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ARTICLE

Irrigant selection for treating trauma wounds on injured wildlife patients

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Abstract

Contaminated wounds are frequently encountered on injured wildlife patients. Left untreated, contaminated wounds may result in infection with ongoing complications. Wound irrigation is an essential part wound treatment and arguably the most effective means of preventing wound infection. Successful treatment depends on a number of factors but selecting the most appropriate irrigant for the type of wound, degree and type of contamination, species and patient status is up to the informed caregiver. This article discusses some of the pros and cons of common irrigants used in veterinary wound management and best practices for application.

BIO

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Keywords

Antiseptic; irrigant; isotonic; non-antiseptic; solution; wound

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Abbreviations

LRS: Lactated-Ringer's Solution
SOS: super-oxide solution

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Introduction

Wound irrigation is the steady flow of a solution across an open wound surface to achieve wound hydration, to remove deeper debris and to assist in visual examination (Gabriel 2015). Wound healing has three distinct yet interrelated phases. The inflammatory phase is characterized by the body's efforts to eliminate infectious microorganisms, foreign debris and necrotic tissue. The proliferative or fibroblastic phase creates granulation tissue over the wound comprised of inflammatory cells, fibroblasts and new blood vessels. Granulation tissue is covered with new epithelial cells from the wound edge leading to contraction and eventual closer of the wound. The final stage is maturation and is characterized by collagen remodelling, which strengthens the overall wound repair. Together with debridement of dead tissue, irrigation helps to transition wound healing from the inflammatory phase (Rosdahl & Kowalski 2008).

Wound irrigation has been described as the cornerstone of wound management (Singer et al. 1994). Wound irrigation can be divided into irrigation technique (pressure related) and the irrigant used (Chatterjee 2005). Together, these factors attempt to remove foreign material, necrotic tissue and bacteria from wounds through mechanical forces (Atiyeh et al. 2009). There is clear evidence that wound irrigation reduces infection compared to non-irrigation methods of treatment (Chatterjee 2005). However, even with irrigation, outcomes are dependent on many factors, including the properties of the irrigant, the severity of contamination, type of pathogen in the wound, wound location and depth, local tissue hypoxemia, and age and nutritional status of the patient (Busse 2016). Irrigation is considered a universally accepted technique in both veterinary and human medicine.

Irrigants

Ideal irrigants should be isotonic, nonhemolytic, nontoxic, transparent, easy to sterilize and inexpensive. There is no one ideal solution, and so the caregiver must evaluate each irrigant and make an informed decision as to which product will be appropriate for a particular patient. Current research suggests that normal saline (0.9% saline) may be amongst the most appropriate irrigants for trauma wounds; however, other antiseptic and non-antiseptic solutions can be used under certain circumstances. Choosing the best irrigant may also depend on the species. It is contraindicated to irrigate deep wounds in birds that

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might connect to the air sacs or lungs within the body cavity. Likewise, some irrigants can interfere with the waterproofing of feathers and fur in aquatic birds and mammals and should be selected only after alternatives have been considered. The remainder of this article discusses these choices and a summary of solution selectin and considerations for wound irrigation can be found in Table 1.

Antiseptics

Acetic acid

Acetic acid, commonly known as vinegar, may be one of the oldest used antiseptics. It is usually diluted to a 1–5% concentration (10–50 ml of vinegar to 1 L of water) when used as an irrigant. A couple of studies suggest that acetic acid, when compared to other widely used antiseptics, has equal or greater activity against *Pseudomonas aeruginosa*, *Proteus vulgaris* and *Acinetobacter baumannii* (Main 2008; Madhusudhan 2016). Due to its low pH, acetic acid is toxic to host tissues to some degree. Thus, it should be reserved for wounds infected with the aforementioned organisms in which other antiseptics are failing. When it is used, a 15-minute per day compress or soak is recommended, rather than flushing action (González-Espinosa et al. 2007).

Chlorhexidine (4 and 0.05%)

Similar to povidone-iodine, chlorhexidine use is steeped in differing opinions and research. Its effects on healing tissue have increasingly come into question (Koburger et al. 2010).

Chlorhexidine comes in two concentrations: 4 and 0.05%. Chlorhexidine 4% is intended for use on intact skin—for scrubbing surgical sites and cleaning hands in preparation for sterile procedures. It is not intended as a wound irrigant (Main 2008).

Chlorhexidine 0.05% is the concentration traditionally used for irrigation. It has excellent antiseptic properties, low cellular toxicity to most cell types and bonds strongly to skin and muscle cell membranes extending its antimicrobial duration. Despite its beneficial properties, the cytotoxic effects increase with its concentration. Chlorhexidine has a well-established toxicity to the cornea of the eye, synovial membranes, the middle ear and components of the nervous system. Chlorohexidine should never be used in or around these tissue types.

Whilst an excellent antiseptic on intact skin, the negative cytotoxic properties lead one to question its use as an irrigant. Studies comparing infection rates following irrigation with a range of chlorhexidine solutions (0.5, 0.05 and 0.005%) versus irrigation with saline showed no significant difference in results (Penn-Barwell et al. 2012). A study in 1992 examining wounds in six dogs suggested that irrigation with chlorhexidine led to the same healing times as irrigation with LRS (Kalteis et al. 2003). Results from such a small sample size cannot be a sole guide for all clinical choices made. Examining the study from a different angle, the results imply that use of chlorhexidine does not necessarily improve wound healing over the use

Table 1 Summary of solution selection and considerations for wound irrigation.

Irrigant	Dilution	Considerations
Antiseptics		
Acetic acid	1–5% concentration; provide via compress or soak	Some toxicity to cell tissue. Use when *Pseudomonas aeruginosa*, *Proteus vulgaris* or *Acinetobacter baumannii* are present and when other irrigants are ineffective.
Chlorhexidine	0.05% concentration	4% concentration only to be used as pre-surgical scrub on intact skin. May cause antibiotic resistance.2% concentration may be used as an irrigant except around the eyes, ears, joints and nervous system.
Dilute bleach	1–5% concentration	Toxic to cell tissues; do not use in wound care.
Hydrogen peroxide	N/A	Toxic to cell tissues; use only to remove blood and debris from intact skin surface.
Polyhexanid solutions	N/A	Low cell toxicity and irritation; useful in infected wounds.
Povidine iodine	0.02% concentration	Toxic to cell tissues. Use in infected wounds unresponsive to other treatments and intact tissues, such as the skin around wounds.
Super-oxide solutions	N/A	Useful for irrigation of both acute, contaminated wounds and chronic, infected wounds.
Non-Antiseptics		
Isotonic solutions	N/A	Least comparative toxicity to cells and blood vessels. Safest irrigants for newly contaminated wounds.
Water	N/A	Can cause host-cell swelling; hypotonic; tap water preferable to distilled water. Decrease bacterial load in wounds likely due to irrigation action, rather than irrigant choice.

of saline. More and more, many veterinary surgeons are moving towards reserving chlorhexidine as an irrigant for visibly infected wounds.

Dilute bleach (i.e., Dakin's solution)

A 0.05% dilution of bleach has been used to flush necrotic wounds (González-Espinosa et al. 2007). Nevertheless, it is well known that bleach is toxic to animal cells. In fact, one study found that to allow 50% of keratinocytes and fibroblasts—two cell types important to wound healing—to survive, bleach had to be diluted 1145 times (Ryssel et al. 2009). There is also little actual data to prove using a bleach solution is beneficial in wounds. Due to the availability of other antiseptic options, mechanical debridement and systemic antibiotics, bleach is to be avoided in wounds.

Hydrogen peroxide

Hydrogen peroxide is readily available and low cost, often offered in the first-aid aisle of drug stores. Its bubbling action can be mistaken for cleansing and bacteria-killing activity. Repeated studies have shown hydrogen peroxide is to interfere with cell functions and to kill fibroblasts and keratinocytes (Singer et al. 1994; Ryssel et al. 2009; Sauer et al. 2009). The bactericidal activity of hydrogen peroxide is not enough to justify the damage it can do within wounds. For this reason, it is not an appropriate irrigant. It can be used to remove blood and organic debris from intact skin surfaces.

Polyhexanid solutions (e.g., Lavanid™ Serag-Weissner, Naila, Germany)

Polyhexanid solutions are marketed as irrigants for cleaning, moistening and decontaminating chronic skin wounds and in common products such as contact lens solution and cosmetics. A series of case studies in chronic human wounds showed improvement in 70% of patients when irrigation with a polyhexanid solution was started. Improvement was demonstrated by decreased biofilm, less exudate, shrinking dimensions of the wound and decreased pain according to the patients (Hirsch et al. 2009).

Additional studies used the chorioallantoic membrane of chicken eggs as a model for blood vessels; a polyhexanid solution had an irritation score of 0, even after 60 minutes of contact time, demonstrating the least toxicity of all antiseptics studied (Landa-Solis et al. 2005; Hedlund 2007). Furthermore, polyhexanid solutions were found to have antiseptic activity comparable to chlorhexidine and povidone-iodine (Hendrickson 2005; Fossum et al. 2007). Most intriguing is the fact that no bacterial resistance has been demonstrated with polyhexanid solutions despite being in use for over 60 years. Reactions to this irrigant are also extremely rare (Butcher 2012).

Povidone-iodine, 0.02% (e.g., Betadine® Purdue Fredrick Company, Norwalk, CT)

Povidone-iodine is an irrigant over which there is considerable debate. Recent studies imply that whilst it does have good antiseptic activity, it may also harm tissues and delay wound healing. Three recent studies proved that when used at standard bactericidal concentrations, povidone-iodine reduced fibroblast migration and proliferation and was toxic to both fibroblasts and keratinocytes (Landa-Solis et al. 2005; Svoboda et al. 2008; Sauer et al. 2009). Piaggesi et al. (2010) looked at the healing times of diabetic foot ulcers, which are excellent examples of chronic, difficult to heal wounds. One group was treated with povidone-iodine and another was treated with an SOS. Povidone-iodine-treated wounds had a healing time of 1.5 times longer than wounds treated with the SOS (Lozier et al. 1992).

Unless solid research can refute povidone-iodine's apparent tissue toxicities, it should be reserved for use in infected wounds unresponsive to other treatments and intact tissues, such as the skin around wounds.

Super-oxide solutions (e.g., Microcyn™ Sonoma Pharmaceuticals, Petaluma, CA and Veteracyn™ Inovacyn Inc., Rialto, CA)

SOSs were initially acidic solutions developed for the disinfection of surfaces. They work by inciting oxidative damage (Tanaka et al. 1996). Their activity includes many gram-positive and gram-negative bacteria, fungi, and several spores and viruses. SOSs demonstrated faster bactericidal effects than chlorhexidine, working effectively within 30 seconds of contact (Rodeheaver et al. 1975; Horrocks 2006).

Because acidic solutions can damage tissues, a new generation of neutral-pH SOSs was developed for use in wounds. One paper reports that SOSs left at least 75% of animal cells viable after prolonged contact (Davidson 2015). In addition to causing cell death, it was feared that SOSs could have the potential to damage DNA and RNA and accelerate cell aging. González-Espinosa et al. found that this is not to be true in vitro (Davidson 2015).

A very persuasive study of diabetic wounds healing by secondary intention found that those irrigated with an SOS had three-quarters the healing time of those irrigated with povidone-iodine (Piaggesi et al. 2010). These in vivo data combined with the fast activity of SOSs suggest that they could be useful for the irrigation of both acute contaminated wounds and chronic infected wounds.

Non-antiseptics

Isotonic solutions (e.g., Saline [0.9% NaCl], LRS, Normosol-R [Hospira, Inc, Lake Forest, IL], Plasma-Lyte [Baxter Healthcare Corporation, Deerfield, IL])

These fluids are specifically formulated to rehydrate patients via intravenous and subcutaneous administration. They contain a balance of electrolytes similar to that within cells; saline has a mildly acidic pH when compared to cells.

When compared to antiseptics used for irrigation, saline showed the least toxicity to fibroblasts, keratinocytes and growing blood vessels (Landa-Solis et al. 2005; Singer et al. 1994). Additionally, Sauer et al. (2009) noted a decreased "rebound effect" with saline. Immediately following irrigation, it did not decrease bacterial levels quite as much as the antiseptics used. However, the bacterial load several hours after the treatment was lower in those flushed with saline than any flushed with the antiseptics. It was hypothesized that this is due to the tissue damage caused by the antiseptics (Marquardt et al. 2010). Other papers reported it to be one of the only irrigants that did not damage small blood vessels (Anglen 2001; Landa-Solis et al. 2005). Isotonic solutions may be one of the safest irrigants for fresh wounds and wounds that have excessive contamination.

Water

Because of its easy access, water has long been used as an irrigant. A few studies have shown that it can decrease the bacterial load of wounds; this is most likely due to the physical action of irrigating (Moscati et al. 1998; Moscati et al. 2007). As innocuous as it seems, water is hypotonic and can cause host-cell swelling because it does not contain the electrolyte balance of tissue. Since it is desirable to irrigate wounds whenever possible, water may be an acceptable irrigant when others are not available or as an initial solution to remove gross contamination. Tap water is preferred over distilled water as it is less hypotonic.

Irrigation technique

All trauma-related wounds are categorized as contaminated and require appropriate irrigation (Rodeheaver et al. 1975). There is no agreement in the literature on the exact irrigation pressure to use in different situations; however, most studies favour low-pressure irrigation between 5 and 15 pounds per square inch (psi; Fry 2017). High-pressure irrigation, defined as 15–70 psi, may damage host cells (both soft tissue and bone) and drive bacteria and debris deep within the wound, which can impede healing (Rodeheaver et al. 1975; Hedlund 2007). A common technique utilizes a 35 ml syringe and an 18-gauge needle to generate 7–8 psi. Lower-pressure irrigation can also be created by dripping sterile solution through a drip set from a spiked bag or pouring sterile fluid directly from a bottle onto the wound (Davidson 2015). Free drip methods of irrigation like these generally produce less than 4 psi and may be insufficient to remove surface pathogens and debris (Luedtke-Hoffmann & Schafer 2000). The volume of solution used to irrigate a wound is also important. In human medicine, 50–100 mls of irrigant is recommended per centimetre of laceration length, but this volume is influenced by the location of the wound and degree of contamination (Chisholm et al. 1992; Lammers et al. 2003). There are multiple types of equipment used for irrigating wounds, most of which are uncommon in veterinary and wildlife rehabilitation settings. The most commonly used equipment in our field are pour bottles, bulb syringes and piston syringes with an attached needle. The first two options are acceptable for removing loose debris and surface pathogens, but as mentioned, they generally have insufficient pressure for adequate wound cleaning. Piston syringes are effective at cleaning traumatic sounds, but they need to be refilled frequently (unless attached to a solution bag and hoses) and they are more time consuming to use (Luedtke-Hoffmann & Schafer 2000). Another complication with the syringe and needle combination is the risk of accidentally jabbing the patient with the needle. For this reason, a similar gauge intravenous catheter is often used to avoid this hazard.

To start irrigation, hold the syringe just above the top edge of the wound and gently start a continuous stream with enough force to remove visible debris but not so much as to cause splash-back. Start by irrigating the cleanest portions of the wound and finish with the dirtiest sections make sure not to recontaminate areas that have already been flushed. Do not force the solution into unexposed pockets as this may force debris deeper into the tissue and increase the risk of infection. Irrigation is complete when the appropriate amount of solution has been administered or until the solution running off the wound flows clear. Continue bandaging as appropriate for the situation.

Irrigation technique and product selection are the only two components of appropriate wound management. Whilst this article summarizes appropriate and inappropriate irrigant choices, it is only one part of effective wound treatment which includes the following (Davidson 2015):

- Providing emergency and supportive care to stabilize the patient
- Providing appropriate analgesia
- Administering antimicrobial medications when necessary and ideally based on culture and sensitivity results
- Clipping fur or plucking feathers surrounding the wound
- Irrigating the wound with appropriate solution using an appropriate technique (to be discussed further)
- Debriding necrotic tissue (specific dressing is designed to facilitate this, in addition to surgical debridement under general anaesthesia)
- Covering the wound with appropriate bandaging material for the species
- Monitoring wound healing and adjusting dressing types as needed depending on progress

Conclusion

Until further studies directly compare antiseptic and non-antiseptic irrigants in vivo in wounds, one is left piecing together bits of research to make the best decision for each individual animal. Normal saline seems to be the safest choice for trauma wounds at the present time. No matter the irrigant selected, it should only be accompanied by complete wound management.

Disclosure statement

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