SECTION 1

# Surgical Infections

# 1 Surgical Wound Infections

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Surgical wound infections are the most common causes of postoperative morbidity and can cause serious complications after surgery despite constant improvements in surgical practice. In small animals, the overall postoperative wound infection rate ranges from 5.1% (Vasseur *et al.* 1988) to 5.8% (Eugster *et al.* 2004); however, the overall information available in the veterinary literature is still limited regarding the epidemiology of wound infections. The classification of surgical procedures has been based on the degree of bacterial contamination (Table 1.1). Infection rates have been reported as 2.5% to 4.9% in clean wounds, 4.5% to 5.9% in clean-contaminated wounds, 5.8% to 12.0% in contaminated wounds, and 10.1% to 18.1% in dirty wounds (Vasseur *et al.* 1988; Brown *et al.* 1997; Nicholson *et al.* 2002; Eugster *et al.* 2004). In addition to the degree of wound contamination, many other factors, both patient and operation related, are shown to influence the occurrence of surgical wound infection.

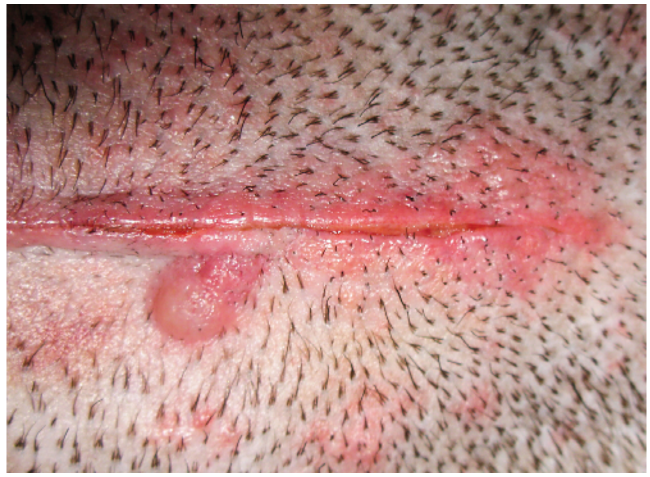

**Figure 1.1** Surgical wound infection 6 days after surgery. Signs of redness, swelling, and purulent discharge are seen in the wound.

## Definition

*Surgical wound infection* is not well defined in veterinary medicine. In humans, surgical wound infections are defined as those that occur within 30 days after a surgical operation or within 1 year if a surgical implant was left in place after the procedure. In most veterinary studies, surgical wounds are defined as infected if there is purulent discharge from the wound within 14 days after surgery. In some studies, the definition also includes signs typical of infection such as redness, pain, swelling, and heat (Figure 1.1).

**Table 1.1** Classification of operative wounds based on the degree of bacterial contamination

| | |
|---|---|
| Clean | Nontraumatic, noninflamed operative wound<br>No entry into the GI, urogenital, or respiratory tracts or oropharyngeal cavity |
| Clean contaminated | Entry into the GI, urogenital, or respiratory tracts or oropharyngeal cavity<br>Clean procedure in which a drain is placed<br>Minor break in aseptic technique |
| Contaminated | Spillage from the GI or urogenital tract<br>Fresh traumatic wound (<4 hours old)<br>Major break in aseptic technique |
| Dirty | Acute bacterial infection encountered<br>Traumatic (>4 hours old) wound with devitalized tissues or foreign bodies or fecal contamination |

GI, gastrointestinal.

## Risk factors

The factors that may influence the risk of veterinary surgical wound infection are adapted from human studies (Mangram *et al.* 1999; Owens and Stoessel 2008). In the following, the factors marked with asterisks have been shown to be associated with surgical wound infections in veterinary studies.

Patient-related factors include:

- Age*
- Nutritional status
- Diabetes
- Obesity*
- Colonization with microorganisms (particularly *Staphylococcus aureus*)
- Coexistent infections at a remote body site
- Altered immune status
- Length of preoperative stay

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Operation-related factors include:
- Duration of surgical scrub
- Skin antisepsis*
- Preoperative hair clipping*
- Preoperative skin preparation*
- Duration of surgery and anesthesia*
- Antimicrobial prophylaxis*
- Operating room (OR) ventilation
- Inadequate sterilization of instruments
- Foreign material in the surgical site
- Surgical drains*
- Surgical technique

## Diagnosis

The diagnosis is based on clinical signs and possible positive bacterial culture from the infection site. The identification of surgical wound infection is not always straightforward. If only redness, tenderness, swelling, or heat is present, one has to differentiate it from the normal inflammatory response that occurs in early wound healing. Normally, these signs subside within 24 to 48 hours after surgery.

**Local signs** of wound infection include:
- Serosanguineous to purulent drainage from the wound or pus accumulation associated with
- Swelling, redness, heat, and pain or discomfort

**Systemic signs** and findings may include fever, tachypnea, and leukocytosis with a left shift. Fever and leukocytosis can also occur in the normal inflammatory response to the surgical wound.

If the infection involves deep tissues (bone or an organ), radiologic or ultrasonographic examinations may be warranted.

**Bacterial isolation and identification** requires:
- Proper cleaning of the sampling site to avoid contamination of the sample with normal flora
- Taking samples aseptically by swabbing or aspiration depending on the infection site for aerobic and possibly anaerobic cultures and sensitivity testing
- Gram staining from the swab or aspirate in order to distinguish between gram-positive and gram-negative bacteria may aid in early selection of antimicrobials

## Treatment

Treatment consists of surgical drainage or wound debridement (or both) depending on the extent of soft tissue or bone involvement and selection of appropriate antimicrobials, which should be based on bacterial culture results.

### Drainage or debridement of the wound

- Adequate opening of the surgical incision and evacuation of purulent material are crucial (Figure 1.2). Systemic antimicrobials are not always necessary in patients lacking signs of deep infection or systemic signs.
- After drainage, the wound must be covered with a sterile dressing.
- Extensive soft tissue or bone involvement, the presence of implants, or systemic effects of the infection may warrant surgical exploration of the wound and debridement of all necrotic, devitalized tissue and foreign material.
- Lavage of the tissues can be done with sterile isotonic saline or local antiseptics, such as 0.05% chlorhexidine.
- If there are doubts as to the viability of the tissues, the wound should be treated as an open wound.

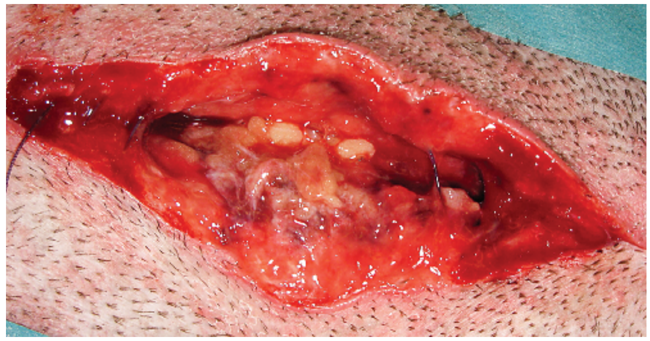

**Figure 1.2** Surgical exploration of the infected surgical wound. This is the same wound as in Figure 1.1 after removal of the intradermal sutures.

### Selection of antimicrobials

- If antimicrobials are indicated before the bacterial culture results are available, treatment should be started with an antimicrobial that is likely to have an effect against the most probable pathogens(s).
- When the results of the bacterial culture and sensitivity test are available, the antimicrobial should be changed if needed.

### Other supportive treatment

- Pain control

## Outcome

The prognosis depends on the location and extent of the wound infection and the causative agent. In any case, the wound infection prolongs recovery and causes discomfort to the patient along with increasing the costs of the treatment. The prognosis is good for superficial infections that involve the skin and subcutaneous tissues; however, if infection involves deep tissues or bone, it can seriously affect the outcome of the surgery.

## Prevention

### Preoperative

- Sterilization of surgical equipment
  - Routinely monitor the quality of sterilization process.
- Preparation of the patient
  - Identify and treat all infections remote to the surgical site before elective surgery.
  - Hair clipping should be done immediately before surgery.
  - Clean the clipped area with either a non-antiseptic or an antiseptic soap to remove gross contamination followed by drying the area. Wipe the area with suitable skin antiseptic (chlorhexidine–alcohol, povidone–iodine–alcohol, or 80% alcohol). Let the antiseptics have a proper influence time according to the manufacture's recommendations (usually 3 minutes).
- Preparation of the surgical team
  - Use surgical hand antisepsis with either a suitable antimicrobial soap or alcohol-based hand scrub. When using antimicrobial soap, scrub the hands and forearms for 2 to 5 minutes. When using alcohol-based surgical hand scrub, prewash hands and forearms with a non-antimicrobial soap and dry them completely. After application of alcohol-based product following the manufacturer's instructions for application

Table 1.2 Bacterial species colonizing different surgical sites and examples of the use of prophylactic antimicrobials*

| Site | Species | Examples of Prophylactic Antimicrobials |
|---|---|---|
| Skin | Staphylococci, streptococci, corynebacteria | First-generation cephalosporins |
| Elective orthopedics | Skin flora as above | First-generation cephalosporins |
| Neurosurgery | Skin flora as above | First-generation cephalosporins |
| Oral cavity | Pasteurellae, streptococci, corynebacteria, actinomycetes fusobacteria, porphyromonas, *Prevotella,* bacteroides | Aminopenicillin (+/- clavulanate)<br>or<br>clindamycin |
| Upper GI tract | Staphylococci, streptococci, enterococci, clostridia, bacteroides, fusobacteria, other aerobic and anaerobic gram-positive cocci and rods, coliforms | Aminopenicillin (+/-clavulanate)<br>or<br>Aminopenicillin+ aminoglycoside |
| Lower GI tract | Clostridia, anaerobic positive cocci, bacteroides, fusobacteria, coliforms, enterococci, streptococci, gram-positive rods | Aminopenicillin (+/-clavulanate)<br>or<br>Aminopenicillin + aminoglycoside (+/-metronidazole) |
| Urinary tract | Coliforms, enterococci, staphylococci | Sulfonamides + trimethoprim<br>Ampicillin if enterococci |
| Reproductive tract | Coliforms, streptococci, pasteurellae, staphylococci | Sulfonamides + trimethoprim |

*A prophylactic antimicrobial should be targeted to the most likely organisms that cause wound infection. The selection is based on degree of contamination, operation type and degree of difficulty, knowledge of the local resistance situation, and possible regulatory issues such as local antimicrobial policy and legislation.

GI, gastrointestinal.

times, allow hands and forearms to dry completely before donning sterile gloves.

- Antimicrobial prophylaxis
  - Use prophylactic antimicrobial agents in clean-contaminated and in clean surgeries lasting more than 90 minutes.
  - Choose a narrow-spectrum antimicrobial that is effective on the bacteria likely to contaminate the surgery site (Table 1.2).
  - Administer the antimicrobial by the intravenous route between 30 minutes and 1 hour before the incision to ensure that the bactericidal concentration of the drug is established in both serum and tissues.
  - Maintain therapeutic levels of the drug in both serum and tissues throughout the operation. In clean and clean-contaminated surgeries, the antimicrobial rarely needs to be continued postoperatively. In contaminated and dirty surgeries, the antimicrobials are continued for treating the infection.

### Intraoperative

- Surgical team
  - Keep the amount of personnel to a minimum in the OR.
  - Scrubbed surgical teams member should use facemasks, surgical caps, and sterile surgical gowns.
- Operative technique
  - Gentle tissue handling
  - Good hemostasis
  - Obliteration of dead space
  - Prevention of hypothermia during surgery
  - Keep the operation and anesthesia time to a minimum.

### Postoperative

- Wound care
  - Protect the wound with a sterile dressing for 24 to 48 hours postoperatively if possible.
  - Always follow strict hand hygiene when in contact with the wound.
- Adequate postoperative care
  - Pain control
  - Prevention of hypothermia and hypoperfusion

### Surveillance

- Develop guidelines for controlling surgical wound infections and ensure that they are followed.
  - Develop effective surveillance methods for surgical wound infections.
  - For surveillance purposes, clear definitions of surgical wound infection are needed within an institution.

## Relevant literature

The definition of *surgical wound infection* varies among veterinary reports. In human medicine, the term *surgical wound infection* was replaced in 1992 with the term *surgical site infection* (SSI), which was adapted to veterinary medicine by Frey *et al*. (2010) in a retrospective study on risk factors for SSI in anterior cruciate ligament (ACL) surgery. According to the Centers for Disease Control and Prevention, SSIs are divided into superficial (infection involves only subcutaneous tissue of the incision), deep (infection involves deep soft tissues such as fascial and muscle layers), and organ or space SSI (infection involves any part of the anatomy other than the incision) (Mangram *et al*. 1999). The identification of SSI involves interpretation of clinical as well as laboratory findings. There is also a need to standardize the definition of postoperative wound infections in veterinary medicine, too.

Several risk factors are identified in veterinary studies. When looking at **patient-related risk factors,** Nicholson *et al*. (2002) found that intact males and animals with endocrinopathy were at a higher risk for postoperative wound infections after clean-contaminated surgeries. Increasing weight of the dog was found to be a risk factor in a study in which the outcome was classified as infected or infected/inflamed (Eugster *et al*. 2004). In the same study, the authors also showed that an increasing American Society of Anesthesiologists score was associated with increasing wound infection rates. Further potential patient-related risk factors have been identified in human studies on different surgical procedures, including older age, preexisting infection, obesity, colonization with microorganisms, diabetes, preoperative anemia, use of corticosteroids, malnutrition, low serum albumin levels, and postoperative hyperglycemia (Mangram *et al*. 1999; Ata *et al*. 2010; Moucha *et al.* 2011). Some of the risk factors remain controversial, and more studies are needed to show their direct scientific evidence in various procedures.

**Surgical site preparation** is an important **operation-related risk factor.** Preoperative clipping immediately before surgery has been shown to decrease the risk of infection in small animals (Brown *et al.* 1997). Because the patient's skin is a major source of pathogens that cause wound infections, optimization of preoperative skin antisepsis is important. Nevertheless, study results are conflicting regarding the superiority of chlorhexidine–alcohol versus povidone–iodine (Darouiche *et al.* 2010) or chlorhexidine–alcohol versus povidone–iodine–alcohol for surgical site antisepsis in humans (Swenson *et al.* 2009). It was concluded, however, in a recent meta-analysis by Noorani *et al.* (2010) that preoperative cleansing with chlorhexidine is superior to povidone–iodine in reducing postoperative SSI after clean-contaminated surgery. In a recent canine study, it was shown that there was a reduction in bacterial counts from the skin with an increasing concentration of chlorhexidine gluconate from 1% to 4% (Evans *et al.* 2009).

The **duration of surgery** has been investigated in several studies, but drawing conclusions from these studies is challenging because variation is evident for the definition of surgical wound infection, the study design, antimicrobials regimen, and number of animals involved. However, it has been shown in one retrospective and two prospective studies that longer surgical procedures (>90 minutes) have a greater risk of infection (Vasseur *et al.* 1988; Brown *et al.* 1997; Eugster *et al.* 2004).

Increased **duration of anesthesia** has also shown to increase wound infection rates (Nicholson *et al.* 2002; Eugster *et al.* 2004; Owen *et al.* 2009). A 30% greater risk of postoperative wound infection in clean wounds for each additional hour of anesthesia has been reported (Beal *et al.* 2000). The proposed multifactorial causes resulting from anesthetic duration were impairment of function of phagocytic leukocytes (Mangram *et al.* 1999), prolonged use of anesthetic drugs (Beal *et al.* 2000), perioperative hypothermia (Dellinger 2006), and increased risk for wound contamination (Owen *et al.* 2009).

Wound infection rates increase with the **degree of bacterial contamination** (Vasseur *et al.* 1988; Brown *et al.* 1997; Eugster *et al.* 2004). The causative agent is most often endogenous, originating from the patient, and is site dependent (see Table 1.2). Surgical suction tips have been shown to become contaminated during surgery and could influence the risk of wound infection (Sturgeon *et al.* 2000). The use of adhesive incise drapes did not reduce wound contamination in clean surgeries in dogs (Owen *et al.* 2009), but it has also been reported that a sterile, impermeable barrier is needed in addition to sterile surgical drapes to prevent bacterial strikethrough when wrapping the distal limb in orthopedic surgeries (Vince *et al.* 2008).

In humans, there appears to be a clear consensus that **antimicrobial prophylaxis** is necessary and helpful in reducing the risk arising from bacterial contamination of the surgical wound in clean-contaminated procedures and in clean procedures that involve implantation of a graft or a device. In contaminated or dirty procedures, antimicrobials are administered with therapeutic intent (Mangram *et al.* 1999; Nichols 2004). Timing of the administration of prophylactic antimicrobials is crucial; 2 hours before surgery has shown to be effective in reducing surgical wound infections in humans (Classen *et al.* 1992). In veterinary medicine, only a few studies have been conducted on the effect of antimicrobial prophylaxis in clean and clean-contaminated procedures. In earlier reports, no difference was found in infection rates between the group receiving antimicrobials or not (Vasseur *et al.* 1985; Brown *et al.* 1997; Nicholson *et al.* 2002). These contradictory findings compared with human studies are most probably attributable methodologic limitations. There is one prospective, randomized, controlled study by Whittem *et al.* (1999) in which there was a lower postoperative infection rate in dogs undergoing elective clean orthopedic surgery that received cefazolin or potassium penicillin within 30 minutes before the incision and received a second dose if surgery lasted longer than 90 minutes compared with placebo control animals. It is noticeable that antimicrobial prophylaxis was not continued after surgery.

When **selecting an antimicrobial** for prophylaxis, it should have activity against the pathogen most likely to contaminate the surgery site. Other factors that should be taken into consideration are pharmacokinetics, side effects, toxicity, and cost of the drug as well as the antibiotic resistance, which varies in different countries. Antimicrobials should be used in a targeted manner in which minimal use provides maximal effect with minimal adverse reaction. For most procedures, antimicrobials active against β-lactamase–producing staphylococci should be administered. These include β-lactamase–resistant penicillins and first-generation cephalosporins (Dunning 2003).

**The duration of antimicrobial prophylaxis** should encompass the entire procedure (Dohmen 2008); thus, redosing during surgery may be required depending on the half-life of the antimicrobial and the duration of the surgery. The majority of evidence in humans has demonstrated that antimicrobial prophylaxis after wound closure does not provide any additional protection against surgical wound infection (Evans and American Academy of Orthopaedic Surgeons Patient Safety Committee 2009b). Continuing antibiotic prophylaxis for longer than 24 hours after wound closure does not reduce rates of surgical infections, but it may contribute to the development of antimicrobial resistance (Dohmen 2008; Evans and American Academy of Orthopaedic Surgeons Patient Safety Committee 2009b). In veterinary studies, the postoperative use of antimicrobials has shown to increase the risk of wound infection in clean surgeries (Brown *et al.* 1997; Eugster *et al.* 2004), although contradictory findings have also been reported (Frey *et al.* 2010).

Despite the presence of strict protocols, discrepancies still exist between the protocols and practice. In one retrospective study in which the use of antimicrobials in ACL surgery was evaluated at a veterinary teaching hospital, it was noticed that whereas 85% of dogs received the first dose of antimicrobials within 60 minutes of the incision, 29% of dogs received antimicrobials after surgery (Weese and Halling 2006).

Minimizing the risk factors is the most effective way of **preventing** surgical wound infections. For instance, a **preoperative** issue that has been vigorously studied is hand cleansing before surgery. It has long been known that preoperative scrubbing with a brush has no advantage over nonscrubbing methods of hand preparation (Loeb *et al.* 1997). The current guidelines on hand hygiene are based on consensus recommendations that rely on the evidence of well-designed clinical and epidemiologic studies. According to the recommendations, surgical hand antisepsis should be done either by scrubbing with an antimicrobial soap or with non-antimicrobial soap followed by an alcohol-based hand rub (Boyce and Pittet 2002; Pittet *et al.* 2009; Verwilghen *et al.* 2010).

**Intraoperatively,** the number of persons in the OR during surgery should be kept to a minimum. For each additional person in the room, the risk for wound infection has shown to be 1.3 times higher (Eugster *et al*. 2004). Perioperative mild hypothermia has not shown to be a significant risk factor for wound infections in dogs and cats (Beal *et al*. 2000), but in human studies, there is evidence that systemic warming reduces wound infections and reduces blood loss and the need for transfusions (Leaper 2010). It has also been shown that supplemental administration of 80% oxygen in the recovery room could reduce SSIs (Qadan *et al*. 2009; Leaper 2010).

There are very few veterinary studies on **postoperative factors** associated with wound infections; however, the duration of the postoperative stay in the intensive care unit has been shown to be associated with SSI (Eugster *et al*. 2004).

The **surveillance** of surgical wound infections in humans has been effective in reducing SSIs (Owens and Stoessel 2008). Surveillance has an important information-gathering function that can be very helpful in the detection and prevention of nosocomial outbreaks.

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