Advanced Wound Management

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Wounds may fail to heal because tension, infection, hematoma or seroma formation, ischemia, molestation, pressure, motion, foreign materials, neoplasia, drugs (corticosteroids, neoplasia), radiation, severe malnutrition, or underlying metabolic disease. When wounds fail to heal, the veterinarian should examine and treat the animal for underlying disease, culture a punch biopsy of the wound to evaluate for infection and determine sensitivity, and apply local wound management techniques to encourage development of a healthy wound bed that can either be left to heal by second intention or closed primarily.

Review of dressings and bandages

Dressings

Dressings are used on wound surfaces to prevent infection, maintain moisture, enhance healing, or facilitate debridement. Some dressings such as triple antibiotic ointment and silver sulfadiazine will speed wound healing, likely because of their broad spectrum antibacterial activity and ability to keep wound surfaces moist. Spray or foam topical dressings containing debriding agents are useful when an animal cannot be anesthetized or when all viable tissue must be spared (such as in burn wounds). One example is a salt-lysosyme foam (VetAid Spray). Hexamethyldisiloxane acrylate copolymer (No-Sting Barrier Film) produces a nontoxic film on the skin that protects the skin from fecal, urine, or serum scald. It is applied to clean dry skin every third day and allows underlying skin inflammation to resolve.

Antiseptic-impregnated dressings may reduce the amount of contamination through and under the dressing. Bandage materials impregnated with silver products have a great spectrum of activity but are expensive. Alternative options include biguanide impregnated bandages (e.g.,Kerlix AMD,Tyco/Kendall), which are less expensive and can come in a variety of materials such as roll gauze.

Specific types of dressings that enhance healing

Hydrocolloids

Hydrocolloids are usually made of pectin, gelatin, or carboxymethylcellulose attached to a film or adhesive backing. Hydrocolloid bandages absorb 67-75% of their weight in wound fluid or exudates while maintaining a moist environment. They are used for partial or full thickness wounds and can be used on granulating and necrotic wounds. They enhance healing, protect wounds from contamination, and aid in autolytic debridement, and may reduce infection rates compared to gauze, film, foam, or hydrogel coverings. They can be left on wounds up to seven days but should be changed any time strike-through occurs. They may cause exuberant granulation tissue; therefore, wounds should be checked frequently. The gel formed may have an unusual odor and texture like purulent material but washes off easily. Dressings that form gel should be cut to fit inside the wound (on the wound bed only) so they don't cause maceration of the skin.

Hydrogels

Hydrogels are 80-90% water- or glycerin-based wound dressings that come as sheets, amorphous gels, or impregnated gauze. They absorb minimal amount of fluid but provide large amounts of moisture to dry wound beds, facilitating autolytic debridement, reducing pain, and enhancing healing. They can be applied as often as twice daily or left on the wound for up to five days. They are used for minimal to moderately draining wounds (scrapes, burns, ulcers, blisters) and on wounds in the late stages of healing that have healthy granulation tissue, decreased drainage, and evidence of epithelialization. They can cause maceration to surrounding healthy skin and therefore should only cover the wound bed.

Alginates (e.g. curasorb, C-stat, kalginate, tegagen)

These polysaccharide dressings are produced from kelp, and are available as twisted fibers or mats that are held in place with an overlying bandage. Alginates form a soluble gel when they come in contact with sodium from wound exudates, providing a nonadherent moist wound environment that promotes autolytic debridement and enhances wound healing. They are used on moderately heavy exudating wounds in the early stages of healing. They also aid in hemostasis. If used on dry wounds, they must be moistened with saline to avoid dessicating the wound. They can be left on moist wounds for up to seven days, as long as there is no strike-through of the overlying bandage. The gel formed may have an unusual odor and texture like purulent material but washes off easily.

Collagen (e.g. collamend, fas cure, collasate, HyCure)

Processed collagen comes in sheets, powders, gels, or sponges. It enhances inflammation and hemostasis and provides a scaffold for cellular colonization, thus accelerating fibroplasias and epithelialization. In dogs (but not horses) it increases the rate of epithelialization, probably because it maintains a most environment.

Tripeptide-copper Complex (e.g. Iamin-Vet)

Tripeptide-copper complex is a hydrogel that acts as a growth factor, chemotactic agent, and wound activator. It stimulates wound neovascularization, epithelialization, collagen deposition, and wound contraction to enhance wound healing. It is used for partial and full thickness wounds that have been debrided and thoroughly cleansed. It is applied under a nonadherent dressing that is changed daily, or can be applied to unbandaged wounds up to four times a day. It has been shown to speed healing of diabetic ulcers in people, ischemic wounds in rats, and open wounds in dogs.

Acemannan (e.g. carravet, carrasorb)

Acemannan is derived from the aloe vera plant. It acts as a synthetic growth factor that stimulates macrophages, resulting in release of interleukin-1 and tumor necrosis factor alpha secretion, cytokines that stimulate wound healing. Interleukin-1 stimulates fibroblast proliferation, neovascularization, epidermal growth and migration, and collagen deposition. Tumor necrosis factor alpha induces wound angiogenesis. Acemannan increases granulation tissue formation, speeds the rate of healing of foot pad wounds, and stimulated non healing wounds to begin to heal. The freeze-dried form attracts water and reduces tissue edema and inflammation. Acemannan is used for partial and full-thickness burns, lacerations, ulcers, abrasions, and slow-healing wounds. Its greatest effect is within the first week of injury. Wounds should debrided and lavaged as needed before application, and acemannan should be reapplied during daily bandage changes.

Maltodextrin (i.e. intracell multidex)

Maltodextrin is a hydrophilic powder made of D-glucose polysaccharide with 1% ascorbic acid that pulls fluids from the wound, keeping the wound moist while helping to remove exudates. It also attracts white blood cells to the wound to increase growth factor concentration and, when hydrolyzed to glucose, provides an energy source for the wound to speed healing. It works in infected and non-infected wounds, but should be applied after the wound is debrided and lavaged. The powder form is used on exudating wounds, while the gel form is used for drier wounds. Wounds treated with maltodextrin should be lavaged before each application and rebandaged daily. In horses maltodextrin decreases pain and stimulates granulation tissue.

Honey

Honey decreases inflammatory edema, stimulates macrophage migration, accelerates sloughing of dead tissue, provides an energy source, and forms a protective protein layer over the wound bed. It stimulates development of healthy granulation tissue and has some antibacterial properties because of its hydrogen peroxide contents, which also stimulates angiogenesis. It is effective against a wide variety of gram positive and gram negative organisms, including *E. coli, Pseudomonas, Serratia, Salmonella, Staphylococcus, Streptococcus,* and *Candida*. Honey used on wounds should be unpasteurized and not heated above 37ºC. Surgical gauze soaked in honey is laid directly on the lavaged and debrided wound, and covered with an absorbent secondary bandage. The bandages are changed one to three times daily as needed for strike through. Because honey absorbs a large amount of fluid, it could exacerbate fluid and electrolyte imbalances is used on large wounds.

Sugar

Because of its high osmolality, granulated sugar decreases edema, attracts macrophages, accelerates sloughing of necrotic tissues, provides energy, promotes development of a protective protein layer, and stimulates development of healthy granulation tissue. Before use, wounds are thoroughly lavaged. A deep layer (at least 1 cm) of sugar is placed over the wound and covered with absorbent bandages. Bandages and sugar are changed at least twice a day, and as soon as strike through occurs. Sugar is discontinued once a healthy granulation bed forms. Wounds infected with *Staphylococcus, Streptococcus, Enterobacter, E. coli, Klebsiella, Pseudomonas, and Serratia* respond to sugar treatment. Like honey, it can also cause metabolic imbalances when used on large wounds.

Silver

Silver has broad spectrum antimicrobial properties. It can be found in wound ointments and creams or bound in foam sponges and nonadherent dressings. Although expensive, some of these dressings can be reused for several days because of continual release of silver ions into the wound fluid.

Polyurethane foam (e.g. Hydrasorb)

Polyurethane foam absorbs exudates and keeps wounds moist. It is used in the early inflammatory stage and through the repair stage. Polyurethane foam can be used to deliver medications, but will not be absorptive if saturated with medicinal fluids. Bandages are usually changed daily. If exudation is minimal, it may be left on for more than a day.

Selection of Bandage Materials should be based on the stage of wound healing and character of the wound. Moisture increases the rate of healing of wounds; the wound itself should be kept moist; however, the adjacent skin edge should be kept dry.

For wounds with minimal debris or necrosis, use a smooth, nonadherent contact layer in the first 24-48 hours to avoid disturbing blood clots, and apply an absorptive second layer. A thin coating of antimicrobial dressing may be placed on the contact layer after debridement and flushing. The outer layer is applied with pressure if there is bleeding. Distribute pressure evenly throughout the bandage and leave the central toes exposed so they can be evaluated for swelling, excessive coolness, and abnormal color. Remove pressure bandages within 24-48 hours, or earlier if the animal is actively traumatizing the bandage.

If the wound needs debridement, adherent contact material such as wide mesh gauze is applied wet or dry to the wound surface. Dry gauze may be used as a contact layer when the wound produces large amounts of thin fluid and loose necrotic tissue or debris.

The wider the mesh, the more debridement the wound undergoes. Gauze moistened with sterile saline or dilute antiseptic solution (0.05% chlorhexidine) is more effective at dissolving and removing thick wound drainage and debris. The bandages may need to be changed 2-3 times a day until the debris or excess lessens. Opioids may be necessary to limit pain and sedate the animals during bandage changes.

When the wound is beginning to "heal", some drainage is still present and new granulation tissue is forming. Blood vessels in the granulation tissue give the wound a pink, cobblestone appearance. Use nonadherent semiocclusive bandages for the contact layer and cover with a thick, absorptive second layer.

Once new skin begins to form and drainage is decreased, the contact layer may be composed of semiocclusive or occlusive, nonadherent material. Petroleum based products should be avoided at this time since they slow new skin formation. The intermediate and outer layers should allow some wound mobility to allow wound contraction.

After 3 weeks the wound begins to mature. Bandages are usually not required during this stage but may help to protect the wound.

Summary of wound management for challenging wounds

Punch biopsy for culture

Swabs of wounds are not sufficient for culture in most cases because of local contamination. The wound surface should be prepped as for surgery and a punch biopsy of deep tissue obtained for culture. Antimicrobials will be selected based on sensitivity results. In some instances, resistant bacteria are best treated by topical antimicrobials. Animals with swelling, inflammation, redness, CBC changes, or other indicators of systemic effects should receive systemic antibiotics. Systemic antibiotics are also administered when healing does not progress with topical therapy.

Moist wound healing

Moist wound healing is preferred over wet-to-dry techniques. Wet-to-dry bandages traumatize healthy tissue with debridement, are detrimental to cellular healing, disperse bacteria during bandage changes, leave fibers in the wound bed, and are painful to change.

Topical antimicrobials

High local antimicrobial concentrations will reduce bacterial numbers without causing systemic effects. For soupy infected wounds, use an antimicrobial impregnated gauze within the wound. For drier infected wounds, use a gauze or sponge impregnated with antibacterial ointment, silver sulfadiazine solution, or a silver/alginate/dextran combination. Once the infection has cleared, use a topical that keeps the wound slightly moist.

Occlusive or semiocclusive dressings

Occlusive and semiocclusive dressings promote moist wound healing.Incidence of infection rate is 63% lower in wounds treated with occlusive dressings because they serve as a barrier to bacteria, prevent dessication, lower oxygen tension, increase angiogenesis, and encourage white blood cell viability and activity.

Appropriate bandages

Tie over bandages help secure the dressing to the wound and reduce tesion on wound edges. A sterile adhesive drape (e.g. Ioban) acts as an occlusive barrier; it works great for preventing strike through and retaining fluid.

Wound cookbook

Practices should consider developing a consistent plan for management of challenging wounds so that their staff can assist with client education and wound management. Of course, plans may need to be changed for financial reasons, and should be changed if the wound is not healing appropriately. An example of wound-based planning using dressings combined with tie-over bandage or Ioban adhesive drape is as follows:

Soupy wounds: Kerlix AMD with Ioban covering; change daily.

Nasty, nonsoupy wound: Honey on Kerlix AMD or gauze and Ioban covering; change daily.

Necrotic wounds: Medical maggots. Change bandage 2-3 times daily.

Infected nonsoupy wound: Algidex with Ioban covering; change every 2-7 days.

Granulating wound: Telfa pad with triple antibiotic and VetWrap; change every 2-7 days.

Superficial scrape: Adaptic or Telfa pad with thin layer of triple antibiotic.

Maggots

Like honey, maggot therapy has been used for thousands of years to treat wounds. Popularity of maggot therapy waned with introduction of antibiotics in the 1940's but rose once more with the advent of antibiotic-resistant bacteria, such as MRSA. Maggot therapy is recognized by the US Food and Drug Administration and the UK Prescription Pricing Authority and thus can be officially prescribed. Sterile maggots are currently used in human patients for treatment of bed sores, leg ulcers, diabetic foot wounds, primary burns, osteomyelitis, and postoperative incisional infections. They are particularly useful for chronic wounds that have not responded to conventional therapy. *Lucilia sericata*, the green-bottle blowfly larvae, prefer necrotic over live tissue and therefore are well suited for clinical use. Since maggot secretions are effective against vancomycin-resistant MRSA, they are important complement to current wound therapy.

Maggot therapy provides three advantageous processes in wounds: wound debridement, acceleration of wound healing, and wound disinfection. Maggots clean necrotic tissue from a wound to an extent matched only by microsurgery. This removes material that would otherwise serve as a nidus for infection and inflammation. During debridement, the green-bottle fly larvae secrete proteolytic enzymes, including serine- and metallo- proteinases, which digest bacterial byproducts and necrotic tissue. These enzymes also breakdown components of the extracellular matrix within the wound, such as collagen and fibrin, which allows initiation of healing, and they disrupt biofilms that form around devices and necrotic tissue. Dissolution of these biofilms permits bactericidal activity by antimicrobials and the host's immune system. Maggots also secrete ammonia, which increases wound pH and optimizes protease activity. Interestingly, maggot excretions that are incorporated into hydrogel wound dressings will also stimulate debridement and wound healing.

Although not reported in every study, maggot therapy can accelerate wound healing in some cases. Factors implicated in this effect include the physical movement of the maggots within the wound, excreted chemicals that increase wound pH, and stimulation of fibroblast growth. Maggots also modulate mammalian immune system by inhibiting migration, activation, and pro-inflammatory responses of certain white blood cells, which reduces tissue damage caused by these cells.

Maggots secrete or excrete a variety of substances with antimicrobial properties. Factors within these products are active against Gram-positive, Gram-negative, and methicillin-resistant bacteria; viruses; fungi; and even cancer cells. Some of the factors, such as alloferon, stimulate human natural killer lymphocytes *in vitro* and induce interferon production *in vivo*. Alloferon has been shown to be clinically active against herpes simplex and human papilloma viruses and is sold as the product Allomedin, which is used to treat cold sores, genital herpes, and gingivitis. Other factors, such as 5-S-GAD, generate hydrogen peroxide and are active against bacteria, inhibit angiogenesis in some cancers, protect retinal ganglial cells from apoptosis associated with glaucoma, and prevent cataract formation.

Several descriptive clinical studies of maggot therapy have been published in people. In one study, use of maggots in 30 patients with chronic wounds (arterial or venous stasis ulcers, diabetic or pressure ulcers, or chronic surgical wounds) resulted in decrease in wound bacterial counts and healing of 83.2% of the wounds. In a case series of 34 chronic leg wounds (>12 weeks duration), 85% of wounds healed, usually within 7-10 days. In another study of 70 patients with chronic leg wounds, 86% had 66% to 100% reduction in wound size. About a third of these patients perceived an increase in pain during the treatment period. Outcomes for larval therapy are worse in patients with greater wound depth, old age, or septic arthritis. A randomized, controlled comparisons of patients with venous or arterial ulcers treated with maggots or conventional hydrogel dressing found no difference in rate of healing; however, maggot treatment resulted in complete wound debridement 2.3 days faster than hydrogel treatment. Again, the patients receiving maggot therapy significantly reported higher pain scores.

In veterinary medicine, most reports of maggot therapy are either experimental or case series; controlled studies of large numbers of animals are still lacking. Maggot therapy has been used in horses for treatment of septic navicular bursitis, hoof infections, complicated laminitis, supraspinous bursitis, ulcers, cartilage necrosis, septic joints, and rattle snake bites. In donkeys, sheep, dogs, cats, and rabbits, it has been used for wound debridement and infection control.

Leeches

Within their saliva, leeches secrete pure anti-coagulating substances hirudin and calin, along with hyaluronidase, which facilitates spread of the anticoagulant through the wound, and a variety of chemicals that stimulate vasodilation and prolong bleeding. Other secretions inhibit proteoloysis, dissolve fibrin, and reduce or prevent inflammation. Plastic surgeons use medicinal leeches to salvage flaps, microvascular free-tissue flaps, digit reimplantations, and facial reconstruction sites that suffer from postoperative venous congestion. Leeches have also been used to treat osteoarthritis, tenosynovitis, sialadenitis, and other inflammatory conditions.

The site is prepped with warm, heparinized saline to encourage vasodilation. Alcohol and iodine may potentially interfere with attachment. A barrier, such as a moist gauze with a hole in it, is placed over the wound to limit leech migration. The leeches are carefully placed on the wound and left there until they are fully distended, usually 30 to 60 minutes. The leeches will detach themselves when full; alternatively, common salt can be sprinkled on their heads. Forcible removal is avoided because it may cause regurgitation. If the wound bleeds persistently, place pressure over the site. Leeches are disposed of as clinical waste.

Potential complications associated with leech application include infection, often evidenced by local cellulitis or abscess formation. In people, the incidence of leech associated infection ranges from 2 to 20% and can result in extensive tissue loss and septicemia. The most common pathogen is *Aeromonas*, a resident flora of leeches. *Aeromonas* produces beta-lactamases, so first generation cephalosporins and pencillins are likely to be ineffective. Options for prophylactic treatment include fluoroquinolones or animoglycosides. Sites should not be prepped with alcohol or hypertonic saline, either of which could cause the leech to regurgitate into the wound and possibly infect the site. Leeches may also result in persistent bleeding, anemia, and local or systemic allergic reactions. Leeches may also migrate (e.g., under flaps, into airways) and therefore should be watched while they are in place. Leeches have the potential to transmit viral infections and should therefore not be reused in people. Most patients require multiple treatments to reduce venous congestion; since leeches can consume 10 times their weight in blood, transfusions may be necessary over the course of the treatment.

As with other adjunctive therapies, controlled clinical trials for leech therapy in people are lacking. In one study, leech therapy resulted in survival of 8 free tissue transfers considered unsalvageable; most patients required 6 or 7 days of treatment with 215 leeches used per patient. At least half of patients receiving leech therapy for chronic sialadenitis/sialadenosis. In 113 patients with advanced osteoarthritis of the stifle, leech application resulted in statistically significant reduction of pain scores, long term reduction in joint stiffness, and improved mobility. In another randomized control trial, a single course of leech therapy effective relieved pain and improved function and quality of life for at least 2 months in women with carpometacarpal thumb osteoarthritis. The reason for the response in patients with osteroartrhitis is not known.

Leech therapy has anecdotally been used in veterinary medicine for treatment of congested flaps, grafts, penis, and paws; drainage of auricular hematomas; treatment of cats with saddle thrombus; relief of pressure or pain in horses with tenosynovitis, tendinitis, and acute laminitis; and reduction of red cells in cats with polycythemia vera. Leech sellers claim it treats joint malformation, arthritis, disc disease, neuritis, muscle stiffness, eczema, abscesses, mastitis, and lymphagitis. All of these claims are unproven in animals.

Negative pressure wound therapy

Open wound management is frequently used for treatment of wounds with extensive tissue injury or infection or those that are chronic and nonhealing. Negative pressure wound therapy stimulates wound healing by a variety of mechanisms, including removal of fluid, reduction of edema, and stimulation of granulation tissue formation. One major advantage of NPWT is the ability to delay bandage changes to every 2 to 3 days. NPWT has also been used to enhance skin graft attachment, decrease seroma formation after primary wound closure, and treat peritonitis and myofascial compartment syndrome. NPWT should not be used in sites that have neoplasia, active bleeding, or exposed vessels or in patients with coagulopathies.

In a prospective, controlled, experimental study of dogs with open wounds NPWT stimulated early appearance of high quality granulation tissue but delayed wound contraction and epithelialization and did not enhance bacterial clearance from the wounds. NPWT results in extensive loss of fluid and protein, and a large amount of bacteria is trapped in the dressing, so it is important to keep the negative pressure working. In some experimental studies it provides no additional benefits over traditional bandages. We find it works well to stimulate wound healing in wounds that are not dry or necrotic. Dry, necrotic wounds are better treated with medical maggots, while wounds with a large amount of debris are better treated with honey bandages changed daily or twice daily or with surgical debridement.

Laser therapy

Low level laser therapy (LLLT) affects various aspects of the healing process, including minimizing inflammation, formation of edema, improvement of skin regeneration and enhancement of collagen synthesis. Like HBOT and other modalities, there are few randomized, blinded, controlled studies in companion animals and people. Additionally, studies report a variety of dose ranges, wavelengths, and duration and frequency of treatment. In general doses ranging from 3 to 6 J/cm2 appear to be more effective in promoting wound healing, and doses 10 above J/cm2 are associated with deleterious effects. The wavelengths ranging from 632.8 to 1000 nm seem to provide more satisfactory results in the wound healing process. Experimentally pulsed LLLT with 11.7 J/cm(2)/890 nm of a deep second-degree burn model in rat significantly increased the rate of wound closure compared with control burns. In mice, reepithelialization of wounds being treated with LLLT was the same as those in mice receiving an NSAID. In a rat operative wound model (incisional healing), LLLT with a He-Ne laser was found to promote the healing of operative wounds when used at 17.0 mW setting of 15 seconds a day with a frequency of every other day. In horses and mice, LLLT had no significant effect on second intention healing of full thickness wounds. In dogs, healing of full thickness wounds was delayed with LLLT treatment. In a rat Achilles tendon blunt injury model, LLLT resulted in increased edema of the tendon. In another rat model, LLLT reduced the number of bacteria in the wound. In a dog model of palatal surgery, LLLT had no effect on palatal healing

Lavage systems

Interestingly, in people infection rates of wounds lavaged with tap water are similar to those lavaged with sterile saline. So, a cheap lavage system is a hose or sprayer. Specific lavage systems are useful for cleaning wounds focally but they must be used properly. Wound irrigation is most effective when performed at pressures between 5 and 10 psi; pressures above 10 PSI cause tissue trauma. Benefits of pulsed lavage over a bulb syringe or whirlpool bath are the need for less fluid. Previously clinicians used a 35 cc syringe with an 18 gauge needle for flushing, but that actually generates pressures of 25-40 PSI. A more effective method is to put a bag of fluids in a pressure cuff, attach a fluid set and needle (18 or 20 gauge), and pump up the pressure cuff to 300 mmHg to drive fluid through the needle. DeRoyal has a JetOx unit that uses pressurized oxygen from an anesthesia canister to produce an aerated lavage. A wound can be easily cleaned with 50 mls of saline using this system. The PSI depends on the oxygen flow: 11 L/min will provide 6 PSI, and 13 L/min will provide 9 PSI.