reach the skin in a concentration of 50% or less of the concentrations obtained in the serum.[229] Meropenem and aztreonam seem to obtain relatively high skin concentrations.[229] Similarly, flouroquinolones and azithromycin also have good skin accessibility, azithromycin shows even supra-serum concentrations.[229] However, for macrolides the majority of the concentrations are located intracellularly, including in the inflammatory cells. Surprisingly, concentrations of fucidic acid and rifampicin did not reach high skin concentrations, rifampicin only reached 20% of the corresponding serum concentration.[229] The reason may be that the measurement was after a single dose only or measurements in blisters — a hydrophilic milieu.[229]

Trimethoprim with sulfamethoxazole reached independent concentrations of 40–50 %, the latter lower than trimethoprim.[229] Doxycyclin showed a moderate skin penetration relative to the serum concentration of approximately 50%.[229] Although, serum concentrations are also low and most antibiotic may be located intracellularly.

An important issue on antibiotic penetration to the skin is the specimen material used for measurements. In almost all the cases referred to the blister method was used.[229] This is not necessarily representative. A more recent study used micro dialysis to assess the antibiotic concentrations of the muscles and subcutis, in addition to the blister method.[230] In accordance with the statements above, meropenem (and doripenem) reached acceptable levels of approximately 60%. However, for ertapenem significant differences were obtained, depending on the used detection method. In micro dialysis ertapenem only reached a level of 5–10% of the corresponding plasma level, comparing area under the curve (AUC) levels.[230] Lipopeptides (daptomycin) and glycopetides (vancomycin) had poor penetration to the skin by means of micro dialysis.[230] Oxazolidinones (linezolid and tedizolid) reached good skin penetration, supra-plasma skin levels were obtained, and glycylcycline (tigecyclin) also had good skin penetration (all micro dialysis).[230] Trimethoprim showed supra-plasma levels whereas a sulphamethoxazole only reached 20% of the plasma levels (skin blister, AUC) (Table 10).[230]

These measurements are important to take into account when introducing antibiotic treatment of a SSI. If sufficient concentrations for optimal PK/PD parameters for best outcome cannot be obtained, induction and selection of antibiotic resistant pathogens will occur and the SSI will become even more difficult to treat. This has the additional risk of the potential for dissemination of resistant strains in the hospital environment.

NPWT has been recommended as a method to increase the antibiotic concentrations in wounds.[231] In 32 burn or trauma patients NPWT was found to increase concentrations to near the serum level or even above for three β-lactam antibiotics and tazobactam, ciprofloxacin and most pronounced for vancomycin.[231] A therapeutic consequence could be that when NPWT is used, antibiotics with poor skin penetration may be used—although more data are needed to support such a conclusion.

The issues described above illustrate the importance of prescribing maximum doses of antibiotics. Most antibiotics are well tolerated with low toxicity and a high therapeutic index, with aminoglycosides as the most obvious exception. In addition, most antibiotic treatments of SSI are short term. Increasing dosage to the levels used for meningitis to cross the blood-brain barrier is an open question to be considered.

## Topical antibiotic therapy

Topical antibiotic therapy can be considered an alternative approach to compensate low penetration of antibiotics to the skin site of SSIs. However, in some clinical specialisations topical antibiotics still have an important role in topical treatment of superficial infections (such as opthalmology). In wound management, the topical usage of antibiotics is related with risk and should be avoided. It is a well-known fact, that improper use induces resistance to antibiotics. This makes the treatment less effective and more costly. The increase of resistant pathogens is now a global issue across all fields of human and animal medicine.[232] Application of systemic antibiotics should be reserved for prophylaxis and treatment of serious bacterial infections in high-risk patients when other treatment options are not available or ineffective. Reduction in the use of antibiotics via Antimicrobial

Stewardship Programmes (ASPs) can reduce antibiotic resistance.[233] The ASP goals for wound management focus especially on minimising the unnecessary use of antibiotics, overly broad-spectrum treatment regimen avoidance and exclusion of prescribing antibiotics for uninfected wounds. The combination of infection control measures and antimicrobial stewardship can lead to a greater reduction in antibiotic resistant bacteria.[121]

## Impact of oxygen

Oxygen's impact on antibiotic efficacy has attracted substantial attention in recent years. It has been reported that β-lactam antibiotics and fluoroquinolones activity is dependent on intrabacterial accumulation of cytotoxic reactive oxygen radicals.[234] Metabolic changes are induced in the bacteria as a stress response with superoxide formation, displacement of iron from the iron clusters and formation of toxic reactive oxygen radicals.[115] The generated and accumulated reactive oxygen radicals react with the bacterial DNA, lipids and proteins contributing to the killing effect of the bactericidal antibiotics.[234] The effect has been shown in an experiment exposing *Pseudomonas aeruginosa* to ciprofloxacin under anaerobic conditions.[235] Brochman et al. reported that killing *Pseudomonas aeruginosa* was effective in the presence of oxygen but almost completely stopped in absence of oxygen,[235] this was followed by an accumulation of oxygen radicals. In contrast, bacterial killing by colistin was independent on the presence of oxygen and was not accompanied by accumulation of toxic oxygen radicals.[235] Similar observations have been demonstrated in *Pseudomonas aeruginosa* biofilms.[236] Another consequence of a combination of relatively low antibiotic concentration in the SSI and intrabacterial accumulation of toxic oxygen radicals, is an increased rate of DNA damage, and thereby increased induction of antibiotic resistance.[237]

**Table 10. Antibiotic penetration to the skin after systemic administration**

| Antibiotic | Penetration to skin compared with serum/ plasma concentrations | Comments (mode administration, method) |
|---|---|---|
| **Benzylpenicillin** | + | I.M. skin window |
| **Flucloxacillin** | + - ++ | I.V. blister |
| **Ampicillin/ amoxicillin** | ++ | I.V. threads/blister |
| **Cefuroxime** | ++ | I.V. threads |
| **Meropenem** | +++ | I.V. blister. microdialysis |
| **Ertapenem** | + | I.V. microdialysis |
| **Ciprofloxacin/ Levofloxacin** | +++ | Oral. blister. microdialysis. * |
| **Fusidic acid** | ++ | Oral. blister |
| **Rifampicin** | + | Oral. blister. * |
| **Trimethoprim with sulfamethoxazole** | ++/++ | Oral. blister |
| **Doxycyklin** | ++ | Oral. blister |
| **Azithromycin** | ++++ | Oral. blister. * |
| **Clindamycin** | + | Oral. skin window. * |
| **Vancomycin** | + | I.V. microdialysis |
| **Teicoplanin** | ++ | I.V. blister |
| **Daptomycin** | + | I.V. blister. microdialysis |
| **Linezolid/ Tedizolid** | +++ - ++++ | I.V/oral. microdialysis |
| **Tigecyclin** | +++ | I.V. blister. microdialysis |
| **Gentamicin/ Tobramycin** | + - ++ | I.M. skin window |

+(poor) <20%;++; fair 30–70%; +++similar to serum concentration 70–100%; ++++supra serum conc >100%; *High intracellular concentration; IV—intravenous; IM—intramuscular

From these observations and knowledge on the antibiotic effect, it has been obvious to test whether exposure to excess oxygen by means of hyperbaric oxygen therapy (HBOT) could

improve the bacterial killing.[234] Studies in biofilm models have investigated the HBOT effect. An increased killing effect on *Pseudomonas aeruginosa* of ciprofloxacin in conjunction with HBOT has been observed in a biofilm model.[238,239] In an animal model of left-sided *Staphylococcus aureus* endocarditis, HBOT was shown to improve bacterial killing by tobramycin as well as reducing levels of inflammatory markers.[239,240]

## Conclusion

In conclusion, it is recommended to be reasonable consistent in the use of antibiotic therapy for the treatment of SSIs. Treatment should be guided by site of the infection, the condition of the patient, and microbiological diagnosis. Sufficient, if not high antibiotic dosing should be used. Termination of the antibiotic therapy should occur when the infection is resolved.

# 9. Conclusion

Surgical site infections are an important health-care associated complication with a potential to be prevented in some cases. They exert a considerable effect on patient morbidity, mortality and QoL.

Adherence to evidence-based guidelines and recommendations for SSI prevention is necessary to reduce the risk of the patient developing SSI following surgery. These include clinical and surgical practices that minimise the number of microorganisms introduced into the operative site, prevent the multiplication of microorganisms at the operative site, enhance the patients' defences against infection and prevent access of microorganisms into the incision postoperatively.

The primary principles of acute wound management include promotion of healing by primary intention, protection of the incision site, use of aseptic technique, prevention of wound-related complications and promotion of patient recovery and wellbeing.

Proper sampling technique can assist in the identification of the causative microorganism(s) and selecting appropriate antibiotic treatment, if indicated. It is recommended to be conservative in the use of antibiotic therapy of the prevention and management of SSIs. Treatment should be guided by the site of the SSI, the condition of the patient and microbiological diagnosis. Antimicrobial agents should be administered in a sufficient dose to effective treat the infection. If indicted, surgical treatment should be undertaken as soon as possible after diagnosing the infection. The type and extent of surgical treatment depends on the extent and severity of infection, type of surgery and presence of an implant.

From the patient's perspective, an individualised approach with the aim of lowering the impact of identified risk factors is essential. This requires communicating with the patient and their carers about the planned surgery, possible complications, safety precautions and preventive procedures. Consistent communication between health-care providers and patients, communicating medical reports in a timely and expedient manner, clearly defined roles and the education of patients and health professionals, are some of the factors which can improve the outcomes across inpatient and outpatient settings.

# 10. Future perspectives

In this final chapter the authors responsible for this EWMA position document agree on the following perspectives of the prevention, diagnostics and treatment of SSI.

It is crucial that development and validation of objective definitions related to wound infection and SSI are considered; without clear definitions there will be a failure for accurate recording of SSI incidence rates.

## Prevention and risk assessment

The research and evidence has identified that SSIs impose a substantial burden on both the patient and the healthcare system, yet little is known about the true rates of infection and the cost in the post-discharge follow-up. The subsequent reporting and publication of findings are particularly limited. Surgical infection prevention and control teams need to work collaboratively to increase effective surveillance of SSI employing standardised and validated methods, using the results to drive improvement and reduce the risk of SSI. Rigorously validated and standardised risk assessment tools that are designed to identify patients at risk of SSI, need to be fit-for-purpose for maximum clinical impact. Risk profiling of the patient can assist the clinician in understanding the risk level of the patient and provide an opportunity to implement preventative measures based upon a sound risk assessment. Implementation of any therapy or dressing must be determined through the use of a risk assessment of the patient and surgery as a whole not determined by a single risk factor.

There is evidence that care bundles for the prevention of SSI promote positive outcomes and these should be reviewed and adherance with them measured and recorded.[241] There is limited level one evidence supporting the use of antiseptic dressings[128] or the use of NPWT in prevention of SSI; as such, there is an urgent need for suitably powered, high-quality trials to evaluate the effects and outcomes of these types of therapeutic interventions.

## Treatment

Early and reliable identification of SSI is essential in order to ensure timely and appropriate treatments. A multidisciplinary approach to treatment is required and should be underpinned by a minimum standard of interprofessional education supporting linking and understanding of theory into clinical practice to identify, reduce and manage SSIs. Use of antibiotics should be guided by relevant laboratory results and assessment of the patient, to include localisation of the SSI, any signs of sepsis and local policies.

## Diagnostics

Health professionals are constantly seeking to identify and implement evidence-based diagnostics in the identification and management of SSI. Digital photography has been evaluated as increasing diagnostic confidence in identification of SSI although this can be subjective.[242] Infra-red thermography is demonstrating positive results in being able to detect temperature changes associated with wound infection and inflammation.[243] Early and reliable identification of SSI is essential in order to ensure timely and appropriate treatments. A multidisciplinary approach to treatment is required and should be underpinned by a minimum standard of inter professional education supporting linking and understanding of theory into clinical practice to identify, reduce and manage SSIs. Use of antibiotics should be guided by relevant laboratory results and assessment of the patient, to include, localisation of the SSI, any signs of sepsis and local policies.

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# Appendix

## Appendix 1: GRADE recommendation explanation

The committee used the GRADE approach (Grades of Recommendation Assessment, Development and Evaluation) system[153] to rate the quality of evidence (confidence in the estimates) and grade the strength of recommendations. This system, adopted by more than 70 organisations, categorises recommendations as strong **GRADE 1** or weak **GRADE 2**, based on the quality of evidence, the balance between desirable effects and undesirable ones, the values and preferences and the resources and costs.

**GRADE 1** recommendations are meant to identify practices where benefit clearly outweighs risk. These recommendations can be made by clinicians and accepted by patients with a high degree of confidence. **GRADE 2** recommendations are made when the benefits and risks are more closely matched and are more dependent on specific clinical scenarios. In general, physician and patient preferences play a more important role in the decision-making process in these latter circumstances.

In GRADE, the level of evidence to support the recommendation is divided into 3 categories: ***A (high quality)***, ***B (moderate quality)***, and ***C (low quality)***.

### GRADE approach to treatment recommendations

| Recommendation | Benefit *versus* risk | Quality of evidence | Comment |
|---|---|---|---|
| **1A** | Clear | High: consistent results from RCTs or observational studies with large effects | Strong recommendation, generaliseable |
| **1B** | Clear | Moderate: RCTs with limitations and very strong observational studies | Strong recommendation; may change with further research |
| **1C** | Clear | Low: observational studies<br>Very low: case series, descriptive reports, expert opinion | Intermediate recommendation; likely to change with further research |
| **2A** | Balanced or unclear | High: consistent results from RCTs or observational studies with large effects | Intermediate recommendation: may vary with patient values |
| **2B** | Balanced or unclear | Moderate: RCTs with limitations and very strong observational studies | Weak recommendation; may vary with patient values |
| **2C** | Balanced or unclear | Low: observational studies<br>Very low: case series, descriptive reports, expert opinion | Weak recommendation; alternative treatments may be equally valid |

Adapted from Guyatt G et al. Applying the grades of recommendation for antithrombotic and thrombolytic therapy.[243]

# Appendix 2: Microbiological assessment for surgical site infection (SSI), investigation of the swabs

| **Clinical form of SSI** | **Superficial SSI: skin and soft tissue infection, presence of abscess or purulent discharge within an incision, infected wound dehiscences and skin lesions at the place of surgery** | **Deep-seated and organ affecting surgical site infections** | **SSI associated with osteomyelitis** | **Implant-associated SSI** |
|---|---|---|---|---|
| **How to diagnose** | Clinical presentation of infection, local signs of infection, microbiological assessment of the wound | Full clinical assessment of the patient and the place of surgery, plain X-rays and further imaging (e.g. MRI scan, CT scan, ultrasound), blood cultures (particularly in acute cases), organ, bone and/or soft tissue biopsies and/or surgical sampling | | Clinical presentation of infection: ***Acute infection:*** hot, swollen painful joint, febrile or septic patient, inflammatory markers raised. ***Chronic infection:*** painful and stiff joint, inflammatory markers slightly raised, presence of a discharging sinus. Joint aspirate for cell count, culture and histology, periprosthetic joint biopsy (with sonication to disrupt the bacterial biofilm on the prosthetic material), blood cultures, explanted prostheses microbiological investigation, plain X-rays, ultrasound (fluid in the joint itself), nuclear radiology, magnetic resonance imaging, computerised tomography |
| **Recommended type of specimen** | No or low wound exudation: skin swab, swab from superficial surgical wounds, swab of pus, irrigation-aspiration method. Copious discharge: microbiological assessment of a pus or exudate | Pus, tissue biopsy (percutaneous thin needle biopsy samples, an open biopsy procedure at operation), artificial materials sent to the laboratory (prosthetic cardiac valves, pacemakers, grafts, artificial joints and tissue implants) | Intraoperative samples of bone, percutaneous bone biopsies, soft tissue specimens, aspirates, samples from around devices | Pus, exudate, prosthetic joint aspirate, periprosthetic biopsy, intraoperative specimens (debridement and retention or revision arthroplasty), prostheses, fixation devices |
| **Specimen collection, transport and storage** | Use aseptic technique. Collect swabs into appropriate transport medium and transport in sealed plastic bags. Compliance with postal, transport and storage regulations is essential. Recommended incubation time for specimens: 48 hours to 7 days, implant associated SSIs samples can be cultured for up to 14 days. All results should be issued to the requesting clinician as soon as they become available. Urgent results should be telephoned or transmitted electronically in accordance with local policies | | | |

| | | | | |
|---|---|---|---|---|
| **Optimal method of collection** | No wound exudation: Superficial swabs, skin and tissue biopsies, blood or fluid from bullae culturing. Wound exudation present: Samples of pus/exudate are preferred to swabs. Ideally, a minimum volume of 1ml of pus should be submitted. If only a minute amount of pus or exudate is available it is preferable to send a pus/exudate swab in transport medium to minimise the risk of desiccation during transport. When using a swab disinfect the superficial area of the wound first, the deepest part of the wound should be sampled, avoiding the superficial microflora. If specimens are taken from ulcers, the debris on the ulcer should be removed and the ulcer should be cleaned with saline. A biopsy or preferably, a needle aspiration of the edge of the wound should be the taken | If specimen is small, place it in sterile water to prevent desiccation. Grind or homogenise specimen | If specimen is small, place it in sterile water to prevent desiccation. Grind or homogenise specimen. Acute infections in patients who have not recently received antimicrobials are often monomicrobial (almost always with aerobic Gram-positive cocci such as *S. aureus* and β-haemolytic streptococci), whereas chronic infections are often polymicrobial | If possible stop all antibiotics at two weeks before sampling and consider not giving routine surgical prophylaxis until after sampling. For aspirates and radiologically guided biopsies the specimen size should approximate 1ml |
| **General key recommendation** | The specimen type and clinical details must be taken into consideration when processing samples. Collect specimens before starting antimicrobial therapy where possible. Specimens should be transported and processed as soon as possible. A mechanism for urgent reporting should be in place to communicate significant results. The volume of specimen influences the transport time that is acceptable. Large volumes of purulent material maintain the viability of anaerobes for longer. Non-healing wounds are invariably colonised by a polymicrobial flora and microbiology samples should be taken only if a clinical diagnosis of infection has been made | | Osteomyelitis is a progressive infection which results in inflammation of the bone and causes bone destruction, necrosis and deformation. Hospitalisation, surgical procedures, and, especially, prolonged or broad spectrum antibiotic therapy may predispose patients to colonisation and/or infection with antibiotic resistant organisms | Collect specimens before starting antimicrobial therapy where possible. Specimens should be transported and processed as soon as possible. In cases of suspected prosthetic joint infection, with low virulence organisms culture may be extended to 14 days. Once infection is established around a prosthetic joint, organisms can form a biofilm. The 'persisters' within the biofilm are very difficult to kill so that infection may not be eradicated without removal of the prosthesis. |

| | | | | |
|---|---|---|---|---|
| **Common cause** | *Staphylococcus aureus,* β haemolytic streptococci groups A, C and G , *Streptococcus anginosus, Enterobacteriaceae* | Group A streptococci, anaerobes, *Staphylococcus aureus*, E*nterobacteriaceae*, Mycobacterium species and fungi | *Staphylococcus aureus*, coagulase negative staphylococci, *Enterococcus* species. Always consider other organisms such as Mycobacterium species, fungi and actinomycetes. The bacterial species in haematogenous osteomyelitis are usually dependent on the age of the patient. | *Staphylococcus aureus*, coagulase negative staphylococci, streptococci, coliforms, enterococci |
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# Appendix 3: A protocol for the prevention of surgical site infection (SSI)

A protocol for the prevention of surgical site infection [after NICE (2008)(2013), WHO (2016) & CDC (2017)][3,4,120,211]

## 'Offer patients and carers appropriate information and advice throughout all stages of their care'

| **Recommendations for your consideration/inclusion into your local protocol:** |
|---|
| **Note:** During the initial process of consideration/assessment of any patient's suitability for surgery, it is important for all health care workers (HCW's) to use/be aware of an appropriate validated 'Risk Assessment tool' that has been used that helps identify a patient's potential risk of surgical site infection (SSI). Especially in patient groups where SSIs are particularly problematic or common, such as those having Orthopaedic, Colorectal or Gynaecological surgery; or any patient having a surgical procedure who has also has a diagnosis of Cancer. Furthermore, for all patients undergoing surgery, it may also be helpful for HCW's to incorporate an appropriate validated health-related quality of life (HRQoL) Assessment Score/tool as part of the patients initial assessment process, as this can help the clinician's identify in particular social factors that may increase a patient risk of SSI |
| **Before surgery; HCW's and patients should be encouraged to discuss the following as part of a holistic assessment process, so that modifiable issues such as a patient diets, smoking and exercise habits may be addressed in advance of planned surgery** |
| |
| **Preoperative phase: patients and health care workers** |
| • **Multidrug-resistant organism risk (MDRO)**: Patients should inform their HCW's about any travel history or previous recent hospitalisation |
| • **Staphylococcus aureus screening and decolonisation:** If undergoing high-risk surgery (including cardiothoracic and orthopaedic surgery) patients should have screening swabs taken. Any patient with nasal carriage of *Staphylococcus aureus* should receive perioperative intranasal applications of mupirocin 2% ointment with or without a combination of chlorhexidine gluconate (CHG) body wash |
| • **Smoking:** Patients should inform their doctor about their smoking history in advance and or be encouraged to quit at least four weeks before the surgery or earlier |
| • **Body temperature:** Patients when in hospital should ask for blankets to keep themselves warm when transferring between hospital departments and not be afraid of speaking up if they feel cold, want an extra blanket |
| • **Diabetes mellitus:** If patient have diabetes mellitus, they should have an appointment with their general practitioner at least one month before surgery; maintain stable blood glucose levels before (and after) surgery and inform all HCW's about their normal management regime |
| • **Modification of long term existing medical conditions:** HCW's and patients should work together to minimise any risks associated with surgery and the medical condition that the patient suffers with such as cardiovascular disease and chronic obstructive pulmonary disease |
| **Preoperative Phase: Health Care Workers** |
| • Advise patients to **shower or bathe** (full body) with soap (antimicrobial or non-antimicrobial) either the day before, or on the day of surgery |
| • **Hair removal** should only be undertaken if required to visualise the site as per local hospital protocol. If hair has to be removed, use electric clippers with a single-use head on the day of surgery. Do not use razors for hair removal because they increase the risk of SSI |

- **Provide patients with specific theatre wear** that is appropriate for the procedure and clinical setting and that provides easy access to the operative site and areas for placing devices, such as intravenous cannulas. Consider also the patient's comfort and dignity
- **All staff should wear specific non-sterile theatre wear** in all areas where operations are undertaken. All staff should keep their movements in and out of the operating area to a minimum
- Do not use **nasal decontamination** with topical antimicrobial agents aimed at eliminating *Staphylococcus aureus* routinely to reduce the risk of SSI
- Do not use **mechanical bowel preparation** (MBP) routinely to reduce the risk of SSI
- Preoperative **oral antibiotics** combined with MBP (mechanical bowel preparation) are suggested for use in adult patients undergoing elective colorectal surgery
- **MBP** alone (without the administration of oral antibiotics) should not be used in adult patients undergoing elective colorectal surgery
- **Surgical antibiotic prophylaxis** (SAP) should be administered before the surgical incision when indicated. SAP should be administered within two hours before incision. Give antibiotic prophylaxis to patients before:
  - Clean surgery involving the placement of a prosthesis or implant
  - Clean-contaminated surgery
  - Contaminated surgery

  Do not use antibiotic prophylaxis routinely for clean non-prosthetic uncomplicated surgery

  Use the local antibiotic formulary and always consider potential adverse effects when choosing specific antibiotics for prophylaxis

  Only give a repeat dose of antibiotic prophylaxis when the operation is longer than the half-life of the antibiotic given

  Give antibiotic treatment (in addition to prophylaxis) to patients having surgery on a dirty or infected wound

  Inform patients before the operation, whenever possible, if they will need antibiotic prophylaxis, and afterwards if they have been given antibiotics during their operation

  Immunosuppressive medication should not be discontinued before surgery.

**Intraoperative phase:**

- **Surgical hand preparation** should be performed either by scrubbing with a suitable antimicrobial soap and water or using a suitable alcohol-based hand rub before donning sterile gloves. Before subsequent operations, hands should be washed using either an alcoholic hand rub or an antiseptic surgical solution. If hands are 'contaminated' during a surgical procedure, then they should be washed again with an antiseptic surgical solution and another pair of gloves donned
- Do not use non-iodophor-impregnated **incise drapes** routinely for surgery as they may increase the risk of SSI If an incise drape is required, use an iodophor-impregnated drape unless the patient has an iodine allergy
- The surgical team should wear **sterile gowns** in the operating theatre during the operation
- Surgeons and the immediate 'scrub team' should consider wearing two pairs of **sterile gloves** when there is a high risk of glove perforation during a procedure, as the consequences of contamination may be serious
- **Prepare the skin at the surgical site** immediately before incision using an antiseptic (aqueous or alcohol-based) preparation: povidone-iodine or chlorhexidine gluconate (CHG) are most suitable. If diathermy is to be used, ensure that antiseptic skin preparations are dried by evaporation and pooling of alcohol-based preparations is avoided
- **Antimicrobial sealants** should not be used after surgical site skin preparation for the purpose of reducing SSI
- Do not use **diathermy** for surgical incision to reduce the risk of SSI
- Maintain perioperative **normothermia**
- Maintain a **patient's temperature** in line with 'Inadvertent perioperative hypothermia' guidance (NICE clinical guideline 65)[211]
- Maintain optimal **oxygenation** during surgery. In particular, give patients sufficient oxygen during major surgery and in the recovery period to ensure that a haemoglobin saturation of more than 95% is maintained

- Implement intraoperative glycaemic control and use **blood glucose** target levels less than 200 mg/dl in patients with and without diabetes
- Do not give **insulin** routinely to patients who do not have diabetes to optimise blood glucose postoperatively as a means of reducing the risk of SSI
- Do not use **wound irrigation** to reduce the risk of surgical site infection. Do not use **intracavity lavage** to reduce the risk of SSI
- Do not apply **antimicrobial agents** (i.e., ointments, solutions, or powders) to the surgical incision for the prevention of SSI
- Cover surgical incisions with an appropriate **interactive dressing** at the end of the operation (see Table 9)

## Postoperative phase

- Consider the administration of oral or enteral multiple **nutrient-enhanced nutritional formulas** in underweight patients who undergo major surgical operations
- Use an aseptic technique for **changing or removing surgical wound dressings**
- Use a sterile solution for **wound cleansing** for at least 48 hours after surgery. Advise patients that they may shower safely 48 hours after surgery
- Do not use topical **antimicrobial agents** for surgical wounds that are healing by primary intention to reduce the risk of SSI
- Do not use Eusol and gauze, or moist cotton gauze or mercuric antiseptic solutions to manage surgical wounds that are healing by secondary intention

  **Use an appropriate interactive dressing to manage surgical wounds that are healing by secondary intention**

  Refer to an appropriately qualified health professional with tissue viability expertise (such as a tissue viability nurse) for advice on appropriate dressings for the management of surgical wounds that are healing by secondary intention
- When **SSI is suspected** (i.e. cellulitis), either *de novo* or because of treatment failure, give the patient an antibiotic that covers the likely causative organisms. Consider local resistance patterns and the results of microbiological tests in choosing an antibiotic
- **Wound care after discharge from hospital:** community or home care nurses should be informed before the patients discharge from hospital or patients should be informed how to care for their wound at home and to recognise early signs of an infection (redness/fever/swelling/pain) — as per local policy

References:

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# Appendix 4: Patient's Guide – frequently asked questions about SSI

## What is a surgical site infection?

A surgical site infection, SSI, is an infection that occurs after surgery in the part of body where the surgery took place. SSIs can be sometimes superficial, involving only the skin. Other SSI can be more serious, involving deeper tissues under the skin, organs of the body affected by the procedure or implanted material.

## When should I be concerned?

SSI generally appears within a month after surgery. However, if an implants e.g. a prosthetic joint or graft is left in the body during surgery, an SSI may develop very slowly and not become apparent for several months.

## What are the symptoms of SSI?

They include redness and increased pain around the area where you had a surgery, drainage of green/yellow, cloudy fluid from the wound and fever.

## What are my chances of having a SSI?

The risk of SSI is influenced by factors the health of the patient, the type of surgery and the performance of the procedure. Operations on parts of the body where there are few germs such bones, have a low risk of SSI at around 1% of procedures. In parts of the body such as the gut, where a lot of germs are present, the risk of SSI is much greater, at around 10% of procedures. The risk of SSI is also increased by smoking, malnutrition, obesity, or blood supply disorders.

## Can SSIs be treated?

Yes, most SSIs can be treated with antibiotics. Sometimes patients with SSIs also need another operation to treat the infection.

## What can I do to help to prevent SSI?

Here are some things that you can do to help reduce the risk that you will develop a SSI:

**Before surgery:**

- Tell your physician about other medical problems you may have. Give up smoking as patients who smoke get more infections
- Clean your skin thoroughly by having a shower before you have your operation
- Do not remove hair from the area where the incision will be made. If necessary, this will be done by the operating team using electric clippers rather than razors as close to the time that the incision is made as possible

.

**After surgery**

- Make sure you understand how to care for your wound before you leave the hospital
- Be sure to ask your health worker how to clean the area of the wound 48 hours after surgery
- Always clean your hands with soap and water before and after caring for your wound.
- If the wound starts to look red, leak green/yellow fluid, become more painful or the edges of the skin split apart then contact you doctor who can assess whether there might be an infection.

# Glossary

## Definitions

**Biologic treatment:** a type of treatment that uses substances made from living organisms to treat disease. Types of biological therapy include immunotherapy (such as vaccines, cytokines, and some antibodies), gene therapy and some targeted therapies

**Cribriform:** scars perforated like a sieve

**Immunomodulatory therapy:** treatment that modulates the activity of the body's immune system

**Immunosuppressive therapy:** treatment that lowers the activity of the body's immune system

**Multidisciplinary team:** a group of health professionals who are members of different disciplines each providing specific services to the patient. The team members independently treat various issues a patient may have, focusing on the issues in which they specialise[1]

**Interdisciplinary team:** An interdisciplinary clinical team is a consistent grouping of people from relevant clinical disciplines, ideally inclusive of the patient, whose interactions are guided by specific team functions and processes to achieve team-defined favourable patient outcomes[2]

**Pathergy:** A skin condition in which a minor trauma leads to the development of specific skin lesions

**Purpura:** Red to dark purple spots in the skin that do not disappear on compression. Associated with vessel damage in the dermis

**Systemic treatment:** Treatment using substances that travel through the bloodstream, reaching and affecting cells all over the body

## Abbreviations

**AAWC:** Association for the Advancement of Wound Care

**ABPI:** ankle brachial pressure index

**ASA:** American Society of Anaesthesiologists'

**AUC:** Area under curve

**ARC:** Augmented renal clearance

**BSR**: blood sedimentation rate

**ciNPT:** Closed incision negative pressure therapy

**CABG:** coronary artery bypass graft

**CAD**: coronary artery disease

**CDC:** Centres for Disease Control and Prevention

**CFUs:** colony forming units

**CHG:** chlorhexidine gluconate

**CoNS:** coagulase negative staphylococci

**CT:** computerised tomography

**COPD:** chronic obstructive pulmonary disease

**CRP**: C-reactive protein

**DNA:** Deoxyribonucleic acid

**EWMA:** European Wound Management Association

**ECDC:** European Centre for Disease Prevention and Control

**HBOT:** hyperbaric oxygen therapy

**HCAI:** health care acquired infections

**HCW:** health care worker

**HRQoL:** health related quality of life

**IPS:** Infection Prevention Society

**MDT**: multidisciplinary team

**NICE:** National Institute for Health and Care Excellence

**NPWT:** negative pressure wound therapy

**NHSN:** National Healthcare Safety Network

**MRI:** magnetic resonance imaging

**MRSA:** Methicillin-resistant *Staphylococcus aureus*

**OR:** Odds Ratio

**PI:** povidone iodine

**PK/PD:** pharmacokinetic/pharmacodynamic - this interplay is important for the correct dosing regimens of antibiotics, to obtain the most optimal effect (dynamic)

**QoL**: Quality of life

**RCT:** randomised controlled trial

**SD**: standard deviation

**SSI:** surgical site infection

**VRE:** vancomycin-resistant enterococci

**Wound navigator:** usually, a clinician who acts as an advocate for the patient

**WHO:** World Health Organization

# Notes

A JOINT DOCUMENT