

# Wound irrigation within the surgical treatment of osteomyelitis

## Wundspülung im Rahmen der chirurgischen Osteitis-Therapie

### Abstract

The basic treatment of osteomyelitis remains even today the surgical debridement in combination with a wound irrigation by lavage systems. Next to a comprehensive knowledge of the surgical techniques a profound knowledge of the lavage systems, the rinsing solutions used and the philosophies of revision programs are a must.

In this article the typical hardware of modern lavage systems is analysed, their advantages and disadvantages are pointed out.

In addition we investigate the value of common antiseptic wound irrigation solutions for their use in osteomyelitis therapy.

Finally the two basic philosophies of wound revision and irrigation in the course of osteomyelitis therapy are presented and discussed.

**Keywords:** osteomyelitis, lavage systems, wound irrigation

### Zusammenfassung

Auch heute stellt die chirurgische Herdsanierung in Kombination mit der intraoperativen Wundspülung die Basistherapie zur Beseitigung von Knocheninfektionen dar. Neben dem umfassenden Wissen über die chirurgischen Möglichkeiten ist die profunde Kenntnis der Lavage-Systeme ebenso wie der möglichen antiseptischen Spül-Lösungen eine *conditio sine qua non*.

In diesem Artikel werden die typischen modernen Lavage-Systeme analysiert und ihre Vor- und Nachteile beschrieben.

Zusätzlich widmen wir uns den gängigen antiseptischen Lösungen zur Wundspülung und ihrem Wert bei der Osteomyelitistherapie.

Schlussendlich werden die beiden grundsätzlichen Philosophien der Revisions-/Lavage-Konzepte bei der Behandlung der Osteomyelitis dargestellt und diskutiert.

**Schlüsselwörter:** Osteomyelitis, Lavage-Systeme, Wundspülung

### Introduction

The therapy of osteomyelitis is based on three principles:

- Local surgical debridement
- Application of antibiotics
- Use of adjuvant therapies (for example hyperbaric oxygenation HBO ...)

The local treatment itself is based on another five principles [41]:

- Local bone and soft tissue debridement
- Stabilization of the bone
- Local antibiotic therapy
- Reconstruction of the soft tissue
- Reconstruction of the osseous defect zone

This surgical eradication of the infected part of the bone and the surrounding soft tissue still remains the basic treatment of osteomyelitis. The systematic debridement of all infected tissue is given support by extensive fluid irrigation [41]. This approach to the problem of infected wounds and osteomyelitis is proposed by various authors [2], [6], [25], [31], [33], [34], [38].

In a contaminated situation the quantity of bacteria present is one of the main factors for the formation and/or the persistence of the infect. Thus one of the defined goals and the initial step in infection treatment is the decrease of the bacterial colonization and the removal of the necrotic tissue by the above named irrigation [2]. The quality and efficiency of the fluid lavage depends on various factors. According to Carr 2006 and others it is based on [10], [24], [29], [30]:

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- The technique
  - Irrigation pressure (low vs. high pressure irrigation)
  - Showering, bathing, washing under a running solution
  - Total immersion in a whirlpool
- The solution
  - Type of solution (physiological saline, water, antiseptic solution, soaps ...)
  - Amount of irrigation solution
- The equipment
  - Syringes, needles, catheters

The knowledge of these key facts in the implementation of the fluid wound cleansing as well as the proper time to use them ("stage lavage concept" vs. "individual lavage concept") is the basis for successful cure of osteomyelitis.

## Technique of irrigation

As long ago as 1987 Plaumann et al. recommended the use of pulsative lavage irrigation for the treatment of septic complications in trauma surgery. Benefit was seen by these authors during the removal of pus, foreign bodies, sequestra especially from wound cavities [35].

The irrigation systems are used in order to support the surgical site debridement during the infect eradication phase of an infected wound or osteomyelitis.

According to the literature it should lead to [4], [16], [20], [34]:

- Mechanical wound cleansing
- Removement of foreign bodies
- Removement of sequestra
- Removement of necrotic tissue
- Decrease of the bacterial load of the affected tissues
- Decrease of the bacterial load on contaminated surfaces (implants, prostheses ...).

As shown above there exist various methods of irrigation for the cleansing of infected surgical sites.

Focussing the technical aspect of irrigation systems, one may differentiate between:

- No pressure systems
- Low pressure systems
- High pressure systems

And

- Systems with pulsatile lavage irrigation
- Systems with constant lavage flow

The debate continues whether constant fluid lavage or pulsatile lavage irrigation has greater efficiency [13]. In addition there is no clear choice for the lavage device either [33].

In their 2003 study Bahrs et al. compared the efficiency of three different irrigation systems (conventional 50 ml syringe, manual pump irrigation, jet lavage) in terms of the reduction of bacteria (*P. aeruginosa*, *S. aureus* and *E. faecalis*) on biological and metal surfaces in vitro [4]. They could demonstrate, that an effective statistically

relevant reduction was achieved by any of the systems regardless what kind of surface was tested. The manual pump irrigation achieved significantly better results on biological surfaces than on the metal surfaces.

## Low pressure irrigation systems (LPIS)/ high pressure irrigation systems (HPIS)

When we analyse the aspects of pressure irrigation, there must be differentiated between LPIS and HPIS. As a matter of fact in the case of LPIS the pressure of the solution jet is between 0.5 and 1.0 bar. In HPIS it amounts from 1.4 to 4.8 bar. In addition one has to differentiate between continuous flow and pulsatile irrigation methods. The pulsatile lavage is widely accepted in orthopedic and trauma surgery [20]. Nevertheless the debate continues to whether pulsatile lavage or continuous lavage has greater efficiency and less side effects in the cleansing of contaminated surgical sites [13]. LPIS seem to be the better option for the soft tissue [15], [39].

According to the literature the effect of pressure irrigation systems may be outlined as follows [2], [9], [14]:

- The reduction of the bacterial load correlates with the system pressure (HPIS > LPIS).
- The reduction of infected and necrotic soft tissue correlates with the system pressure (HPIS > LPIS).
- The level of efficiency of HPIS is higher than LPIS and higher than bulb syringe irrigation.
- The cleansing effect varies depending on the tissue treated.
- There is no substantial difference between pulsatile and continuous lavage systems.

These results are achieved by experimental studies in vitro, in animal models or in human cadaver studies and thus somehow limited.

Some investigators believe, that the use of HPIS may have a negative effect on the soft tissue and the bone itself [6], [8], [9], [11], [12], [22], [36]. They believe that:

- HPIS may lead to deeper penetration of the bacteria within the soft tissue
- HPIS may lead to deep seeding of bacteria into the bone
- HPIS may damage the bone
- HPIS may impair bone- or fracture healing
- HPIS may lead to a reduction and promotion of stem cell differentiation toward the adipocyte cell type rather than osteoblasts
- As a result of their effect on the stem cell population HPIS may lead to a significant decrease in fracture callus strength

In their 2008 study Petrisor et al. examined the surgeon's preferences of the management of open fracture wounds including their behaviour on the use of irrigation systems. These authors could prove, that the majority (71% ~ 695 surgeons) performed irrigation with LPIS, 317 of whom (32.2%) performed it with a bulb syringe [34].

Theoretically the negative effect of HPIS especially on soft tissues might be comparable to the pathophysiology of high-pressure water jet injuries which involves the following three factors [40]:

Physical: Initially the pure kinetic energy generated by the water jet may cause a local tissue destruction.

Chemical: Reaction of the involved tissue like vasculitis edema, venous obstruction, thrombosis, cellular death.

Biological: The jet injury may lead to inflammation, necrosis and soft tissue fibrosis.

In conclusion one may say, that, even if HPIS are more efficient from the mechanical point of view, the LPIS are the better choice from the biological one.

## Irrigation solutions

Next to the right choice of the irrigation system it is important to have notice of the proper irrigation solution. Purpose of the use of specific wound rinsing solutions (WRS) is the elimination of pathogens from the infection site additional to the surgical debridement.

The effect of WRS is based on 4 factors [26], [27]:

- The rinsing effect: Reduction of the number of pathogens just by the amount of solution used
- The antimicrobial effect: Reduction of the number of pathogens antibacterial pathways
- Fast onset of the antimicrobial effect
- Safe application without side effects

## The rinsing effect

According to the literature an extensive rinsing in addition to the surgical debridement is needed. Hofmann et al. recommend to use up to 5 l of WRS in order to rinse out the remaining pathogens after surgical debridement [21].

## WRS and their antimicrobial spectrum

Many different antimicrobial and antiseptic WRS may be used. Table 1 gives a brief exposure of the main substances that may be deployed [3].

## WRS and their side effects

In the last decades many scientific articles deal with the problem of the cytotoxic effect and the tissue toxicity of WRS. In 2003 Kalteis et al. measured the irritation score and the irritation threshold of some common WRS. Their results showed, that some of the antiseptic solutions may cause severe vascular injuries and thus may be considered to be cytotoxic (Dibromol<sup>®</sup>, Kodan<sup>®</sup>, Jodobac<sup>®</sup>, Octenisept<sup>®</sup>, Chlorhexidindigluconate 0.5% and 2-propanol 60%) [23]. The authors could prove, that the tissue toxicity of Lavasept 0.2%<sup>®</sup> was significant lower than the one of the above named solutions. Langer et al. analysed the impact of topical antiseptics on skin microcirculation of hairless mice in 2004. They investigated Softasept<sup>®</sup>, Octenisept<sup>®</sup>, Lavasept<sup>®</sup> and 70% ethanol. Sodium chloride

0.9% served as control. All antiseptic solutions tested showed an influence to the skin microcirculation. This effect was the most aggressive in the alcoholic solutions [28]. In 2008 Müller et al. investigated both the antimicrobial effect and the cytotoxicity of antiseptic agents. These authors defined a biocompatibility index (BI) by measuring the antimicrobial activity against *E. coli* and *S. aureus*. On the other hand, in parallel, cytotoxicity was tested on cultured murine fibroblasts [32]. A ranking was formed for the ratio  $BI_{E.coli}/\text{fibroblast toxicity}$  and  $BI_{S.aureus}/\text{fibroblast toxicity}$ .

$BI_{E.coli}/\text{fibroblast toxicity}$ :

Octenidine-dihydrochloride > polyhexamethylene biguanide > chlorhexidine digluconate > PVP-I > benzalkonium chloride > cetylpyridinium chloride > triclosan > mild silver protein.

$BI_{S.aureus}/\text{fibroblast toxicity}$ :

Octenidine-dihydrochloride > polyhexamethylene biguanide > chlorhexidine digluconate > cetylpyridinium chloride > benzalkonium chloride > PVP-I > triclosan > mild silver protein.

These findings support the results of Kalteis et al. 2003 and Langer et al. 2004 and show, that antiseptic capacity and cytotoxicity may diverge. Especially the toxic side effects of Octenisept<sup>®</sup> were pointed out again by Schupp and Holland-Cunz [37]. They came to the conclusion not to recommend the use of Octenisept<sup>®</sup> in any wound cavity. In 2009 Hirsch et al. saw significant changes of cell activity and cell proliferation after wound irrigation with Lavasept<sup>®</sup>, Betaisodona<sup>®</sup> and Octenisept<sup>®</sup>, Protosan<sup>®</sup>, Braunol<sup>®</sup> [18], [19]. These side effects were distinctly smaller when Lavasept<sup>®</sup> and Protosan<sup>®</sup> was used. In 2011 Bowling and co-workers introduced a very interesting pilot study. They analysed the effect of superoxidized aqueous solution versus standard saline solution (NaCl 0.9%) on the reduction of bacterial load and wound size on diabetic foot ulcers. No significant difference could be shown between the two solutions when being use for jet lavage [7]. According to the authors the use of superoxidized aqueous solution as well as standard saline solution is safe and effective.

Finally we would make mention of investigations of Best et al. in 2007. They analysed the effect of chlorhexidine 0.05% on human cartilage [5]. The authors measured the cartilage metabolism by using radiolabelled sulphur uptake. This metabolism was analysed for chlorhexidine 0.05% exposure on osteoarthritic and non-osteoarthritic human cartilage in-vitro. After brief exposure (1 min) the metabolism of non-osteoarthritic cartilage was not significantly affected. Osteoarthritic cartilage was impaired markedly. After prolonged exposure (1 h) both cartilage types were affected significantly. Even if these results may have an effect on the future treatment of open joint injuries in young patients (no osteoarthritic changes) the use of chlorhexidine solution is not recommendable on soft tissue, because of the above shown side effects.

**Table 1: Examples for antimicrobial substances to be used for wound irrigation [3]**

Substance	gram +	gram –	fungi	protozoa	spores	viruses
PVP-I	+	+	+	+	+/-	+
Polyhexanide	+	+	+	+	–	?
Alcohols	+	+	+	+/-	–	+
Octenidin	+	+	+	–	–	+
Chlorhexidine	+	+/-	+/-	–	–	+

## Conclusion

Counting the above named facts into consideration we recommend the use of standard saline solution (NaCl 0.9%) as the WRS used for jet lavage.

## Wound irrigation: philosophies

There are two basic philosophies about how to manage the irrigation procedure during the infect eradication phase (time and number of revision operations needed in order to eradicate the bone infection).

### Staged revision program (revision procedures with fixed distance of time)

This procedure was originally introduced by visceral surgeons who needed a sufficient tool for the treatment of severe peritonitis [1]. The patient was taken to the operation theater in a specific time schedule with fixed distance of time for revision surgery and lavage of the abdomen. The idea of this temporal programmed lavage system was assumed for the treatment of septic bone infections. Hofmann et al. recommended an electrical calendar for the planning of the revision operations [21]. The programmed lavage is continued until no pathogens could be detected in the microbial analysis of the samples taken from the surgical site.

### Individual revision program

After the initial surgical debridement with additional jet lavage the next revision operations will be proceeded according to the local clinical situation and the paraclinical findings [17]. There is no fixed time schedule. When there is no macroscopic evidence of infection anymore and the paraclinical parameters (WBC, CRP) are back to normal, the revision program is stopped, even, and this is the important difference to the above named revision program with fixed time distances, if pathogens might be detected in the samples taken from the surgical site.

## Conclusion

The basic treatment of osteomyelitis remains even today the surgical debridement in combination with a wound irrigation by jet lavage systems. Next to a comprehensive knowledge of the surgical techniques a profound know-

ledge of the lavage systems, the rinsing solutions used and the philosophies of revision programs are a must.

According to the literature, there are many antiseptic solutions, that may be used for the lavage procedure. All of them have more or less severe side effects, that render them unusable for this specific purpose.

One may state the following résumé:

- Basic osteomyelitis treatment: Surgical debridement obligatory including the wound irrigation.
- Wound irrigation procedure: Low pressure lavage systems
- Pulsatile or constant flow lavage: According to the literature there is no significant advantage for one method or the other.
- Irrigation fluid: Because of their severe side effects none of the common antiseptic solutions may be recommended. Standard saline solution (NaCl 0.9%) remains the correct choice. Further investigations in this field are indispensable.
- Amount of irrigation fluids: 5 l and more
- Staged revision program/individual revision program: No significant differences. Further investigations in this field are indispensable.

## Notes

### Competing interests

The authors declare that they have no competing interests.

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