Importance of pre-operative skin and nail preparation of the foot and intra-operative surgical irrigation in reducing infection after surgical nail avulsion

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Orthopedic surgical procedures involving the foot and ankle are associated with high rates of infection. A common challenge of nail avulsion surgery is the associated bacterial contamination and post-surgical infection that can manifest. Data from multiple randomized controlled clinical studies have provided detailed information regarding effective optimization procedures for intra-operative irrigation protocols. It was established that the addition of alcohol to povidone-iodine increased the efficacy of the nail preparation method prior to nail avulsion surgery. Consistently incorporating this pre-operative step may aid in the prevention of increased bacterial load often associated with this type of nail surgery. Based on this finding, further clinical studies examined the antispetic efficacy of distinct intra-operative methods of irrigation for nail avulsion surgery. Polihexanide was significantly more effective in this reduction than saline or nitrofurazone, and no patient acquired post-surgical infection when treated with polihexanide. Together, these clinical studies highlight the importance of utilizing an antisptic approach at multiple stages of phenol-based nail surgery, to combat the high rate of infection that can result from such procedures.

Keywords: nitrofurazone; polihexanide; povidone-iodine; phenol-based nail avulsion

Background

Many complications can arise from nail surgery, including anesthetic allergy, hematoma, nail deformity, pyogenic granuloma, persistent pain and swelling, and infection. Types of post-operative infection include superficial, acute purulent tenosynovitis, osteomyelitis, and septic arthritis[1, 2]. Studies using phenol for ingrown toenail surgery have reported infection rates up to approximately 15%[3-6]. This suggests that while the addition of phenol to the nail avulsion procedure dramatically decreases symptomatic recurrence, it is at the cost of increased post-operative infection[7].

The associated bacterial contamination and post-surgical infection that can manifest represents a common dilemma of nail avulsion surgery. Adequate removal of bacteria from the nailfolds and web spaces of the foot presents a challenge, leading to an aerobic bacterial culture rate higher than 70% for foot specimens treated with standardized methods involving povidone-iodine. The complex anatomy of the toe provides a difficult area for proper antisptic preparation prior to nail avulsion surgery, further exacerbating potential for development of disease. The inclusion of an effective pre-operative skin preparation method in the protocol for surgical preparation is a key step in preventing infection. Data from multiple randomized controlled clinical studies have provided detailed information regarding effective optimization procedures for intra-operative irrigation protocols.

Skin and nail preparation

Four methods of skin and nail preparation have been evaluated for their efficiency in eliminating bacteria from the hallux nailfold and first web space of the foot[8]. The foot-preparation solutions included 4% chlorhexidine gluconate, 70% isopropyl alcohol, and 7.5% or 10% povidone-iodine. Additionally, it was determined that immersion of the foot in a solution of water and 4% chlorhexidine gluconate before the skin and nail preparation protocol further increased the treatment efficacy (Figure 1). The post-treatment culture rates were significantly higher in methods 1 and 3 compared to methods 2 and 4, which included a pre-wash step. These results indicated that an alcohol pre-wash plays an important role in decreasing the bacterial load that can manifest in the nailbed of the foot when undergoing nail avulsion surgery. Of the microorganisms that were isolated from 224 nailbed specimens, six distinct potential pathogens were isolated, including coagulase-negative staphylococci (CNS), Staphylococcus aureus, Bacillus species, Diphtheroids, Micrococcus species, and Enterobacteriacea.
Figure 1: Pre-treatment and post-treatment positive culture rates (%) for specimens from nailfold and first webspace associated with 4 different methods of preoperative skin and nail preparation. Method 1: 7.5% Povidone-iodine scrub for 5 min + 10% povidone-iodine paint. Method 2: Prewash with 70% isopropyl alcohol for 3 min + 7.5% povidone-iodine scrub for 5 min + 10% povidone-iodine paint. Method 3: 4% Chlorhexidine gluconate scrub for 5 min + 70% isopropyl alcohol paint. Method 4: Immersion of foot in 5 L of water and 250 mL of 4% chlorhexidine gluconate + prewash with 70% isopropyl alcohol for 3 min + 7.5% povidone-iodine scrub for 5 min +10% povidone-iodine paint.

This was an instrumental study because while previous studies had demonstrated the difficulty of effectively eliminating skin flora from the forefoot[9-13], none had measured data in a quantitative fashion with regard to bacterial load. Effective treatments became acutely apparent when total colony counts (log10 CFU/cm²) were determined over a more qualitative means of measure. Some individual patients may have a higher or lower baseline bacterial load than others, but measuring the actual colony count for isolated microorganisms both prior to and after each treatment shed light on which type of treatment most effectively cleared the nailbed and web space prior to surgery. These results emphasize the importance of bacterial load detection both before and after treatment to determine the efficacy of any chosen method.

Method 2 (pre-wash with 70% isopropyl alcohol for 3 min + 7.5% povidone-iodine scrub for 5 min +10% povidone-iodine paint) is less time consuming and did not yield significantly different results with an additional immersion step in a solution of chlorhexidine gluconate (Method 4), thus representing an optimal choice for preparation of the foot prior to nail avulsion surgery. It was established that the addition of alcohol to povidone-iodine increased the efficacy of the nail preparation method prior to nail avulsion surgery. Consistently incorporating this pre-operative step may aid in the prevention of increased bacterial load often associated with this type of nail surgery.

Intra-operative surgical irrigation

Although the pre-treatment protocol greatly reduces bacterial load in the nailbed of patients, unfortunately, the nail can still remain contaminated afterwards. The basis of this contamination can contribute to infection during surgery, emphasizing the importance of a further means of reduction and antiseptic modes of action. While use of an effective pre-operative skin preparation method is important in limiting surgical wound contamination to help prevent infection, intra-operative antiseptic irrigation is also important to decrease the risk of post-contamination and infection.

Phenol and alcohol matricectomy involves removing matrix and granulation tissue. The superficial layer of the soft tissue is sterilized by the phenol, but not the deeper layer that has potential bacterial contamination from the surgical instruments used to remove the matrix and redundant nailfold. Intra-operative irrigation is a key step prior to manipulation or surgical removal of the soft tissue to effectively reduce the bacterial load and the risk of bacterial contamination to the deeper layers of soft tissue, which could contribute to contamination, infection, or both before phenol application.

To address these issues, further clinical studies examined the antiseptic efficacy of three distinct intra-operative methods of irrigation for nail avulsion surgery[14]. Nitrofurazone is a synthetic nitrofuran used as a topical anti-infective agent. This treatment has a broad antibacterial spectrum and acts by inhibiting bacterial enzymes involved in
carbohydrate metabolism[15]. Its effective at eradicating most bacteria that commonly cause surface infections, including *Staphylococcus aureus* and *Streptococcus*[15]. Another antiseptic that possesses microbicidal activity against a broad spectrum of bacteria is the fast-acting biguanide compound, Polihexanide (polyhexamethylene biguanide), an anti-bacterial agent introduced in Europe in the 1980s. It is the first known antiseptic with a specific action against negatively charged cell layers of prokaryotic cells and is less effective on the neutral lipid membranes of eukaryotic cells[5, 16]. Polihexanide has been used to effectively eliminate various pathogens in a chronic wound setting[17] and can prevent the penetration and systemic spreading of *Pseudomonas aeruginosa*[18]. Its structure and mode of action are similar to those of antibacterial peptides that function by disrupting microbial membranes. Importantly for clinical use, no known resistance to polihexanide has been reported, most likely because of its rapid and nonspecific bactericidal activity[19].

A 0.2% solution of local nitrofurazone is an effective treatment for second- and third-degree burns, skin infections, and preparation of skin grafts in areas where bacterial contamination can cause graft rejection or infection at the donor site, especially in regions with a history of bacterial resistance. A solution of 0.1% polihexanide is effective for cleaning wounds and for intra-operative wound irrigation, even in cases of severe injuries of the extremities. This evidence provided a strong rationale for the use of nitrofurazone and polihexanide to irrigate the surgical site after nail plate avulsion to effectively reduce local contaminants compared with the traditional choice of sterile saline.

Irrigation solutions of 0.9% sterile saline, 0.2% nitrofurazone, and 0.1% polihexanide were compared for their antiseptic capacity throughout nail avulsion surgery. Samples were acquired from over 70 patients at various timepoints throughout the phenol-based nail removal procedure, and bacterial cultures grown to assess positive culture rate for each method of intra-operative irrigation (Figure 2). Further analyses included quantitation of total inocula, reduction of bacterial load, and identification of specific microorganisms. In the intra-operative irrigation phase, total inocula were significantly higher in the saline solution group compared with the nitrofurazone and polihexanide solutions. A dramatic increase in total inocula was observed after the surgery phase for all 3 groups. After surgery, treatment with polihexanide yielded a greater reduction in bacterial load compared to treatment with saline or nitrofurazone.

After phenol-based nail removal, the number of positive cultures increased to similar levels as those measured before application of the pre-operative skin and nail preparation in the pretreatment phase. Positive cultures were often observed in the surgery phase that had been negative in the post-treatment phase. After saline or nitrofurazone irrigation of the surgical site, a slight reduction in positive cultures was observed for CNS. However, after the surgical site was irrigated with polihexanide, there was a significant reduction in CNS-positive cultures from 22 to 5. After intra-operative irrigation, 4 different species were recovered from the saline solution group, 6 from the nitrofurazone group, and 2 from the polihexanide treated group. Patients in all irrigation groups underwent partial phenolization of the nail matrix. Of the patients treated with saline, there were 3 post-operative infections in 24 patients (12.5%), similar to the nitrofurazone group which had 3 infections in 22 patients (13.6%). Importantly, there were no post-surgical infections in the 25 patients that were treated with polihexanide.

It seems that pre-operatively, the antiseptics did not have adequate access to all of the nail spaces, resulting in a reappearance of positive cultures after the surgical step (Figure 2), independent of pre- and post-treatment regimens. These findings suggest that upon nail removal, when the distal aspect of the hyponychium and lateral nailfold are freed, a large amount of tissue remains without antiseptic and may have serve as a reservoir to contaminate the nail bed after nail plate removal. This underscores the importance of an intra-operative treatment immediately after the surgicual nail plate avulsion, preferably with polyhexanide.
Conclusions
Devitalized tissue is a risk factor for post-operative infection. Hence, it is important to antiseptically irrigate the nail bed to reduce bacterial load before removal of the matrix or exuberant granulation tissue. Inclusion of an alcohol-based pre-wash and an intra-operative polihexanide irrigation are important additions to traditional protocols. These key steps will help avoid bacterial contamination from reaching the deepest layers of the nail bed. With intra-operative irrigation, the bacterial infection is decreased and there is a lowered risk of post-operative infection. It has been found that the highest bacterial load and greatest infection occurs with saline and nitrofurazone, whereas polihexanide treatment results in the lowest bacterial load and no subsequent infection. Surprisingly, the wound remains highly contaminated after nail plate ablation at levels similar to those of the pre-operative surgical preparation, emphasizing that a more concerted effort must be made during the procedure to effectively reduce the presence of harmful microorganisms. While all three tested methods of intra-operative irrigation reduced the total bacterial load, polihexanamide was significantly more effective in this reduction, and no patient acquired post-surgical infection with this treatment. Since the amount of bacteria available to contaminate the deep layer of soft tissue during the surgical step was reduced, the absence of infection in the polyhexanide group could be a result of the lower contaminant level in the nail bed before phenol application, consequently increasing its effectiveness.

This highlights the importance of a low bacterial existence before tissue devitalization with phenol to decrease the risk of infection. Together, these clinical studies highlight the importance of utilizing an antiseptic approach at multiple stages of phenol-based nail surgery, to combat the high rate of infection that can result from such procedures.

References