# The use of hypochlorous acid in an infected burn wound – a case study

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It is estimated that biofilms cause up to 80 per cent of all wound infections, necessitating both the use of antiseptics and the drainage of purulent discharge. In the inflamed and infected wound, it is sometimes difficult to recognise the presence of bacterial biofilms. Here we describe an example of a non-healing, inflamed superficial to partial thickness burn wound that appeared to be associated with biofilm. Special reference to the relationship among biofilm, inflammation and non-healing of burn wounds is illustrated in the case study given. This case study also explores the use of hypochlorous acid (HOCl) in an infected burn wound.

**Keywords:** biofilm, burn wound, hypochlorous acid, infection, infected wound, inflammation



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## Introduction

Burns are often infected by biofilms[1] and can have a severe impact on the physical and psychological wellbeing of patients.[2] In cases of localised burns, the most prevalent problem is scarring. Management of the infection to limit the extent of the injury and to provide an environment for wound healing is the most important clinical consideration. The control of infections and antibiotic resistance as a result of the indiscriminate overuse of antibacterial agents has become a major concern.[3] Silver sulfadiazine has been the gold standard topical agent for antibacterial effect for many years.[4] Several reports now refer to the resistance of bacteria to silver sulfadiazine.[3] The need for new agents for the treatment of burn wounds with less adverse problems and better efficacy have become paramount in the successful treatment of infection and the control of long-term inflammation.

When there is not expedient control of wound infection, bacterial biofilms can develop which complicate clinical management. Biofilms consist of complex microbial communities that exist in a polysaccharide extracellular matrix that enables reduced diffusion of environmental and antibiotic stresses. This leads to the development of resistance against antibiotics and antiseptics as well as inflammation, which in turn delays healing. It is therefore imperative that measures be taken to treat infection, including biofilm infection, and to control inflammation.

## Study case presentation

### Patient history

The patient is a 44-year-old male who burned his hand while controlling a bush fire. He then visited the emergency room at his local private hospital. Wound care was done per local protocol every 2–3 days. By day 16, the wound appeared inflamed with an area of infection.

### Wound dressings

Day 0 – The wound was cleaned with chlorhexidine and dressed with Burnshield® (burn dressing containing *Melaleuca alternifolia* [tea tree] oil, water and polyurethane foam).

Day 1 – A follow-up at the emergency room where the wound was cleaned as per standard protocol with chlorhexidine solution and dressed with Bactigras (chlorhexidine acetate 0.5% paraffin gauze). The dressing was changed every 2–3 days.

Day 16 – HOCl (Trifectiv® Plus) was introduced as the primary wound cleanser. Also, wound dressing consisted of daily dressing with HOCl impregnated (wetted/moistened) gauze fixed with a crepe bandage.

Day 30 – No more dressing was needed. The patient had to apply moisturiser to the skin and protect the wound from direct sunlight.

### Wound progress

Wound healing was slow during the first 16 days, and the patient presented clinical signs of biofilm development and secondary infection. After four days of applying HOCl (Trifectiv® Plus) no clinical signs of inflammation or infection were present, and healthy epithelialisation was seen (Figure 1). Within two weeks of starting HOCl treatment, the wound appeared mostly healed and dressing was no longer used, ultimately resulting in complete healing and full restoration of movement. These events, with pictures of the wound healing process, are depicted in Figure 1.

Shown are pictures of a burn resulting from a bush fire. After two days, the wound appeared inflamed and infected, progressing to sepsis and necrosis by day 16. Thereafter, application of HOCl resulted in a reduction of inflammation and resolution of the infection. The wound was mostly healed after two weeks of HOCl treatment.


**Figure 1:** Progression of wound infection and subsequent healing in a burn case

## Discussion

According to the National Institute of Health in the USA, it is estimated that 65 to 80 per cent of infections in humans are caused by bacterial biofilms.[5-7] Some bacteria have the capacity to resist antiseptics and attach to the surface of the wound, leading to wound healing problems. Bacterial biofilms have the capacity to attach to an inanimate surface,[6,8,9] for example, a wound bed, suture or implanted medical device, and secrete substances to protect the resident bacteria from environmental influences such as the immune response and ultraviolet light.[5,6] Unfortunately, biofilms cannot be identified using routine diagnostics, and some form of light or electron microscopy is necessary to make diagnosis.[5,6]

In the described clinical case study, the patient presented with the development of an infection and biofilm formation, which led to inflammation. Traditional methods to remove infection include surgical scrubbing and the removal of the granulation tissue.

In order to provide a wound with the best environment in which to heal, it is important to eradicate infection, biofilm and necrotic material, and to control inflammation and stimulate wound healing.[10,11] The control of infection has become a major factor that determines treatment time to wound resolution. The problems in the control of an infection is further compounded by the development of multiple drug resistant (MDR) bacteria. If antiseptics are needed to control the microbiological load of the wound, these products should be effective in eradicating the wound infection, not cytotoxic to viable wound cells or prone to the development of resistance against its use. Commonly-used disinfectants like povidone-iodine, hydrogen peroxide, citric acid and chlorhexidine have all been reported to be cytotoxic.[12-18] There have been few controlled studies on the efficacy of povidone-iodine and other antiseptics, such as ionised silver, alcohol, acetic acid or hydrogen peroxide.[19,20]

Necrotic tissue also impairs healing as it provides a rich environment for bacteria growth, increasing the chance of infection and so increasing inflammation in the wound. Tissue necrosis can be the result of long-standing infection, wound exposure to the environment, non-viable tissue, ischaemia or trauma. The debridement of necrotic material through sharp debridement or wet-to-dry dressing debridement assists with the control of infection.[21] The importance of debridement cannot be over-emphasised, as the presence of non-viable tissue in the wound complicates infection control measures. Debridement is also used in the removal of biofilm bioburden along with senescent cells, and it is suggested to be performed at each dressing change.[22,23]

Excess secretion of proteases can induce uncontrolled tissue degradation, including new granulation tissue and growth factors. This delays collagen formation, thus impairing the repair process. The continued

production of pro-inflammatory cytokines and chemokines further attract and activate additional inflammatory cells, perpetuating the non-healing condition.

The search for a safe and effective topical antiseptic without any cytotoxicity remains the biggest challenge.[24] HOCl is a naturally occurring, powerful oxidation/reduction agent[25] that is produced by white blood cells in the human body as the main ingredient used by our immune systems to destroy disease-forming bacteria and other harmful microorganisms, and to heal wounds. These immune cells, termed phagocytes, can sense pathogens (microorganisms such as bacteria, fungi and viruses) both chemotactically and by direct physical contact causing phagocytosis, which is the process by which certain cells engulf and destroy microorganisms and cellular debris. HOCl is an essential component of the microbial capacity of these phagocytes. HOCl destroys pathogens due to its strong microbiocidal properties.[25] It is reported that HOCl can kill bacteria without a cytotoxic effect on human cells.[20] It, therefore, could be an alternative to povidone-iodine and other antiseptics with cytotoxic effects. HOCl has shown antimicrobial efficacy against many pathogens and antibiotic-resistant bacteria, such as methicillin-resistant *Staphylococcus aureus* (MRSA) , *Pseudomonas*, *Proteus*, carbapenem-resistant *Enterobacteriaceae* (CRE), *Klebsiella* and *A. baumannii* without inducing toxicity.[20] HOCl is highly active against all bacterial, viral and fungal human pathogens[26,27] and a small amount of HOCl can kill spore-forming and non-spore bacteria in a short period of time.[28] HOCl has also been shown to have a powerful anti-biofilm effect.[29,30]

The modulation of the inflammatory response further supports the beneficial effect of HOCl.[31,32] Inflammation has four symptoms and signs: redness, pain, heat and swelling. Excessive inflammation is at the centre of the process that leads to scarring and a delay in wound healing (e.g. if infection develops) and it is therefore essential that inflammation be kept under control during the healing phase.[21] HOCl modulates inflammation through its effect on nuclear factor $_{k}$B and activator protein-1 of monocytes. After chlorination of taurine by HOCl, taurine chloramine is mostly anti-inflammatory. HOCl also neutralises various pro-inflammatory cytokines and chemokines (IL-1$^{beta}$, IL-2, IL-6).[31,32] The effect of this powerful suppression of inflammation thus reduces pain, redness and swelling, and allows for more expedient wound healing.[33]

HOCl also induces the production of cellular growth factors (i.e. insulin-like growth factor, epidermal growth factor, keratinocyte growth factor [also called FGF-7], FGF-1, FGF-2, PDGF, vascular endothelium growth factor and connective tissue growth).[30] HOCl may also affect the signal transduction pathway in inflammatory cytokine formation. HOCl concentrations induce cell proliferation and stimulate extra-cellular matrix (ECM) component production in human fibroblasts.[34] The complete absence of a cytotoxic effect of HOCl on human cells form an important component in its ability to promote healing in wounds.

## Conclusion

Care of patients with burns is complex, could be lengthy and could be complicated by infection, especially if the prevailing bacteria are present as biofilms. This complication can be anticipated and treated with the use of HOCl, an effective agent against planktonic and biofilm bacteria. Furthermore, its effect on the modulation of inflammation ultimately yields improved outcomes. The patient in this case study, despite the formation of biofilm and inflammation, responded well to the local application of and daily dressing with HOCl and gauze. The results suggest that treatment of wounds with HOCl should be investigated for all burn cases where the wounds are not following the normal wound healing trajectory according to the wound healing phases.

**Conflict of interest**

The authors declare no conflict of interest.

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