

Irrigation With Potable Water Versus Normal Saline in a Contaminated Musculoskeletal Wound Model

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Background: Although the use of potable water for wound irrigation is attractive in an austere environment, its effectiveness has not been tested. We sought to compare the effectiveness of potable water irrigation in reducing bacterial number with that of normal saline irrigation.

Methods: We used an established caprine model involving the creation of a reproducible complex musculoskeletal

wound followed by inoculation with luminescent bacteria that allowed for quantitative analysis with a photon-counting camera system. Six hours after injury and inoculation, wound irrigations were performed using pulsatile lavage. Fourteen goats were randomized into two treatment groups: irrigation with 9 L potable water versus irrigation with 9 L normal saline. Images obtained after irrigation were compared with baseline images to deter-

mine the reduction in bacterial luminescence resulting from treatment.

Results: The irrigation in both groups reduced the bacterial counts by 71% from the preirrigation levels.

Conclusion: Potable water reduced the bacterial load as effectively as normal saline in our model.

Key Words: Irrigation, Contamination, Infection, Wound management.

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Irrigation and debridement of open fractures is imperative to prevent wound infection and sepsis. Use of 9 L or 10 L of sterile normal saline has been advocated for these wounds.^{1,2} In austere environments such as mobile military hospitals, supply lines may not be able to meet these requirements, especially in a mass casualty situation. Alternative irrigation solutions may be necessary in the absence of saline, or in a situation where a limited saline supply is reserved for casualty intravenous resuscitation.

Potable water is widely available even in the most austere hospital environments and is inexpensive. The use of potable water as a wound irrigant would be an attractive alternative for surgeons in such difficult environments. Although the use of potable water as an irrigant has been studied in contaminated skin lacerations,^{3,4} it has not been evaluated in complex musculoskeletal wounds.

The purpose of this study was to compare the ability of potable water to reduce bacterial levels with that of standard normal saline irrigation using an established large animal wound model contaminated with bioluminescent bacteria. We hypothesized that potable water irrigation would remove same amount of bacteria as normal saline irrigation.

MATERIALS AND METHODS

We used a large animal contaminated wound model that was established in previous work at our laboratory.⁵ All

procedures were performed in an Association for Assessment and Accreditation of Laboratory Animal Care accredited laboratory after obtaining protocol approval from the Institutional Animal Care and Use Committee. After adequate anesthesia, we created a complex musculoskeletal wound in the proximal left leg of goats. This wound involved injury to all musculoskeletal tissues: a cortical defect was created in the proximal tibia, thermal injury was created in the periosteum and fascia, and thermal and crush injury was performed in the muscle of the anterior compartment. This technique resulted in a reproducible complex wound intended to mimic an open fracture that did not necessitate stabilization. This wound was inoculated with 1 mL of $>10^8$ cfu/mL *Pseudomonas aeruginosa* (lux) and was spread evenly over the wound surfaces with a sterile cotton-tipped applicator.

After surgery, goats were recovered in their pens for 6-hours and allowed activity ad libitum. At this time, the goat was placed supine on the operating table in a custom light-free room and the left lower extremity was mounted to the camera with an external fixation frame and percutaneously placed Schanz pins in the tibia. The extremity was then aseptically prepared and draped. A photon counting camera (Charge Couple Device Imaging System Model C2400; Hamamatsu Photonics, Inc., Hamamatsu-City, Japan) was used to capture the quantitative and spatial distribution of the bacteria in the wound and express these data as the relative luminescent units (RLUs). These images were superimposed over black and white images of the wound taken with ambient lighting to determine the distribution of bacteria within the wound.

Once the baseline luminescent data were collected, treatment was rendered as determined by randomization. The potable water group was treated with irrigation with 9 L of water obtained from the municipal water supply available in

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the laboratory delivered by a pulsatile lavage device (Interpulse Irrigation System; Stryker Instruments, Kalamazoo, MI) operated at its highest setting (19 pounds per square inch). The normal saline group was treated with 9 L of normal saline delivered by the identical pulsatile lavage device operated at its highest setting. After treatment, repeat images were obtained of the wounds.

Raw data were collected in the form of RLUs generated by the Charge Couple Device camera and image processor. All data were saved in Microsoft Excel XP (Microsoft, Redmond, WA). For the RLUs, the Aquacosmos imaging software (Hamamatsu Photonics, Inc.) provided a count of RLUs for the entire field within view of the camera. All values are expressed as mean \pm standard error. All ratios were analyzed between potable water and saline irrigation groups using a hierarchical mixed model Analysis of variance with statistical significance inferred for $p < 0.05$. Post hoc analysis used t tests for further within group comparisons of ratios and includes Bonferroni correction for multiple comparisons. SAS Statistical Software (SAS, Inc., Cary, NC) was used for all statistical calculations.

RESULTS

The quantitative reduction in bacteria was similar for both treatment groups. The mean RLU before irrigation in the potable water group was 1.32×10^7 ($\pm 4.01 \times 10^6$) (Fig. 1). After irrigation, the mean RLU was reduced to 3.89×10^6 ($\pm 1.31 \times 10^6$). The mean RLU before irrigation in the normal saline group was 1.52×10^7 ($\pm 4.96 \times 10^6$). After irrigation, the mean RLU was reduced to 4.45×10^6 ($\pm 1.80 \times 10^6$). There were no statistically significant differences between the mean RLUs in the two groups (potable water and saline) both before ($p = 0.76$) and after irrigation ($p = 0.80$). Both irrigation treatments reduced the bacterial counts to 71% of the pretreatment levels. The differences between the pre- and post-treatment bacterial counts were statistically significant for both the potable water and normal saline groups ($p = 0.0093$ and $p = 0.0039$, respectively).

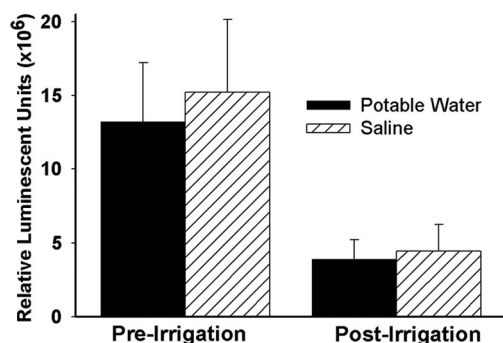


Fig. 1. Average relative luminescent units in pre- and post-treatment images for potable and normal saline groups.

DISCUSSION

Although the use of potable water has been recommended for the irrigation of complex musculoskeletal wounds and open fractures,⁶ there is little scientific data to support its use. Potable water has been compared with sterile saline in the irrigation of simple dermal lacerations. Two studies using an animal model of contaminated lacerations reported no difference in bacterial reduction between potable water and sterile saline.^{3,4} Three prospective randomized clinical trials have been performed in the treatment of simple lacerations in the emergency department demonstrating no benefit in using sterile saline instead of potable water.⁷⁻⁹ Beyond this work on simple skin lacerations, no studies have examined the treatment of complex musculoskeletal wounds with potable water irrigation. To determine the performance of potable water as a wound irrigation solution compared with normal saline, we used an established contaminated wound animal model.

The treatment of contaminated musculoskeletal wounds is of particular interest to military surgeons given the large percentage of combat wounds to the extremities.¹⁰ The significant logistic needs associated with multiple wound irrigation procedures in forward environments make alternate irrigation fluids necessary. Similar conditions and limitations may occur in civilian medical practice as well. When natural disasters such as earthquakes or hurricanes disrupt normal commerce and result in significant numbers of injuries, demand for sterile irrigation solutions may outstrip supply, and necessitate use of other fluids for irrigation. One recent study demonstrated effective elimination of bacterial presence in standing water (e.g., lakes and ponds) after treatment with sodium hypochlorite solution and recommended this option as a field-expedient alternative.¹¹ Our results suggest that the use of potable water (or treated nonpotable water) may be as effective as sterile saline for irrigation of musculoskeletal wounds.

Although the predominant bacterial species present during initial wound management are generally gram-positive, gram-negative bacteria, such as *P. aeruginosa*, are also present up to 33% of the time at initial debridement of open fractures.² However, care should be taken in extrapolating the current results to conditions involving other organisms until other species are applied to this model. Another limitation of our study is its acute nature that did not allow following contaminated wounds for any time after initial irrigation to evaluate for signs of clinical infection. The use of a hypotonic solution such as water can cause an undetermined amount of host cell lysis. Further research should be performed in a chronic model to assess the host tissue effects of treatment of musculoskeletal wounds with potable water irrigation.

Recognizing the limitations of the current study, the findings establish that potable water is as effective as normal saline in removing bacteria from a contaminated musculoskeletal wound. Before applying this basic science finding to clinical practice, further testing must be completed to resolve

the aforementioned issues relating to late tissue effects and bacterial spectrum. The ability to use potable water as an alternate irrigation solution in austere environments would be a major benefit to surgeons in such settings. The current study establishes its efficacy in the acute setting.

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