Pressure Dynamics of Various Irrigation Techniques Commonly Used in the Emergency Department

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Received for publication July 29, 1993. Revisions received November 24, 1993, and January 25, 1994. Accepted for publication February 4, 1994.

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Study objective: To evaluate the pressure dynamics of common irrigation techniques used in the treatment of traumatic wounds.

Design: Matched experimental trial.

Participants: Ten male volunteers.

Interventions: Pressure curves were obtained while performing manual irrigation with 250-mL boluses of normal saline with 19-gauge needles on 35-mL syringes, 19-gauge needles on 65-mL syringes, IV bags pierced with 19-gauge needles, and plastic bottles pierced with 19-gauge needles. Measurements also were obtained using an IV bag with tubing attached to either a 19-gauge or 16-gauge needle within a pressure cuff inflated to 400 mm Hg.

Results: Median peak pressures were 35 lb/in.^{2} (psi) (range, 25 to 40 psi) and 27.5 psi (range, 15 to 40 psi) using a 35-mL syringe and a 65-mL syringe, respectively. Median peak pressures with the IV bag and plastic bottle were 4 psi (range, 2 to 5.5 psi) and 2.3 psi (range, 1.2 to 4.5 psi), respectively. The IV bag in a pressure cuff generated pressures of 6 to 10 psi and 4 to 6 psi using 19-gauge and 16-gauge needles, respectively.

Conclusion: Both 35-mL and 65-mL syringes with a 19-gauge needle are effective in performing high-pressure irrigation in the range of 25 to 35 psi. The use of IV bags and plastic bottles should be discouraged when high-pressure irrigation is required.

[Singer AJ, Hollander JE, Subramanian S, Malhatra AK, Villez PA: Pressure dynamics of various irrigation techniques commonly used in the emergency department. *Ann Emerg Med* July 1994;24:36-40.]

INTRODUCTION

An estimated 10 million wounds are cared for in emergency departments throughout the United States each year.[1] Wound irrigation forms one of the cornerstones of proper wound management. Although its value is undisputed, it is not clear what constitutes the ideal irrigation pressure. Most authors agree that a pressure of 5 to 8 lb/in.^{2} (psi) is adequate for the majority of routine wounds.[2-4] A well-controlled, machine-generated model has been calculated to attain a wound impact pressure of 8 psi using a 19-gauge needle on a 35-mL syringe.[5] These inexpensive appliances are widely touted as the ideal method of irrigation.[2-5] Unfortunately, this technique has not been evaluated in the clinical setting, where human variation and fatigue may impair the ability to generate and maintain these pressures over the time required for proper wound irrigation and cleansing.

This study was designed to measure the pressures obtained by physicians using the various manual, inexpensive, and widely available irrigation techniques commonly used in EDs.

MATERIALS AND METHODS

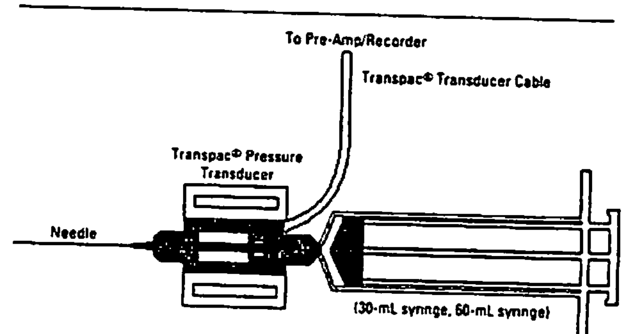
Volunteers from the departments of emergency medicine and biomedical engineering participated in the study. Each volunteer performed four irrigation procedures using 250-mL boluses of normal saline with a 35-mL syringe attached to a 19-gauge needle; a 65-mL syringe attached to a 19-gauge needle; an IV bag pierced with a 19-gauge needle compressed manually; and a plastic saline bottle pierced with a 19-gauge needle compressed manually. In addition, an IV bag attached to infusion tubing and either a 19- or 16-gauge needle placed within a pressure cuff was assessed.

The experimental setup consisted of a four-channel recorder with preamplifiers, two disposable pressure transducers, two transducer recorder cables, a mercury manometer, a digital pressure meter, needles, 35-mL and 65-mL syringes, and bottles. Two pressure lines were connected to the preamplifiers and pressures were recorded on two channels simultaneously. The recorder channels were calibrated to a sensitivity of 4 psi/cm for the syringes using a manometer and 8 psi/cm for the bottles using a pressure meter. The pressure meter also was used to confirm the manometer calibration. We observed that the recorder channels were linear for the entire range of pressures for the experiment. Fluid delivery pressures generated at the tip of saline-filled syringes (35 mL and 65 mL), IV bags, and plastic bottles were recorded for each participant.

A Gould (Cleveland, Ohio) series 2000 four-channel recorder with DC preamplifiers was used to record the pressure characteristics. The preamplifiers provided a maximum sensitivity of 50 mV full scale on the recorder and frequency response of less than 3 dB down at 3 KHz flat to ±0.5% from DC to 200 Hz. An eight-position rotary switch on the preamplifier allowed the selection of 0.05, 0.1, 0.25, 0.5, 1.0, 2.5, and 5.0 V full scale for overall system sensitivity. A multiplier switch control expanded the sensitivity to 100 times the full-scale sensitivity. In addition, the preamplifiers had a variable control for selecting intermediate sensitivities between the fixed settings of the sensitivity control. The four-channel recorder had five (1, 5, 10, 25, and 50) selectable recording speeds in both mm/sec and cm/sec. The recorder provided controls for pen position adjustment and recorder trace intensity adjustment.

Two Sorenson Transpac® IV disposable transducers (Abbott Critical Care Systems, North Chicago, Illinois) were used to measure fluid delivery pressure. The pressure transducer was placed immediately proximal to the needle hub (Figure 1). The pressures generated by the bottle and IV bag were measured through the use of a modified apparatus. We replaced the bottle cap with the distal tip of a syringe (corresponding to the size of the bottle cap). This allowed us to attach a needle to the end

Figure 1.
Experimental setup using a syringe and needle pressure irrigation system.



of the bottle. We attached a needle with an internal diameter of 0.047 in. to simulate the external diameter of a 19-gauge needle (0.042 in.) that would puncture the bottle. The needle was shortened to correspond to the thickness of the bottle cap. This modified bottle maintained the same dimensions of an unadapted bottle while allowing us to obtain pressure measurements. The IV bag was similarly adapted. The pressure transducer had a sensitivity of 5 μV/V per mm Hg ±1% at 6.0 V, an operating pressure range of −50 to 300 mm Hg (−1 to 6 psi), and a maximum pressure range of −50 to 5,000 mm Hg. These transducers typically are used to measure physiological pressures in the range of −50 to 300 mm Hg in the clinical setting. Two Sorenson Transpac® reusable transducer cables with adapter cables mated to the Gould preamplifier connectors were used to connect the pressure transducers to the Gould recorder system.

A mercury manometer (Pymah Corporation, Sommerville, New Jersey) was used as the bench reference to calibrate the recorder for pressures up to 6 psi. A Universal Pressure Meter (Bio-Tek Instruments, Highland Park, Vermont) was used as a second reference source for calibrating the recorder for pressures above 6 psi and to confirm the manometer calibration. The pressure meter was calibrated to National Institute of Science and Technology standards.

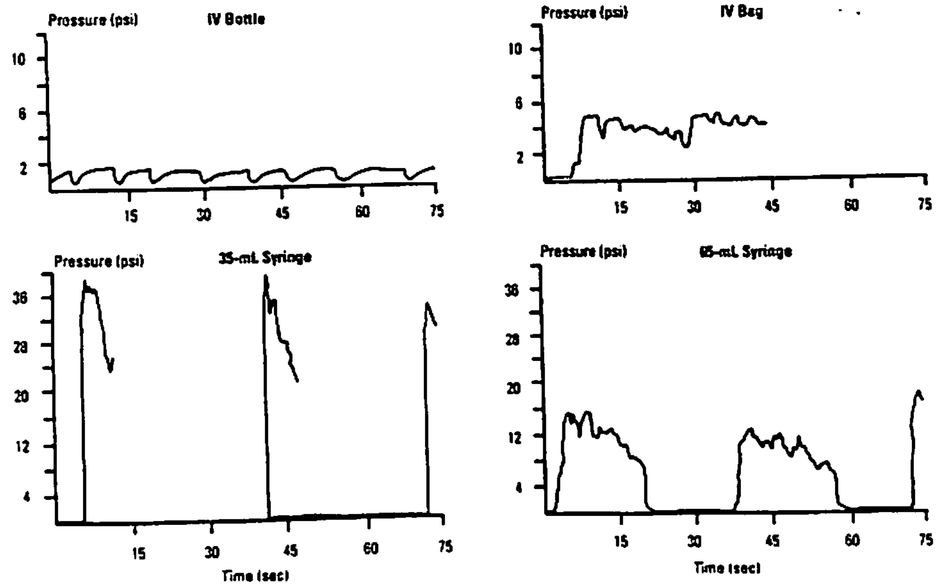
Because each of the ten volunteers performed each method once, matched tests were used for analysis. Data are presented as medians with an accompanying range. Comparisons among irrigation techniques were performed using the signed-rank test. Spearman's rank correlation was used to evaluate whether the pressure obtained was participant dependent. A two-tailed $\alpha < .05$ was considered statistically significant for all tests.

RESULTS

Ten male physician and engineer volunteers participated in the study. The mean age was 38±12 years. The mean height and weight were 173±5 cm, and 80 ±13 kg, respectively. Almost all volunteers performed irrigation using two hands.

Median peak and trough pressures and length of irrigation are shown in the Table. The 35-mL syringe resulted in higher pressures than the 65-mL syringe (signed-rank test, $P=.01$). The pressure measured with the 35-mL syringe in each volunteer was greater than or equal to the pressure measured with the 65-mL syringe. Similarly, the IV bag method resulted in higher pressure than the bottle method (signed-rank test, $P=.009$). All volunteers achieved equal or higher pressures with the bag compared to the bottle.

Figure 2.
Representative pressure tracings using four pressure irrigation techniques.



Correlations between peak pressures obtained using the 35- and 65-mL syringes were quite high (Spearman's $r=.85$, $P=.002$). They were similarly high (Spearman's $r=.74$, $P=.014$) between pressures obtained using the IV bag and the plastic bottle.

Visual inspection of the pressure curves (Figure 2) obtained showed no significant decrement over time for the 250-mL boluses using the syringe techniques. Use of the IV bag or the plastic bottle was characterized by short bursts of low pressure. The IV bag within a pressure cuff method showed a gradual yet steady decline of pressure over time that could be corrected by intermittent reinflation of the pressure cuff to 400 mm Hg.

DISCUSSION

Irrigation has been demonstrated to become more effective in bacterial decontamination as the irrigation pressure is increased.[6] However, the risk of infection has been shown to increase with the use of sustained high pressures secondary to tissue damage.[7] Therefore, many authorities recommend irrigation in the range of 5 to 8 psi.[2-4] In order to achieve such a pressure, a 19-gauge needle on a 35-mL syringe has been recommended.[2-5] This recommendation has been based on one experimental, machine-generated model using indirect measurements of irrigation pressure.[5] In this model, a pressure of 19 psi within the irrigation system was calculated to provide 7 psi at the wound surface.[5] Our study demonstrated that when this machine-generated model is applied to human subjects, the direct irrigation system pressures generated are considerably higher than previously believed. Using direct measurements, we obtained a median peak pressure of 35 psi using a 35-mL syringe on a 19-gauge needle. This is two times greater than previously reported. Using a 65-mL syringe was found to lessen both wound irrigation time and the pressure generated (Table). However, the pressure still exceeded that recommended for routine wound cleansing. Use of either an IV bag or plastic bottle failed to achieve adequate pressures for the purposes of irrigation. Only 50% of the subjects could generate an irrigation system pressure as high as 2 psi using the plastic bottle. Insertion of an IV bag inside a pressure cuff inflated to 400 mm Hg generated pressures in the range of 6 to 10 psi when infused through a 19-gauge needle. When a 16-gauge needle was used, irrigation was more rapid, but the pressure fell to a range of 4 to 6 psi. Though easy to assemble, this technique required considerably more time.

Some investigators[8] have hypothesized that manually generated pressures could not be maintained consistently throughout the wound cleansing process. Our data clearly demonstrate that adequate pressures were maintained with repeated syringe irrigation. All of the methods of irrigation yielded relatively square pressure tracings with only occasional drops below the level of these sustained pressures (Figure 2). There was no significant pressure decrement over the 250-mL boluses using the syringe method.

All of the irrigation techniques that we assessed are readily available and inexpensive, costing less than $2.00 per disposable setup. All techniques can be performed in less than 6 minutes. The time to irrigation in our study was shorter than that in the only previous study.[8] This may be due to lack of patient interaction in our study. Alternatively, it is unclear whether the previous study included the time to set up the irrigation supplies.[8]

This study was limited by the fact that pressure measurements were not obtained in the clinical setting during actual wound irrigation. We used both physician volunteers and biomedical engineers. It is possible that the physicians were trying unduly hard to attain higher pressures than they would during patient care. However, physicians were instructed to simulate their clinical practice and were observed by more than one investigator during all phases of the trial. The high correlations

Table.
Characteristics of various irrigation techniques.

Method	Median Peak Pressure in psi (range)	Median Trough Pressure in psi (range)	Median Duration (sec)	Cost ($)
35-mL syringe, 19-gauge needle	35 (25-40)	17 (12-34)	160	1.27
65-mL syringe, 19-gauge needle	27.5 (15-40)	11 (7-25)	138	1.37
IV bag pierced with 19-gauge needle	4 (2-5.5)	0 (0-2)	67	1.36
IV bottle pierced with 19-gauge needle	2.3 (1.2-4.5)	0 (0-0.8)	100	1.04
Pressure bag with 19-gauge needle	10	6	340	1.57
Pressure bag with 16-gauge needle	6	4	65	1.94

obtained between pressures generated by each individual suggest that the relative pressure differentials are reliable. Therefore, we believe that the physician volunteers simulated their own wound irrigation techniques.

Ideally, the irrigation impact pressure on the surface of the wound should be measured. However, measurement of pressures in an open system is complex. Based on the Bernoulli equation, an ideal system with negligible fluid friction along the walls of the needle, a pressure measured in a fairly large reservoir (relative to the needle cross-sectional area) and a needle placed at the wound surface will exert an impact pressure on the tissues two to four times greater than that measured at the needle hub. However, using a 19-gauge needle, the impact pressure is approximately 40% that of the system.[5]

The further the irrigant is from the wound, the lower the impact pressure exerted on the tissues. Use of a syringe and needle apparatus enables closer contact with the wound, minimizing the drop in pressure. Use of the bottle or bag method does not allow as close proximity to the wound surface, thereby decreasing the impact pressures.

CONCLUSION

Using a 19-gauge needle on either a 35-mL or 65-mL syringe generated steady peak pressures of 25 to 35 psi within the irrigation system. These methods are both rapid and effective in achieving high-pressure irrigation and require only 2 to 3 minutes. The use of either a pierced IV bag or plastic bottle is ineffective in generating the pressures recommended for routine irrigation. Their use should be discouraged, especially when high-pressure irrigation is required.

We have measured irrigation system pressures attained by several widely used irrigation methods. Further study is required to determine the optimal irrigation pressure for traumatic wounds.

REFERENCES

1. Edlich RF: Current concepts of emergency wound management. *Emerg Med Rep* 1984;5:165-180.

2. Edlich RF, Rodeheaver GT, Morgan RF, et al: Principles of emergency wound management. *Ann Emerg Med* 1988;17:1284-1302.

3. Edlich RF, Rodeheaver GT, Thacker JG: Wound preparation, in Tintinalli JE, Kvome RL, Ruiz E (eds): *Emergency Medicine: A Comprehensive Study Guide*, ed 2. New York, McGraw-Hill, 1992, p 1037-1039.

4. Mulliken JB: Management of superficial wounds, in May HL, Aghababian RV, Fleischer GR (eds): *Emergency Medicine:* Boston, Little, Brown and Co, 1992, p 631-641.

5. Stevenson TR, Thacker JG, Rodeheaver GT, et al: Cleansing the traumatic wound by high pressure syringe irrigation. *JACEP* 1976;5:17-21.

6. Rodeheaver GT, Petry D, Thacker JG, et al: Wound cleansing by high pressure irrigation. *Surg Gynecol Obstet* 1975;141:357-362.

7. Wheeler CB, Rodeheaver GT, Thacker JG, et al: Side effects of high pressure irrigation. *Surg Gynecol Obstet* 1976;143:775-778.

8. Chisolm CD, Cordell WH, Rogers K, et al: Comparison of a new pressurized saline canister versus syringe irrigation for laceration cleansing in the emergency department. *Ann Emerg Med* 1992;21:1364-1367.

The authors acknowledge the assistance of Henry C Thode, Jr, PhD, with the statistical analysis of the data.

Reprint no. 47/1/56270

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