Infection is a major factor in delayed wound healing and an important cause of dehiscence after wound closure. Knowledge of the contributing factors to development of wound infections will provide the clinician with an improved ability to prevent its occurrence. Author’s address: 965 Los Alamos Road, Santa Rosa, CA 95409; e-mail: tstashak@sbcglobal.net. © 2006 AAEP.

1. Introduction

Wound infection is defined as the presence of replicating microorganisms within a wound with subsequent host injury. Infection must be distinguished from wound contamination (microorganisms are not replicating) and wound colonization (replicating microorganisms are present but do not cause host injury). Interestingly, some recent studies of dogs suggest that the organisms that infect a wound may be a subset of those organisms that colonize the wound site.

Wound infection is considered a major factor in delayed wound healing, reduced tissue-tensile strength gain, and dehiscence after wound closure. Potential pathogenic bacteria adhere and/or bind to extracellular matrix proteins (e.g., fibronectin and laminin) of exposed tissue, which may have a direct effect on wound healing. By binding fibronectin, this protein is not available for promoting tissue adherence. Additionally, bacteria that produce cytotoxic exotoxins (e.g., Clostridium spp, Strep. pyogenes, and Staph. aureus) cause more tissue damage, creating a microenvironment conducive to their survival. Those with thick capsules (e.g., Strep. pyogenes, Staph. aureus, and Klebsiella pneumoniae) are more resistant to phagocytosis by leukocytes. During the process of bacterial degradation, liberated endotoxins can activate coagulation pathways; this may cause thrombosis of the microvasculature, systemic organ or immune dysfunction, and macrophage activation that releases more inflammatory mediators. Circulatory alterations decrease the efficiency of glucose and oxygen delivery; this creates an environment where the host’s main non-specific defense, the polymorphonuclear leukocyte, is deprived of the materials necessary for optimum bacterial killing.

Whether infection develops depends on many factors: (1) The dose of microorganisms (we have the most influence over this); (2) Wound microenvironment/degree of contamination; (3) The virulence and pathogenicity of the microorganism; (4) Functional capacity of the host; and (5) Mechanism of injury.

Generally, when bacterial numbers exceed $10^6$ organisms per gram of tissue or per milliliter of exudate in an open wound, the wound becomes infected. A significant increase in failure of delayed wound closure because of infection is seen when the wound bed contains $>10^5$ organisms/g tissue. Contaminated wounds with lesser concent-
tations of bacteria may become infected when foreign bodies are present (e.g., sutures, glove powder, etc.), necrotic tissue is left in the wound, a hematoma develops, local tissue defenses are impaired (e.g., burn patients or immune-suppressed patients), and the vascular supply is altered.9,16,17

Dirty wounds have a 25-fold greater infection rate than clean wounds.7 Wounds contaminated with dirt have a higher risk of infection because of specific infection potentiating fractions (IPFs) found in the organic components and inorganic fraction. These IPFs decrease the effects of white blood cells and humoral factors, and they neutralize antibiotics. As few as 100 organisms can cause infection.17

Wounds contaminated with feces are very susceptible to infection. Feces may contain up to 10^{11} organisms/g.16

Hemoglobin liberated from hemorrhage in a wound suppresses local wound defenses. The ferric ion from hemoglobin also inhibits the natural bacteriostatic properties of serum and the intraphagocytic killing capabilities of bacteria by the granulocyte.7 The ferric ion also can increase the virulence and replication of infecting bacteria. Hematoma formation is believed to be a leading factor in decreasing local wound resistance to infection.18

The use of drains is somewhat controversial, because they represent a foreign body within the wound; however, if drainage of a hematoma from “dead space” is needed, the consequences of not using a drain are considerably more serious than the complications from the drain.18

What caused the injury influences the wound’s susceptibility to infection. Lacerations caused by sharp objects such as metal, glass, and knives are generally resistant to infection. Shear wounds from barbed wire, sticks, nails, and bites are more susceptible to infection because of the degree of soft-tissue damage. Wounds caused by entanglement/entrapment, impact with a solid object, and/or a kick are more susceptible to infection because of the degree of the soft-tissue injury and resultant reduction in blood supply.16 The greater the magnitude of the energy on impact, the more severe the soft-tissue damage and the greater the alteration in blood supply. Wounds created by impact injury are reported to be 100 times more susceptible to infection compared with wounds caused by shearing forces.19

Susceptibility to infection rises in multiple trauma patients even when the injury/injuries occur at a site other than the surgical site; reduced tissue perfusion is believed to be the cause.20

Bacterial infection delays healing by mechanically separating the wound edges from the accumulation of exudate, reducing the vascular supply (a result of mechanical pressure and a tendency to form microthrombi in small vessels adjacent to the wound), increasing cellular responses with prolongation of the inflammatory phase of wound healing, producing proteolytic enzymes that digest collagen, adhering/binding to extracellular matrix proteins, and releasing endotoxins that inhibit growth factors and collagen production.4,8,9 Bacterial injury from infection results in a cellular and vascular response typical of inflammation.

Wound infection develops in ~5–5.9% of our small-animal surgical patients overall.31–33 In small animals undergoing clean, elective procedures, ~2.5–4.7% of the patients develop infection.21,22,24 In clean, contaminated wounds, postoperative wound infections develop in ~5.9% of patients.25 These rates are comparable with those reported in humans.18 In a study done on 451 horses that evaluated the occurrence of surgical wound infection after orthopedic surgery, it was found that infection developed in 10% of the patients overall and 8.1% of the patients undergoing clean surgical procedures.25 The reason for the increased infection rate in this study compared with studies done in humans and small animals was believed to be caused by the exclusive use of orthopedic patients.

2. Selected Techniques for Prevention

The following section will review selected techniques in the management of wounds that will help reduce the incidence of infection.

General Anesthesia and Duration of Surgery

The depth and duration of anesthesia and the duration of surgery have been shown to be significant risk factors for the development of post-operative infection.21,23,26 Excessive depth of anesthesia reduces tissue perfusion and oxygenation, which can cause acidosis and impaired resistance to infection. Prolonged anesthesia impairs the alveolar macrophage function and depresses systemic leukocyte migration and function.27–29 Wound-infection rates have been shown to increase by 0.5% for each 1 min after 60 min of anesthesia.26 This translates to a 30% greater risk of post-operative infection for each additional 1 h. Logical recommendations include reducing the depth and duration of anesthesia and making sure that the patient is well hydrated. The use of propofol should be avoided, because it has been shown to increase infection rates by 3.8 times in clean wounds.30 Mixing thiopentone and propofol at a ratio <1:1 does not improve the bactericidal properties.31

Reducing the surgery time is also logical; wound infection rates doubled after 90 min of surgery and nearly tripled when surgery was >120 min.21,32 The use of electrocautery should be limited. Excessive use of electrocautery has been shown to double infection rates.33 However, if bleeding vessels are grasped with fine non-serrated tissue forceps and electrocautery is used, the infection rate is not increased over that of other methods of hemostasis.18

Wound and Skin Preparation

Proper wound and skin preparation includes hair removal adjacent to the wound, wound cleansing,
lavage/irrigation, antiseptic preparation of the skin adjacent to the wound, preparation of the wound for exploration, and wound debridement.16

1. Hair Removal

If possible, do not clip the hair before the induction of anesthesia. Clipping the hair with a No. 40 clipper blade before induction of anesthesia has been shown to significantly increase infection rates in two large studies done in small animals.21,26 In attempt to answer the reason why clipping was a risk factor for infection, Hamilton et al.34 used a scanning electron microscope to examine human skin prepared with electric clippers and found that the clipper “nipped” the skin at the creases. This produced gross cuts in which bacteria could colonize.

Before beginning hair removal, protect the wound with a sterile, moist gauze sponge. Dampen the hair with water or coat it lightly with K-Y water-soluble jelly before clipping to prevent hair from falling into the wound. Clip a wide area of hair around the wound, and shave only the wound edges using a recessed-head razor. Using a razor with a recessed head will minimize damage to the infundibulum of the hair follicle, which reduces skin contamination from bacteria located in the hair follicle and sebaceous glands.35 Sponges used to pack the wound are discarded and replaced by new ones. Scrub the clipped area of skin at least three times with antiseptic soap and rinse between scrubs with sterile 0.9% saline solution.

2. Wound Cleansing

Wound cleansing is one of the most important components of effective wound management. In the strictest sense, wound cleansing is the use of fluids to gently remove loosely adhered contaminants and devitalized tissue from the wound surface. If contaminants cannot be removed with gentle wound cleansing, then more specific cleansing and debridement techniques can be used.

In clean, acute (<3 h duration) wounds, water or saline may be all that is needed for adequate wound cleansing. For field use, an acceptable saline solution can be made by adding 2 teaspoons of salt to 1 l of boiling water (8 teaspoons to 1 gallon).36

When enhanced wound cleansing is needed, a commercial wound cleanser may be used. Unfortunately, most ionic and many non-ionic surfactants in wound cleansers have been shown to be toxic to cells, which can delay wound healing and inhibit the wound’s defenses against infection.37,38 An in vitro study evaluating the effects of several wound cleansers on human fibroblasts, red and white blood cells found; Constant Clensa was the most biocompatible, and Shur Clens was the least biocompatible. 39

In contrast, another in vitro study ranking the relative toxicity of several commercial wound cleansers found that Shur Clens had a lower toxicity index than Constant Clens.40 Antiseptics should not be added to wound cleansers, because their addition results in a higher cytotoxic index.36 In a heavily contaminated wound, the wound bed can be gently cleansed with a wound cleanser and sterile gauze sponges. This should be followed by thorough lavage with a sterile salt solution. The coarseness of the scrubbing device should be as low as possible while still providing a cleansing action. Wounds scrubbed with coarse sponges have been shown to be significantly more susceptible to infection.36 An advantage to using a commercial wound cleanser is that the surfactant properties significantly reduce the coefficient of friction between the scrubbing device and wound tissue.36

Antimicrobial cleansers that are formulated to remove fecal contamination from intact skin (Dermal wound cleanser and MicroKlenz4) are more cytotoxic than wound cleansers and therefore, should not be used in a wound.37 Antiseptic soaps, detergents, and alcohol should not be allowed to contact raw tissue.41

3. Wound Lavage/Irrigation

Lavage cleans the wound of debris and reduces the bacterial numbers and IPFs in the acute wound. Because bacteria and contaminants initially adhere to the wound surface by an electrostatic charge, adequate fluid pressure must be used to dislodge them from the wound. Lavage solutions are most effective when delivered at an oblique angle by a fluid jet at a pressure of at least 7 lbs per square inch (PSI). Pressure ≥7 PSI cannot be achieved by gravity flow or lavage with a bulb syringe.42,43 Pulsatile pressures of 10–15 PSI have been shown to be 80% effective in removing adherent bacteria from a wound.43 Increasing the lavage pressure to 20–25 PSI does not significantly improve the result.44 However, 70 PSI was found to be more effective in removing wound-tissue fragments and debris than 25–50 PSI.44 The use of this pressure is not recommended, because it results in fluid dispersion into wound tissue.45 Thirty PSI delivered from a single orifice has been shown to penetrate and damage tissue.46 In a study comparing the effects of irrigation with saline at 15 PSI to irrigation at 20 PSI on penetrating partial-thickness wounds, it was found that 20 PSI penetrated the entire wound thickness. In contrast, irrigation with 15 PSI resulted in superficial (10–15%) penetration of the wound tissue.47 Results of this study suggest that wounds should not be irrigated with fluids delivered at a pressure >15 PSI.47

As for the methods of delivery, the superiority of a pulsatile-fluid stream over a continuous stream has not been established.48 Pulsatile pressures (7–15 PSI) can be achieved by (1) forcefully expressing lavage solutions from a 35-ml or 60-ml syringe through a 19-gauge needle, (2) using a spray bottle, (3) using a “Water Pik,” (4) using a Stryker interpulse irrigation system, or (5) using a Hydro-T massage nozzle.7 The “Water Pik” at a low or intermediate setting delivers 40–50 ml/min at
10–15 PSI. The “Water Pik” seems to be most effective for cleaning heavily contaminated avulsion dental wounds. The spray bottle or the Stryker inter-pulse irrigation system are preferred for lavage of most other wounds. The Hydro-T can deliver tap water to the wound surface at a pressure of ~15 PSI. Lavage with tap water should be discontinued after a bed of granulation tissue develops. If continued, it will delay wound healing. When using pressure lavage, care must be taken not to drive contaminants deeper within the wound and not to inadvertently separate loose fascial planes.

The clinical benefits of wound lavage have been established in several studies. In an experimental study comparing irrigation with a bulb syringe to fluid delivered at low pressure (8 PSI using a 35-ml syringe and 19-gauge needle), it was found that there was a significant reduction in bacteria and a reduced incidence in infection. In a clinical study done on 335 humans presenting with a traumatic wound <24 h duration, it was found that wounds irrigated at 13 PSI using a 12-ml syringe and 22-gauge needle had a significant decrease in wound inflammation and wound infection compared with wounds irrigated with a standard-bulb syringe.

The efficacy of low-pressure irrigation (15 PSI) in removing bacteria is decreased as the wound ages. In an acute wound, the majority of the bacteria reside on the wound’s surface. As time passes, the bacteria invade the wound tissues; therefore, they are not removed with irrigation alone, and debridement is required. The exact time period for bacteria to begin to invade the tissue is unknown, but 3–6 h has been suggested as a reasonable time.

4. Antiseptics Used for Lavage/Irrigation

Hydrogen peroxide (HP) is still commonly used for wound irrigation. HP has a narrow antimicrobial spectrum; it is an effective sporocide but has little value as a wound antiseptic. It is, however, very effective in dissolving blood clots. A 3% solution of HP damages tissues, is cytotoxic to fibroblasts, and causes thrombosis in the microvasculature adjacent to wound margins. HP is not recommended for wound lavage.

Povidone iodine solution (PI) is commonly used as an antiseptic for wound lavage. A 10% solution of PI has a broad antimicrobial spectrum against Gram +/− bacteria, fungi, and candida; bacterial resistance has not been identified. The iodine in PI is complexed with polyvinyl-pyrrolidone to increase its stability and reduce its irritation and staining. Diluting PI uncouples the complexed bond, which makes more free iodine available for antimicrobial activity. PI solutions diluted to 0.1 and 0.2% (10–20 ml/1000 ml) concentrations are best for wound lavage. These dilutions have also been shown to be effective in reducing bacterial numbers in dog wounds. Diluted solutions have been shown to kill many bacteria within 15 s. PI (5%) inhibits white blood-cell migration, which results in increased wound infections compared with wounds irrigated with 1% PI or saline. A 1% PI solution used for wound lavage of abdominal incisions after closure of the peritoneum was shown to be significantly superior to saline in reducing postsurgical wound infection. PI (0.5%) powder sprayed in contaminated incision wound beds after gastrointestinal surgery significantly reduced infection rates to 9.9% compared with 24.4% for non-sprayed controls. Bacterial contamination (established by cultures) at the time of surgery was associated with a 52% infection rate in control groups; the infection rate was reduced to 11% in the PI-treated group. Irrigation with (1%) PI does not seem to effect tensile strength gain in healing wounds.

There are disadvantages to using PI. It is inactivated by organic material, serum, and blood. Less than 0.1% concentrations are inactivated by a large number of neutrophils. Concentrations of >1% are required to kill Staph. aureus. PI can cause contact dermatitis, metabolic acidosis, thyroid dysfunction, and ototoxicity. Thyroid dysfunction may be seen in humans that use PI exclusively for rinsing and scrubbing their hand and arms. The disadvantages cited do not diminish the benefits seen with dilute PI irrigation of wounds.

Chlorhexidine diacetate solution (CHD) is commonly used for antiseptic purposes and wound lavage. CHD has a wide antimicrobial spectrum against Gram +/− bacteria and viruses. Unfortunately, Proteus spp. and Pseudomonas spp. have developed or have an inherent resistance to this product, and it has no effect against fungi or Candida. When applied to the intact skin, its antimicrobial effect is immediate and has a lasting residual effect because of binding to proteins in the stratum corneum. CHD 0.05% has more bactericidal activity than PI. Faster wound contraction was reported in wounds treated with dilute CHD or PI compared with saline controls; however, the differences were only statistically significant for CHD. Currently, 0.05% CHD (1:40 = 25 ml to 975 ml dilution of the 2% concentrate) solution is recommended for wound lavage. Greater concentrations are deleterious to wound healing. The precipitate that forms when CHD is diluted in salt solutions does not affect its antiseptic quality or delay wound healing. CHD (0.05%) seems to be the superior lavage solution in dogs and humans; however, the applicability of these results to the treatment of equine wounds is unknown.

Advantages of CD over PI include residual antibacterial capacity and continued activity in the presence of blood, pus, and organic debris with less systemic absorption. Disadvantages of CHD are <0.05% solutions result in significant survival of Staph. aureus, but >0.05% solutions inhibit epithelialization and granulation-tissue formation. Additionally, contact with the eyes causes ocular toxicity.
Sodium hypochlorite (SH) 0.5%, also referred to as Dakin’s solution, releases chlorine and oxygen to kill bacteria. SH is more effective in killing Staph. aureus than PI or CHD. Unfortunately, SH is cytotoxic to fibroblasts. The clinical benefit of Dakin’s solution is probably caused by its ability to dissolve necrotic tissue. Removal of the necrotic tissue decreases the bacterial load, which results in improved wound healing. In this situation, it is being used as a chemical debriding agent, and as such, its use should be discontinued when the necrotic tissue is gone. SH should not be used routinely as a topical disinfectant. If it is used for debridement, it is suggested that it be diluted to one-quarter strength (0.125%). In a pinch, it is suggested that an acceptable approach is to dilute 5% SH with tap water to achieve a 0.025% solution. In a study evaluating field water from five different sources used to dilute SH, no bacterial growth was found in 99 of 100 samples. The conclusion was that this field-expedient modification of Dakin’s solution could substitute for sterile irrigation fluid when it is neither available nor logistically feasible.

In conclusion, several studies have shown that dilute PI or CHD are superior to saline alone in removing bacteria from the surface of the bone and in soft tissues. An in vitro study comparing sterile saline to diluted solutions of PI and CHG that were delivered at 14 PSI to the surface of bone contaminated with a fixed number of bacteria found that the antiseptic solutions reduced the bacteria numbers 19-fold compared with saline controls. Antiseptics seem to be most effective in reducing bacterial numbers in acutely contaminated wounds but not in chronic wounds or wounds with established infection. The latter should be treated with topical antibiotics.

5. Antibiotics for Wound Lavage

The addition of antibiotics to the lavage solution markedly reduces the number of bacteria in a wound. Experimentally, 1% Neomycin solution was found to be very effective in preventing infection in wounds contaminated with feces. In a double-blind study done on 260 sutured lacerations; penicillin sprayed on the wound before closure prevented 3 of 4 infections.

6. Amount of Fluid Needed for Wound Lavage

In general, the amount of fluid needed for wound lavage depends on the size of the wound and the degree of contamination. Minimally, the gross contaminants should be removed, and lavage should be discontinued before the tissue becomes waterlogged.

7. Antiseptic Skin Preparation

The two most commonly used surgical scrubs for skin preparation are PI (Betadine) and chlorhexidine (Hibiclens). Rinsing with saline or 70% isopropyl alcohol after scrubbing does not seem to alter the antimicrobial effect of PI; however, rinsing with 70% alcohol reduces the residual effect and antiseptic quality of chlorhexidine. Therefore, using a saline rinse is recommended.

A disadvantage to PI is skin reactions, particularly in small animals. Occasionally, an acute skin reaction to PI occurs in horses, but it is rare. The reaction is most commonly seen in the horse after clipping, scrubbing, and rinsing with 70% alcohol, spraying with a PI solution, and bandaging. Skin reactions include SC edema and skin-wheal formation.

A disadvantage to the use of chlorhexidine scrub is that short exposure to the eye, even in weak concentrations, results in corneal opacification and ocular toxicity.

Although the mechanical effects of scrubbing the wound with these antiseptic soaps can be helpful in removing wound debris, they are very cytotoxic and therefore, should not be used for cleansing wounds. Also, PI surgical scrub was shown to be ineffective in reducing bacterial levels in wounds.

Even with the high bacteriocidal effects of these antiseptics, 20% of the bacterial population in the skin resides in protected hair follicles, sebaceous glands, and crevices of the lipid coat of the superficial epithelium.

8. Surgeon Hand and Arm Preparation

Hand cultures immediately after standard surgical hand preparation and 4 h in surgical gloves found that alcohol (70% ethyl) and chlorhexidine (4%) were effective surgical scrubs with good residual effect. PI was found to have little residual effect. The article concluded that (1) chlorhexidine preparations are superior, (2) PI has poor prolonged effect, (3) triclosan is not effective, and (4) 70% ethanol (V/V) has low antibacterial effectiveness. Seventy percent ethyl alcohol is superior.

A waterless skin preparation seems to have many desirable qualities. Avagard contains 1% chlorhexidine gluconate and 61% ethyl alcohol in an emollient. A blinded study comparing Avagard to 4% CHG or PI for hand and arm preparation over 5 days and under surgical gloves for 6 h found that Avagard was superior in antiseptic quality and was less irritating than the PI or CHG. Besides being an effective antiseptic prep for hospital use, it seems to be very useful in ambulatory practice.

9. Wound Exploration

Wound exploration is done to document the extent of the wound, identify if a bone or a joint is exposed, and determine if a foreign body is present. After the wound is cleaned and free of debris, the wound can be explored digitally using sterile gloves; make sure that the talcum powder is rinsed from the outer surface of the gloves before this is done. If the wound has a small opening precluding the use of the digit, then a sterile probe can be used to identify the depth of the wound, determine if a foreign body is
present, or determine if bone is contacted. After the depth of the wound is reached, a radiograph can be taken to identify its location in relationship to bone or synovial cavities. Synovial fluid can be identified by stringing it between the thumb and forefinger, and if questions remain, a sample of the fluid should be submitted for cytology and culture/sensitivity. If synovial penetration is suspected, a needle is placed in the synovial cavity at a site remote to the wound. If synovial fluid can be retrieved, it is submitted for cytology and culture/sensitivity. After this, sterile saline solution is injected into the synovial structure; if the synovial capsule has been penetrated, fluid will flow from the wound site (Fig. 1). If a synovial structure is involved, it is lavaged with 3–5 l of sterile saline or crystalloid solution followed by lavage with 1 l of a 10% dimethyl sulfoxide (DMSO) solution. Intrasynovial instillation of antibiotics is also recommended.\textsuperscript{35}

Radiographs (plain and contrast) can be useful in identifying fractures, joint subluxations and luxation, and some foreign bodies. Ultrasound is most useful in identifying damaged soft-tissue support structures, gas accumulation, muscle separation, and radiographically unapparent foreign bodies (Fig. 2, A and B).\textsuperscript{35}

Arthroscopy or tenoscopy can be invaluable tools to identify radiographic occult lesions, particularly those involving cartilage, and to identify foreign

Fig. 1. An example of a sterile needle placed in the distal interphalangeal (coffin) joint in a site remote to the wound.

Fig. 2. This figure shows the value of ultrasound in identifying a piece of wood that was not found using contrast radiography. (A) Transverse ultrasound image in the mid-metacarpal region that identifies a hyperechoic density (cursor) located at the distal extent of carpal-canal sheath between the carpal-check ligament and deep digital flexor tendon. (B) Longitudinal ultrasound image of the same; note the hyperechoic density (cursor).
bodies with the joint or tendon sheath (e.g., hair, dirt, or other foreign bodies; Fig. 3).

10. Wound Debridement

Wound debridement can either be done with a scalpel, CO₂ laser with enzymes, debridement dressings, or chemically with Dakin’s solution. Its purpose is to reduce the bacterial load, remove wound contaminants (dead tissue and foreign bodies), and improve the vascular supply. The standard approach is sharp debridement to convert a contaminated wound into a clean wound. The types of sharp debridement include (1) excisional (layered), (2) en block, (3) simple or piecemeal, and (4) staged. Bone devoid of periostium should also be debrided.

Layered debridement begins with the removal of the most superficial tissues and continues deeper in the wound bed until its depths are reached. En block debridement is used primarily for small animals and therefore, will not be addressed in this presentation. Piecemeal debridement is used for large wounds, usually involving the body. Beginning at one wound margin and then moving toward the other margin, all devitalized tissue is removed in a piecemeal fashion (Fig. 4). Staged debridement is used over a number of days. The advantage of the staged approach is that it avoids inadvertent removal of viable tissue. Governing criteria are color and attachment. White, tan, black, or green tissue that is poorly attached is debrided. Pink to dark purple tissue that is well attached is left in place and debrided later if needed. Exposed cortical bone devoid of periostium should be debrided to promote the formation of granulation tissue on its surface and reduce the chances of a sequestrum developing. If the exposed bone is debrided to reach bleeding/oozing bone, granulation tissue will proliferate from the surface. Bone debridement can be accomplished with a hip arthroplasty rasp (Fig. 5), bone rasp, bone chisel, or osteotome. Hydrogel dressings containing acemannan can be used to accelerate the migration of granulation tissue over exposed bone.

A CO₂ laser can be used instead of a cold-steel scalpel. The advantages to the laser is that it sanitizes the wound, causes contracture of the collagen fibers, photoablates exuberant granulation tissue, reduces post-operative pain, and causes minimal hemorrhage.

Proteolytic enzymes (PEs) can be used to debride the wound-surface coagulum and bacterial bio-film that encompasses contaminants and bacteria, which prevents access of topical antibiotics/antiseptics and systemic antibiotic. PEs are indicated when surgical debridement is contraindicated, because it could result in damage to or removal of tissue needed for reconstruction of a
wound; they are also indicated for wounds that approximate nerves and vessels. Products include pancreatic trypsin, streptodornase or streptokinase, collagenases, proteases, fibrinolysin, and deoxyribonuclease. Recently, collagenase has been shown to have the highest proteolytic activity and the greatest likelihood of achieving a clean wound.

There are several debridement dressings available: (1) an adherent open-mesh gauze (e.g., 4 x 4 gauze sponges), (2) a wet to dry bandage using 4 x 4 mesh gauze or sheet cotton, (3) an antimicrobial dressing; this is an excellent choice, because it contains a broad-spectrum antiseptic that has been shown to kill bacteria on the surface of the wound and prevent strike through, (4) a hypertonic saline dressing that is best used for necrotic, heavily infected exuding wounds, and (5) an occlusive dressing that can be used for clean wounds (this dressing promotes moist-wound healing and “autolytic debridement”).

Antibiotics
The ultimate aim of antibiotic treatment is to inflict an insult on infecting bacteria that is sufficient to kill the organism or render it susceptible to inactivation by natural host defenses.
Topical Antibiotic Application

Topical antibiotics (TAs) can be effective in preventing the development of infection, particularly against sensitive organisms.\(^\text{37,67}\) TAs are most effective when they are applied within 3 h after wounding.\(^\text{19}\) However, if a wound older than 3 h or a chronically infected wound is debrided, a new wound is created, which makes TA use appropriate.\(^\text{45}\) In the latter, systemic antibiotics are also recommended.\(^\text{1}\) Although some TA can retard wound healing (e.g., gentamicin cream, Furacin, etc.), others have been shown to accelerate wound healing (e.g., triple antibiotics).\(^\text{48,77–79}\) TA solutions are best used in wounds that are to be sutured, and ointments or creams are best used for bandaged or open wounds.

Because the development of multiple antibiotic-resistant strains of bacteria continues to be a major health concern, new emphasis is being placed on the development and use of alternative wound-care antimicrobial products, particularly those with no known development of bacterial resistance. Dressings containing antiseptics\(^\text{m}\) and silver ions\(^\text{n,p}\) have shown great promise and are experiencing a resurgence.\(^\text{76}\) Dressings that absorb exudates and reduce bacterial numbers\(^\text{6,7}\) are now available.\(^\text{76}\) Additionally, the antimicrobial properties of alternative products such as honey and melaleuca alternifolia oil (tea tree oil) are being investigated.\(^\text{81–86}\) Extracellular matrices and topical oxygen also seem to have antimicrobial effects.\(^\text{87,88}\)

3. Conclusion

There are myriad contributing factors that influence infection rates in our equine patients. We can influence many of these factors and reduce the chances of infection occurring under most circumstances. Continued work needs to be done to further clarify the role of topical agents and dressings that will improve the chances of preventing infection.

References and Footnotes

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