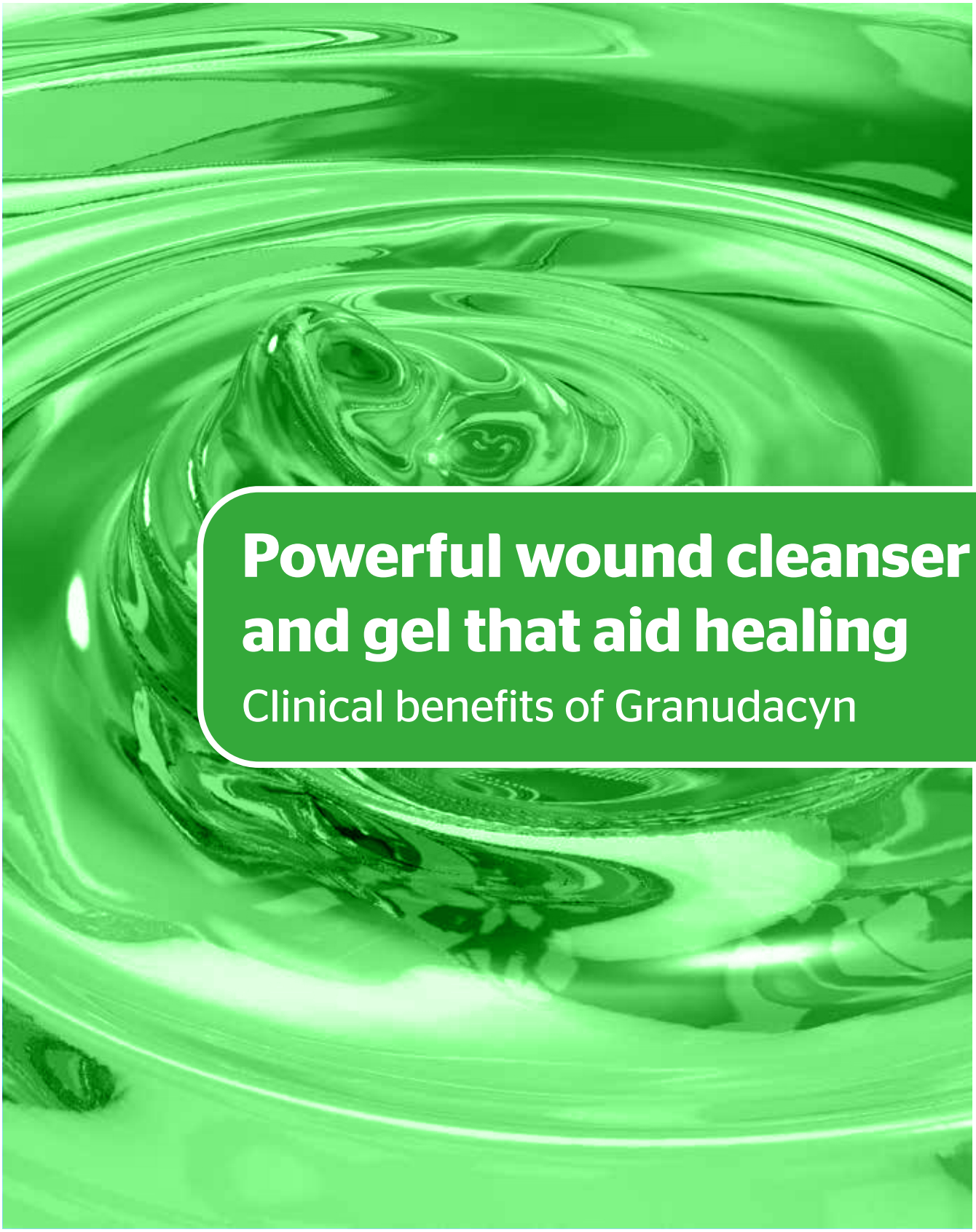

Powerful wound cleanser and gel that aid healing

Clinical benefits of Granudacyn

An educational supplement in association with

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Case for wound cleansing

Axel Kramer, MD, Consultant Clinical Microbiology and Infection Control, Institute of Hygiene and Environmental Medicine, University Medicine Greifswald, Germany

The acronym M.O.I.S.T. (Moisture, Oxygen, Infection control, Support and Tissue management) is a recent wound healing concept that aims to improve the local treatment of wounds and address factors that can adversely affect desired clinical outcomes.[1]

It is widely accepted that the presence of devitalised tissue, such as necrotic tissue and slough, and foreign materials, such as dressing remnants, can delay wound healing.[2] Furthermore, devitalised tissue can be a focus of infection, which itself can impede healing.[3] Interventions designed to address these barriers to wound healing therefore comprise a vital part of the health professional's armoury.

One such essential intervention is cleansing, a process in which loosely adhering debris and microorganisms are mechanically removed from the wound bed, usually using fluids. Wound cleansing is often undertaken in conjunction with wound debridement, an intervention that aims both to remove any devitalised tissue that cannot be removed by fluids[5] and combat biofilm.[6] Other reported benefits of wound cleansing include improved visualisation of the wound bed and edges, removal of organic and non-organic material and excess exudate, and patients feeling socially clean.[7]

Although all wounds will potentially benefit from wound cleansing, it is a particularly valuable intervention for those that:

- Are exhibiting clinical signs of infection
- Contain slough
- Are contaminated with faecal material
- Contain debris.[8]

Historically, sterile physiological (0.9%) saline, Ringer's solution and tap water have been the mainstays of wound cleansing solutions, with practices varying between geographical regions. For example, in Germany, tap water is not recommended for wound cleansing unless it is applied through a sterile filter.

More recently, there appears to be an increasing interest in the use of antiseptic-containing solutions for cleansing wounds with a raised bioburden, including biofilm. This might reflect ongoing initiatives to reduce the use of systemic antibiotics owing to concerns about resistance.[8,9]

Nevertheless, it is important that topical wound antisepsis is used appropriately, as emphasised in the recent publication of consensus on this topic (Box 1).[10]

Numerous different types of wound-cleansing fluids are described in the literature, including isotonic solutions (sterile physiological (0.9%) saline) and hypotonic solutions (sterile and potable tap water). In addition, a variety of topical antiseptic agents (chlorhexidine, cetrimide, octenidine hydrochloride, polyhexamethylene biguanide (PHMB), povidone iodine and hypochlorous acid/sodium hypochlorite) are used to cleanse and irrigate wounds.[11]

When selecting wound cleansing solutions, the following criteria should be considered:

- Wound type
- Risk of infection,[12] recurring infection, or current infection[13]
- Need for a solution with a low cytotoxicity (ie, not high enough to damage healthy cells)
- Ease of use and availability
- Clinical efficacy
- Cost-effectiveness.[7]

Box 1. Statements contained in the updated consensus guidelines on wound antisepsis[10]

'The local application of antibiotics for locally confined wound infections and colonization is to be avoided, not only because of the promotion of resistance development, but also because of their microbiostatic mode of action and concentrations that are hard to adjust. Any systemic escalation of the infection, such as positive blood cultures, must be treated with systemic antibiotics in combination with topical antiseptics, if necessary.'

'An infected or critically colonized wound must be microbiologically remediated in order to heal properly. It must be determined whether the topical use of antiseptics is sufficient or if a systemic antibiosis is necessary due to septic spreading. If a wound is at risk of becoming infected, antiseptics can prevent the emergence of infection.'

'The use of antiseptics for prophylaxis or therapeutic indications in wound treatment is possible for the following objectives:

- Prevention of infection of acute wounds, eg, after trauma, bite or gunshot wounds
- Prevention of surgical site infections (SSI)
- Decolonization of wounds colonized with MDRO
- Treatment of clinically manifested wound infection, including so-called critical colonization
- Preparation for debridement or wound cleansing of chronic wounds in outpatient facilities*'

[MDRO = multidrug-resistant organisms]
*To ensure this is not overlooked

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With these criteria in mind, this supplement focuses on the Granudacyn (Mölnlycke Health Care, Gothenburg, Sweden) solution and gel products for the cleansing, moisturising and rinsing of acute and chronic wounds.

Granudacyn Wound Irrigation Solution is a pH-neutral hypotonic wound cleansing solution and Granudacyn Wound Gel is an amorphous gel. Both products include the preservatives sodium hypochlorite (NaOCl) and hypochlorous acid (HOCl) in their formulations.

The next article in this supplement reviews the published literature on the use of wound cleansers with HOCl. This is followed by a short section describing the composition and mode of action of Granudacyn Wound Irrigation Solution and Granudacyn Wound Gel. Finally, a number of case studies are presented that describe the use of these products on challenging wounds.

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Wound cleansing: benefits of hypochlorous acid

Joachim Dissemond, MD, Department of Dermatology, Venereology and Allergology, University Hospital Essen, Germany

Cleansing provides an opportunity to remove pathogens from the wound bed, thereby preventing an increase in the bioburden and delayed healing. This article describes the reported efficacy of hypochlorous acid-containing wound cleansers

Hypochlorous acid (HOCl) is a powerful oxidising agent that, depending on the dose and concentration, is capable of damaging multiple cellular components of microorganisms, such as proteins, lipids and nucleotides, simultaneously.[1] It can inflict lethal damage, even in low concentrations, within milliseconds, thereby rapidly and selectively inhibiting the growth and cell division of bacteria and fungi.[2–4]

Introduced in the First World War as a means of treating wound infections, HOCl has a long history of use in wound care. Recently, there has been a resurgence of interest in its use as a wound cleanser.[5] This article describes the biochemistry of HOCl and explores the evidence on its efficacy.

Biochemistry

When chlorine is dissolved in water, a weak acid (HOCl) is produced that, in a further reaction, can dissociate (split into smaller molecules) to form the hypochlorite ion (OCl-). These equilibrium reactions are pH dependent.

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-$$
$$HOCl \rightleftharpoons H^+ + OCl^-$$

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Cl_2 = chlorine; H^+ = hydrogen ion; H_2O = water; HOCl = hypochlorous acid; OCl^- = hyperchlorite ion

The microbiocidal activity of a chlorine solution is largely attributed to undissociated HOCl. However, as the pH of the solution increases, the microbiocidal activity decreases, paralleling the conversion of undissociated HOCl to OCl^-. At pH 4–6, HOCl is the predominant species. As the pH increases, OCl^- is formed, and at a physiological pH (around 7.4) HOCl and OCl^- are presented in approximately equimolar quantities.[6]

Mode of action

Antimicrobial properties

HOCl is a naturally occurring bactericidal agent produced by the body's innate immune process. It is released as an endogenous substance by the enzyme myeloperoxidase (MPO) from hydrogen peroxide (H_2O_2) during oxidative burst. (MPOs are expressed by neutrophils; oxidative burst, also known as respiratory burst, releases reactive oxygen species (ROS), whose role is to destroy pathogens.)

The powerful oxidising potential of HOCl results in its reaction with many microbial molecules, especially those involved in growth and cell division, resulting in bacterial and fungal killing.[4] In addition, the modification of microbial cell membrane proteins by HOCl is thought to play a role in HOCl-mediated cell lysis.[7]

Antibiofilm activity

In vitro studies have shown that HOCl has microbiocidal action against bacterial and fungal biofilms, and can disrupt the biofilm extracellular polysaccharide matrix.[2,8,9]

Biofilms are frequently associated with medical procedures involving medical devices and prostheses, diseases such as chronic sinusitis and cystic fibrosis, and infections in hard-to-heal wounds.[10] In fact, biofilms are assumed to be a central factor in the delayed healing of many hard-to-heal wounds.[11] A recent consensus paper stated: 'For wound care and scar management, topical stabilised HOCl conveys powerful microbicidal and antibiofilm properties, in addition to potency as a topical wound healing agent. It may offer physicians an alternative to other less desirable wound care measures'.[12]

Anti-inflammatory properties

In addition to its microbicidal activity, HOCl has anti-inflammatory and immunomodulatory properties. Laboratory studies have demonstrated that HOCl can:

- Decrease the activity of histamine, neutrophil-generated leukotrienes (LTB4) and interleukins (IL-2 and IL-6)
- Downregulate matrix metalloproteinases (eg, MMP-7 and collagenases)
- Diminish mast-cell degranulation and cytokine release (induced by immunoglobulin E)
- Induce favourable effects on the migration of keratinocytes and fibroblasts.[13]

Protection of human cells from the effects of hypochlorous acid

Importantly, taurine, the most abundant free amino acid in the human body, which is found at especially high concentrations in inflammatory cells such as neutrophils, acts as a scavenger molecule that targets HOCl. In this way, it protects human cells from damage caused by HOCl.[6,14]

Hypochlorous acid formulations for the clinical setting

Technological advances in electrochemical activation processes using salt, such as sodium chloride (NaCl), and water have resulted in the manufacture of stable electrochemically activated solutions (ECAS) containing HOCl that exhibit high tissue tolerability[15] and are not cytotoxic to human cells.[16] These HOCl solutions have several indications within the clinical setting.

Use of hypochlorous acid in wound care

Solutions containing HOCl act as mechanical cleansers for removing debris and microorganisms from a variety of wound types:

- Diabetic foot ulcers (DFUs), leg ulcers, pressure ulcers,[17–22] many of which can be hard to heal
- Acute wounds such as burns, skin grafts,[23,24] soft tissue injuries[25] and surgical wounds[18,24,26,27]

These cleansers can be applied to infected wounds to help reduce the microbial load, thereby reducing the use of systemic antibiotics.[28] They can also be employed as a lavage during surgical procedures to reduce the risk of surgical site infections (SSIs).[18,24,26,27] HOCl solution can also be delivered by instillation with negative pressure wound therapy (NPWT).[29,30,31]

Irrigation solutions containing HOCl can be applied to body cavities, such as the mouth, nose and ears[32,33] and to the eye.[34] Research also indicates that, due to their powerful antimicrobial properties and anti-inflammatory effects,[35] HOCl solutions present a potential tool for wound and scar management,[12] and the treatment of inflammatory skin disorders such as atopic dermatitis.[13,36]

Clinical effectiveness in wound care

A literature search identified 11 published randomised controlled trials (RCTs) that evaluated the use of several ECAS containing HOCl to treat skin grafts, DFUs, surgical wounds and traumatic wounds. A brief overview of each RCT is presented in Table 1.

The different study designs and some low sample sizes limit the generalisability of the results. Nevertheless, it is noticeable that, in all 11 RCTs, use of the HOCl-containing irrigation solutions was associated with positive wound healing results. Several studies reported significantly reduced bacterial bioburden, an improvement in the clinical signs of wound infection and accelerated healing in wounds irrigated with HOCl. Other studies also reported improvements in wound malodour and wound-related pain, as well as a reduction in the length of hospital stay and consequent costs.

Conclusion

The use of HOCl-containing solutions positively influences various aspects of wound healing. They are an easy-to-use and safe method for different types of wounds. However, it should always be noted that, in the long term, treatment can only be successful if the causes of the wound healing

Table 1. Details of randomised controlled trials that have used HOCl-containing wound irrigation solutions

Reference	Wound aetiology	Intervention group(s)	Control group	Outcomes
Foster et al.[23]	Skin grafts	HOCl solution (n=11), (10% TBSA burned)	Mafenide acetate 5% solution (n=8) (6.5% TBSA burned)	Equivalent efficacy (healing at day 14 post-grafting) and safety demonstrated in intervention and control groups. Significantly lower costs in intervention group: cost savings in excess of $406 per patient (after taking into consideration burn size and quantity of solution used)
Sridhar and Nanjappa[17]	Lower limb ulcers (traumatic, DFU, VLU)	HOCl (SOS) (n=34)	PVI (n=34)	Significantly greater reduction in signs of inflammation, microbiological clearance, pain and accelerated healing in intervention group at day 9: ■ Ulcer size reduction: 49% (HOCl) vs 28% (PVI) (p=0.02) ■ Microbial growth reduction: 52% (HOCl) vs 24% (PVI) (p=0.04) ■ Periwound erythema/oedema reduction: 91% (HOCl) vs 70.5% (PVI) (p=0.031) ■ Granulation tissue increase: 100% (HOCl) vs 79.4% (PVI) (p=0.005) ■ Epithelialisation increase: 70.5% (HOCl) vs 41% (PVI) (p=0.015)
Ragab and Kamal[28]	Infected DFUs	HOCl solution (n=30)	H_2O_2 + PVI (n=30)	Significantly greater reduction in infection in intervention group, i.e. infection-free at: ■ Day 10: 70% (HOCl) vs 3.3% (H_2O_2 + PVI) ■ Day 15: 100% (HOCl) vs 13.3% (H_2O_2 + PVI) ■ Day 30: 53.3% (H_2O_2 + PVI) HOCl killed Candida, Proteus and Klebisella species within 15 days, Pseudomonas species after 20 days and MRSA after 25 days. H_2O_2 + PVI failed to kill any of the microorganisms after 30 days
Hiebert and Robson[18]	Infected chronic wounds (PU, VLU, surgical, DFU)	HOCl solution + UD (n=9)	Saline + UD (n=8)	Similar reduction in bacterial bioburden (4 to 6 logarithmic units) immediately following irrigation and debridement in both groups. Significantly greater reduction in bacterial bioburden after day 7 (time of the definitive wound closure procedure) in the intervention group (p<0.05): ■ HOCl + UD: 10^2 log or fewer ■ Saline + UD: 10^5 log Lower rate of postoperative closure failure in intervention group: 25% (HOCl + UD) vs >80% (saline=UD)
Mekkawy and Kamal[37]	Septic trauma wounds	HOCl (0.5% NaCl and 51.5% HCl) (n=30)	PVI (n=30)	Significantly greater reduction in bacterial burden, improvement in wound condition and reduction in pain and malodour in intervention group after 2 weeks: ■ Bacterial load reduction: 90% (HOCl) vs 0% (PVI) (p<0.00001) ■ Proportion of wounds with serous exudate: 100% (HOCl) vs 10% (PVI) (p=0.004) ■ Proportion of wounds with low exudate levels: 100% (HOCl) vs 30% (PVI) (p=0.005) ■ Absence of wound malodour: 100% (HOCl) vs 13% (PVI) (p=0.001) ■ Absence of wound pain: 100% (HOCl) vs 17% (PVI) (p=0.004)

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Garg et al.[26]	Peritoneal laparotomy	HOCl (SOS) + saline (n=50)	Saline (n=50)	Significantly more effective lavage of the peritoneal cavity during laparotomy in the intervention group in terms of reducing occurrence of postoperative complications: ■ SSI occurrence: 14% (HOCl + saline) vs 40% (saline) (p=0.0034) ■ Burst abdomen occurrence : 4% (HOCl + saline) vs 16% (saline) (p=0.025)
Landsman et al.[19]	Mildly infected DFUs	HOCl solution (n=21), HOCl solution + AB (n=25)	Saline + AB (n=21)	Higher clinical success rate (cure or improvement), based on clinical signs and symptoms of infection, after 2 weeks with HOCl alone: ■ HOCl: 75% ■ HOCl + AB: 72% ■ Saline + AB: 52% Clinical success rate per pathogen was greatest after treatment with HOCl solution alone after 10 days: ■ HOCl: 80% ■ HOCl + AB: 58% ■ Saline + AB: 64%
Mohd et al.[27]	Stenotomy wounds	HOCl solution (n=88)	PVI (n=90)	Significantly greater reduction in postoperative infection rate (coronary bypass grafting) at 6 weeks in the intervention group (p=0.033): ■ HOCl: 5/88 (6%) ■ PVI: 14/90 (16%)
Piaggesi et al.[20]	Postoperative infected DFU wounds	HOCl solution (n=20)	PVI (50% solution) (n=20)	Significantly greater reduction in bacterial count after 1 month of treatment in the intervention group: 88% (HOCl) vs 11% (PVI) (p<0.05) Significantly greater proportion of wounds healed after 6 months in intervention group: 90% (HOCl) vs 55% (PVI); p=0.002 Significantly shorter healing time (within 6 months) in the intervention group: 10.5 weeks (HOCl) vs 16.5 weeks (PVI)
Hadi et al.[21]	Infected diabetic wounds	HOCl solution (n=50)	Saline (n=50)	Significantly greater proportion of wounds downgraded from category IV (necrotic tissue/pus) to category I (epithelial tissue present) after 1 week in the intervention group: 62% (HOCl) vs 15% (saline) (p<0.05) Significantly greater proportion of patients with a hospital stay ≤1 week in the intervention group: 62% (HOCl) vs 20% (saline) (p<0.05)
Martinez-De Jesus et al.[22]	Infected DFU	HOCl solution (n=21)	Saline with PVI (switch from PVI to surgical soap when infection resolved) (n=16)	Significantly better outcomes in the intervention group reported in this 20-week study: Fetid odour reduction: 100% (HOCl) vs 25% (control) (p=0.001) Cellulitis reduction: 81% (HOCl) vs 44% (control) (p=0.01) Periwound skin improvements: 90% (HOCl) vs 31% (control) (p=0.001)

AB = antibiotic (levofloxacin); DFU = diabetic foot ulcer, H_2O_2 = hydrogen peroxide; HCl = hydrochloric acid; HOCl = hypochlorous acid; MRSA = meticillin-resistant *Staphylococcus aureus*; NaOH = sodium hydroxide; PU = pressure ulcer; PVI = povidone iodine; SOS = superoxidised solution; TBSA = total body surface area; VLU = venous leg ulcer; UD = ultrasonic debridement

disorder have been diagnosed and, if possible, treated. A modern moist and phase-adapted treatment that includes HOCl will help support this.

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Granudacyn Wound Irrigation Solution and Wound Gel

Granudacyn is a range of solution and gel products marketed by Mölnlycke Health Care. Incorporating sodium hypochlorite (NaOCl) and hypochlorous acid (HOCl) in their formulations; these products are intended for use in the cleansing, irrigation and moisturisation of various wound types. This supplement focuses on Granudacyn Wound Irrigation Solution and Wound Gel (Figure 1).

As well as being used for irrigation purposes, Granudacyn Wound Irrigation Solution can be used to keep wounds moist and to help loosen bandages and dressings, making them easier and less painful to remove. It can be applied directly to wounds from a distance of approximately 15–30cm in the case of the spray version, or with soaked compresses.

Granudacyn Wound Gel can also be used to moisten wounds and dressings. After cleansing the wound and surrounding area with Granudacyn Wound Irrigation Solution and dabbing dry, Granudacyn Wound Gel can be applied and covered with a suitable dressing. Granudacyn Wound Gel can be used with foam dressings (e.g. Mepilex, Mepilex Border, Mepilex Border Flex; Mölnlycke Health Care).

Figure 1. Granudacyn Wound Irrigation Solution: available in 50ml (spray), 100ml (spray), as well as 500ml and 1000ml formats; also available in 500ml and 1000ml for instillation with negative pressure wound therapy; Granudacyn Wound Gel: available in 50g (pump), 100g (spray) and 250g (spray)

Mode of action

Granudacyn Wound Irrigation Solution facilitates the removal of debris and microorganisms from a wound by the mechanical effect of rinsing. This physical action helps reduce the microbial burden of the wound, thereby promoting healing and reducing malodour.[1] It also can be left to soak in a wound, thereby moistening the wound tissue. In this way, it can promote autolytic debridement and provide a moist environment that is conducive to wound healing.

Composition

Granudacyn Wound Irrigation Solution is a hypotonic wound care solution that contains water, sodium chloride and low concentrations of the preservative agents HOCl and NaOCl.

Granudacyn Wound Gel is an amorphous gel that contains water, sodium chloride, HOCl, NaOCl and colloidal silicate.

The preservative agents used in both products are stabilised by a propriety technology based on electrochemical activation (ECA). They prevent the growth of bacteria, viruses and fungi, ensuring the safe use of the wound irrigation solution and wound gel for 60 and 90 days, respectively, once opened, thereby allowing multipatient use.

A neutral pH results in a solution that contains both HOCl and NaOCl in equal concentrations, offering an effectively preserved irrigation solution without the potential to irritate wound tissue. Preservation of the irrigation solution occurs by two processes:

- Osmolysis: this purely physical effect of cell lysis ensures the highly effective prevention of microbial growth in the Granudacyn Wound Irrigation Solution
- HOCl oxidation: the powerful oxidising potential of HOCl interacts with biological molecules of pathogenic microbes, such as proteins, lipids and DNA, causing molecular damage and microbial cell death[2] This reaction imitates the 'oxidative burst' reaction naturally found in the human innate immune response, as described in the article by Joachim Dissemond page S5.

To highlight the clinical effectiveness of Granudacyn Wound Irrigation Solution Granudacyn Wound Gel, seven case studies on different wound types are presented.

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Post-amputation wound on diabetic foot

Domagoj Cuzic and Maja Lenkovic, Specialists in Dermatovenerology, Clinical Hospital Centre Rijeka, Croatia

A 71-year-old man presented with a post-amputation surgical wound resulting from the removal of the third toe on his right foot due to gangrene. He had a medical history of type II diabetes mellitus mostly well controlled with medication.

Following surgery, the amputation wound measured 200mm^2, with a depth of 5mm. The wound bed comprised 80% granulation tissue and 20% slough, and there were no clinical signs of wound infection. Exudate was moderate in volume and serosanguinous in nature. The peri-wound skin was healthy and intact.

Post-surgery, the specialist surgeon cleansed the wound with povidone-iodine antiseptic solution and covered it with gauze. The patient was prescribed prophylactic antibiotics (clavulanic acid and metronidazole).

Fig 1. Start of Granudacyn therapy (day 1): post-amputation surgical wound with moderate levels of serosanguinous exudate. The peri-wound skin is healthy and intact

Fig 2. Day 15 of Granudacyn therapy: the wound has reduced in size and the condition of the wound bed has improved

After seven days, the surgeon referred the patient to our clinic. On presentation, the wound measured 2x1cm and was completely covered with granulation tissue. There were no clinical signs of infection (Figure 1).

The amputation wound was irrigated with Granudacyn Wound Irrigation Solution, which was soaked in gauze and applied for 10 minutes. (The health professional ensured an appropriate moisture balance was maintained throughout.) After this, topical haemoglobin therapy (Granulox, Mölnlycke Health Care) and a soft silicone foam dressing (Mepilex Lite, Mölnlycke Health Care) were applied.

Granudacyn was selected because of its efficiency and non-cytotoxicity. According to consensus guidance on wound antisepsis, the preservatives in its formulation (hypochlorous acid (HOCl) and sodium hypchlorite (NaCl)) are the first choice for decontaminating acute and chronic wounds.[1] The combined use of a topical haemoglobin spray and a soft silicone bordered foam dressing had proved effective when used on other wounds in our clinic.

The Granudacyn and Granulox were applied at each dressing change, which took place every 2 days. (At this clinic, it is common for patients with complex wounds to attend for frequent assessment and dressing changes.)

Outcome

The wound steadily reduced in size throughout the treatment period (Table 1). At the first follow-up assessment after one week of treatment, the condition of the wound bed had improved, and was covered with 100% granulation tissue. At the second follow-up visit (week 2), the exudate volume had reduced to low (Figure 2). The periwound skin

Table 1. Reduction in wound size reported over the 30-day follow-up period

Day 1: 2x1cm
Day 9: 2x0.8cm
Day 15: 1.6x0.6cm
Day 21: 1x0.4cm
Day 30: wound closure

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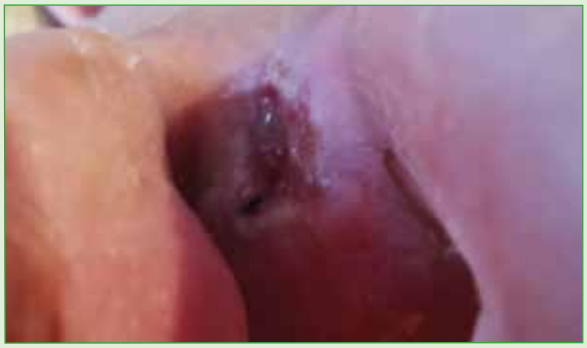

Fig 3. Day 21 of Granudacyn therapy: the wound has further reduced in size and continues to improve

Fig 4. Day 30 of Granudacyn therapy (final evaluation): the wound has healed

remained healthy and intact throughout. The patient did not report any pain at dressing changes, or experience any clinical signs of infection during the treatment. Figure 3 shows the wound at week 3. Full healing occurred in 30 days (Figure 4).

Due to its non-cytotoxic nature, it was possible to use Granudacyn until wound closure occurred. This is especially important in the case of diabetic foot ulcers, which are particularly prone to infection.

The patient noted the value of the Granudacyn, stating after every dressing change that the wound was 'better'. He said that the quick progression towards closure encouraged him to self-manage his diabetes more effectively. He recognised this was an opportunity to lead a 'normal life' without diabetic complications.

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Non-healing surgical wound with exposed bone

Joachim Dissemond, MD, Department of Dermatology, Venereology and Allergology, University Hospital Essen, Germany

An 87-year-old man presented at our certified wound care centre, which is located at a university hospital, one month after a surgical procedure to remove a squamous cell carcinoma on the frontoparietal left scalp. The wound had been left to heal by secondary intention. (Figure 1).

The patient's comorbidities included actinic skin damage and arterial hypertension, which was well controlled with medication. His mobility and appetite were good for his age, as was his nutritional status.

During the first five postoperative months, the wound was treated with a variety of therapies including hydrogel and hydrofiber dressings. The treatments were prescribed by the wound care centre and administered by the outpatient nursing service, with the patient attending the centre every 3–4 weeks for follow-up consultations. During this period, the wound developed multiple local infections, which were

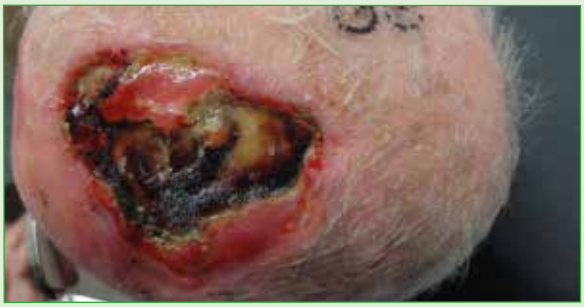

Fig 1. The wound on presentation to the clinic (one month after surgery). In the first five postoperative months, the wound was treated with various therapies, but with no progression towards healing

Fig 2. Start of Granudacyn therapy (day 1): there is exposed bone on this 5-month-old postoperative wound

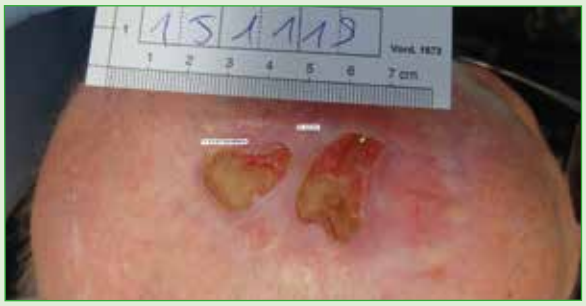

Fig 3. After two months of Granudacyn therapy: the wound area has reduced significantly. There are no clinical signs of a local wound infection and the composition of the wound bed tissue has improved

treated with silver or polihexanide (PHMB)-containing dressings. A PHMB-containing wound irrigation solution was also used. The exact cause of the infection could not be determined, but was likely due to the patient's age and the difficulties associated with dressing the cranium.

Initially, the dressings were changed daily and then, after 4 weeks, on every alternate day. The wound was assessed

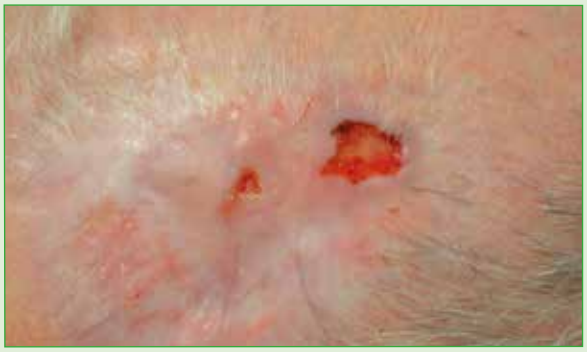

Fig 4. After five months of Granudacyn therapy (final evaluation): the wound has almost healed

at each dressing change. Although there was some improvement at the end of this period, parts of the skull calotte were still exposed.

At five months post-surgery, the wound, which was located on the left parietal capillitium, measured 18.2cm^2, with a depth of up to 12mm. It primarily comprised exposed bone with a few areas of granulation tissue. The patient was presenting with the classical clinical signs of chronic local wound infection (heat, pain, erythema and oedema). The wound margins were temporarily eroded. Exudate levels were low and sometimes bloody in nature.

The wound surface was cleansed, covered with a layer of Granudacyn Wound Gel, after which a non-adherent paraffin gauze dressing was applied (Figure 2). An advanced wound dressing was not considered necessary given that Granudacyn has interactive properties.

Outcome

Over the next 5 months of this treatment, during which the wound was cleansed with Granudacyn three times a week, the wound steadily improved, with an increase in granulation and epithelial tissue and a reduction in size. The exudate volume remained low and serous in nature. The patient did not experience any local signs of wound infection, nor any

Table 1. Reduction in wound size reported following the patient's first postoperative assessment

	Wound area (cm^2)	Wound depth (mm)
One month post-surgery (first visit)	23.8	14
After 2 months of wound-care therapies*	21.4	12
After 4 months of wound-care therapies*	20.2	12
After 5 months of wound-care therapies*	18.2	12
After 1 month of Granudacyn	12.4	8
After 2 months of Granudacyn	6.8	4
After 3 months of Granudacyn	4.2	2
After 4 months of Granudacyn	1.8	2
After 5 months of Granudacyn	0.9	2

*Therapies included hydrogel, hydrofiber, silver-containing dressings and PHMB-containing dressings

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wound-related pain. The condition of the periwound skin was healthy. Figure 3 shows the wound after two months of this treatment regimen.

After five months of treatment with Granudacyn Wound Gel, the wound area had reduced significantly to 0.9cm^2, with a depth of 2mm; it had remained infection-free throughout (Figure 4). Table 1 summarises the reduction in wound size achieved with the various therapies applied to this patient following the first postoperative assessment.

The health professionals considered the gel easy to use. Both they and the patient were very satisfied with the treatment outcome. In the health professionals' experience, wounds with exposed bone in elderly patients usually take a long time (many months or even years) to heal.

Infected cardiac pacemaker pocket

Martin Oberhoffer, Cardiac Surgeon, Department of Cardiothoracic and Vascular Surgery, University Hospital Mainz, Germany

A 78-year-old man presented for an evaluation of his cardiac resynchronisation therapy (CRT) device pocket. He had a medical history of dilated cardiomyopathy, which resulted in the implantation of the device in 2014. His comorbidities comprised paroxysmal atrial fibrillation, for which rivaroxaban was prescribed, and renal impairment. The complication described in this case study occurred 5 years after implantation of the device and was probably anticoagulation-related.

Physical examination of the patient on hospital admission identified painful swelling and erythema at the device pocket side (Figure 1). Clinical signs of infection comprised a palpable, painful subcutaneous mass. Laboratory results revealed signs of mild infection (C-reactive protein 8.3mg/dl; white blood cell count 11.6 /nl) and subfebrile temperature (37.8°C). (In German hospitals, this temperature is not considered feverish).

Treatment was initiated by surgical revision. After wound incision, 50cc of thrombotic material and purulent fluid were evacuated and swabs taken.

The wound was surgically debrided of infected tissue, resulting in a clean bed, with a good blood supply. Microbiology testing confirmed the presence of *Enterobacter cloacae*, and the antibiotic regimen was switched from empirical clindamycin to levofloxacin. Granudacyn Wound Irrigation Solution was applied via instillation with negative pressure wound therapy (iNPWT).

Fig 1. Intraoperative baseline evaluation: inflammation around the cardiac resynchronisation therapy device is clearly visible

Outcome

At the first iNPWT foam dressing change three days later, there were no visible signs of infection and good consolidation of the wound bed was evident. There was no change in wound size. The Granudacyn iNPWT was continued. Wound swabs taken three days later at the second iNPWT foam dressing change were negative for bacteria. By day 10 post-surgical revision, the wound had closed in a standard multilayer fashion.

The patient was discharged from hospital one day after wound closure; oral levofloxacin 500mg bid was prescribed for a further 10 days. Four weeks later, the patient's post-discharge course was reported as uneventful.

The application of Granudacyn in conjunction with iNPWT contributed to the rapid elimination of *Enterobacter cloacae* in the wound.

The CRT device was left in place, contributing to the medical and economic success of the treatment.

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Necrotising fasciitis

Peter Kurz, Wound Specialist Nurse, Wund Pflege Management (WPM), Bad Pirawarth, Austria

A 59-year-old man presented with surgically debrided necrotising fasciitis on the right of the scrotum (three weeks' duration) at a local nurse-led practice, where there are specialists in dermatology and surgery. The resultant wound measured 40cm^2 and was up to 200mm deep. The wound bed comprised 90% granulation tissue and 10% slough, but there were also clinical signs of local infection including malodour and a high volume of serosanguineous exudate (Figure 1). Wound cultures detected the presence of bacteria-producing extended spectrum beta-lactamase (ESBL) enzymes, for which systemic antibiotic therapy was prescribed. Based on the slow healing process and results of microbiological testing, it was assumed that a biofilm was present. A dimethicone oil-based barrier cream was used to preserve the condition of the peri-wound skin, which was healthy and intact.

The wound was subjected to a 10-minute wet phase, during which it was cleansed with Granudacyn Wound Irrigation Solution to remove the sloughy tissue. Granudacyn Wound Gel was then applied, after which an open-pore foam dressing was inserted into the wound cavity. A superabsorbent padded dressing was used as a secondary dressing. The patient's wife changed the dressings and irrigated the wound daily in the patient's home for the duration of this treatment regimen.

Fig 1. Start of Granudacyn therapy (day 1): wound resulting from surgical debridement of necrotising fasciitis. Moderate levels of serosanguineous exudate are present

Fig 2. Day 5 of Granudacyn therapy: deep wound (stretched)

Outcome

Throughout this time, the wound steadily reduced in size. At the first follow-up visit (day 5 of treatment), the wound had

Fig 3. Day 43 of Granudacyn therapy: the wound size and exudate volume have reduced and there are no clinical signs of wound infection

Fig 4. Day 69 of Granudacyn therapy: the wound has significantly reduced in size. The peri-wound skin is still healthy and intact

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reduced in size by 25%. The wound bed comprised 100% granulation tissue and there were no clinical signs of local wound infection (Figure 2).

During the first two weeks of treatment, the exudate volume remained high, but thereafter it decreased as the wound reduced in size. After approximately three weeks, epithelial tissue began to appear. Figure 3 shows the wound on day 43, by which time the exudate volume had reduced and there were no clinical signs of infection.

After 69 days of the treatment, the wound measured 7.5mm^2, which is a 65% reduction in area from baseline (Figure 4). Full healing occurred by day 95 (Figure 5). The peri-wound skin remained healthy and intact throughout the treatment regimen, which was maintained as there was no need to change it.

Due to the rapid reduction in wound size, the patient's mental state and quality of life quickly improved. He did not experience any soreness during the course of treatment, which was pleasing, bearing in mind the wound location.

Fig 5. Day 95 (final evaluation): the wound has healed

Given the size of the wound and especially its depth, the health professionals were surprised that it healed so quickly and easily. The wound was still closed at the 10-month follow-up after the end of the treatment.

Diabetic foot ulcer with connecting sinus tracts

Peter Kurz, Wound Specialist Nurse, Wund Pflege Management (WPM), Bad Pirawarth, Austria

At a local nurse-led practice with specialists in dermatology and surgery, a 70-year-old man presented just before Christmas with an infected diabetic foot ulcer (DFU). He had a long-standing medical history of type II diabetes mellitus and Crohn's disease, both of which were well controlled with medication. However, while receiving corticosteroid therapy for Crohn's disease, the patient experienced numerous hyperglycaemic episodes and diabetes-related foot problems.

The ulcer (Wagner classification grade 3), which was located on the right forefoot, had resulted from pressure damage caused by a long-standing hyperkeratosis. It measured 300mm^2 and had three connecting sinus tracts (Figure 1). A blister that had formed around the infected ulcer had burst three days before the patient's presentation at the clinic. A probe to bone test was positive. The wound bed comprised 10% necrotic tissue, 20% slough and 70% granulation tissue.

Fig 1. Start of Granudacyn treatment (day 1): the infected diabetic foot ulcer had three connecting sinus tracts

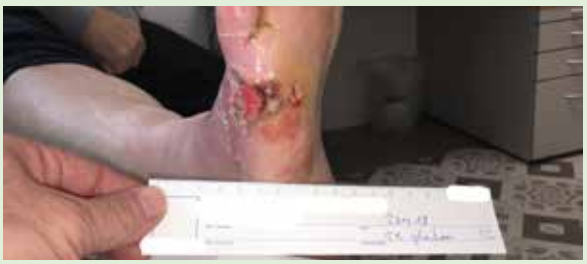

Fig 2. Day 3: a conservative treatment regimen (Granudacyn therapy) was continued despite a recommendation to amputate the infected area

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Fig 3. Day 52: the wound bed is completely covered with granulation tissue

The wound was exhibiting clinical signs of wound infection: oedema, mild pain, erythema and a high exudate volume. The patient also had a slightly elevated temperature and was fatigued. The exudate was haemopurulent. There was erythema around the peri-wound skin. Clearly, osteomyelitis was present. The wound was irrigated with 50ml Granudacyn Wound Irrigation Solution. Due to lack of staff at the nurse-led practice during the holiday season, the patient was referred to a local outpatient clinic for surgical debridement.

At the clinic, the patient was immediately prescribed broad-spectrum oral antibiotics and given pressure relief for the forefoot. The patient underwent X-ray, culture and assessment. The X-ray confirmed that osteomyelitis was present. The patient was advised to have his fourth and fifth toes amputated, but refused to undergo this procedure. As the patient discharged himself early from the outpatient clinic, the culture results were never received.

On the patient's return to the nurse-led practice, irrigation with 50ml Granudacyn Wound Irrigation Solution, applied with a cannula, was resumed (Figure 2). This was maintained throughout the rest of his treatment period, during which pressure redistribution of the forefoot was also provided.

During the first 4 weeks, the wound was filled with Granudacyn Wound Gel applied with a cannula. The aim was to rapidly cleanse and decontaminate the wound cavity. To prevent the wound closing from the outside and thus increasing the risk of re-infection within the fistulas, some form of fine drainage had to be applied to the wound bed. A nanocrystalline silver-containing strip of net, which was pulled through the wound cavity, was selected for this purpose. A superabsorbent dressing was used as a secondary dressing. No reaction occurred between the gel and the nanocrystalline silver net dressing.

Outcome

During the treatment period, the ulcers steadily reduced in size. After two weeks, the wound area had reduced by 50%, although it was still exhibiting clinical signs of local wound infection (mild oedema, erythema and moderate levels of exudate). By day 45, the inflammation and pain had disappeared. Three days later an X-ray showed no sign of osteomyelitis on the bone. Shortly after this (day 51) the oral antibiotics were discontinued.

On day 52, the wound measured 45mm^2 and comprised 100% granulation tissue (Figure 3). The peri-wound skin was healthy and intact. Two of the sinus tracts were still connected, but were showing clear healing tendencies.

The nanocrystalline silver net was discontinued and the Granudacyn Wound Gel wound was used along with a betaine and polyhexanide cleansing solution. This combination is regarded as safe and effective by Kramer et al[1], and, in my considerable experience of using these two therapies, they complement each other well. Figure 4 shows the wound at day 88.

The Granudacyn Wound Gel and betaine and polyhexanide cleansing solution were applied every 2–3 days with the wound steadily progressing towards healing. Wound closure was achieved after approximately 15 weeks of treatment (Figure 5). The peri-wound skin remained healthy and intact throughout.

At a 10-month follow-up visit, X-ray showed that the os calcaneus had stabilised and was mostly solidified. The wound had not yet healed, but the foot had been saved.

1. Kramer A, Dissemond J, Kim S et al. Consensus on wound antisepsis: Update 2018. SPP 2018;31:28–58. https://doi.org/10.1159/000481545

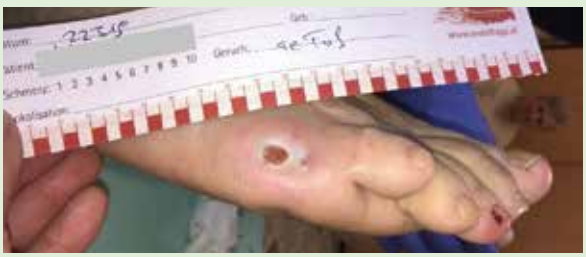

Fig 4. Day 88: the wound has reduced in size and the peri-wound skin is healthy and intact

Fig 5. Day 109 (final evaluation): the wound has healed after 15 weeks of treatment

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Diabetic foot ulcer

Peter Kurz, Wound Specialist Nurse, Wund Pflege Management (WPM), Bad Pirawarth, Austria

A 63-year-old man presented with a deteriorating infected diabetic foot ulcer (DFU). The wound had developed in the location of an older, almost-healed wound in a Charcot foot that had undergone a partial amputation five years previously (Figure 1).

The patient had a medical history of type II diabetes mellitus, which was well controlled with medication.

A shoe problem may have been the trigger for the deterioration. A fracture management system for offloading the leg was being used, but the orthosis was broken and the patient, who had been self-caring for a few weeks before seeking medical help, had patched it up with tape.

The ulcer (Wagner classification grade 3) was located on the left heel and measured 3cm^2, with a depth of 8–10cm. The os calcaneus was exposed and an X-ray showed that the bone had been partly destroyed by osteomyelitis. It was likely that the osteomyelitis was of one month's duration. The wound bed was entirely comprised of necrotic tissue and slough. The wound and peri-wound skin were both exhibiting clinical signs of infection (oedema, erythema, pain, warmth and increased exudate). The wound was producing a high volume of haemoserous exudate, and the patient had a high temperature that had been present for some time.

Following surgical debridement, a culture was taken, which grew *Enterobacter cloacae*. Oral antibiotics (ciprofloxacin), were prescribed. Due to the pronounced soft-tissue infection, a positive outcome was not expected. The shoe was renewed, enabling good pressure relief.

Over the lifetime of the ulcer, numerous dressings had been used, including silver-containing dressings, medical grade honey, Sorbact-technology dressings, and the combined use of an alginate and a superabsorbent dressing.

It was considered that there was little chance of saving the leg, although the patient really wanted to avoid an amputation. He refused to be admitted to hospital for fear that his leg would be amputated. We asked four surgeons to examine him: three said that the bone was so badly destroyed that it was essential that a major amputation be performed, but the fourth surgeon, who is a specialist in osteitis, said he would try a new surgical technique once the inflammation and wound size had significantly reduced.

Each day, the wound cavity was irrigated with 50ml Granudacyn Wound Irrigation Solution applied with a cannula. Granudacyn Wound Gel was then used to pack the wound. A soft superabsorbent dressing was used as a secondary dressing. Micronutrients were prescribed to re-establish the bone structure. Figure 2 shows the wound at the start of this regimen. The patient was treated over a 90-day period, during which the dressing was changed daily

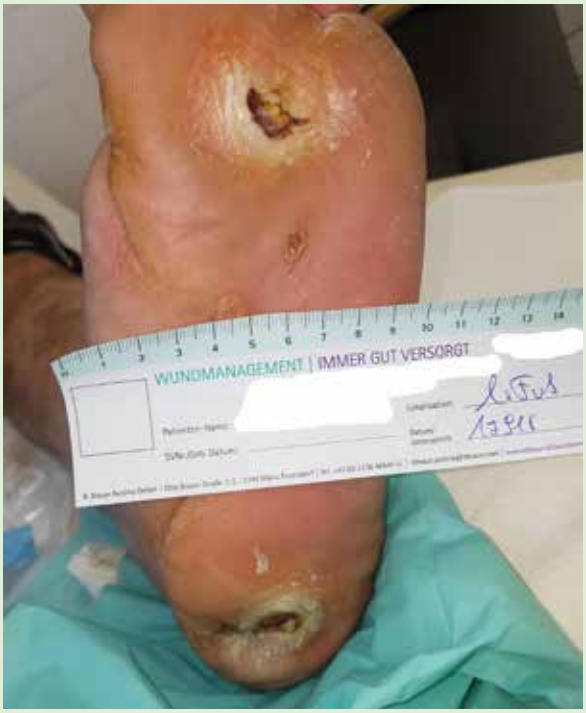

Fig 1. Diabetic foot ulcer approximately three months before the patient first presented at the clinic: there are no clinical signs of infection

Fig 2. Start of Granudacyn therapy (day 1): the wound is infected with high levels of serosanguinous exudate

by the patient's wife, who was taught how to do this. This frequency was necessary due to the deep infection with pronounced bone involvement. The patient attended a local nurse-led practice for twice-weekly assessments.

Outcome

After 5 days of this treatment, there were no longer any clinical signs of infection, although oral antibiotics continued

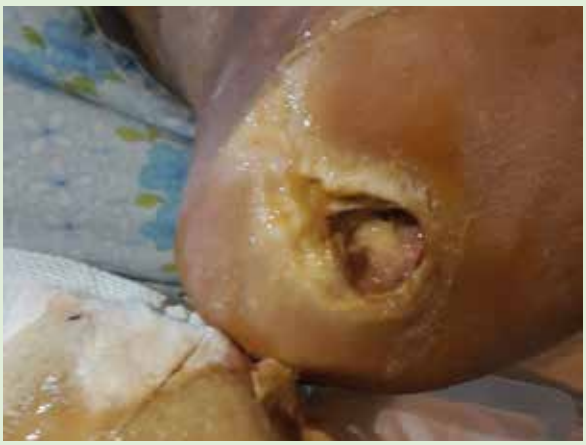

Fig 3. Day 34 of Granudacyn therapy

to be administered. Wound swabs were indicative of a significant improvement in the wound environment, although antibiotics continued to be prescribed. The wound exudate volume had reduced to moderate but was still serosanguineous. The periwound skin was slightly macerated. The patient was no longer experiencing wound-related pain.

The condition of the wound bed improved steadily over the treatment period and the wound reduced in size. The oral antibiotics were discontinued after approximately one month. Figure 3 shows the ulcer on day 34 of this treatment regimen. At the final follow-up visit on day 90, the wound had almost (95%) healed (Figure 4): it was now covered with 100% granulation tissue and measured 2cm^2, with a wound depth of 1cm, representing a 33.3% and approximately 90% reduction, respectively, from day 1 of treatment. The peri-wound skin was healthy and intact. Radiography revealed that the calcaneus was now more stable. The patient was

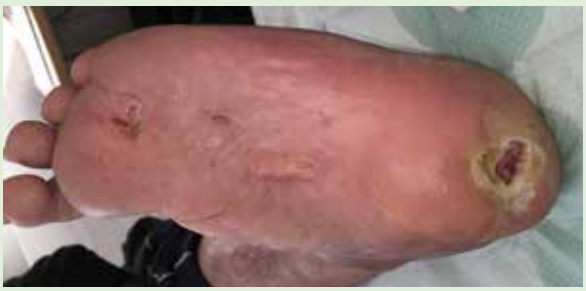

Fig 4. Day 90 of Granudacyn therapy: the ulcer has 95% healed and the peri-wound skin is healthy and intact

now able to attend the outpatient treatment at the osteitis centre in preparation for orthopaedic surgery. Amputation had been avoided.

The patient's partner continued to change the dressing daily throughout the treatment period, reporting that the products were particularly easy to use.

In our view, the daily rinsing with Granudacyn Wound Irrigation Solution and filling with Granudacyn Wound Gel had a positive influence on the soft tissue and bone structure, although other factors would also have played a role. Our wound clinic is 150 kilometres away from the nearest specialist hospital, and does not have ready access to advanced treatment. We therefore required a simple treatment regimen, to be used in accordance with evidence-based practice, to help prepare the wound bed for surgery.

At a follow-up visit, approximately 20 months after the patient's first visit, the os calcaneus had further stabilised. Although the wound had not yet healed, it was progressing well. The patient continues to rinse the wound with Granudacyn Wound Irrigation Solution.

Dehisced surgical wound

Ibby Younis, Consultant Plastic and Reconstructive Surgeon, University College Hospital, London, UK

A 61-year old woman presented with two dehisced wounds resulting from complications following her fourth total knee replacement (TKR) revisional surgery for juvenile idiopathic arthritis (JIA). Her comorbidities included hypertension, stage 3 chronic kidney disease and a recent episode of atrial flutter. The proximal tibial wound was successfully covered with a medial gastrocnemius flap and split skin graft (Figure 1).

The mid-tibial wound failed to heal. Debridement of the necrotic tissue and purulent discharge revealed an exposed prosthesis; the wound now measured 3x4cm.

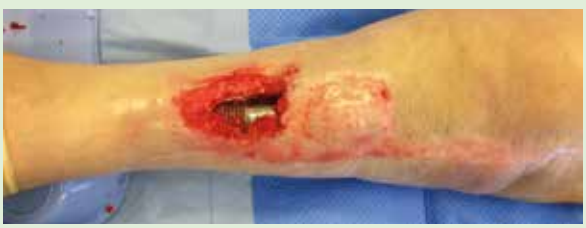

Fig 1. Dehisced wound post-debridement: infection was present along the length of the prosthesis (6 October 2018)

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During the debridement, it became apparent that the purulent discharge was tracking along the entire length of the hardware, which extended from the ankle up to the hip. Failure to clear the infection around the prosthesis would place the patient at risk of requiring a hindquarter amputation or a hip disarticulation, due to the proximal extension of the prosthesis (Figure 2).

Microbiology sampling confirmed the presence of *Enterococcus faecalis*, gentamicin-resistant *Proteus mirabilis* and *Pseudomonas aeruginosa*.

It was decided to use a negative pressure wound therapy (NPWT) with instillation and dwell time (NPWTi-d) system. Two proximal incisions were made within a previous scar (knee and thigh) to allow for the tunnelling of the foam that connects to the NPWT device (Figure 3). An antimicrobial solution (polyhexanide and betaine) (80ml) was instilled along the length of the prosthesis for 20 minutes, followed by NPWT (-125mmHg) every two hours for three days. This allowed for regular cyclical cleansing of the prosthesis. Despite debridement, sampling, targeted antibiotics with microbiology input every time the dressing was changed in the operating room, the *Pseudomonas* infection proved difficult to eradicate. This remained the case when the instillation solution was changed to acetic acid for an additional 10-day period.

In a final attempt to save the limb, Granudacyn Wound Irrigation Solution was used as the NPWTi-d instillation solution, with the same settings as described above (Figure 4).

Outcome

After three days of instillation with Granudacyn solution, flap closure of the original defect was achieved with a free latissimus dorsi flap and split skin graft (Figure 5). The two proximal wounds were closed directly at the same time.

At both two and four weeks postoperatively, a steady reduction in the inflammatory markers in the fluid aspirated around the prosthesis under aseptic conditions was observed; and ultrasound guidance was negative on extended culture.

Over a period of three months, the skin graft gradually stabilised over the muscle and the patient's C-reactive protein (CRP) remained between 30 and 50. All the periprosthetic fluid cultures remained negative for growth of any pathogens including *Pseudomonas* (the last culture was taken six weeks post-free flap surgery).

By 15–17 months after the surgery, and for the first time in three years, the patient's CRP was consistently in single digits (5–8). At 18 months, the flap had healed well (Figure 6).

This was a challenging but successful salvage of a very complex infected and exposed prosthesis that extended from the hip down to the ankle. Along with the debridement, NPWTi-d and flap cover, the instillation solution (Granudacyn) played a vital role in this salvage by facilitating the eradication of the persistent, chronic *Pseudomonas* infection. All the antimicrobials used previously had been ineffective. Against all the odds, at 18 months' post-salvage surgery, the aim of avoiding a high-level amputation had been achieved.

Fig 2. The prothesis in the leg left extended from the hip to the ankle

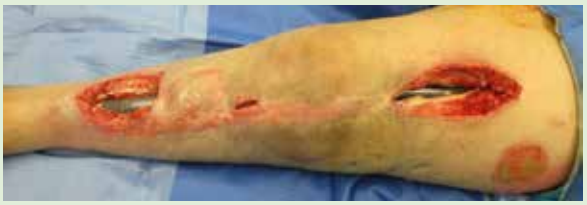

Fig 3. Application of negative pressure wound therapy with instillation and dwell time (NPWTi-d): two proximal incisions were made to tunnel the NPWTi-d along the prosthesis (9 November 2018)

Fig 4. Use of Granudacyn Wound Irrigation Solution as the instillation for the NPWTi-d expediated the surgical closure of the wound

Fig 5. Surgical repair of the wound: a free flap and skin graft were used to close the defect (11 December 2018)

Fig 6. Final outcome: the skin graft has healed and the prosthesis is infection-free (3 October 2019)

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