Evaluation of fluid pressures of common wound-flushing techniques

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Objective—To evaluate fluid pressures generated via common wound-flushing techniques.

Sample Population—24 combinations of bottles, needles, a syringe, and a bag.

Procedures—12 medically trained individuals used the following devices to forcefully expel fluid as for wound flushing: full and half-full 1-L and 500-mL bottles with holes in the cap made with 16-, 18-, 20-, and 22-gauge needles; a 35-mL syringe with the same needle sizes; and a 1-L bag placed in a cuff pressurized to 300 mm Hg, with the same needle sizes. Fluid expulsion pressures were measured and compared.

Results—The highest pressure generated with the bottle was 3.90 ± 1.30 psi (mean ± SD) with a 16-gauge needle and a full 1-L bottle. The highest pressure generated with the 35-mL syringe was 18.40 ± 9.80 psi with a 16-gauge needle. The lowest pressure generated with the 35-mL syringe was 16.70 ± 6.50 psi with an 18-gauge needle. The bag under pressure generated a pressure of 7.3 ± 0.1 psi with a 16-gauge needle. Needle size did not have a significant effect.

Conclusions and Clinical Relevance—Solution bottles of any size and needle gauge do not meet the requirement for satisfactory flushing pressure of 7 to 8 psi. Use of a 35-mL syringe can produce pressure substantially > 7 to 8 psi, which could damage tissues. The most consistent delivery method to generate 7 to 8 psi was use of a 1-L plastic bag within a cuff pressurized to 300 mm Hg. (*Am J Vet Res* 2010;71:1384–1386)

Wounds are among the injuries encountered most frequently in veterinary and human medicine. It has been estimated that between 10 and 11 million lacerations or wounds are treated annually in human emergency departments.[1,2] Although the number of lacerations or wounds encountered every year in veterinary medicine has not been reported, our clinical impression is that such cases represent a large portion of emergency cases.

Flushing the wound is required for daily cleaning in the initial phase of wound healing. The goals of wound flushing are to remove particulate debris and bacteria via mechanical contact, inertial forces, and fluid dynamic forces; remove exudates from infected wounds; and dilute and remove toxins associated with infection.[3] The forces that must be overcome to remove bacteria from wound beds include capillary, molecular, and electrostatic adhesive forces generated by the bacteria.[4] Despite numerous studies, there has yet to be determined an optimal pressure for all lacerations or wounds. The most cited and agreed upon pressure for initial wound irrigation is from 7 to 8 psi.[1,2,5–11] These pressures are also in the range that the US Agency for Healthcare Research and Quality recommends for flushing wounds to remove bacteria and foreign materials.[9,12] Although a pressure of 1.6 psi adequately reduces bacterial contamination from wounds,[13,14] most authors still recommend a pressure of approximately 7 to 15 psi to flush wounds to remove bacteria and foreign materials.

Multiple methods are commonly used to flush wounds, including use of a syringe (35 mL to 60 mL) with a hypodermic needle (typically a 19-gauge needle), a saline solution bag placed in a pressure cuff attached to an extension line with a hypodermic needle at the end, or a saline solution bottle with holes in the cap. The holes in the bottle cap are made with various sizes of hypodermic needles. Through informal surveys of local veterinarians and observations in the authors' clinic, the bottle flushing technique seems to be popular for flushing wounds. The purpose of the study reported here was to evaluate fluid pressures generated via these common wound-flushing techniques to identify a technique that consistently produced the desired pressure of 7 to 8 psi.

Materials and Methods

Twelve individuals (faculty, residents, interns, and technicians), compromising 7 females and 5 males, took part in the study; these individuals commonly perform

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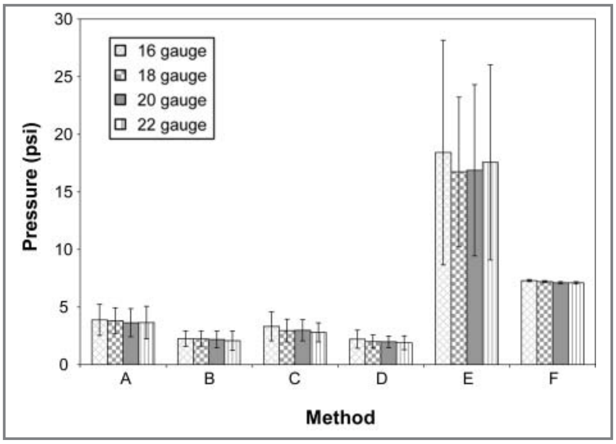

Figure 1—Mean ± SD pressures resulting from use of various techniques for flushing wounds with various gauges of needles. A = 1-L bottle, full. B = 1-L bottle, half full. C = 500-mL bottle, full. D = 500-mL bottle, half full. E = 35-mL syringe. F = 1-L saline solution bag in a pressure cuff. To convert psi to Pa, multiply by 6,800.

wound flushing at our clinic. The flushing apparatus tested included a full 1-L bottle, a half-full 1-L bottle, a full 500-mL bottle, a half-full 500-mL bottle, a 35-mL syringe, a 1-L saline solution bag in a pressure cuff, and 16-, 18-, 20-, or 22-gauge needles. Water was used in each construct because of availability and because the difference in viscosity between saline (0.9% NaCl) solution (1.01×10^{-3} Pa•s) and water at 21°C (1.0×10^{-3} Pa•s) is negligible.

Each bottle was punctured through the cap with a needle. The needle was left in place, a short IV extension line was connected to the needle, and each construct was attached to a pressure transducer[a] that was connected to a pressure-recording machine.[b] Each participant squeezed each construct 5 times for 5 seconds with both hands, and a pressure curve for each needle size was recorded. Each participant was asked to squeeze the constructs as he or she would in a clinical setting. To minimize fatigue as a factor, half the constructs were squeezed in 1 session and half in a later session, with a minimum of 2 days between sessions.

A 35-mL syringe with the same needle sizes as used for the bottles was attached to a pressure manometer,[c] and a peak pressure value for each needle size was recorded as for the bottles by depressing the plunger; the same syringe was used for each needle size. One hand only was used to depress the plunger.

A 1-L bag was placed in a pressure cuff[d] and pressurized to 300 mm Hg; the bag was connected to the manometer in the same fashion as the syringe group. There was no manual squeezing, just that generated by the pressure cuff. A peak pressure value was recorded for the same needle sizes; each needle size was tested in a different bag.

Statistical analysis—All pressures were recorded in pounds per square inch (1 psi = 6,800 Pa). The mean peak pressure generated was used for statistical analysis. A multivariate ANOVA was performed to compare the mean peak pressure values among the constructs. For all comparisons, values of $P \leq 0.05$ were considered significant. Statistical software was used for all analyses.[d]

Results

Within each bottle-needle construct, needle size did not have a significant ($P = 0.54$) effect on mean peak pressure generated **(Figure 1)**. No significant ($P = 0.10$) differences were detected among the full or half–full 1-L and 500-mL bottles for any needle size; therefore, data from the bottles were pooled together into a bottle group. Similarly, no significant differences between needle sizes were detected in the syringe group ($P = 0.55$) or the pressure bag group ($P = 0.10$). Pressure generated in the syringe group was significantly greater than that in the bottle group ($P = 0.003$) and the bag group ($P = 0.003$). Pressure in the bag group was significantly ($P < 0.001$) greater than that in the bottle group.

Discussion

On the basis of the recommendation to use a pressure close to 7 to 8 psi to flush a wound, results of the present study indicated that use of a 1-L bag under pressure was the best technique. Thirty-five–milliliter syringes with various sizes of needles produced much greater pressure (possibly harmful), and bottles punctured with various sized needles did not generate sufficient pressure.

The standard recommended technique—use of a 35-mL syringe and an 18- or 19-gauge needle—produced pressure much > 7 to 8 psi. Reports by Rodeheaver et al[5] and Stevenson et al[6] indicated this technique would produce 8 psi, but the pressure was never directly measured; instead, the pressure of 8 psi was based on a calculation from the Bernoulli equation and a mechanical-pressure canister system. Results of the present study were consistent with those of a study performed by Singer et al,[7] in which the pressure generated from the 35-mL syringe had a median peak pressure of 35 psi with a range from 25 to 40 psi. A pressure of 25 to 40 psi could cause barotrauma to the wound and be detrimental to the surrounding tissue.[1,2,4–7] Some dental oral rinsing devices[e] have been used for wound flushing. The newer models have settings that range from 5 to 90 psi.

Pressures generated from plastic bottles (regardless of bottle size, needle size, or the fluid level in the bottle) did not reach the targeted pressure of 7 to 8 psi. A maximal pressure of 3.9 ± 1.35 psi might be sufficient to flush bacteria out of a musculoskeletal wound[13] but is not sufficient to flush foreign material out of the wound.[1,2,5,6] This construct failed to produce pressures of 7 to 8 psi because the plastic bottles were too hard and were difficult to squeeze efficiently. On the basis of these results, we do not recommend use of plastic bottles with holes punched in the cap for wound flushing.

Use of a saline solution bag placed in a pressure cuff, at a cuff pressure of 300 mm Hg, was the most consistent technique for generation of 7 to 8 psi. This technique was so consistent that during the 5 pressure readings for each needle size, the SD was 0.1 psi. This technique is simple, and the clinician can deliver a large amount of irrigation solution over a short amount of time. Also, having the needle at the end of the IV tubing allows for easy maneuverability and the clinician has greater control of the needle, compared with holding and squeezing the syringe.

a. Uniflow Pressure Transducer, Baxter, Irvine, Calif.
b. Series 7000 Pressure Monitor, Marquette, Milwaukee, Wis.
c. Ashcroft Industries, Baesweiler, Germany.
d. JMP 5.1 statistical software, SAS Institute Inc, Cary, NC.
e. Waterpik Inc, Fort Collins, Colo.

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