A review of post-operative infections in veterinary orthopaedic surgery

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Summary

Surgical site infections are an inherent risk in orthopaedic surgery and many of the infections that develop are likely to be non-preventable. However, a variety of measures can be undertaken to reduce the risk and impact of surgical site infections. The development and implementation of an infection control program, including surgical site infection surveillance, can be an important tool for patient management. All veterinary practices should have some form of infection control program in order to address surgical site infections, among other issues, and to provide the optimal and expected level of care.

Introduction

Post-operative infections have been a concern for as long as there has been surgery. Prior to widespread use of aseptic technique, modern surgical practices and availability of antimicrobials, post-operative infections were common and often fatal. The development of the field of surgical asepsis by pioneers such as Joseph Lister, combined with prophylactic and therapeutic use of antimicrobials, created a period of optimism where it seemed as if infectious diseases would no longer be major concerns (1). In hindsight, this optimism was clearly misguided, and post-operative infections remain an inherent risk of any surgical procedure.

Definitions

Any proper discussion or evaluation of surgical site infections (SSIs) requires a common understanding of what constitutes an SSI. Standard definitions must be used to allow for reasonable comparison of data from different locations, and to facilitate proper identification of SSIs. The US Centers for Disease Control and Prevention (CDC) has developed standard criteria for defining SSIs (2). These classify SSIs into superficial incisional, deep incisional and organ/space SSI (Table 1). It is reasonable to apply these criteria equally to veterinary medicine and it is critical to use an objective definition when evaluating SSIs.

Incidence

In human medicine, national surveillance programs, such as the CDC's National Nosocomial Infections Surveillance (NNIS) system and Canada's Canadian Nosocomial Infection Surveillance Program collect large amounts of data from both active and passive surveillance, and provide excellent information on nosocomial infections. Surgical site infection incidence data can be highly variable depending on the population studied, as not all surgical patients and procedures carry the same degree of risk. Various studies have evaluated the incidence of SSI following different orthopaedic procedures (Table 2).

Comparable surveillance systems are lacking in veterinary medicine. Fewer studies have evaluated post-operative infections, and large multicenter studies using clearly defined criteria are lacking. However, there are a variety of studies of variable size that provide some insight into the veterinary situation (Table 3). A lack of application of standard definitions and clear differentiation of infection from inflammation weaken the data in some studies and make comparisons between studies difficult.

Impact in veterinary medicine

Various impacts can be attributed to SSIs. Some, such as patient morbidity, patient mortality and increased treatment costs, are readily quantifiable. Others, such as client frustration and grief, veterinary frustration, potential liability and negative public perceptions may be very important but difficult to evaluate. From a population standpoint, the impact of post-operative infections in veterinary medicine may be low because of the low incidence in most populations. However, severe or fatal infections that develop in a small number of patients can be economically and emotionally draining for clients and veterinarians alike, irrespective of their low incidence. While SSI outbreaks

Table 1 Criteria for defining a surgical site infection (2).

	Superficial incisional SSI	Deep incisional SSI	Organ/space SSI
Timing	Within 30 days of surgery	Within 30 days of surgery or 1 year if implant in place	Within 30 days of surgery or 1 year if implant in place
Location	Only skin or subcutaneous tissues of the incision	Deep soft tissues (i.e. fascial and muscle layers) of the incision	Any area other than the incision which was opened or manipulated during surgery
Clinical aspects*	– Purulent discharge – Organisms isolated from an aseptically collected sample of fluid or tissue – One or more of pain or tenderness, localized swelling, redness, heat *and* incision is deliberately opened by surgeon *unless* culture negative	– Purulent drainage from the deep incision but not organ/space – Deep incision spontaneously dehisces or is deliberately opened when patient has one or more of fever, localized pain or tenderness *unless* culture negative – Abscess or other evidence of infection on direct exam, during re-operation or by histopathology or radiology	– Purulent drainage from drain that is placed into the organ/space – Organisms isolated from aseptically collected sample from organ/space – Abscess or other evidence of infection on direct exam, during re-operation or by histopathology or radiology – Diagnosis of organ/space SSI by attending clinician

*One or more must be present.

Class	Description
Clean	Non-traumatic, uninfected No break in aseptic technique No inflammation encountered. Elective, primarily closed and no drains used
Clean-contaminated	Controlled entering of a hollow muscular viscus Minor break in aseptic technique
Contaminated	Open, fresh traumatic wound Incision into a site with acute, nonpurulent inflammation Major break in aseptic technique
Dirty	Pus encountered during surgery Perforated viscus found Traumatic wound with devitalized tissues, foreign material or fecal contamination, or of more than 4 hours duration Perforated viscus Acute bacterial infection with purulent exudates encountered during surgery

Table 2
National Research Council risk index for surgical infections.

n*	Procedure	SSI incidence	Reference
1231	Arthroscopic anterior cruciate ligament reconstruction	0.5%	(46)
34141	Total hip arthroplasty	1.3%	(47)
21522	Total knee arthroplasty	0.9%	(47)
107825	Various orthopaedic	0.4%	(48)
3231	Knee arthroscopy	0.15%	(27)
2500	Anterior cruciate ligament rupture repair	0.3%	(49)

*Number of surgical procedures.

Table 3
Incidence of surgical site infection (SSI) in orthopaedic surgery in humans.

(diabetes, nicotine use, obesity, immunosuppressive therapy, malnutrition, methicillin-resistant *Staphylococcus aureus* (MRSA) colonization, prolonged hospitalization), procedure (wound classification, surgeon operation volume), pre-operative (hair removal, patient skin preparation, surgical team hand/forearm preparation, antimicrobial prophylaxis), surgical (operating room environment, duration, surgical instrument management, surgical attire and drapes, surgical aseptic technique) and postoperative (incision care, antimicrobial therapy) factors (3–5). Many of the aforementioned factors are probably applicable to veterinary medicine, yet the relative importance of each is unknown as risk factor data in veterinary medicine are limited.

Classification of surgical wounds into clean, clean-contaminated, contaminated and dirty, is an established procedure in human medicine (3, 6). Surgical classification has also been reported to be associated with SSIs in both general small animal surgery and equine orthopaedic surgery (7, 8), however one study questioned its usefulness in small animals (9).

Duration of surgery has been associated with increased SSI rates in both horses and small animals (7–10). The number of people present in the operating room was also significant in a large study of dogs and cats (8). Other factors that have been associated with SSIs in small animals include: presence of a drain, gender, increasing body weight, concurrent endocrinopathy and the use of pro-

are uncommon (or at least uncommonly reported), their impact may also be tremendous. There has been little specific analysis of the impact of SSIs in veterinary medicine.

Risk factors

Risk factors for a variety of surgical procedures have been extensively evaluated in human medicine. These include: patient

pofol (8, 11). Conflicting results are present regarding the role of peri-operative antimicrobial therapy in SSI prevention. Peri-operative antimicrobials have been associated with lower SSI rates in some studies, but not in others (12–14). Discrepancies have even been present within studies, such as a study that reported a protective effect of antimicrobials in clean procedures performed by senior veterinary students but not those performed by faculty or residents that required 90 minutes or less to complete (13). Differences in study population, case definitions and study power may account for these discrepancies. Antimicrobial administration has also been associated with development of SSI in clean-contaminated equine orthopaedic procedures (7). This may relate to an increased use of antimicrobials in procedures that are at higher risk of infection for other factors if those factors could not be adequately controlled for in the analysis.

Infection prevention and control

Absolute prevention of SSIs is not a practical goal (15). It is important to remember that hospital-associated and post-operative infections are an inherent risk of hospitalization and surgery, regardless of the level of care provided. As such, SSIs can be divided into two groups: preventable and non-preventable. Preventable infections are those that could plausibly have been prevented using reasonable infection control and medical/surgical methods, while non-preventable SSIs are those that occur despite implementation of the best reasonable measures. The size of the preventable fraction in veterinary medicine is unknown but it is reasonable to assume that a significant percentage of veterinary SSIs are potentially preventable. The objective, therefore, is to 'achieve the lowest SSI rates that state-of-the-are prevention tactics can provide' (15).

A key component of infection control is development and implementation of a proper infection control program, an area that is often overlooked in veterinary medicine.

Table 4 Incidence of surgical site infection (SSI) in veterinary medicine.

Species	n*	Surgical procedure(s)	SSI incidence	Reference
Dog, cat	239	Various	5.9%	(10)
Dog, cat	863	Clean procedures	4.5%	(11)
Dog, cat	1010	Various	5.8% 'inflammation/infection' 3% 'infection'	(8)
Dog, cat	1100	Clean procedures	2.5%	(13)
Dog, cat	554	Clean-contaminated procedures	4.5%	(13)
Dog, cat	172	Contaminated procedures	5.8%	(13)
Dog, cat	237	Dirty procedures	18.1%	(13)
Dog, cat	200	Elective joint surgery	3.5%	(50)
Dog	112	Clean orthopaedic procedures	7.1%	(12)
Dog, cat	129	Various	0.8%	(14)
Dog	83	Cranial cruciate rupture surgery	3.6%	(30)
Dog	221	Total hip replacement	7.7%	(51)
Dog	65	Total hip replacement	3.1%	(52)
Dog	20	Total hip replacement	10%	(53)
Dog	101	Tibial tuberosity advancement	2.6%	(54)
Dog	77	Cemented total hip replacement	1.3%	(55)
Horse	433	Clean orthopaedic	8.1%	(7)
Horse	19	Clean contaminated orthopaedic	53%	(7)
Horse	97	Elective arthroscopy	0%	J. S. Weese, (unpublished data)
Horse	1604	Various clean elective	1.4%	(56)
Horse	38	Femur fracture repair	38%	(57)
Horse	591	Carpus arthroscopy	0.5%	(58)

*Number of surgical procedures.

Every veterinary clinic, regardless of type or size, should have a formal infection control program that is coordinated by one specific person. This 'infection control practitioner' (ICP) should develop protocols, ensure that protocols are being followed, act as a resource for infection control questions, ensure proper training of new staff, direct and interpret surveillance and communicate with staff regarding infection control issues. This is not necessarily a cumbersome or time-consuming job, as the day-to-day responsibilities are typically minimal. In human hospitals, ICPs are typically nurses with specialized infection control training. Either veterinary technicians or veterinarians would be appropriate in veterinary clinics. Formal training would be ideal but is not readily available, and the key require-

ment for the position is an interest in infection control.

Comprehensive discussion of infection control programs is beyond the scope of this review. However, there are certain aspects pertaining to orthopaedic surgery that require specific attention, some of which can be extrapolated from comprehensive guidelines from human medicine (3). General guidelines for veterinary infection control programs have recently been published (16), although a detailed description of surgical infection control practices is still lacking. Selected aspects that are potentially important in veterinary orthopaedic surgery are outlined below.

Surveillance is a key component of any infection control program. The landmark Study on the Efficacy of Nosocomial Infec-

tion Control (SENIC project) demonstrated the beneficial effect of organized surveillance as part of an infection control program in human hospitals (17). Subsequently, it has been declared that proper infection control is impossible without surveillance (15), and some form of surveillance should be practiced by all veterinary facilities. There are two main forms of surveillance; active and passive. Active surveillance involves gathering data specifically for infection control purposes. As a result, it can be expensive and time consuming but usually provides the highest quality data. An example of this would be the collection of MRSA screening swabs from patients prior to surgery as part of MRSA outbreak investigation. Passive surveillance is useful, easy and cost-effective. It involves the use of data that are already available. As such, it can be an easy and cost-effective means of gathering basic infection control data. The quality of passive surveillance data, however, can be limited by poor or incomplete record keeping. The most basic and perhaps most useful surveillance information is the SSI rate, both overall and for individual procedures. This can be further evaluated in terms of individual surgeons, services, day of the week, time of day, the pathogen involved or other potentially relevant factors.

Surveillance is only as good as the data that are obtained. Obtaining quality data requires a mechanism to identify most, if not all, potential SSIs, the use of a standard classification system to define SSIs and to access to denominator data consisting of the number of procedures performed. Identification of infections can be difficult, especially in outpatients. While inpatient surveillance is relatively easy, post-discharge surveillance is more problematic but essential because a significant percentage (12–84% in humans) of SSIs are detected after discharge (3). Since the duration of hospitalization in veterinary medicine may be shorter than in human medicine, this percentage could be higher in animals. Post-discharge surveillance can consist of direct examination of the patient during recheck or suture removal, evaluation of re-admission data or telephone or mail contact with owners. None are optimal and combinations of these may be required in certain situations. Surveillance efforts may also be complicated in referral practices as infections that are identified after discharge may be treated at the primary care veterinary clinic and information may not be relayed to the surgical facility. Despite the challenges, efforts should be made to identify at least a reasonable proportion of SSIs. Any SSI data collection should be centralized, ideally through the ICP, so that early stages of outbreaks do not go unnoticed. This is particularly important in large veterinary practices as early stages of outbreaks can be missed if different veterinarians receive reports of SSIs but do not communicate that to others, and the scope of the problem is not initially realized. Once collection of SSI information has been established, routine monitoring of SSI rates can be used for infection control and educational purposes. Changes in SSI rates, especially procedure-specific rates, or differences in SSI rates between similar facilities could indicate a need for investigation to determine the cause and appropriate action (18, 19). Care should be taken when analyzing data regarding individual surgeons or surgery services. The multifactorial nature of SSIs, the potential for confounding factors and the stigma associated with reporting individual SSI rates must be considered, as individual rates do not always indicate issues with the surgeon. However, feedback of appropriate SSI information to individual surgeons has been shown to be an effective component of SSI reduction programs in human medicine (17, 20). Individual surgeon or service data should be kept confidential.

Wound classification should be considered for all surgical techniques. Most veterinary orthopaedic procedures would be classified as clean, but higher risk categories may also be encountered. All surgical procedures should be classified in advance, and this classification used to determine appropriate pre-operative, operative and post-operative care.

The sterilization of surgical instruments and any items that might come in contact with the surgical field is obviously an important practice. Autoclave sterilization is most commonly performed. Quality control testing of autoclaves should be performed and documented. Sterility indicator strips should be placed in each surgical pack (21), and biological indicators should be used periodically (22). Autoclave indicator tape should not be relied on as it does nor provide any information about pack contents (23). 'Flash sterilization' should not be used as a routine measure (3). It should only be used when there is a need for emergency sterilization and should never be used for surgical implants. Similarly, 'cold sterile' solutions should be avoided and implants should never be sterilized in this manner (21). Contamination of cold sterile solutions in veterinary clinics is not uncommon (C. Murphy et al, unpublished data). Further, this method is only effective if used properly, include proper dilution, adequate changing of solution, proper pH, adequate temperature, minimal organic load and adequate contact time (24). Ethylene oxide is an effective form of gas sterilization. It is typically reserved for the sterilization of items that cannot undergo autoclave sterilization. Because of cost, access and environmental concerns, it is not widely used. Plasma sterilization, using hydrogen peroxide gas, offers relatively quick and environmentally friendly sterilization but is typically reserved for items that cannot be autoclaved. All sterilized items should be labeled with the date that sterilization was performed. Recommended maximum storage times have been described (23), and items should be discarded or re-sterilized after this time.

Peri-operative antimicrobial administration is an important and complex area. The goal of peri-operative antimicrobial therapy is to reduce the risk of infection while having minimal negative impact on the patient's microflora and minimizing the risk of antimicrobial-associated complications (i.e. diarrhea). The proper discussion of this complex and controversial area is not within the scope of this review and detailed information is available elsewhere (25, 26). It is reasonable to assume that antimicrobials are indicated in clean-contaminated, contaminated and dirty procedures. The need for prophylaxis in clean procedures is unclear. In human medicine, antimicrobials are not typically recommended for procedures such as arthroscopy (27, 28), however there are conflicting

opinions (29). It is unclear whether human recommendations can or should be directly extrapolated to the veterinary field. There are obvious differences in post-operative incision care and patient environment, especially in large animals, which may increase the risk of infection. Additionally, infectious complications in some animals, particularly athletic animals, may be life-threatening if they affect long-term performance ability. Specific study of the need for peri-operative antimicrobial therapy for different procedures, particularly clean procedures, is needed. Concerns that have been raised include inappropriate timing of administration, excessive duration of therapy, inadequate dosing and inappropriate drug choice (30). The improper use of antimicrobials can be associated with higher infection rates (9).

The pre-operative management of the surgical site may be an important factor but veterinary-specific information is limited. Bathing of the patient is reasonable if there is significant contamination of the hair coat (31). It has been suggested in human surgery that shaving should be avoided because any method of hair removal can be associated with higher SSI rates (32). This is rarely practical in veterinary medicine and shaving or clipping is almost always necessary. Shaving or clipping of the surgical site should not be performed until the day of surgery, ideally right before surgery, as shaving the night before has been associated with higher SSI rates in humans (33, 34). A study of dogs and cats reported significantly higher SSI rates when clipping was performed before induction of anesthaesia compared to after induction (9). Care should be taken when clipping or shaving, and good quality, well-maintained instruments should be used to reduce the risk of skin abrasions. Abrasions or microabrasions can facilitate colonization and proliferation of various opportunistic bacteria. If skin lesions are noted at the time of clipping or after surgery, the incident should be recorded and investigated in order to determine whether instrument cleaning, maintenance or replacement, or personnel training is required. Clipping should be done outside of the operating environment if at all possible. There is currently a lack of information regarding

optimal methods of cleaning and disinfecting clippers. Repeated use of clipper blades without sterilization not surprisingly results in higher levels of bacterial contamination of blades (35), however the clinical relevance of this is unclear. Regular cleaning and disinfection are probably useful. Blades should be sterilized after use on animals that are known to be harboring potentially infectious pathogens such as *Salmonella* spp or MRSA.

Skin preparation is an important factor. Skin preparation practices have been discussed in detail elsewhere (3, 31, 36). Potential problems that may be encountered include contamination of preparation solution (37), inadequate initial cleaning, failure to prepare a large enough area, inadequate antiseptic contact time and contamination of the area during or after preparation.

It is has been accepted for decades that everyone involved in direct contact with the surgical field or sterile items should perform a surgical scrub and don sterile gloves. Surgical scrub techniques have been evaluated extensively elsewhere (38, 39). Recently, application of alcohol-chlorhexidine combinations have been evaluated as a replacement for surgical scrubbing and have been shown to be more effective than standard surgical scrub methods (40, 41). This method is less time consuming and is associated with less skin irritation compared to repeated surgical scrubbing. Similarly, the application of chlorhexidine (without alcohol) resulted in similar reduction in hand bacterial counts compared to surgical scrubbing in a veterinary hospital (42). Regardless of the method used, a thorough handwash with careful cleaning under the fingernails must be performed at the beginning of each day (43). Long (> 1/4") and artificial nails are prohibited in many human healthcare facilities and some veterinary hospitals because they can harbor pathogenic bacteria (44) and be associated with surgical glove tears.

The surgical environment must be conducive to proper application of aseptic technique. The surgical suite should be in a restricted area so that unnecessary traffic does not occur. Limiting the number of people present in an operating room has been recommended based on the reported associ-

ation number of people in the room with infection in dogs and cats (8). It may be difficult to limit personnel in all environments, especially teaching situations, but attempt to restrict the operating room to essential personnel is a reasonable measure. Ideally, positive pressure ventilation is used in order to prevent flow of air from 'dirtier' areas into the surgical suite (3). The use of laminar flow with HEPA filtration is ideal. Methods to provide 'ultraclean' air have been shown to reduce SSIs in humans (45), but these are often impractical in established veterinary facilities. Optimal air handling should be considered in new facilities and those where large numbers of surgical procedures are performed, especially when higher risk procedures or patients may be involved. Routine bacteriologic evaluation of the air or general operating room environment is not indicated (3).

Because duration of surgery has been shown to be important in veterinary SSIs (8–10), efficiency is important. However, surgical technique should not be compromised to shorten surgical time, as that could be associated with a concurrent increase in risk.

Post-operative care of the incision site may be an important factor. Contact with the surgical incision, particularly with bare hands, should be avoided. Covering or bandaging wounds for a minimum of 24 to 48 h post-operatively has been recommended in humans and horses (3, 26). Bandage changes should be performed using aseptic technique (3). Animal owners or handlers should be educated on proper incision management and signs of SSI. There is no objective information regarding the need to cover incision beyond 48 hours in veterinary or human medicine, and arguments can be made for both sides. Covering wounds reduces the risk of contamination from environmental, personnel or endogenous sources, however it may also create a more hospitable site for bacterial growth by maintaining a warm, moist and protected environment and negatively affect the ability to detect an early SSI.

Routine hand hygiene must not be overlooked. Human hands are a major, if not the most important, source of infection and can be sources of SSIs through post-operative

contact with surgical sites. Hand hygiene, either proper handwashing or the use of alcohol-based hand rubs, should be practiced routinely and performed before and after every animal contact.

Conclusions

Surgical site infections are important complications in veterinary orthopaedic surgery, and will continue to be an issue regardless of the quality of care delivered. Improvements in patient care and infection control can offset increasing numbers of higher risk procedures, higher risk patients and continued emergence of multidrug resistant pathogens. While development of an SSI in a patient should not always be construed as failure to provide adequate care, it is the responsibility of veterinary surgeons and veterinary practices to provide optimal care, including infection control, and the expected standard of care with respect to infection control is increasing. Close attention to surgical and infection control practices should be useful to minimize the impact of SSIs on patients undergoing orthopaedic surgery.

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