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Review

Irrigation in open fractures: current concepts

Matthaios S. Savvidis, MD, PhD[1], Vasileios Pegios, MD, MSc[1], Antonios Kouzelis, MD, PhD[2], Konstantinos Kokorogiannis, MD, PhD[3], Emmanouil Brilakis, MD, MSc, PhD[4], Athanasios Badekas MD[5]

[1]*Second Orthopaedic Department, 424 General Military Training Hospital, Thessaloniki*
[2]*Orthopaedic Department, University Hospital of Patras, Patras*
[3]*Fifth Orthopaedic Department, KAT Hospital, Athens*
[4]*Third Orthopaedic Department, Hygeia Hospital, Athens, Greece*
[5]*Third Orthopaedic Department, Henry Dunant Medical Center, Athens*

Abstract

Open fractures are most commonly the result of high-energy injuries. They present a higher rate of infection, when compared with closed fractures. On that account, the management of open fractures ought to be immediate and effective. Many steps are involved in this procedure, with one of them being wound irrigation. The research community has demonstrated a great interest in the best practices around the irrigation of open fractures. Nevertheless, a widely accepted protocol is yet to be determined. The timing of rinsing should be as early as possible, certainly in the first 24 hours after the injury. The quantity of fluids for irrigation is calculated, depending on the size of the wound, the extent of contamination and the coexistence of nerve or vascular damage. Low, non-pulsating pressure is ideal for most cases; high-pressure or pulse lavage can be reserved for highly contaminated wounds. Normal saline is a cost-effective, sterilized and isotonic solution, that is characterized by lower rates of infection, when compared with other fluid options and does not impede the wound healing process due to its low cytotoxicity. The existence of a standardized protocol for irrigation of open fractures is of great importance and, therefore, more relevant high-quality studies are needed.

Keywords

Open fractures; irrigation; saline; infection; review

Corresponding author

Matthaios S. Savvidis
email: makisorto@hotmail.com

Introduction

Open fractures have always been considered, by their very nature, as an Orthopaedic and Trauma emergency. The incidence of open fractures is reported to be about 30.7 per 100,000 persons per year. [1] Most commonly, they are the result of high-energy injuries, such as crash accidents, falls from height and gunshots. [1] The risk for infection of open fractures in the United States of America can range from 18% to 30%. [2] Management of open fractures has evolved substantially throughout the years, considering that the treatment of choice during the American civil war was emergency amputation to diminish the risk of sepsis. [3] Nowadays, effective treatment of open fractures involves administration of intravenous antibiotics and tetanus-preventing measures ideally in the first hour, followed by immediate irrigation, debridement and fracture stabilization within the first 24 hours and wound closure within the first 7 days after the injury.[4] Irrigation and debridement of open fractures is a critical step of this protocol and therefore has received a lot of attention from the research community.[5] Timing, delivery pressure and type and quantity of irrigation fluids are factors that can vary a lot among surgeons.[1] This study aims to critically appraise the available literature for the best practices of irrigation procedures, by answering common questions that each surgeon faces when dealing with open fractures.

When should we irrigate?

Immediate and effective management of open fractures can be decisive for the patient's outcome.[6] Since the 19th century, the "common rule" of six hours was considered the gold standard; the first washing should ideally be done within the first six hours after the injury.[2,3] Of course, there is a plethora of different factors that should be taken into account before deciding the ideal irrigation plan, such as the size of the open wound and the extent of contamination.[1] (Fig. 1) A consensus among the authors and surgeons is still missing. According to several studies, the longer irrigation is delayed, the stronger the bonds of pathogens on bone and soft tissues become, and consequently, the harder their rinsing.[3,4] The benefits of early debridement and lavage, in the first six hours, have also been confirmed in experimental animal models.[3] On the other hand, there are publications available in the literature that report no differences in infection rates when comparing open fracture irrigation before and after the first six hours, as long as the 24-hour limit is not surpassed.[2,4,6]

Which is the ideal fluid-volume for irrigation?

The amount of fluids used to irrigate an open fracture is another important predictive factor of a patient's outcome.[1] There are no clear guidelines in literature, other than it ought to be plenty and, as a result, the amount is usually determined by the surgeon's judgment and clinical experience. It is common sense that the characteristics of an open fracture, such as the size of the exposed area, the contamination, the existence of debris, soil, dirt or foreign bodies and their attributes, such as material and size, can impact significantly the severity of the trauma and thus the need for a greater quantity of lavage solutions.[3,7] Furthermore, in the presence of coexisting disruption of noble elements, such as vessels and nerves, the surgeon in charge should adjust the plan of action accordingly, modifying the amount of irrigation fluids as well.[1,3,8] A very popular course of action among surgeons bases the quantity of fluids on the Gustilo-Anderson classification for open fractures; according to an easy rule of thumb, Gustilo-Anderson type 1 fractures should be irrigated with at least three liters of solution, type 2 with at least six liters, and type 3 with at least nine liters.[8,9] Unfortunately, there are no data in the literature proving the validity of this concept. Ultimately, the effect of the amount of solution, in reducing the microbial load of open fractures and, by extension, the patient's risk for infection, is still undetermined. (Table 1)

Which is the ideal pressure for irrigation?

Another topic of extended debate is the ideal fluid delivery pressure when debriding and irrigating an open fracture. The most convenient and cost-effective method, which is commonly preferred by surgeons in acute settings, involves the use of syringes or intravenous fluid bags with gravity flow to rinse the exposed area.[1,2] In recent years, new lavage devices have arisen and quickly gained field in the management protocols of open fractures. (Fig. 2) More specifically, these lav-

Figure 1a: *Gustilo IIIB distal femoral fracture*

Figure 1b: *Preoperative X-ray*

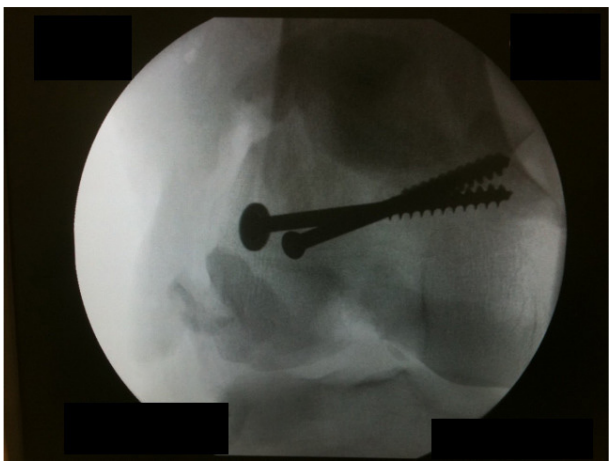

Figure 1c: *Intraoperative fluoroscopy of the screw fixation*

Figure 1d: *End-to-end wound closure*

Figure 2: *Mölnlycke® Pulsed Lavage system (source: https://www.molnlycke.co.uk/products-solutions/molnlycke-pulsed-lavage/)*

Table 1: Gustilo Classification (source: https://www.orthobullets.com/trauma/1003/gustilo-classification)

	I	II	IIIA	IIIB	IIIC
Energy	Low	Moderate	High	High	High
Wound size	≤ 1 cm	1-10 cm	usually >10 cm	usually >10 cm	usually >10 cm
Soft tissue damage	Minimal	Moderate	Extensive	Extensive	Extensive
Contamination	Clean	Moderate	Extensive	Extensive	Extensive
Fracture Comminution	Minimal	Moderate	Severe	Severe	Severe
Periosteal Stripping	No	No	Yes	Yes	Yes
Skin Coverage	Local coverage	Local coverage	Local coverage	Free tissue flap or rotational flap coverage	Typically requires flap coverage
Neurovascular Injury	Normal	Normal	Normal	Normal	Exposed fracture with arterial damage that requires repair

age systems offer adjustable delivery pressure and are usually powered by an external source, thus constituting an easy-to-carry and handle option when dealing with an open fracture. Additionally, irrigation fluids loaded in these lavage systems, can either be delivered at a constant or a pulsing pressure, offering the surgeon more versatility in his treatment plan of choice.[2,3]

The scientific community has shown a particular interest in these lavage systems and the impact of the variety of available settings on the different types of open fractures. Nevertheless, there is still controversy among authors regarding the classification of delivery pressures. However, a widely accepted theory categorizes lavage pressure from 1 to 10 psi as low, 11 to 19 psi as moderate, and pressure from 20 psi and above as high.[2,10] Several studies have concluded that irrigation of open fractures with high pressure increases the likelihood of infection, especially after the first 72 hours. Furthermore, high pressure can not only cause intramedullary dispersion of pathogen bacteria but also affect the natural bone healing process bone through changes in the trabeculae structure.[2,3] All these factors can potentially lead to late-onset infection, delayed union and even non-union.[2,3] Low-pressure rinsing is effective in most open fractures, without the drawbacks of high-pressure irrigation.[2]

On the contrary, some studies have demonstrated the beneficial effect of high-pressure irrigations in treating open fractures with extensive contamination, dirt, soil particles and large foreign bodies.[3,7] Finally, a randomized clinical trial concluded that irrigation of open fractures under low and high pressure did not differ significantly, as far as patients' quality of life 12 months after the incidence was concerned. It is also noteworthy that the quality of life remained lower when compared to prior injury in all the questionnaires that were assessed.[9]

A multicenter randomized study held in 2015 concluded that the use of constant and low pressure offers the best results in most cases, whereas pulse lavage with high pressure should be reserved for cases when irrigation and debridement are executed after the first six hours or in cases with extended contamination involving soil and dirt particles.[7] Additionally, the surgeon should always be alerted and prepared to shift to high pressure upon suspicion findings during irrigation, to avoid adhesion of pathogenic microorganisms on the bone and soft tissues that could lead to undesirable results. Interestingly, the same study also reported that conclusions from clinical trials regarding the irrigation protocols of open fractures do not always translate into significant differences in patient-important outcomes.[7]

What temperature should irrigation fluids have?

Fluids' temperature when rinsing open fractures is

usually not taken into consideration and its impact on the risk of infection is therefore underestimated.[1] Irrigation with warm solutions diminishes the incidence of hypothermia and the lengthening of hospital stay, whereas cold fluids mitigate bleeding, inflammation response and bacteria reproduction.[2] Data on the ideal temperature of irrigation fluids are insufficient and, for that reason, more primary research is needed to resolve this debate.

What type of solution should we use?

Multiple types of solutions are being regularly used in clinical practice for open fracture irrigation without unanimity among authors and surgeons.[2,3] Generally, the solution should be isotonic and non-toxic to the healthy tissues. Moreover, the fluids should be non-hemolytic and ideally free of minerals and chemicals.[2]

Sterile saline, sterile water for injection, tap water

Sterile saline is a mixture of sodium chloride and water. It is a cost-effective, isotonic fluid with low cytotoxicity and thus is considered the gold standard for irrigation among most surgeons.[2,3,7] The FLOW trial concluded that normal saline offered lower rates of infection when compared to saline water mixed with castile soap.[7] Water for injection is another sterile alternative, but the existence of minerals inside renders it hypotonic.[8] Tap water is not only hypotonic but also not disinfected. The use of hypotonic fluids in large volumes can potentially lead to intracellular damage and hinder the natural wound-healing process.[2] Nevertheless, studies have proven that tap water offers similar rates of infection when compared with saline solutions and therefore should be considered a safe alternative in the absence of other sterile options.[2]

Antibiotics

Antibiotic irrigation fluids can be beneficial in preventing the adhesion of microorganisms on bone and soft tissues.[1] However, the results from available data, including in vitro and animal studies, are ambiguous.[3] Some authors have concluded that the application of antibiotics on open trauma diminishes the number of pathogens.[3] On the other hand, antibiotics can impede normal cellular function and disrupt, as a result, the wound-healing process.[2,3] Moreover, they are more costly than sterile saline or castile soap and can trigger allergic reactions that demand urgent treatment.[2] Finally, rinsing with antibiotic solutions is important to be conducted as soon as possible after the injury, as their anti-microbial properties become less potent after the formation of bacteria biofilms.[2,3]

Castile soap

Castile soap is the most commonly used product in the surfactants category. Unlike antibiotics, they owe their anti-bacterial characteristics to micelles that bind with pathogens and are rinsed away from the trauma altogether.[2] Castile soap mixtures offer better results in the irrigation of open fractures compared to antibiotic and antiseptic solutions, despite not being sterilized.[3] Nonetheless, the re-operation rate is higher compared to saline solutions.[7]

Antiseptics

Antiseptics are effective on most types of pathogens, including bacteria, viruses and fungi.[3] The most popular antiseptics being used are povidone-iodine, chlorhexidine, hydrogen peroxide and benzalkonium chloride. It is generally recommended to avoid scrubbing open fractures with antiseptic solutions.[2] Povidone-iodine in small concentrations is non-toxic for the tissues but should be avoided in patients with thyroid diseases. Hydrogen peroxide can break down into oxygen gas and potentially cause gas embolism.[2] Overall, despite their beneficial properties in reducing the microbial count, they are usually not the first choice of surgeons due to their possible side effects and cytotoxicity that can either affect wound healing or lead to systematic complications.[2,3]

Conclusions

Irrigation and debridement of open fractures are of great importance for reducing the risk of infection.

Timing is crucial and for that reason, irrigation should be conducted as soon as possible after the injury, definitely in the first 24 hours.

"The more the better" is a safe practice concerning the quantity of fluids. Gustilo-Anderson grade 1 should be rinsed with at least three liters of fluids, grade 2 with at least six liters and grade 3 with at least nine liters, respectively.

As far as pressure is concerned, most open fractures can be irrigated effectively with low pressure, by using intravenous bags with gravity flow or syringes and needles. High-pressure and pulse lavage systems should be utilized in greatly contaminated wounds with dirt, soil or foreign bodies.

Solutions' temperature is an under-evaluated variable in the management of open fractures that could be proven to play a significant role in patients' outcomes in the future.

Several types of fluids have been thoroughly studied. Sterile saline solutions are cost-effective options that succeed in adequately irrigating most open fractures, mitigating the risk of infection. Solutions with antibiotics, castile soap or antiseptics can also be used, always taking into consideration the possible cytotoxic and wound-healing side effects.

There are multiple factors in the irrigation process of open fractures. Nevertheless, a widely accepted algorithm is yet to be determined. Consequently, the surgeon in charge should always assess each case independently and modify the variables accordingly, based on both the latest research studies and his clinical experience as well.

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