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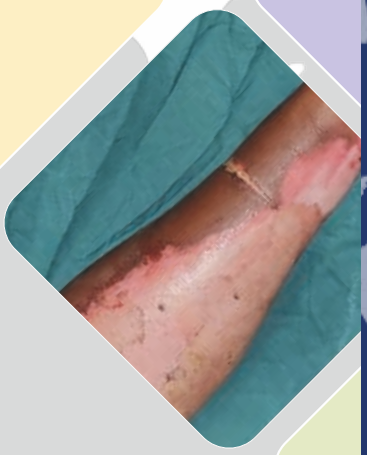

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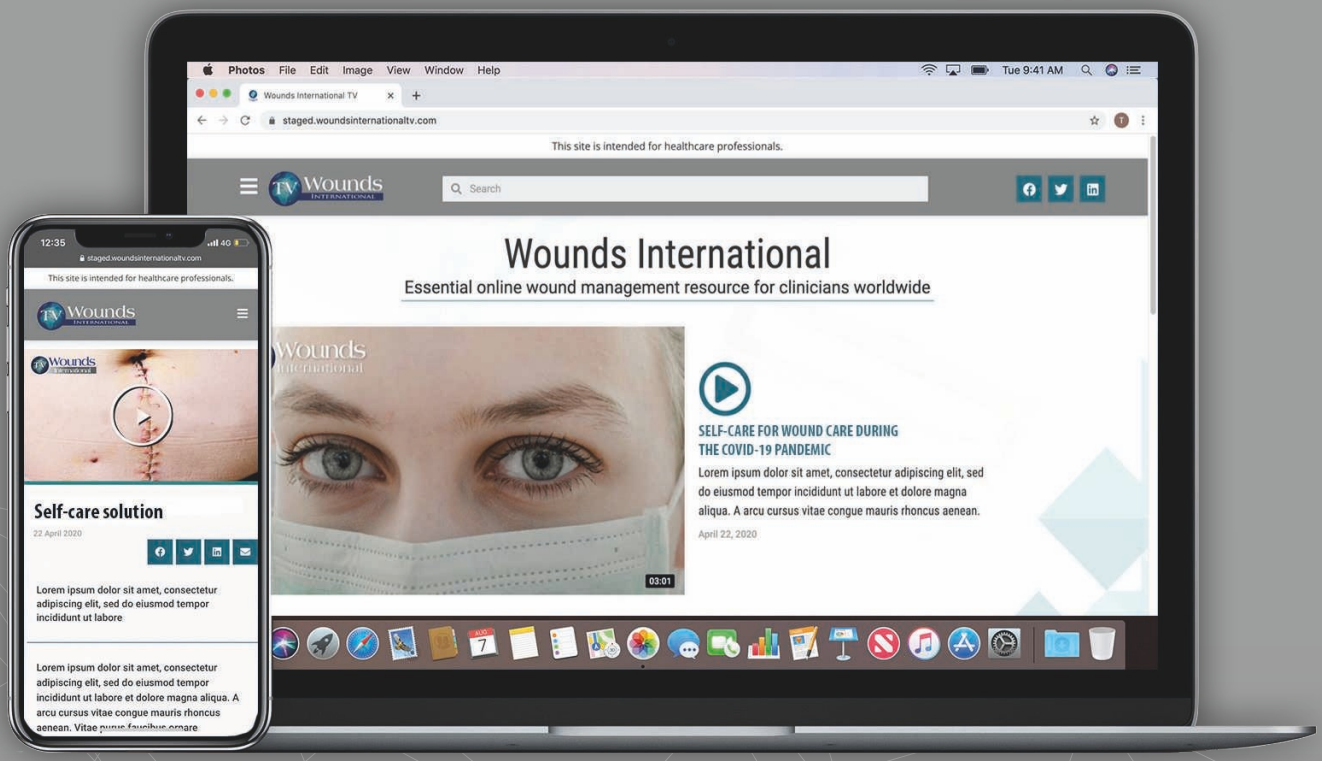

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JOURNAL DETAILS
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Hope is on the horizon

Adam Bushby
Senior Editor,
Wounds International

We may well be entering the end game of the COVID-19 era with the wonderful news that a 90-year-old grandmother from the UK became the first person in the world to receive the Pfizer COVID-19 vaccine (BBC News, 2020). Margaret Keenan received the inaugural dose of the vaccine at 06:31 GMT, which is proposed to be the first of as many as four million by the end of the year. The first to receive the jab are to be the over-80s and some health and care staff.

Ms Keenan declared: "I feel so privileged to be the first person vaccinated against COVID-19. It's the best early birthday present I could wish for because it means I can finally look forward to spending time with my family and friends in the new year after being on my own for most of the year." The second person in the world, and the first male, was the delightfully named William Shakespeare, aged 81. All's well that ends well, eh?

There are high hopes that this vaccine could spell the start of an unprecedented global immunisation effort, designed to direct the world towards a successful route out of a pandemic that has snatched more than 1.5 million lives. At its height, the pandemic not only saw widespread restrictions around the world, but there were large-scale changes to the way in which day-to-day practices took place in hospitals. Resources were redeployed to COVID wards and some wound care specialists found themselves working in community nursing teams. In addition, even dentists found themselves redeployed as district nurses, with wound care accounting for the lion's share of patient care (Sibanda and Muirhead, 2020).

The flexibility of wound care specialists around the globe has been something that everyone can be proud of. However, during the first wave of the pandemic, there was a problem with people not being willing to present in hospitals with a gamut of ailments, including pressure ulcers, leg ulcers and diabetic foot ulcers. Indeed, research by the US Center for Disease Control (CDC, 2020) found that an estimated 41% of adults in the US either delayed or avoided medical care as of June 30, 2020.

The importance of a vaccine cannot be overstated in the US, with the country's citizens actively encouraged to flout sensible COVID-19 measures by Donald Trump throughout 2020. In December, deaths attributed to the pandemic in the US comfortably outstripped those of next highest, Brazil — 291,000 compared to 177,000 (Worldometers, 2020).

While a mass-produced vaccine will facilitate a return to something approaching normality, some of the lessons learned during the fight against coronavirus may well become cemented in future wound care best practice, such as pressure ulcer guidance when patients are lying in a prone position (National Pressure Injury Advisory Panel, 2020; NHS, 2020) and the role of telemedicine in wound management.

I don't think I am over-exaggerating when I say that 2021 cannot come soon enough. 2020 has been unsettling, depressing and scary in equal measure and the new COVID vaccine offers much-needed hope on the horizon. Here's wishing you all a lovely festive season and a happy new year. Stay safe, stay sane and look after each other. WINT

If you would like to contribute to a future issue of the journal, please contact Adam Bushby, Senior Editor, Wounds International, at: abushby@omniamed.com

References

BBC News (2020) *Covid-19 Vaccine: First Person Receives Pfizer Jab in UK*. Available at: https://www.bbc.co.uk/news/uk-55227325 (accessed 08.12.2020)

Centers for Disease Control and Prevention (2020) Delay or avoidance of medical care because of COVID-19-related concerns – United States, June 2020. *Morbidity and Mortality Weekly Report* 69(36): 1250–7

National Pressure Injury Advisory Panel (2020) *Pressure Injury Prevention: PIP Tips for Prone Positioning*. Available at: https://cdn.ymaws.com/npiap.com/resource/resmgr/online_store/posters/npiap_pip_tips_-_proning_202.pdf (accessed 08.12.2020)

NHS (2020) *National Stop the Pressure Programme: Pressure Ulcer Prevention Guidance When Nursing Patients in the Prone Position – May 2020*. Available at: https://www.ahsnnetwork.com/wp-content/uploads/2020/05/Pressure-ulcer-prevention-guidance-when-proning-patients-V6-5.5.20-1.pdf (accessed 08.12.2020)

Sibanda L, Muirhead V (2020) Redeployed as a district nurse. *British Dental Journal* 229: 403–4

Worldometers (2020) *COVID-19 Coronavirus Pandemic*. Available at: https://www.worldometers.info/coronavirus/#countries (accessed 08.12.2020)

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Recovering from COVID-19

Author:
Joyce Black

At the beginning of each year, most people have a wish list or a resolution, which often has something to do with health. My wish for 2021 is that the world recovers from COVID-19. So, you almost stopped reading this, right? I know I'm not the first person to have this wish, whether it be economic recovery or physical recovery; hopefully mine goes a bit further.

Multiple municipalities report new cases daily. Hospitals report daily admissions and daily deaths. While millions of people have contracted COVID-19, who is reporting on recovered patients? If the only numbers we hear are new cases or new deaths, how are the other millions of people faring?

Recovery from serious forms of COVID-19 includes:

- Breathlessness from severe lung and cardiac impairments arising from viral destruction
- Activity intolerance from polyneuropathy and myopathy from both the disease and the need for paralytics while ventilated
- Various complications from accelerated clotting from the virus, such as stroke, pulmonary embolism and deep venous thrombosis
- Catabolism from prolonged hypermetabolic state
- Large pressure ulcers on the buttocks from sitting up to breathe or on the anterior body surfaces from being placed into a prone position
- Lingering fatigue and headache from the inflammatory state
- Marked anxiety and survivor guilt that the person is still alive, while other family members and friends are not
- Grief over not being there with the dying friend/relative.

I recently addressed healthcare professionals on the topic of recovery from COVID-19 and I was startled to find there was so little on how to help these patients and their families recover. To provide some guidance to them, I spoke on cardiac and respiratory recovery, gaining strength and stamina, and appreciating the psychosocial aspects of this disease. How does this affect wound care professionals? In lots of ways; as you read the list of recovery issues from serious COVID-19, did you see the links to pressure ulcer development? (please say yes!). Each condition alone creates immobility and difficulty recovering or healing any wound. These patients will need time to heal and a close watch on the risk of infection.

I cannot prognosticate when we will be back to normal or what 'normal' will look like. But in the interim, we will be caring for many, many patients recovering from COVID-19. Be attentive to their unique risks during the long recovery. My wish list for all of us is that we take the opportunity to cultivate a better world from all we have learned from this deadly disease. WINT

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Ten top tips: managing wound odour


Authors:
Joyce Black and Christine Berke

Chronic wounds are an enormous burden to society, costing billions of dollars annually in the USA alone. Despite the extensive research into methods to heal chronic wounds, many remain unhealed for months to years for various intrinsic and extrinsic reasons. As wounds stall, necrotic tissue, biofilm and/or frank infection can develop and produce significant odour. Wound odour is very distressful for patients, caregivers and healthcare professionals. For patients, it can trigger feelings of shame, embarrassment and depression, and may contribute to malaise, nausea and loss of appetite. Offensive odours can spread to clothing, bedding, furniture and living areas. Wound odours often lead to social isolation for patients and feelings of guilt for caregivers during a critical time when both physical and emotional support are essential. Healthcare professionals face the challenge of controlling odour and providing supportive education for suitable wound care to help improve the patient's quality of life. These 10 top tips focus on the cause of odour from a wound, its significance, prevention and treatment.

1 Understand the causes of odour: Most wound odours are thought to arise from the metabolic processes of anaerobic bacteria. In chronic wounds, such as pressure ulcers, leg ulcers and diabetic foot ulcers, the odour may also be due to tissue degradation and/or poor tissue perfusion. Malignant wounds, especially those from breast, head and neck cancers, also become odourous as the cancer extrudes through the skin. The aptly named, foul-smelling compounds called cadaverine and putrescine, are released by anaerobic bacteria as part of the putrefaction of tissue. Many organisms common to nonhealing wounds create a characteristic smell *[Table 1]*. Electronic nose technology is being developed but, to date, has not been integrated into either diagnostic assessment of potentially infected wound, nor in effective education of healthcare professionals (Akhmetova et al, 2016; Ousey et al, 2017; Edwards-Jones, 2018; Darwin et al, 2019).

2 Label the extent of the odour: Simply stating the wound and its drainage are odourous does not convey the extent of the problem nor guide a management plan. Be specific about the degree of odour. Baker and Haig (1981) clearly identified four degrees of wound odour:

- Strong — odour is evident upon entering the room, or 6–10 feet from the patient with the dressing intact
- Moderate — odour is evident upon entering the room with the dressing removed
- Slight — odour is evident at close proximity to the patient when the dressing is removed
- No odour — no odour is evident, even at the patient's bedside with the dressing removed.

3 Cleanse the odourous wound and periwound skin before applying a clean dressing: Solutions that contain surfactant antimicrobials should be used to remove loose debris in the wound bed, which support bacteria growth. These solutions include polyhexamethylene biguanide (PHMB) and octenidine dihydrochloride (OCT). Antiseptic cleansing solutions reduce bacterial counts and include hypochlorous acid (HOCl), acetic acid, sodium hypochlorite (NaOCl) and povidone iodine (EPUAP et al, 2019). For low-resource patients, buttermilk or plain non-sweetened yogurt may reduce wound bacteria when applied as a compress impregnated in gauze for 10–15 minutes and then rinsed off (Samala and Davis, 2015). Wounds with heavy drainage can contribute to periwound skin breakdown contributing to wound enlargement, additional odour and pain. Consider protecting periwound skin with topical barrier film wipes/sprays, barrier ointments (such as petrolatum) or zinc-based creams/pastes before redressing the wound (Woo and Sibbald, 2010).

4 Remove necrotic tissue: An important step in controlling odour is to remove necrotic/non-viable tissue. Various methods of debridement exist, and the choice of the method depends on the size and status of the wound and the goal of the patient (Samala and Davis, 2015). Conservative debridement (removal of loose hanging non-viable tissue) should be considered in palliative/non-healing wounds (Woo and Sibbald, 2010). Training and licensure also dictate the method of debridement; however, the needs and goals of

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Table 1. Organism and their associated odour.	
Organism	**Characteristic odour (we do not advise you intentionally smell wounds or drainage, to avoid inhaling live organisms)**
Candida albicans	Yeast or musty odour
Citrobacter	Dirty athletic shoes
Clostridium difficile	Putrid, fecal, sickly sweet
Enterococcus faecalis	Faecal
Escherichia coli	Faecal
Peptostreptococcus anaerobius	Faecal
Proteus mirabilus	Fishy
Pseudomonas aeruginosa	Sweet grape juice, almonds, corn tortilla
Staphylococcus	Dirty athletic shoes

the patient are most important. The options available are:

1. Sharp debridement is the most rapid method, but can be painful even with local anesthetic. Malignant wound tissue is often friable and bleeds easily and methods to control bleeding need to be rapidly available. Palliative surgical debridement of large malignant or fungating wounds may be considered if the patient is an appropriate candidate for surgery (Woo and Sibbald, 2010)
2. Enzymatic debridement uses collagenase to break down fibrin and collagen in the necrotic tissue. Because the product takes time (possibly several weeks) to work, it will need to be combined with other methods to reduce odour with increased dressing changes to control anticipated increased exudate
3. Mechanical debridement uses mechanical forces, such as forceful irrigation, ultrasonic treatment, or wet-to-dry dressings. These methods can be painful and require staff time to perform. A newer, reportedly less painful, method of mechanical debridement is available on the market using monofilament fibres imbedded in a pad (Schultz et al, 2018)
4. Biologic debridement uses organisms to digest bacteria and necrotic tissue. Medical maggots/larvae are effective for selective debridement; however, they can be psychologically unacceptable to patients and families (Mumcuoglu, 2001)
5. Autolytic debridement uses occlusive dressings to contain white blood cells at the surface of the wound. This method is slow and may require more frequent dressing changes to control the anticipated increase in exudate. It can increase the risk of sepsis if the patient's immune system is compromised. It is not usually the first option considered for debridement of odourous wounds.

5 **Treat infection:** All chronic wounds have bacteria present. Wound management consists of maintaining the bacterial balance to avoid critical colonisation (infection). Wound infection occurs on a continuum from localised to systemic. Use of mnemonics, such as NERDS and STONEES, can help direct topical (see Tip 6) and/or systemic treatments (Woo and Sibbald, 2010; IWII, 2016). Depending on findings from the wound assessment and clinical examination of the patient, systemic antibiotics may be prescribed. (Institute Wound Infection Institute [IWII], 2016; Virgen et al, 2020)

6 **Use topical antimicrobials to reduce the bioburden:** There are many antimicrobials (e.g. metals, such as silver or bismuth, iodine, medical grade honey) incorporated into numerous dressing materials that can be used to reduce the bacterial load and, thereby, reduce the odour of a wound (Woo and Sibbald, 2010; Akhmetova et al, 2016; IWII, 2016; Wild et al, 2016; Beers, 2019; Darwin et al, 2019). Two randomised control trials (RCTs) were found that reported reductions in malodour from malignant wounds during 4 weeks of a topical dressing with a silver- or honey-coated wound dressing, with no apparent significant difference between the honey- or silver-coated dressings' effects (Lund-Nielsen et al, 2011; Kalemikerakis et al, 2012). Metronidazole in various preparations has been reported to effectively reduce bioburden and decrease wound odour in malignant wounds (Samala and Davis, 2015; Akhmetova et al, 2016; Beers, 2019; Darwin et al, 2019, Virgen et al, 2020). A study by Villela-Castro et al (2018) reported on a double-blinded, RCT to compare the effects of Polyhexamethylene biguanide (PHMB) and 0.8% metronidazole on malignant wound odour; both were found to significantly reduce malodour in the studied wounds within in 4 days.

7 **Absorb and contain the odorous drainage**: There are numerous absorbent dressings on the market. Exudate amount will determine frequency of dressing changes which, in turn,

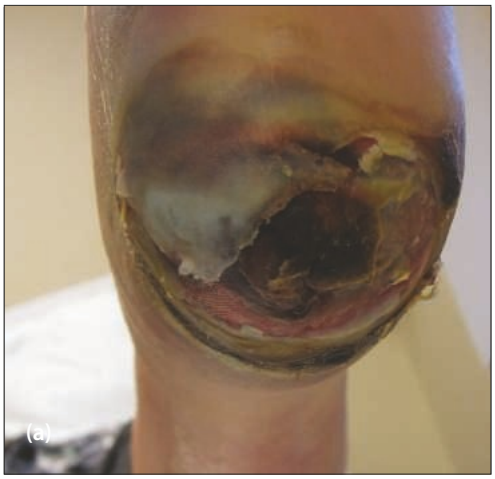

Figure 1. Pressure ulcer on the heel. Patient had arterial disease, end-stage renal disease on dialysis, smoked and was non adherenet. Debrided at bedside, treated with honey, maggots, negative pressure wound therapy, modified compression, offloading boot.

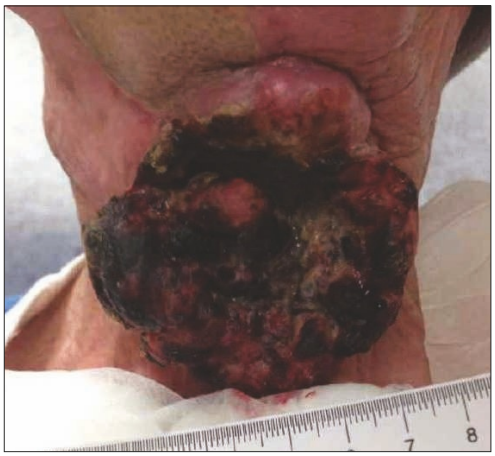

Figure 2. Fungating head and neck cancer. Odor was reduced with topical metronidazole. Drainage managed with super absorbent dressings.

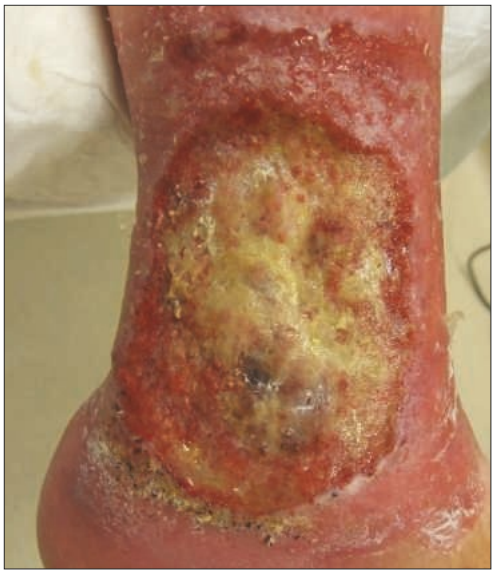

Figure 3. Leg wound with mixed arterial and venous disease. Patient was non adherent. Odour managed with acetic acid for chronic pseudomonas. Periwound protected with skin barriers. Drainage managed with super absorbent dressings. Modified compression and elevation also used.

will determine insurance coverage dependent on the location of the patient. Often controlling bacteria burden and/or biofilm helps to decrease drainage making dressing changes more manageable and affordable. Activated charcoal is a substance that possess a large active surface area that can absorb or trap the volatile organic compounds that produce fetid wound odours. Activated carbon is typically made of natural sources, such as rice, coconut shells, or other woods, and has been incorporated into multiple commercially available dressings such as Carboflex (ConvaTec), Carbonet (Smith-Nephew), CliniSorb (CliniMed) and Actisorb Plus (Acelity). These dressings contain charcoal cloth that are 85% to 98% active carbon. The main difference between these products is the materials used to cover the charcoal cloth. Despite widespread clinical use of charcoal products for management of malodorous wounds, little has been reported on the effect on wound odour (Samala and Davis, 2015; Akhmetova et al and , 2016; Darwin et al, 2019).

The use of negative pressure wound therapy has long been contraindicated in patients with malignancy due to the possible encouragement of tumour growth. A small case series of patients (*n*=5) with cancers received treatment with NPWT for control of drainage, odour and pain with dressing changes. The average duration of NPWT was 49 days prior to death in the sample (Riot et al, 2015). Cai et al (2017) describe a case report using NPWT in a chronic abdominal wound related to treatment-resistant metastatic colon cancer. Skin closure was achieved and remained intact until the patient expired. This case and others demonstrate that individualised approaches should consider the patient's clinical scenario, the available evidence, as well as the risks and benefits of a specific technology.

8 Conceal the odour when it cannot be well controlled: Various aromatics can be used to help conceal odour. Many items have been used including candles, incense, flowers, and air-fresheners in the room. Aromatics can be placed in a container under or near the bed (or patient's primary preferred location). Aromatics include vanilla beans, cat litter, cider vinegar, charcoal, or baking soda. Drops of peppermint or wintergreen can be placed on the outer dressings. Be certain before using concealers that the patient can tolerate their smell. If the scent is strong, it can produce nausea (Woo and Sibbald, 2010; Samala and Davis, 2015; Darwin et al, 2019).

9 Plan ahead when caring for patients with malignant fungating wounds: Advanced cancers of the head and neck, breast commonly erode through the skin. These tumours are often colonised with mixed anaerobic microbes that thrive in moist and necrotic tissue. The cutaneous infiltration produces fetid odour, profuse exudate, pain, and infection. Hu and colleagues (2020) reported on two cases using

crushed topical metronidazole controlling odour within 24 hours of application. da Costa Santos et al (2010) conducted a systematic review of products used with fungating wounds (2010). Within the 59 studies that analysed odour control, seven were clinical trials (35%), five were case series (25%), and eight (40%) were case studies. Eleven topical treatments were identified. Topical metronidazole and hypertonic sodium chloride (Mesalt, Mölnlycke) dressing yielded 2b level of evidence or B grade of recommendation. Activated carbon dressing and curcumin ointment yielded 2c level of evidence or B grade of recommendation.

These wounds can also bleed. Provide haemostatic dressings, absorbable gelatin sponges and/or topic tranexaminc acid (TXA) to control bleeding (Woo and Sibbald, 2010). At some point, profuse bleeding may be expected, and because bleeding is so startling to families, educate them and recommend they use dark red, brown or black towels to clean up the bleeding.

10 Address quality of life related to the odour from the wound and/or drainage: Ask at each visit about quality and quantity of sleep. Odour in the home can alter quality of life for patient and family. A cardinal rule for all healthcare providers is to avoid showing distress at the odour being emitted. If needs be, breathe through your mouth or place an odour concealer in your mask. Address other important factors that contribute to odour including faecal and/or urinary incontinence and general hygiene principles with routine bathing and skin care, clothing and linen changes. If possible, assess the primary caregiver's ability for respite from their role as caregiver.

Conclusion

Wound odour is a manageable condition. Stemming the odour by reducing the bioburden in the wound or disguising the odour are common approaches to improve the quality of life for the patient and family. WINT

References

Akhmetova A, Saliev T, Allan IU et al (2016) A comprehensive review of topical odor-controlling treatment options for chronic wounds. *J Wound Ostomy Continence Nurs* 43(6): 598–609

Baker PG, Haig G (1981) Metronidazole in the treatment of chronic pressure sores and ulcers: a comparison with standard treatment in general practice. *Practitioner* 225(1354): 569–73

Beers E (2019) Palliative wound care: less is more. *Surg Clin North Am* 99(5): 899–919

Cai SS, Gowda AU, Alexander RH et al (2017) Use of negative pressure wound therapy on malignant wounds – a case report and review of the literature. *Int Wound J* 14(4): 661–5

da Costa Santos CM, de Mattos Pimenta CA, Nobre MR (2010) A systematic review of topical treatments to control the odor of malignant fungating wounds. *J Pain Symptom Manage* 39(6): 1065–76

Darwin ES, Thaler ER, Lev-Tov HA (2019) Wound odor: current methods of treatment and need for objective measures. *G Ital Dermatol Venereol* 154(2): 127–36

Edwards-Jones V (2018) Microbiology and malodorous wounds. *Wounds UK* 14(4): 72–5

European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel, Pan Pacific Pressure Injury Alliance (2019) *Prevention and Treatment of Pressure Ulcers/Injuries*. EPUAP, Prague: Czech Republic

Gethin G, Grocott P, Probst S, Clarke E (2014) Current practice in the management of wound odour: an international survey. *Int J Nurs Stud* 51(6): 865–74

Hu JK, Ligtenberg KG, Leventhal J, Bunick CG (2020) Successful management of malodor from fungating tumors using crushed metronidazole tablets: case reports. *Amer Acad Derm Assn* 6(1): 26–9

International Wound Infection Institute (2016) *Wound Infection in Clinical Practice. Principles of Best Practice*. Wounds International, London. Available at: https://bit.ly/377Z5pS (accessed 27.11.2020)

Lund-Nielsen B, Adamsen L, Kolmos HJ et al (2011) The effect of honey-coated bandages compared with silver-coated bandages on treatment of malignant wounds — a randomized study. *Wound Repair Regen* 19(6): 664–70

Mumcuoglu KY (2001) Clinical applications for maggots in wound care. *Am J Clin Dermatol* 2(4): 219–27

Ousey K, Roberts D, Gefen A (2017) Early identification of wound infection: understanding wound odour. *J Wound Care* 26(10): 577–82

Riot S, de Bonnecaze G, Garrido I et al (2015) the use of negative pressure wound therapy for a malignant wound legitimate in a palliative context? "The concept of NPWT ad vitam": a case series. *Palliat Med* 29(5): 470–3

Samala RV, Davis MP (2015) Comprehensive wound malodor management: win the RACE. *Cleve Clin J Med* 82(8): 535–43

Schultz GS, Woo K, Weir D, Yang Q (2018) Effectiveness of a monofilament wound debridement pad at removing biofilm and slough: ex vivo and clinical performance. *J Wound Care* 27(2). Available at: https://bit.ly/37sRBhx (accessed 27.11.2020)

Villela-Castro DL, Conceicao de Gouveia Santos VL, Woo K (2018) Polyhexanide versus metronidazole for odor management in malignant (fungating) wounds: a double-blinded, randomized, clinical trial. *J Wound Ostomy Continence Nurs* 45(5): 413-8

Virgen CA, Barker CA, Lacouture ME (2020) The microbial flora of clinically infected cutaneous metastases: a retrospective study. *Clin Exp Dermatol* 45(6): 722–6

Wild T, Wiegand C, Kamolz L (2016) Used of Bismuth in wound care: review and case report. *Wounds International* 7(3): 34–9

Woo KY, Sibbald RG (2010) Local wound care for malignant and palliative wounds. *Adv Skin Wound Care* 23(9): 417–28; quiz 429–30

Effect of high negative pressure wound therapy in diabetic foot ulcer healing

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The effective range of negative pressure wound therapy (NPWT) lies between 50 mmHg and 150 mmHg, yet no optimal pressure has been identified. This study assessed the effect of negative pressure level on the rate and duration of wound healing in patients with non-ischaemic diabetic foot ulcers (DFUs). Patients were randomised to standard (–120 mmHg; *n*=87) or high (–160 mmHg; *n*=88) NPWT, managed following a standard wound care protocol and followed until complete healing or for a maximum of 12 months. The high NPWT group had a significantly greater rate of complete wound healing ($P<0.00001$), significantly shorter time to healing ($P=0.003$), significantly lower amputation rate ($P=0.003$) and fewer deaths ($P=0.07$) than the standard NPWT group. Greater negative pressure accelerated healing and reduced major amputations and death in patients with non-ischaemic DFUs.

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Negative pressure wound therapy (NPWT) was introduced in clinical practice in the early 1990s (Argenta and Morykwas, 1997). Over the past 15 years, it has revolutionised wound care. NPWT is currently used in the management of complex and non-healing wounds of different aetiologies in various anatomic locations. Studies on porcine models have demonstrated that the application of NPWT at pressures between –50 mmHg and –150 mmHg is effective and recommend a pressure of –125 mmHg (Morykwas et al, 2001). No randomised clinical studies have compared the effects of different levels of negative pressure on wound healing. The objective of this study was to assess the effect of high versus standard negative pressure on the duration and rate of wound healing in patients with non-ischaemic diabetic foot ulcers (DFUs).

Method

This prospective randomised study was performed at one institution over a 6-month period, from July 1 to December 31, 2018. Consecutive patients with DFUs for whom NPWT was prescribed were included in the study. Patients presenting with a DFU on severely ischaemic feet or whose ischaemia was not adequately corrected by vascular intervention were excluded. Eligible patients were randomised to receive standard NPWT (–120 mmHg) or high NPWT (–160 mmHg) in a one-to-one ratio.

Participants were examined and their full medical history taken by the treating physician. Wound size was measured with a plastic ruler and a digital photo taken at a distance of 30 cm from and perpendicular to the wound. Debridement was performed where necessary. Infection was treated according to the Infectious Diseases Society of America guidelines (Lipsky et al, 2012). Ischaemic feet were revascularised according to international guidelines (Bus et al, 2016; Conte et al, 2019). Patients initially presenting with severe ischaemia had their ischaemia corrected prior to randomisation. Patients whose ischaemia was not adequately corrected were excluded. Offloading was performed for plantar ulcers, according to International Working Group on Diabetic Foot recommendations (Bus et al, 2016). DFUs were classified according to the WIFI classification for Wound severity, Ischemia and Foot Infection. Wound severity was graded from W0 to W3 and foot infection graded from FI0 to FI3 (Mills et al, 2014).

The RENASYS ™ NPWT system (Smith & Nephew) was used to treat all of the patients

Table 1. Participant demographics and comorbidities in the groups (*n*=175).			
Demographic/comorbidity	**Standard NWPT, n (%)**	**High NWPT, n (%)**	***P*-value**
Age, years (mean)	60	59	0.120
Male gender	54 (62.0)	59 (67.0)	0.490
Smoker	33 (37.9)	34 (38.6)	0.900
Hypertension	51 (58.6)	39 (44.3)	0.058
Renal impairment	17 (19.5)	14 (15.9)	0.520
Ischaemic heart disease	19 (21.8)	31 (35.2)	0.070
Ischaemia	40 (45.9)	36 (40.9)	0.490

Table 2. Diabetic foot ulcer classification according to WIFI class*.			
Demographic/ comorbidity	**Standard NWPT, *n* (%)**	**High NWPT, *n* (%)**	***P*-value**
W2 + W3	65 (74.7%)	71 (80.6%)	0.34
I2 + I3	40 (45.9%)	36 (40.9%)	0.49
FI2 + FI3	49 (56.3%)	58 (65.9%)	0.19

*W = wound; I = ischaemia; FI = foot infection.

Table 3. WIFI stage of diabetic foot ulcers in the two groups.			
WIFI stage	**Standard NWPT, *n* (%)**	**High NWPT, *n* (%)**	***P*-value**
1	0	0	N/A
2	15 (17.2%)	10 (11.3%)	0.20
3	22 (25.2%)	24 (27.2%)	0.76
4	41 (47.1%)	49 (55.6%)	0.70

Table 4. Outcomes in the two negative pressure wound therapy groups.			
Outcome	**Standard NWPT, *n* (%)**	**High NWPT, *n* (%)**	***P*-value**
Ulcers completely healed	51 (59)	76 (90)	0.00001*
Days to complete healing	216	163	0.003*
Major amputations	16	4	0.003*
Mortality	12	5	0.070

*Significant difference.

in this study. It was applied according to the manufacturer's instructions under aseptic conditions at the centre. Continuous pressure mode was used and patients were provided with instructions on how to operate the system. To ensure reproducibility, all dressing changes were performed at the centre by the research nurse. Foam dressings were changed twice a week and 1,000 mL normal saline was applied during dressing changes. New photos and measurements of the wound were taken at each dressing change.

The total duration of NPWT was determined by the treating physician. After removing the NPWT, patients received wound care according to standard protocols. Patients visited the centre every 14 days for follow-up until complete healing was achieved or one of the other endpoints (major amputation and death) was reached.

The study protocol was approved by the Ethical Committee of the centre. Informed consent was obtained from all participants.

Statistical analysis

Continuous variables were compared using students' t-test and categorical variables compared using chi-squared test. Analysis of variance was used to study the interaction between the method of treatment (standard versus high NPWT), presence of ischaemia at initial presentation (I), wound severity (W) and degree of infection (FI). Multinomial logistic regression was performed to model the relationship between these variables and the outcomes (complete healing, major amputation and mortality). A *P*-value <0.05 was considered statistically significant.

Results

A total of 175 patients were randomised into two groups: standard (*n*=87) and high (*n*=88) NPWT. Patient demographics and comorbidities are presented in *Table 1*. Patients' DFUs were classified according to WIFI class *[Table 2]* and stage *[Table 3]* (Morykwas et al, 2001; Lipsky et al, 2012) on initial presentation. There were no significant differences between the two groups in terms of demographics, comorbidities or WIFI classification on enrolment.

Participants in the standard NPWT group were followed-up for a mean 207 days; the high NPWT group for 203 days. Six patients in the standard NPWT group were lost to follow-up; none from the high NPWT group.

There were significant differences between-group in time to healing and rates of complete healing and major amputation *[Table 4]*. The percentage of wounds that completely healed was significantly greater in the high NPWT group (*P*=0.00001) and the mean time to complete healing was significantly longer in the standard NPWT group (*P*=0.003). Regarding adverse events, major amputation was significantly more frequent (*P*=0.003) and mortality more frequent in the standard NPWT group *versus* the high NPWT group.

Analysis of variance identified a statistically significant interaction between treatment group and foot infection ($F(2,15)= 5.569$, *P*=0.003). The high NPWT group took less time to heal than the standard NPWT group on average, but this effect was greater for patients with FI-1, compared to

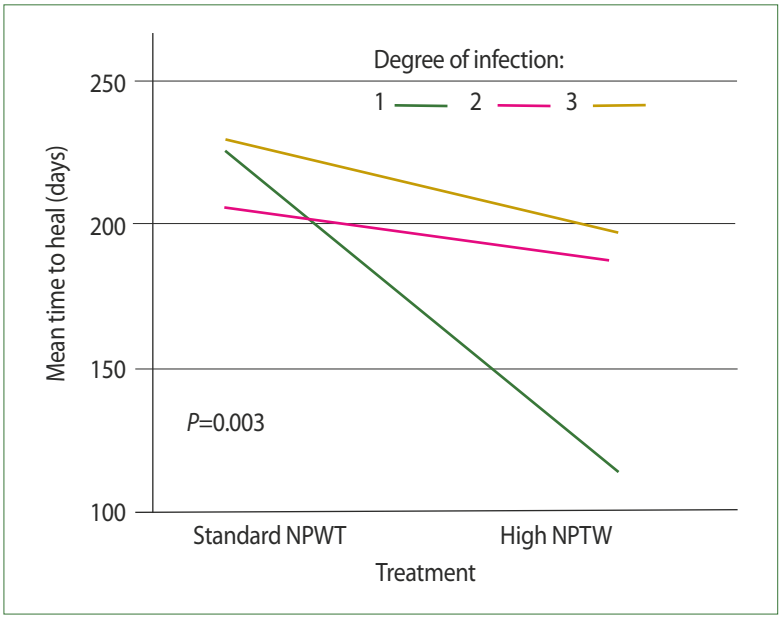

Figure 1. Effect of degree of foot infection on time to complete healing

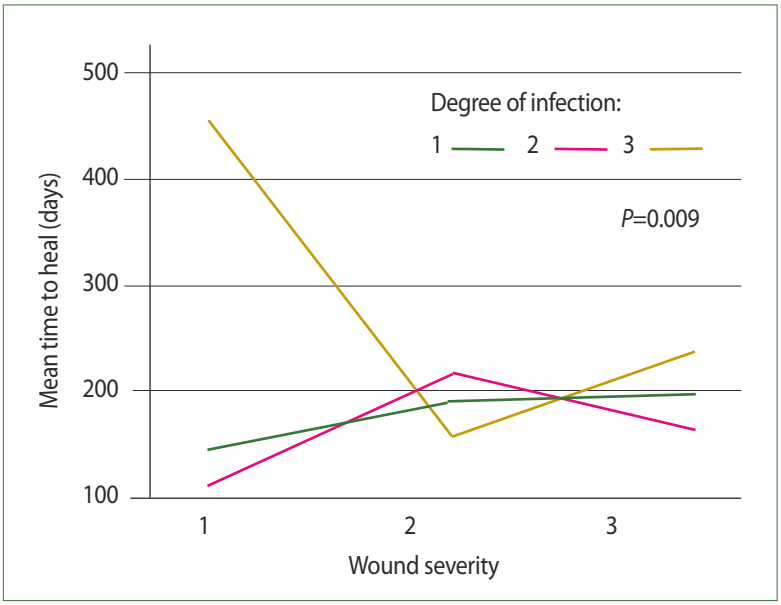

Figure 2. Effect of degree of foot infection and wound severity on time to complete healing

FI-2 and FI-3 *[Figure 1]*. There was also a statistically significant relationship between foot infection and wound severity (F(4,15)=3.557, *P*=0.009) *[Figure 2]*.

Multinomial logistic regression analysis found that the treatment group, ischaemia at initial presentation and wound severity had significant independent impacts on outcomes *[Table 5]*. Patients in the standard NPWT group had 5.3 higher odds of amputation than complete healing when compared to the high NPWT group (*b*=1.68, chi-squared (1)=6.78, *P*=0.009). The odds of dying *versus* complete healing were 4.9 times higher in the standard NPWT group (*b*=1.58, chi-squred (1)=6.4, *P*=0.011). Patients with severe ischaemia were 7.6 times more likely to undergo amputation than achieve complete healing when compared to patients with no ischaemia on presentation (*b*=–2.025, chi-squared (1)=8.873, *P*=0.003). Finally, wound severity significantly predicted the odds of amputation over complete healing:

- W2 was 9 times more likely to result in major amputation than W1 (*b*=–3.173, chi-squared (1)=6.134, *P*=0.013)
- W3 was 6.6 times more likely to result in major amputation than W2 (*b*=–1.884, chi-squared (1)=7.398, *P*=0.007).

Discussion

Diabetic foot disease is one of the most serious complications of diabetes and is a huge burden for patients and the healthcare system (Schaper et al, 2020). An estimated 15% of people with diabetes will suffer from foot ulcers and 10% of patients who have DFUs will eventually undergo major lower-extremity amputation (Schaper et al, 2003). It is, therefore, important to apply effective, rapid and safe treatment that accelerates wound healing and reduces the risk of major amputation. Many studies have assessed the safety, efficacy and cost–benefit ratio of NPWT (Othman, 2012). Based on data from studies, the addition of NPWT to standard care is recommended for the management of diabetic foot wounds by the International Working Group on the Diabetic Foot (Rayman et al, 2020). Although negative pressure of between –50 mmHg and –150 mmHg is effective and safe (Borgquist et al, 2010a,b), guidelines on optimal pressure and the patient groups that will benefit from specific levels of negative pressure are lacking. This study compared the effects of high (–160 mmHg) and standard negative pressure (–120 mmHg) on wound healing rate and time in patients with DFUs.

The Society for Vascular Surgery developed the WIFI classification to overcome the obstacles and limitations of the older classifications (Mills et al, 2014). WIFI has been shown to predict amputation risk and time to wound healing (Behan et al, 2017); the risk of major amputation and wound healing time both increase with increasing WIFI stage (Zhan et al, 2015). There were no significant differences between-group in WIFI classification (wound, ischaemia and infection) or stage in the current study; moreover, nearly 50% of patients enrolled were stage 4 (47.1% of the standard NPWT group and 55.6% of the high NPWT group) and therefore at greater risk of negative outcomes. Major amputations and death were more frequent in the standard NPWT group. Since these endpoints were mainly caused by sepsis in this cohort of patients, it could be argued that more efficient NPWT could reduce these adverse outcomes by reducing septic complications and time to complete healing.

Table 5. Multinomial logistic regression of factors contributing to outcomes (*n*=175).				
Factor	Model-fitting criteria –2 log likelihood of reduced model	Likelihood ratio tests		
		Chi-squared	Degrees of freedom	Significance
Intercept	94.179	0.000	0	–
Treatment*	120.302	26.123	5	0.000
Ischaemia at initial presentation	118.496	24.317	5	0.000
Wound	116.794[b]	22.615	10	0.012
Foot infection	113.953	19.774	15	0.181

Patients were followed until complete ulcer healing over a maximum of 12 months, during which there were statistically significant differences in the rate and mean time to complete healing in favour of the high NPWT group. As the two groups had similar demographics, comorbidities, WIFI stage and care protocol, it is assumed that the differences in outcomes were a result of the pressure used during the application of NPWT.

It must be noted that patients presenting with severe ischaemia or ischaemia not corrected by revascularisation were excluded from this study. There have been previous reports of skin necrosis caused by the application of NPWT at –125 mmHg in ischaemic limbs, resulting in the suggestion of the application of low-pressure (–50 mmHg) NPWT to ischaemic limbs (Kasai et al, 2012).

The limitation of this study is that it examined two levels of negative pressure on a specific clinical presentation: non-ischaemic DFUs. It is hoped the findings will result in further research to investigate the effect of different levels of negative pressure on wound healing in various clinical scenarios with the aim of identifying which pressure is most effective for which category of patients.

Conclusions

High negative pressure (–160 mmHg) resulted in a significantly higher healing rate and shorter healing time, and reduced major amputation rate and reduced the death rate when compared to standard negative pressure (–125 mmHg) in patients with non-ischaemic DFUs. Further studies are required to identify the levels of negative pressure that are more effective in specific disease entities.

WINT

References

Argenta LC, Morykwas MJ (1997) Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. *Ann Plast Surg* 38(6): 563–76

Behan HA, Ewon EK, Reyzelman A (2017) A closer look at the WIfI Classification System for Threatened Limbs. *Podiatry Today* 30(5): 14–8

Borgquist O, Gustafsson L, Ingemansson R, Malmsjö M (2010a) Micro- and macromechanical effects on the wound bed of negative pressure wound therapy using gauze and foam. *Ann Plast Surg* 64(6): 789–93

Borgquist O, Ingemansson R, Malmsjo M (2010b) Wound edge microvascular blood flow during negative pressure wound therapy: Examining the effects of pressure from –10 to –175 mmHg. *Plast Reconst Surg* 125(2): 502–9

Bus SA, Armstrong DG, van Deursen RW et al (2016) International Working Group on the Diabetic Foot. IWGDF Guidance on Footwear and Offloading Interventions to Prevent and Heal Foot Ulcers in Patients with Diabetes. *Diabetes Metab Res Rev* 32(S): 25–36

Conte MS, Bradbury MW, Kolh P et al; Global Vascular Guidelines on the Management of Chronic Limb-Threatening Ischemia (2019) Writing Group for the Joint Guidelines of the Society for Vascular Surgery (SVS), European Society for Vascular Surgery (ESVS), and World Federation of Vascular Societies (WFVS). *Eur J Vasc Endovasc Surg* 58(1S): S1–S109

Kasai Y, Nemoto H, Kimura N et al (2012) Application of low-pressure negative pressure wound therapy to ischaemic wounds. *J Plast Reconstr Aesthet Surg* 65(3): 395–8

Lipsky BA, Berendt AR, Cornia PB et al (2012) 2012 Infectious Diseases Society of America clinical practice guideline for the diagnosis and treatment of diabetic foot infections. *Clin Infect Dis* 54(12): 132–73

Mills JL, Conte MS, Armstrong DG et al (2014) The Society for Vascular Surgery Lower Extremity Threatened Limb Classification System: Risk stratification based on Wound, Ischemia, and foot Infection (WIfI). *J Vasc Surg* 59(1): 220–34

Morykwas MJ, Faler BJ, Pearce DJ, Argenta LC (2001) Effects of varying levels of subatmospheric pressure on the rate of granulation tissue formation in experimental wounds in swine. *Ann Plast Surg* 47(5): 547–51

Othman D (2012) Negative pressure wound therapy literature review of efficacy, cost effectiveness, and impact on patient's quality of life in chronic wound management and its implementation in the United Kingdom. *Plas Surg Int* 374398

Rayman G, Vas P, Dhatariya K et al; International Working Group on the Diabetic Foot (2020) IWGDF Guideline on interventions to enhance healing of foot ulcers in persons with diabetes. *Diabetes Metab Res Rev* 32(Suppl 1): e3283

Schaper NC, Apelqvist J, Bakker K (2003) The international consensus and practical guidelines on the management and prevention of the diabetic foot. *Cur Diab Rep* 3(6): 475–9

Schaper NC, van Netten JJ, Apelqvist J et al (2020) Practical Guidelines on the prevention and management of diabetic foot disease (IWGDF 2019 Update). *Diabetes Metab Res Rev* 36(Suppl 1): e3266

Zhan LX, Branco BC, Armstrong DG, Mills Sr JL (2015) The Society for Vascular Surgery lower extremity threatened limb classification system based on Wound, Ischemia, and foot Infection (WIfI) correlates with risk of major amputation and time to wound healing. *J Vasc Surg* 61: 939–44

Management of burn patients with Technology Lipido-Colloid with silver sulphate to fight local infection and restore the healing process

Authors (clockwise from top left): *Emilio Galea, Sanjeev K Uppal, V Ramadevi and Devika Rakesh*

Burn wounds are predisposed to infection and topical antimicrobial preparations are used both to prevent and treat infection. The choice of topical antimicrobial should be based on the ability of the agent to inhibit microorganisms that may be harmful within the wound bed and on the host. Silver is indicated when a local negative impact of bacterial colonisation is suspected and/or confirmed, because it has a broad antimicrobial effect. Technology Lipido-Colloid (TLC) is a matrix containing hydrocolloid and lipophilic substances that has been shown to promote the proliferation of fibroblasts and to be atraumatic for patients. TLC-Ag incorporates silver sulphate (3.5%) into the TLC matrix. When it is in contact with the wound, the dressing releases a constant supply of antibacterial silver. This article will discuss the use of antimicrobials in burn wound management, show the evidence for the TLC-Ag antimicrobial healing matrix and portray outcomes of cases of burns patients in India who have been managed with TLC-Ag.

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Wound infection has been defined as a proliferation of microorganisms leading to a response that can be either locally within the wound (local infection), around the wound (spreading infection) or systematically (systemic infection) (International Wound Infection Institute, 2016).

Contamination is the occurrence of non-proliferating microorganisms which do not invoke a host response, while colonisation denotes that microorganisms are present with limited proliferation, but still not evoking a host response (Eberlein and Assadian, 2010). Local infection is where microorganisms migrate deeper in the wound and proliferate enough to initiate a host response, which presents with mild signs of infection (Siddiqui and Bernstein, 2010). Spreading infection is the invasion of microorganisms into the surrounding tissue and may also involve deep tissue, muscle, fascia, organs or body cavities, causing signs and symptoms beyond the wound, while systemic infection is where the microorganisms spread in the whole body via the vascular or lymphatic system, invoking an systemic inflammatory response and includes organ dysfunction (Leaper et al, 2012).

The World Union of Wound Healing Societies (2008) consensus document states that the risk of infection is increased by any factor that debilitates the patient, impairs immune resistance or reduces tissue perfusion.

This brings us to the dilemma of whether clinicians should withhold topical antimicrobials if wound infection is present or to prophylactically treat high-risk patients and wounds. This is a controversial subject that needs to weigh the pros and cons of use of antimicrobials for an individual patient against worldwide guidance for antimicrobial stewardship. The use of topical antimicrobials as prophylaxis is interesting because they can be applied *in situ*, thus circumventing potential systemic toxicities and the risk of systemic antibiotics not arriving through avascular tissue to the site of infection (Glasser et al, 2010). Infection control procedures and good hygiene practices are important to prevent

further contamination of the wound and cross-contamination (World Union of Wound Healing Societies, 2008).

Overt signs and symptoms of infection include erythema, local warmth, swelling, purulent discharge, delayed wound healing, new or increasing pain and increasing malodour, while covert signs and symptoms include hypergranulation, bleeding, friable granulation, epithelial bridging and pocketing in granulation tissue, wound breakdown and enlargement, delayed wound healing beyond expectations, new or increasing pain and increasing malodour (International Wound Infection Institute, 2016).

Burn infections

In India, around 7 million people suffer burn injuries each year, with 140,000 dying and 240,000 becoming permanently disabled (Rastogi, 2016). Gupta et al (2010) state that around 10% of burn wounds are life-threatening and require hospitalisation, and approximately half of those who are hospitalised will die as a result of their injuries.

Infection still accounts for approximately 75% of all deaths in burn injuries globally (Al-Aali, 2016). The burn trauma not only destroys the skin, which is the first line of defence, but also contributes to the suppression of the immune system, while the protein-rich eschar produced offers an ideal environment for microorganisms to grow. These factors make burn wounds more prone to infections (Valarmathi et al, 2013; Hasan et al, 2016; Dahag et al, 2018). The avascular zone of coagulation diminishes immunological defences, while the inflammation also impairs wound healing due to the release of proteases from macrophages. Other factors that might predispose the wound for infections are patient factors, such as age, obesity, malnutrition, and endocrine and metabolic disorders (Pujji et al, 2019).

Thermal injuries are suggested to be free from microorganisms during and just after the trauma, due to the high temperature. However, these wounds become colonised within 48 hours with the patient's endogenous bacteria (mostly Gram-positive bacteria, and some Gram-negative bacteria from the gastrointestinal and respiratory tract), and the nosocomial microorganisms present in the environment (Mundhada et al, 2015).

Apart from burn wound sepsis, burn wound infections also may lead to wound alteration, skin graft failure and prolonged hospitalisation (Cartotto, 2017). The virulence, quantity and antibiotic resistance of bacteria also play a part in escalating the problem of wound infection. There are a number of varieties of common bacteria found in burn wounds, and positive bacterial cultures are more frequent in wounds of more than 2 weeks' duration (Valarmathi et al, 2013; Singh et al, 2019).

Bhama et al (2013) found that monomicrobial infection was most common in the early stages of a wound, with the proportion of wounds with polymicrobial infection increasing over time.

Wound dressings and antimicrobials

In a survey, 121 participants from 39 countries, most of whom were surgeons (72.1%), suggested that attributes of the ideal burn wound dressing include non-adhesion, antimicrobial activity, atraumatic removal and requires less frequent dressing changes (Selig et al, 2012). Irrespective of burn depth, topical antimicrobials are indicated when there is clinical suspicion of risk of infection, or when a wound infection is evident (Cartotto, 2017). The choice is based on factors such as wound depth, anticipated time to healing, need for surgical intervention, known cytotoxicity of the agent pain or irritation, and the required frequency of application (Cartotto, 2017).

Modern dressings have been reported to achieve better results than traditional dressings, such as silver sulfadiazine (Ag-SD), which ihas been found to cause wounds to dry up and not support optimal healing (Jiang et al, 2017). It has been argued that the main drawbacks associated with Ag-SD topical creams are their tendency to form pseudo-eschar, which is difficult to distinguish from burn eschar and may impede the penetration of the antimicrobial into the wound. The fatty acids or lipid-soluble carrier are relatively insoluble in water, making it difficult to remove old or residual cream from the wound (Ghodekar et al, 2012). The yellow-gray pseudo-eschar may be several millimetres thick and results from interaction between the cream and the wound exudate (Bessey, 2007). It has also been suggested that Ag-SD cream is relatively short-acting and is time-consuming and messy to apply and remove (International Consensus, 2012). The lipid base may make removal of the product painful for the patient (Black and Drake, 2015). Clinicians show dissatisfaction regarding the necessary daily dressing when using Ag-SD cream (Jester et al, 2008).

It has also been suggested that Ag-SD cream prolongs healing time and inactivates natural enzyme debriding agents, and some have cytotoxic effects (Martindale, 2002; Muller

et al, 2003; Duc et al, 2007). Some topical antimicrobial preparations are cytotoxic to keratinocytes and fibroblasts, and therefore have the potential to delay wound healing (Cartotto, 2017). In a systematic review and meta-analysis, other materials showed better results than Ag-SD (Nimia et al, 2018).

Evidence shows that some topical antiseptics are non-selective and may be cytotoxic if not delivered to the wound in a sustained manner (Siddiqui and Bernstein, 2010; Leaper et al, 2012). Fraser et al (2004) found that there was almost no keratinocyte survival and a reduction in cell survival after 72-hour exposure to Ag-SD and chlorhexidine, and topical Ag-SD was associated with a reduction in cell numbers compared to control. Cytotoxicity may be dependent on concentration (Siddiqui and Bernstein, 2010; Leaper et al, 2012).

Technology Lipido-Colloid with silver

Technology Lipido-Colloid (TLC) comprises a matrix containing hydrocolloid and lipophilic substances, which have been shown *in vitro* to enable proliferation of fibroblasts, stimulate extracellular matrix production and contribute to the formation of new tissue through the creation of a moist environment (Bernard et al, 2005; McGrath et al, 2014). The healing matrix dressing is designed to reduce adhesion to the wound surface, whether the wound is acute or chronic (Meaume et al, 2002).

The atraumatic properties of the healing matrix were demonstrated in an observational study involving 5,850 patients (2,914 with acute wounds, 2,396 with chronic wounds) who were being treated with traditional dressings, such as gauze, paraffin-impregnated gauze, as well as foam and hydrocolloids. When the patients switched to TLC, pain reduction was reported in 88% of patients with chronic wound and in 95% of patients with acute wounds.

Two non-comparative multicentre prospective clinical studies were conducted using the same protocol in France and Germany and involved 100 paediatric patients aged 1–12 years, including 77 with burns (Letouze et al, 2004). At the end of the trial, the dressing acceptability parameters showed that TLC is easy to apply and remove, and is conformable and non-adherent. No pain (including minor pain) was reported using various age-suitable pain scales, confirming the atraumatic removal. Clinicians also noted that the dressing could be left in place for several days. The authors concluded that the product's pain-free removal could result in significant time savings and decrease the need for analgesia. The two studies confirmed the efficacy and safety of TLC.

TLC-Ag incorporates silver into the TLC healing matrix. Silver sulphate (3.5%) has been combined with TLC to produce TLC-Ag, which is indicated for the treatment of non- to low-exuding acute wounds (burns, skin abrasions, traumatic injuries and second-degree burns) and chronic wounds showing signs of infection. It can also be used on more heavily exuding wounds when used in combination with an absorbent dressing

TLC-Ag contains 0.35 mg/cm^2 of silver ions, delivered by silver sulphate (0.50 mg/cm^2). In contact with the wound exudate, the silver sulphate breaks down and releases the silver ion, while the carboxymethylcellulose particles swell to form a surface hydrocolloidal film. It is suggested that this controlled supply of silver at the surface into the lipido-colloid gel guarantees a constant antibacterial activity, when the dressing is in contact with the wound.

An *in vitro* analysis was carried out to determine the antibacterial properties of TLC-Ag on the survival of a range of bacteria, including strains resistant to antibiotics (White et al, 2015). The samples of dressings were inoculated with a bacterial suspension of 108 colony-forming units (CFUs) and then incubated. The number of surviving bacteria was calculated daily up until day 7. From day 1 and throughout the duration of the study, the reduction in the number of CFUs for all the bacterial strains studied was >105, making it possible to conclude that the TLC-Ag contact layer demonstrates antibacterial efficacy on the microorganisms tested.

In vivo evidence was provided through a multicentre, phase III, controlled, randomised trial. One cohort was treated with the TLC-Ag dressing for 4 weeks, followed by the silver-free TLC dressing for 4 weeks, while the control group was treated with a silver-free TLC dressing for the 8-week period (Lazareth et al, 2008). The primary study endpoint was reduction in the surface area of the wounds at weeks 4 and 8 of treatment. At the end of the first 4 weeks, the median surface area of the ulcers had decreased by 4.2 cm^2 in the group treated with silver versus 1.1 cm^2 in the control group (P=0.0223). In the next 4 weeks, the reduction in surface area continued in the group first treated with the silver dressing, in contrast with the control group. At the end of follow-up, the median ulcer surface area had decreased by 5.9 cm^2 in the silver group versus 0.8 cm^2 in the control group (P=0.002). At the end of 8 weeks of treatment, the relative median surface area reduction of

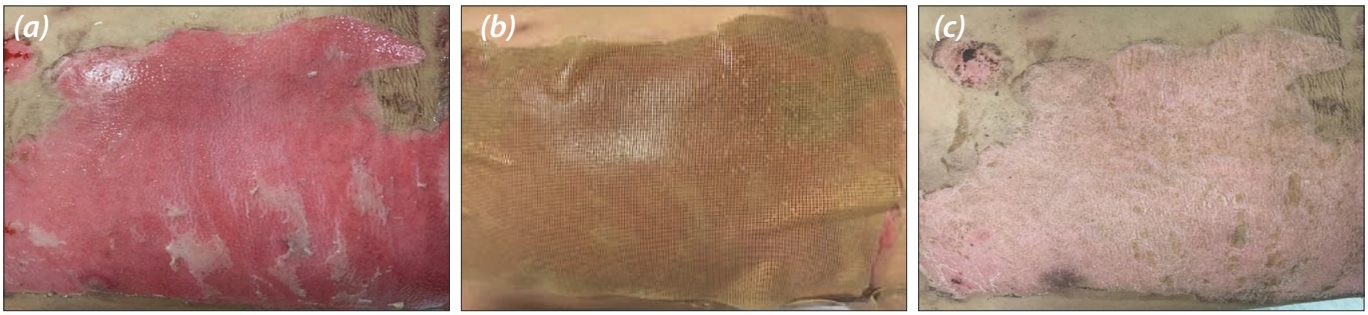

Figure 1. Case 1 at (a) presentation 4 days after the hot water burn; (b) with TLC-Ag dressing in place; and (c) wound closure after 11 days.

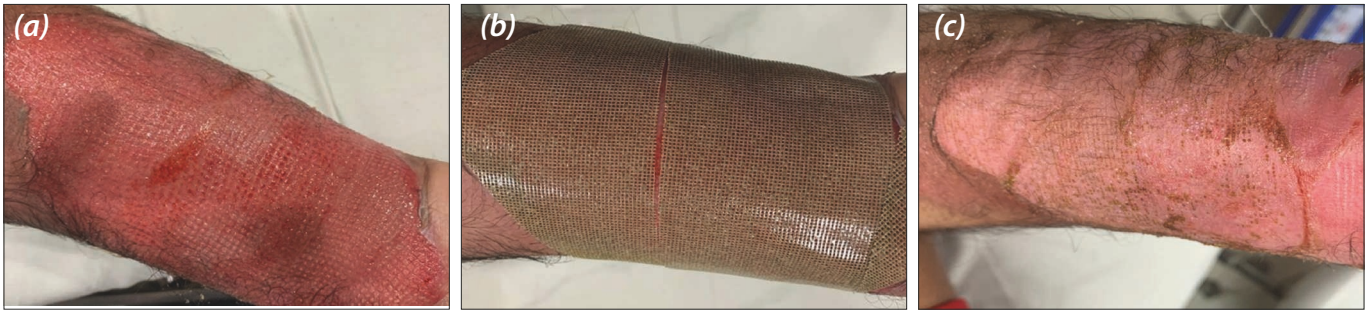

Figure 2. Case 2 at (a) presentation; (b) with TLC-Ag dressing in place; and (c) wound healing after two dressings.

the ulcers was significantly greater in the silver group at 47.9%, versus 5.6% in the control group (P=0.036).

The clinical score for wound colonisation (defined by the presence of clinical signs among five pre-specified signs at baseline) was significantly lower in the TLC-Ag group than in the control group (1.43 versus 2.31, respectively, P=0.0001), while the number of patients with a surface area reduction ≥40% of the initial surface area was higher in the TLC-Ag group: 54.9% of ulcers versus 35.4% in the control group (P=0.051), with an odds ratio 2.7 (95% CI 1.1–6.7, P=0.038) in favour of the silver group. Laboratory tolerance assay of blood silver levels was conducted to analyse if silver passes into the bloodstream (argyremia) at day 0, week 4 and week 8. It was shown that the TLC-Ag dressing did not induce any increase in blood silver levels.

Case studies

The following cases were conducted in view of the robust evidence in favour of the TLC-Ag, discussed above. The authors sought to test if the modality that had been proven effective in Europe would have the same results in patients managed in India using TLC-Ag.

Case 1

An 8-year-old girl presented with a 4-day-old thermal burn from hot water (17 × 20 cm) on the anterior chest wall and abdomen (*Figure 1a*). Initially, the burn had been managed at a local hospital with gauze saline dressing. Her pain score was severe and the wound had moderate exudate with an erythematous periwound area.

The wound was irrigated with normal saline and TLC-Ag was applied (*Figure 1b*). Thereafter, the dressing was reapplied every 3–4 days. After two dressing changes, pain and exudate levels had subsided and the wound bed appeared healthy and granulating. By day 11, after three dressing changes, there was no exudate present and the wound had closed (*Figure 1c*).

Case 2

A 27-year-old man presented with a 5-day-old thermal burn on the right forearm (10 × 7 cm). Pain score was moderate and the wound had mild exudate, along with inflammation and exposed dermis layer (*Figure 2a*). The wound had been initially managed with povidone iodine as the cleansing agent and topically with petroleum jelly gauze dressings.

Management changed to cleaning with normal saline and application of TLC-Ag (*Figure 2b*). The dressing was changed on day 4. The wound was granulating with no exudate and pain was decreased. After two dressings, the wound had completely healed (*Figure 2c*).

Case 3

A 35-year-old man presented with a scald burn on his left forearm (15 × 7 cm). Pain was moderate to severe with no exudate and an erythematous periwound area (*Figure 3a*). TLC-

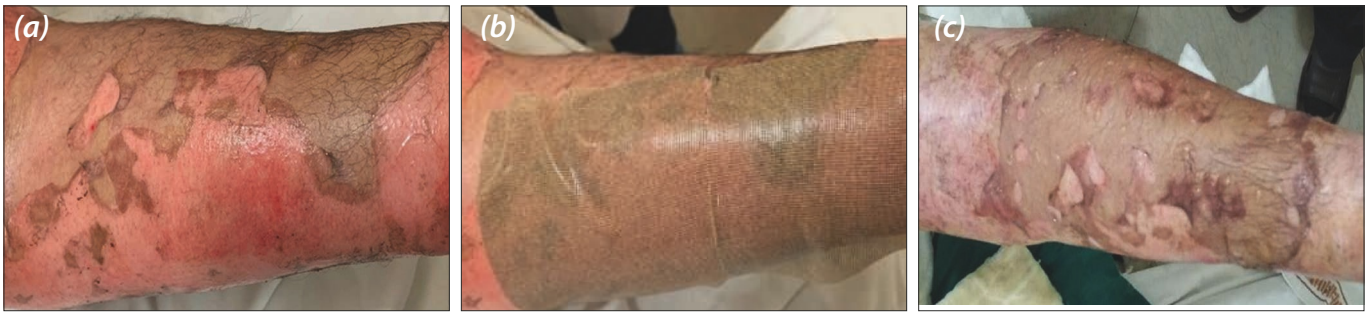

Figure 3. Case 3 at (a) presentation; (b) with TLC-Ag dressing in place; and (c) wound on day 4 at first dressing change.

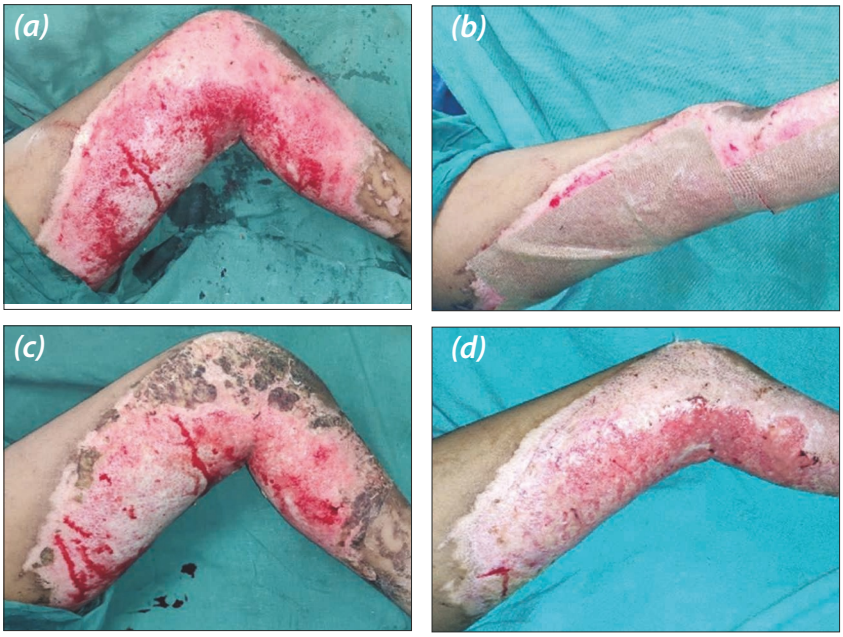

Figure 4. Case 4 at (a) presentation; (b) with TLC-Ag dressing in place; (c) wound on day 4 at first dressing change; and (d) wound on day 5.

Ag was applied after cleaning with normal saline (*Figure 3b*). The dressing was changed on day 4, and the pain and exudate levels had already subsided and the wound bed appeared healthy (*Figure 3c*).

Case 4

A 9-year-old girl presented with a 10-day-old flame burn on the right lower leg (*Figure 4a*), which was initially treated in a local hospital with silver sulphadiazine cream. Pain was moderate to severe, and the wound had minimal exudate with a visibly unhealthy wound bed. TLC-Ag was applied after cleaning with normal saline (*Figure 4b*). The dressing was changed on day 4 (*Figure 4c*). After two dressing changes (day 5), the pain and exudate levels had subsided and the wound bed appeared healthy and granulating (*Figure 4d*).

Case 5

A 30-year-old man presented with an electrical burn on the right forearm (*Figure 5a*). This was initially treated at his local hospital with topical ointments and paraffin gauze dressings for 2 days. Pain was severe and the wound had mild exudate, with sloughy tissue and unhealthy wound bed.

TLC-Ag was applied after cleaning with normal saline (*Figure 5b*). The dressing was changed on day 5. Pain and exudate levels had subsided and the wound bed appeared healthy and granulating. (*Figure 5c*).

Conclusion

The authors have presented five cases of burn wounds in India that were managed by TLC-Ag. These cases showed promising results. However, it is suggested that further cases need to be conducted to suggest policy change to include TLC-Ag in the standard of care in the facilities concerned.

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References

Al-Aali KY (2016) Microbial profile of burn wound infections in burn patients, Taif, Saudi Arabia. *Arch Clin Microbiol* 7(2): 1-9

Bernard FX, Barrault C, Juchaux F et al (2005) Stimulation of the proliferation of human dermal fibroblasts in vitro by a lipidocolloid dressing. *J Wound Care* 14(5): 215–20

Bernard FX, Juchaux F, Laurensou C (2007) [Effects of a lipidocolloid dressing on the production of extracellular matrix by human dermal fibroblasts in vitro. In French.] *Journal des Plaies et Cicatrisations* (58): 9–11

Bessey PQ (2007) Wound care. In: *Total Burn Care*, 3rd ed. WB Saunders, New York

Bhama S, Rajan R, Theodore RB (2013) A study on bacterial profile of burn wound infections. *J Acad Clin Microbiol* 15(2): 54

Black JS, Drake DB (2015) A prospective randomized trial comparing silver sulfadiazine cream with a water-soluble polyantimicrobial gel in partial-thickness burn wounds. *Plastic Surgical Nursing* 35(1): 46–9

Cartotto R (2017) Topical antimicrobial agents for pediatric burns. *Burns Trauma* 5(1): 33

Dahag MA, Louri NA, Dey N, Philip SS (2018) Pattern of the burn wounds infections in Bahrain Defense Force Military Hospital. *Ann Burns Trauma* 2(1): 1007

Duc QL, Breetveld M, Middelkoop E et al (2007) A cytotoxic

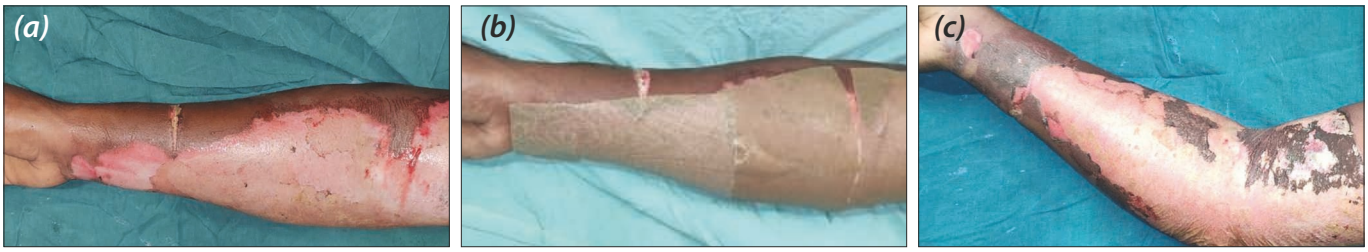

Figure 5. Case 5 at (a) presentation; (b) with TLC-Ag dressing in place; and (c) wound at first dressing change on day 5.

analysis of antiseptic medication on skin substitutes and autograft. *Br J Dermatol* 157(1): 33–40

Eberlein T, Assadian O (2010) Clinical use of polihexanide on acute and chronic wounds for antisepsis and decontamination. *Skin Pharmacol Physiol* 23(Suppl 1): 45–51

Fraser JF, Cuttle L, Kempf M, Kimble RM (2004) Cytotoxicity of topical antimicrobial agents used in burn wounds in Australasia. *ANZ J Surg* 74(3): 139–42

Ghodekar SV, Chaudhari SP, Ratnaparakhi MP (2012) Development and characterization of silver sulfadiazine emulgel for topical drug delivery. *Int J Pharm Pharmaceut Sci* 4(4): 305–16

Glasser JS, Guymon CH, Mende K et al (2010) Activity of topical antimicrobial agents against multidrug-resistant bacteria recovered from burn patients. *Burns* 36(8): 1172–84

Gupta JL, Makhija LK, Bajaj SP (2010) National programme for prevention of burn injuries. *Indian J Plast Surg* 43(Suppl 1): S6–10

Hasan R, Acharjee M, Noor R (2016) Prevalence of vancomycin resistant Staphylococcus aureus (VRSA) in methicillin resistant S. aureus (MRSA) strains isolated from burn wound infections. *Ci Ji Yi Xue Za Zhi* 28(2): 49–53

International consensus (2012) *Appropriate Use of Silver Dressings in Wounds. An Expert Working Group Consensus*. Wounds International, London

International Wound Infection Institute (2016) *Wound Infection in Clinical Practice: Principles of Best Practice*. Wounds International, London

Jester I, Bohn I, Hannmann T et al (2008) Comparison of two silver dressings for wound management in pediatric burns. *Wounds* 20(11): 303–8

Jiang Q, Chen ZH, Wang SB, Chen XD (2017) Comparative effectiveness of different wound dressings for patients with partial-thickness burns: study protocol of a systematic review and a Bayesian framework network meta-analysis. *BMJ Open* 7(3): e013289

Lazareth I, Meaume S, Sigal-Grinberg ML et al (2008) The role of a silver releasing Lipido-colloid contact layer in venous leg ulcers presenting inflammatory signs suggesting heavy bacterial colonization: results of a randomized controlled study. *Wounds* 20(6):158–66

Leaper DJ, Schultz G, Carville K et al (2012) Extending the TIME concept: what have we learned in the past 10 years? *Int Wound J* 9(Suppl 2): 1–9

Letouze A, Voinchet V, Hoecht B et al (2004) Using a new lipidocolloid dressing in paediatric wounds: results of French and German clinical studies. *J Wound Care* 13(6): 221–5

Martindale W (2002) Silver sulfasalazine. In: Sweetman SC (ed). *Martindale: The Complete Drug Reference* (33rd edn.) Pharmaceutical Press, London

McGrath A, Newton H, Trudgian J, Greenwood M (2014) TLC Dressings Made Easy. *Wounds UK* 10(3): 1–4

Meaume S, Senet P, Dumas R et al (2002) Urgotul: a novel non-adherent lipidocolloid dressing. *Br J Nurs* 11(16 Suppl): S42–3, S46–50

Meaume S, Teot L, Lazareth I et al (2004) The importance of pain reduction through dressing selection in routine wound management: the MAPP study. *J Wound Care* 13(10): 409–13

Muller MJ, Hollyoak MA, Moaveni Z et al (2003) Retardation of wound healing by silver sulfadiazine is reversed by aloe vera and nystatin. *Burns* 29(8): 834–6

Mundhada SG, Waghmare PH, Rathod PG, Ingole KV (2015) Bacterial and fungal profile of burn wound infections in tertiary care center. *Indian J Burns* 23(1): 71

Nímia HH, Carvalho VF, Isaac C et al (2019) Comparative study of Silver Sulfadiazine with other materials for healing and infection prevention in burns: a systematic review and meta-analysis. *Burns* 45(2): 282–92

Pujji OJ, Nakarmi KK, Shrestha B et al (2019) The bacteriological profile of burn wound infections at a tertiary burns center in Nepal. *J Burn Care Res* 40(6): 838–45

Rastogi A (2016) *Burns. National Health Portal of India*. Available from: https://www.nhp.gov.in/disease/skin/burns (accessed 07.04.2020)

Selig HF, Lumenta DB, Giretzlehner M et al (2012) The properties of an "ideal" burn wound dressing–what do we need in daily clinical practice? Results of a worldwide online survey among burn care specialists. *Burns* 38(7): 960–6

Siddiqui AR, Bernstein JM (2010) Chronic wound infection: facts and controversies. *Clin Dermatol* 28(5): 519–26

Singh V, Mishra B, Pandey R (2019) Burn wound infection and antibiotic susceptibility patterns in a tertiary care teaching centre in Western India. *Int J Sci Res* 8(9): 7–8

Valarmathi S, Pandian MR, Senthilkumar B (2013) Incidence and screening of wound infection causing microorganisms. *J Acad Industr Res*1(8): 508–10

White R, Cowan T, Glover D (2015) *Supporting Evidence-Based Practice: Clinical Review of TLC Healing Matrix* (2nd edn.) MA Healthcare, London. Available at: https://bit.ly/2sHLVyU (accessed 09.04.2020)

World Union of Wound Healing Societies (2008) *Wound Infection in Clinical Practice: A WUWHS International Consensus*. MEP, London. Available at: https://bit.ly/2UAotie (accessed 18.11.2020)

The SEM Scanner for early pressure ulcer detection: a 360-degree review of the technology

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This article reviews the innovative SEM Scanner (Bruin Biometrics) technology for early detection of a forming pressure ulcer (PU) from a 360-degree perspective, considering the physiological, biophysical, medical-clinical and cost-effectiveness points of view, altogether. The SEM Scanner is designed to help healthcare professionals address a major medical need: pressure ulcer prevention (PUP). Currently, there is no technology other than the SEM Scanner for supporting clinicians in their decision-making with regards to the PU risk at specific anatomical sites of their patients. Based upon well-established physiological and biophysical principles underlying the aetiology of PUs, the SEM Scanner is targeting a specific stage in the PU cascade, in which there is a window of opportunity for detection of a localised change in the biocapacitance property of a tissue region at risk. Such change would indicate inflammatory micro-damage that may still be reversible. This is in stark contrast with the conventional clinical thinking of documenting an already existing structural tissue damage, which occurs much later in the injury spiral, typically days after the onset of the micro-damage. In other words, only when the damage becomes macroscopic and wide-spread, it can be spotted by the traditional visual skin assessment (VSA) practice or by an ultrasound examination. The benefits of a quantitative, standardised and objective early-detection of PUs, using the SEM Scanner as an adjunct to the currently subjective process of PU identification, make this device a disruptive innovation, particularly considering that the risks in using this device, if any, are negligible. The SEM Scanner technology has both proven clinical successfulness and cost-effectiveness. Risk assessment and early-detection are the two essential foundations for effective PUP.

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***Disclosure:** The author acts as a scientific advisor to multiple companies in the field of pressure ulcer/injury prevention, including to Bruin Biometrics LLC (USA) whose SEM Scanner technology is referred to in this paper. This had no influence on the conclusions from the analysis of literature which is presented here.*

This article reviews the innovative SEM Scanner (Bruin Biometrics) technology for early detection of a forming pressure ulcer (PU) from a 360-degree perspective, considering all of the physiological, biophysical, medical-clinical and cost-effectiveness points of view. The SEM Scanner is a unique technology-aid, specifically designed to help healthcare professionals address a major medical need, namely, pressure ulcer prevention (PUP) in patients who are immobile or insensate. Currently, there is no diagnostic or risk as-sessment technology other than the SEM Scanner for supporting clinicians in their subjective decision-making with regards to the PU risk or the early diagnosis of a forming injury at specific anatomical sites of their patients. In this work, the SEM Scanner technology is explained in a non-technical language and the benefits of a quantitative, standardised and objective early detection of PUs using the device (as an adjunct to

the currently subjective process of PU identification) are reviewed. As will be described in this article, the SEM Scanner is clearly a disruptive innovation in the practice of PUP, which should be deployed (based a site-specific cost-benefit evaluation) wherever at-risk patients may be admitted, particularly considering that the risks in using this device, if any, are negligible. As reviewed here, the SEM Scanner technology has both proven clinical successfulness and cost-effectiveness, allowing PUP to finally modernise and become technology-aided.

The contemporary and mainstream published knowledge on pressure ulcer (PU) aetiology

During 2018-2019, the author chaired the Aetiology Working Group responsible for writing the Aetiology Chapter of the 2019 International Guideline for Pressure Ulcer/Injury Prevention and Treatment and have led this panel of experts to publication of the most comprehensive, rigorous and up-to-date work thus far on the aetiology of pressure ulcers (PUs), analysing over than a 100 recent research papers in the field. That contemporary, mainstream published knowledge on PU aetiology, which is detailed in the above 2019 version of the International Guideline is summarised below.

Pressure ulcers are injuries that may develop over a timescale of minutes to hours under sustained tissue deformations. Tissue damage in PUs does not appear instantaneously, but rather, develops from the cell scale to the mesoscale and grows to the tissue level and finally, presents itself on the skin surface and often causes skin and underlying tissue breakdown. This implies that in PUs, the damage spiral onsets and progresses from the micro to the macro. Our current fundamental understanding described in the above 2019 guideline is that this damage spiral ultimately leading to PUs is triggered and then driven by cell and tissue exposure to sustained mechanical deformations, or, in bioengineering terms, to mechanical stress concentrations in soft tissues.

Any bodyweight or device-related forces that cause sustained soft tissue distortions generate large deformations of the cells contained within the affected tissues, with the greatest tissue and cell deformations occurring where these forces are concentrated. With respect to sustained bodyweight forces, the most influenced soft tissue sites are typically found in deep tissue layers under bony prominences, where the highly curved and 'sharp' bone surfaces come into contact with easily deformable soft tissues. The bodyweight forces, which are transferred through the sharp and rigid bony elements, cause large distortions in the soft tissue structures that they encounter, such as under the sacral or calcaneal (heel) bones, with the highest distortions occurring near the sharpest bony surfaces. This is the reason for the tissue damage to typically occur first in the deeper tissues and only then progress towards more superficial layers, until eventually presenting itself on the skin. At the cell scale, the continuous exposure to such mechanical forces that deform soft tissues would gradually damage the integrity of the cytoskeleton — the complex protein scaffold that makes the structural framework of cells. The exterior walls of the cell, called the plasma membrane, are structurally supported by the cytoskeleton. When the cytoskeleton becomes unable to continue providing the sufficient mechanical support to the plasma membrane, pores will form on the membrane. Poration of the plasma membrane will rapidly lead to abnormal transport of ions and molecules from within cell bodies extracellularly, and from the extracellular space inwards into the cell bodies. The inability of multiple cells to control their mass transport yields loss of homeostasis, which results in *en masse* apoptosis within a timeframe of just minutes.

When these multiple cells have been damaged or have died as a direct result of the sustained tissue deformations as described above, the damaged cells and nearby immune cells release pro-inflammatory cytokines, which are signaling proteins that function to attract additional immune cells. This signalling is a programmed normal response which is essential for healing. Recruitment of a large number of immune cells is primarily aimed at counteracting pathogens, clearing dead cell debris and preparing the ground for tissue regeneration. However, in the specific context of PU aetiology, the inflammatory singling itself is a potential contributor to the injury spiral, considering the effects of the pro-inflammatory cytokines on the endothelium in the vasculature adjacent to the initial damage site. Specifically, the secreted pro-inflammatory cytokines act to dilate capillaries and increase the permeability of capillary walls near the initial damage site, by relaxing endothelial cell tight-junctions. This endothelium relaxation facilitates leukocyte extravasation — the migration of immune cells from the blood circulation to the initial damage site. However, the endothelium relaxation also results in leakiness of the vasculature near the damage site and so, plasma fluids build-up in the interstitial tissue spaces, which forms localised oedema. Of note is that this localised oedema, which results from the mechanical insult is fundamentally different from a systemic oedema. Systemic oedematous conditions are typically caused by sodium retention in tissues,

which is associated with heart, liver or kidney dysfunction, or due to a lymphatic disease resulting in lymphoedema, whereas a localised oedema is a characteristic result of a normal immune response trigged by localised tissue damage to allow leukocyte extravasation, as explained above.

Often in a developing PU, soft tissue expansion due to a forming localised oedema is mechanically limited, for example, because the soft tissues are constrained between a bony element and a support surface (e.g. between the sacrum and a mattress). If the affected soft tissues cannot sufficiently expand in volume, the interstitial pressures would increase sharply, causing further cell deformation and thereby, additional deformation-induced cell death. Under such conditions, the inflammatory process would then cause release of reactive oxygen and nitrogen species to degrade the extracellular matrix in an effort to relieve the rising interstitial pressures, which will cause further tissue damage, now to the extracellular structures.

At a certain stage, the growing interstitial pressures may reach a level that would cause obstruction of the vasculature itself, which will impair blood perfusion into the affected tissue site and, thereby, trigger ischaemic damage. These synergistic interactions between sustained cell and tissue deformations, inflammation and ischaemia form the vicious cycle of the development and progression of PUs as we currently understand it. The description of the aforementioned vicious cycle *[Figure 1]*, is the core of the Aetiology Chapter of the 2019 Guideline. The contents of the 2019 Aetiology Chapter visualised in the Figure represent the contemporary understanding from the past decade — a vast change and progress with respect to earlier knowledge.

Of note, inflammation is a critical juncture where the post-injury cascade of events is determined, i.e., whether an early-stage, developing PU will heal normally (without leaving clinically significant tissue damage) or otherwise, would shift to a chronicity state (Cutting and Gefen, 2019). Specifically, the nature of the inflammatory signaling and the associated localised oedema *[Figure 1]* are central factors in any healing process and will ultimately determine the 'fate' of the wound, that is, a good healing and closure outcome, or alternatively, chronicity (Cutting and Gefen, 2019). Conditions of uncontrolled inflammation such as those reported in COVID-19 augment the tissue swelling or the increase in interstitial pressure levels, which then causes a wider spread of the secondary cell death and tissue damage, due to the resulting high cell distortions *[Figure 1]*. Inflammatory signalling further impacts the lymphatic system and as commonly known, typically causes swelling of lymphatic nodes, which adds to the mechanical loading on adjacent cells and, therefore, to the potential for cell damage.

The SEM Scanner is designed to function based upon this contemporary aetiological understanding of PUs and targets the inflammatory phase in the formation of PUs which is characterised by localised accumulation of plasma in the interstitial compartments. Noteworthy is that the localised nature of plasma fluid accumulation in soft tissues due to a forming PU is inherently different from a systemic oedema mechanism, in both the pathophysiology and clinical outcomes, as described earlier.

As mentioned in multiple places in the 2019 guideline, there are a number of physical and chemical biomarkers that characterise the inflammatory phase in PU formation and among these biomarkers, biocapacitance is a very robust biophysical measure of the localisation and extent of the tissue damage. While systemic oedema may develop due to a variety of causes e.g. heart failure, low protein levels, liver or kidney diseases, a localised oedema in a person who is at-risk for PUs will very likely indicate a forming PU. The SEM Scanner is specifically detecting a localised oedema (as opposed to a systemic oedema) by comparing the biocapacitance marker, which correlates with the interstitial fluid content across different tissue locations, e.g. in multiple tissue sites around the sacrum.

The difference between the biocapacitance readings acquired at multiple different tissue locations, which is quantified by the SEM-delta measure, represents the inhomogeneity in interstitial fluid distribution, which only increases if one specific site — a PU formation site — starts accumulating plasma due to a locally inflamed, leaky vasculature *[Figure 1]*. Currently, there is no other feasible technological alternative to use of biocapacitance as the biophysical measure of the build-up of this local inflammatory cell and tissue damage that points to an early-stage, but still likely reversible damage.

The inextricable links between COVID-19 and the pathophysiology of PUs

Based on recent Italian data reported in the literature, a rate of 12% of all positive coronavirus disease 2019 (COVID-19) cases required admission in an intensive care unit (ICU) and the ICU length of stay with this diagnosis is relatively long. At the time of writing this article, there are already nearly 10m positive COVID-19 cases (*www.worldometers.info* accessed on June 25, 2020), which is indicative of approximately 1.2m ICU patients who have already been added or will be added to the healthcare

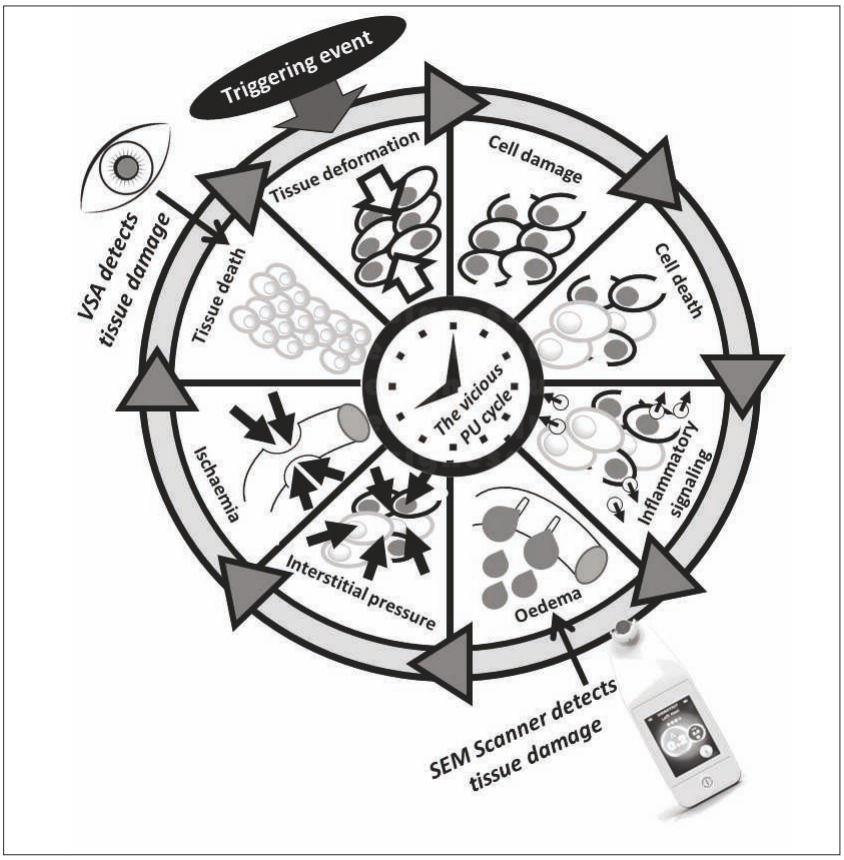

Figure 1. The vicious cycle of pressure ulcer formation and its progress with time. Based on the changes in interstitial fluid contents resulting from the build-up of the oedema The SEM Scanner is able to detect the forming cell and tissue damage early in the cascade, where damage is still at a micro-scale and is highly likely to be reversible. A visual skin assessment, in contrast, will detects an already-existing, macroscopic tissue damage which is unlikely to be reversible.

system worldwide since the outbreak of the pandemic in the western hemisphere, in February 2020. In the context of this current widespread of the first wave of COVID-19, where many of the newly admitted ICU patients are anaesthetised for mechanical ventilation and are, therefore, by definition, at-risk for PUs, it is important and relevant to discuss how COVID-19 interacts with the known aetiological factors described above (please see a comprehensive review of this topic in Gefen and Ousey, 2020 and the monthly updates to this paper).

First, COVID-19 activates the immune system promptly and sharply, which positions COVID-19 patients with a cytokine release syndrome (also known as 'cytokine storm') at a high risk for developing PU-related inflammatory tissue damage. This is because their inflammatory response is unleashed and their cytokine sensitivity thresholds are, therefore, disrupted. In addition, COVID-19 patients are also at a high risk for PU-related ischaemic tissue damage as their oxygen saturation levels are typically low and their cardiac output may be abnormal, e.g. due to myocarditis, acute myocardial infarction or heart failure, all of which are reported cardiovascular complications of COVID-19.

Another potential contributor to tissue ischaemia in COVID-19 is the hypercoagulability leading to a tendency for thrombosis in these patients. These timely examples illustrate how COVID-19 interacts directly with two of the three primary aetiological factors in the vicious cycle of PUs, inflammation and ischaemia and further suggest that COVID-19 may be a confounder of PUs. Indeed, the prevalence rate of PUs in ICUs among COVID-19 patients could be 10-times or more the respective PU rates at the same ICUs prior to the COVID-19 outbreak (Gefen and Soppi, 2020). Considering that already before the COVID-19 outbreak, PUs were a well-recognised independent prognosticator of death among ICU patients, the interaction of the cytokine storm in COVID-19 with the inflammatory damage factor in the PU spiral underpins the importance of PUP for this particular patient population (Gefen and Soppi, 2020). Based on its underlying physical and physiological principles described above, the SEM Scanner as an adjunct to clinical judgment can be a very effective tool for this task.

Visual skin assessments, palpation examinations and pain complaints as limited indications for PU diagnosis

The process by which serious, hospital-acquired deep PUs form under intact skin, spread in deep tissues and eventually present themselves as full-thickness wounds has been rigorously described in the medical literature in the last decade, from a basic science and aetiological perspectives. The mechanobiology of such PUs is that soft tissue damage initiates near bony prominences — typically the sacrum and heels. The force of concentrated bodyweight under these bony prominences causes intensified and sustained cell and tissue deformations which compromise cell integrity, transport function, leading to cell death and eventually, to massive tissue death *[Figure 1]*. Since these PUs may not form initially on skin, even the best nursing skills and diligence relating to tissue care will be ineffective in achieving timely detection of sub-epidermal injuries. In other words, without an insight into deep-tissue health status and viability, there is no feasible way for a nurse relying on current risk assessment scales, visual skin assessments (VSAs) or physical palpation examinations (including where the nurse is attempting to probe skin surface temperature changes) to detect the developing injury in a timely

way (Takahashi et al, 2017; Gefen, 2018; Gefen and Ross, 2020; Gefen et al, 2020). It is not surprising therefore that these deep PUs, which emerge at the skin surface only after considerable deeper tissue damage has already been caused, are the ones associated with the majority of the global expenditure on treating PUs (Gefen et al, 2020).

In terms of nursing time, VSAs cost approximately £6 per patient, per skin check session (Gefen et al, 2020). Accordingly, conducting routine VSAs for each and every hospitalised patient is financially implausible and hence, regular VSAs are only conducted for patients who are determined to be at-risk for PUs based on the outcome of a risk assessment tool upon admission. If VSAs would have been hypothetically implemented for all patients routinely during their hospitalisation period, the result will be spending of many billions of pounds sterling on patients who will never be at a meaningful risk, as only a small fraction are at a true risk for PUs. Indeed, current risk assessments typically classify up to two of five of all hospitalised patients as being at a high risk for developing PUs, but the sensitivity and specificity of risk assessments is often criticised, given the unacceptable extent and rate of deaths from PUs and the total expenditure on PUs (Oliveira et al, 2017; Padula and Delarmente, 2019; Gefen et al, 2020).

Importantly, even for patients correctly identified to be at-risk by risk assessments, who receive a high-specification support surface, as well as other best-practice prophylactic interventions and repositioning, nursing staff will never be able to detect a deep tissue injury (DTI) evolving under intact skin by means of the VSAs. The VSAs currently used in practice are only able to detect the DTI once the damage has reached the skin, which is clearly too late. This simple logical flaw in classic PUP strategies points to the true barrier to effective PUP and to the associated cost reductions: the lack of a reliable technology, based on solid physical and physiological foundations, to evaluate the tissue health of patients under an apparently normal skin at specific anatomies.

Another common misconception hindering the timely clinical diagnosis of PUs is that patients who develop PUs will complain about discomfort or pain. Pain is not a good predictor of PUs, particularly where there is an impaired sensation due to central or peripheral neural damage caused by injury or disease or anaesthetics, sedation or any medications which affect sensation. Pain only becomes relevant where a person is able to sense (but not necessarily move), which is not the case for the majority of the at-risk patients. For example, one (relatively rare) condition where discomfort or pain may predict a later onset of a PU would be a locked-in syndrome (pseudocoma) where a person loses their ability to move, but can still sense discomfort (Gefen and Soppi, 2020).

The SEM Scanner's mode of action

The SEM Scanner *[Figure 1]* measures the biocapacitance of the local skin and subdermal tissues under its sensor. As mentioned above, the biocapacitance is a temporal and spatial physical property of the tested tissue region, and more specifically, a bioelectrical property that is the ratio of the change in an electric charge in the scanned tissue region to the corresponding change in its electric potential (Gefen, 2018; Peko Cohen and Gefen, 2019; Ross and Gefen, 2019; Gefen and Ross, 2020).

A large self-biocapacitance of a tissue region indicates that this tissue region is able to hold more electric charge at a given voltage than a different region with a low self biocapacitance. The biocapacitance is a function of the geometry and architecture, which in the context of a SEM Scanner measurement is the area of the sensor of the device and the composition of the examined soft tissues in the immediate vicinity of the sensor, especially the dielectric properties of these tissues. For tissues, as with many dielectric materials, the biocapacitance is independent of the electrical potential applied by the SEM sensor. The biocapacitance of tissues is, however, variable and highly sensitive to the interstitial water content of the tissue (Gefen, 2018; Peko Cohen and Gefen, 2019; Ross and Gefen, 2019; Gefen and Ross, 2020).

The dielectric constant of water (which is approximately 80) is 10 to 20-times greater than that of all solid tissue components, e.g. collagen and elastin. In a certain anatomical region, with a given anatomical configuration, the SEM Scanner reading of biocapacitance will be predominantly affected by the dielectric tissue properties, which are, in turn, highly sensitive to the amount of water in the examined tissues. Accordingly, any inflammation-related increase in the permeability of the vascular and/or lymphatic walls will almost immediately be measureable due to its impact on the effective dielectric property of the affected tissues. Hence, the tissue biocapacitance will increase rapidly and dramatically even if the inflammatory response has just been initiated and despite visible (clinical) signs of it have not developed yet (Gefen, 2018; Peko Cohen and Gefen, 2019; Ross and Gefen, 2019; Gefen and Ross, 2020).

The SEM Scanner reports the level of biocapacitance of a tissue site as a non-

dimensional 'SEM value.' A comparison of the SEM values at the inflamed tissue site with those from adjacent, healthy tissue sites will identify the maximum difference between the SEM values, which is called the 'SEM-delta.' The greater the SEM-delta, the greater the extent of the developing inflammatory oedema and, therefore, the potential tissue damage to be expected at the scanned site. Indeed, in our published work, we could identify the formation of a heel PU in a patient under their intact skin (i.e. a heel DTI) through a consistent rise in the SEM-delta readings at the examined heel, 2 days before VSA indicated tissue damage and importantly, 3 days before the appearance of a hypoechoic lesion demonstrating the fully-developed macroscopic oedema in an ultrasound examination of that same heel (Gefen and Gershon, 2018). This is strong evidence of the detective power of the SEM Scanner in identifying the forming oedema under a spotless skin, already at the initial, microscopic phase of the oedematous development.

The SEM-delta is an objective, quantitative and standardised reading of the tissue health conditions, wherein a low SEM-delta indicates healthy tissue and a high SEM delta points to a local inflammation as a result of localised cell and tissue death. In particular, a trend of increase in SEM-delta values acquired at a common body site over time (i.e. from one day to another) may indicate an increasing, spreading inflammation that is the response to an ongoing tissue degradation process. What is noteworthy is that if there is a condition of systemic oedema, e.g. lymphoedema or heart or kidney dysfunction, the SEM values acquired at adjacent points will be similar and hence, the SEM-delta would be low. Accordingly, selection of the SEM-delta measure (rather than the individual SEM values) allows to distinguish a localized inflammatory process which most likely indicates a forming PU from any systemic increase in interstitial fluid contents, either normal or abnormal (Ross and Gefen, 2019; Gefen and Ross, 2020).

Using laboratory bioengineering phantoms of soft tissues in organs (the head and heels), the author and his research group have demonstrated in their published work (Peko and Gefen, 2019; 2020) that indeed, the SEM Scanner is able to detect intra-tissue fluid content changes that are as small as 1 millilitre and that the SEM-delta reading is sensitive to these changes. The latter findings were shown to be robust and reproducible for both the SEM-200 (first generation) model and the new SEM-250 (second generation) Scanner model (Peko and Gefen, 2019; 2020).

The clinical efficacy of the SEM Scanner

It is a striking fact that the SEM Scanner technology has been tested in clinical trials more than any other emerging preventative/diagnostic technology in the PU arena, which is known to the author. Specifically, there are multiple clinical studies published in the peer-reviewed wound care literature, which reported a significant diagnostic value of the SEM Scanner, leading to improved health care and reduction in treatment costs post implementation of the device in the care practice. This published literature is reviewed in the work of the author, which is cited here and in particular, in Gefen and Gershon (2018). One example from the latter paper is given below, to demonstrate the clinical importance, applicability and usefulness of the SEM Scanner in different clinical settings.

A clinical study was conducted to evaluate consistency between the SEM Scanner and ultrasound examinations of suspected deep PUs under intact skin, known as DTIs. Specifically, using an observational, prospective cohort study design, patients >55 years of age were recruited (Gefen and Gershon, 2018). In addition to SEM Scanner measurements, conventional VSAs, as well as ultrasound assessments were further performed. These examinations were conducted daily for a minimum of 3 and maximum of 10 consecutive days following patient enrollments. The ultrasound results were considered indicative of a DTI if hypoechoic lesions were present in the acquired images. The SEM Scanner readings were considered abnormal when the SEM-delta at a specific body region (sacrum or each of the heels) was equal or greater than 0.6 for at least 2 consecutive days.

Boolean analysis was utilised to systematically determine the consistency between the ultrasound and SEM Scanner readings where DTI was the clinical judgment. Among the 15 participants (10 of whom were women, mean age 74 ± 10.9 years), which were, in general, a nursing home population at a high risk for PUs, there was consistent agreement between the SEM Scanner readings and ultrasound when DTIs existed. Noteworthy is a case of a patient, which has been reported in another paper (Gefen and Gershon, 2018), where the patient developed a heel DTI during the study. Their SEM Scanner readings in that case were abnormal 2 days before VSA indicated tissue damage and 3 days before the appearance of a hypoechoic lesion in the ultrasound.

Given our current aetiological knowledge, the ability of the SEM Scanner to detect the injury at such an early stage, prior to it being visible on the skin or even detectable under the skin by means of ultrasound, is due to the fact that the SEM Scanner targets early, microscopic damage associated with

inflammation, whereas both ultrasound and VSAs document existing, macroscopic structural damage to tissues *[Figure 1]*. It is not surprising therefore that with respect to subdermal tissue damage or DTIs, ultrasound and SEM Scanner results in Gefen and Gershon (2018) were similar. Moreover, in the evolving DTI case monitored during the aforementioned study, the SEM Scanner detected a lesion earlier than the ultrasound.

As per the medical claims made by the manufacturer, the SEM Scanner is currently being suggested as an adjunct to VSAs, not as a replacement of these conservative manual examinations. Despite the common conception, there is no point in validating the SEM Scanner measurements against the VSAs conducted in a medical facility where the SEM Scanner is considered for use, since VSAs document existing macroscopic structural tissue damage, whereas the SEM Scanner detects early, microscopic-scale damage. The latter event occurs at an earlier time point on the timeline of the PU damage cascade and so, the technology-aided SEM-delta readings should always be abnormally elevated prior to a positive (and subjective) VSA diagnosis, as in the above example Gefen and Gershon (2018) study. Indeed, a large volume of other, independent clinical studies have been reported in the literature and are reviewed in the published work of the author; all of these consistently demonstrated the early-detection feature of the SEM Scanner, which is not surprising based on the known PU aetiology as reported in the 2019 International Clinical Guideline.

Cost-benefit analyses of the SEM Scanner

In collaboration with the manufacturer and a panel of external expert health economists, the author has published a comprehensive cost-benefit analysis focusing on the financial savings associated with implementation of the SEM Scanner technology in hospital settings (Gefen et al, 2020). The latter paper is, in fact, the first ever to report the predicted savings that a diagnostic PUP technology may achieve. Specifically, in the above study, implementation of the SEM Scanner technology as an adjunct to the current VSA standard of care practice has been tested using probabilistic cost-benefit modelling. The author developed a decision-tree model type and Monte Carlo simulations representing the various pathways of care that 10,000 patients, admitted to NHS hospitals in the United Kingdom, may experience.

The author tested two alternate acute hospital scenarios, of lower (1.6%, categories 1–4) and higher (6.3%, categories 1–4) PU incidence rates. Under a conservative range of assumptions and input parameters, we found that implementation of the SEM Scanner technology as an adjunct to the current standard of care is highly likely to lead to significant financial benefits and cost savings. For example, our modelling demonstrated that the expected saving per patient, by routine implementation of the SEM Scanner in care facilities with the above low and high incidence rates, is £15.23 and £80.68 per admission, respectively. For an average UK Trust with 40,802 admissions (excluding day cases) per annum, the estimated total financial savings from implementing the SEM Scanner, using the assumptions and inputs set out here, would range between £0.6m to £3.3m per annum. These cost reductions, even under our conservative modelling assumptions, reflect the above explained (i) detection and treatment of anatomy-specific, non-visible tissue damage which is not possible without the SEM Scanner, (ii) higher rates of detection of category 1 PUs than possible without the technological aid of the SEM Scanner, and (iii) avoidance of some unnecessary treatments of patients without PUs, due to higher confidence by clinicians to rule out PUs with the SEM Scanner readings than without.

The fundamental basis of the above cost-benefit analyses is that patients are in a given PU-state (no damage, sub-clinical damage, Stage 1 or later damage) and, accordingly, the author modelled changes in the probability of correct detection of that state with and without the SEM Scanner. Savings from the aforementioned factors (i) and (ii) arise from earlier and more sensitive diagnostic accuracy of skin and tissue deterioration in the earliest phases of damage, as indicated by the SEM Scanner as an adjunct to VSA, however, the author and colleagues assumed that the efficacy of treatments remains the same as without the SEM Scanner in place. In other words, these considerable savings are from properly including patients with developing but invisible PUs into the care pathway and properly excluding patients without developing PUs from the care pathway who would otherwise have been deemed at risk (which is saving point no. iii above). Accordingly, the work reported in Gefen et al (2020) clearly demonstrates that wide implementation of the SEM Scanner technology in the UK, as well as in other countries, is well justified from a financial perspective and will lead to cost savings. While more research is in need to further establish the cost-benefits of the SEM Scanner, in particular in specific clinical settings, e.g. geriatric or rehabilitation centers,

no other diagnostic PUP technology has ever been investigated so rigorously in breadth and depth as the SEM Scanner was (Gefen et al, 2020) for its financial justification.

Bioengineering evaluation of the second generation SEM Scanner

In the second-half of 2019, Bruin Biometrics LLC introduced a 2nd-generation SEM Scanner model called Provizio™ SEM Scanner. This new version of the SEM Scanner is elegantly designed to include an improved user interface and better wireless connectivity. Peko and Gefen (2020) have conducted a bioengineering study to evaluate the sensitivity of Provizio™ SEM Scanner in identifying fluid content changes in laboratory phantoms of a human heel and skull/face, relatively to their 1st-generation SEM measurement device (also known as the SEM 200 model). They performed SEM measurements on the aforementioned physical phantoms simulating the head and heels of an examined patient, as described in their previously published work (Peko and Gefen, 2019).

Following the experimental protocol detailed in the latter publication, they injected 1ml ('reference'), 2, 3 and 4ml of water to the 'soft tissue' substitutes in each phantom and location. Next, Peko and Gefen (2019) calculated the corresponding SEM-delta, which quantifies the dimensionless difference in these experiments between the biocapacitance properties of the 'soft tissues' at the reference (1ml) site versus each of the 2, 3 and 4ml sites simulating inflammatory oedema. Finally, they conducted Bland-Altman (B&A) statistical analyses to determine the levels of statistical agreement between the Provizio™ SEM Scanner and previous (200 model SEM Scanner) device readings, for each phantom type and location.

Consistent with their published work concerning the 200 model of the SEM Scanner (Peko and Gefen, 2019), the Peko and Gefen (2020) studies of the Provizio™ SEM Scanner demonstrated that this device is sensitive enough to detect water content variations that were as small as 1 ml. Furthermore, the above B&A analyses established that any differences in readings between the Provizio™ and 200 model of the SEM Scanner were clinically negligible. In addition, these differences did not tend to become larger as the mean of the two device readings increased, which indicates stability and precision of both devices. Hence, the Provizio SEM Scanner was shown to perform identically to the 200 model SEM Scanner in laboratory experiments evaluating its sensitivity to small water content variations within physical phantoms of human body tissues (Peko and Gefen, 2020).

Furthermore, the Provizio SEM Scanner is also substantially more compact and user-friendly, has a smaller sensor which facilitates easier access to small and/or curved body sites, and it features improved connectivity with other medical data systems in hospital settings (Peko and Gefen, 2020).

Summary and conclusions

The BBI LLC (Bruin Biometrics) SEM Scanner technology addresses a major and unmet medical need in prevention of PUs and supports healthcare professionals who are currently not supported by any other technology to aid in their clinical decision-making with regards to the PU risk at specific anatomical sites of individuals. The SEM Scanner is built upon well-established physiological and biophysical principles, which were explained here. The SEM Scanner is targeting a specific stage in the PU injury cascade in which there is a window of opportunity for detection of a localised change in the biocapacitance property of a tissue region at risk. Such change in the local tissue biocapacitance would indicate inflammatory micro-damage that may still be reversible *[Figure 1]*. This is in stark contrast with the conventional clinical thinking of documenting an existing macroscopic, structural tissue damage, which occurs much later in the injury spiral (typically days after the onset of the micro-damage) and only then, that structural damage can be spotted by VSAs or ultrasound examinations.

Published literature by the author and by others clearly shows that the above theoretical basis is well supported by clinical data, including laboratory bioengineering work as well as large clinical trials. There is no current feasible technological alternative to the use of biocapacitance, the biophysical measure used by the SEM Scanner technology, for detecting the inflammatory stage of cell and tissue damage in PUs. The benefits of a quantitative, standardised and objective risk assessment and early detection of PUs using a technological tool — the SEM Scanner — to aid and support the currently subjective process of PU identification are significant, and the risks in using the device, if any, are negligible. The SEM Scanner technology has proven cost-effectiveness, demonstrated in comprehensive published work, which has been summarised above. Risk assessment and early-detection

are the two essential foundations for effective PUP, which can finally be based on modern and relevant medical technology — the SEM Scanner — rather than just the art and subjective clinical skills. WINT

References

Cutting K, Gefen A (2019) *Made Easy: PolyMem and Countering Inflammation*. Wounds International: London. Available at: https://www.woundsinternational.com/resources/details/made-easy-polymem-and-countering-inflammation (accessed 08.09.2020)

Gefen A, Gershon S (2018) An observational, prospective cohort pilot study to compare the use of subepidermal moisture measurements versus ultrasound and visual skin assessments for early detection of pressure injury. *Ostomy Wound Manage* 64(9): 12–27

Gefen A (2018) The sub-epidermal moisture scanner: The principles of pressure injury prevention us-ing novel early detection technology. *Wounds International* 9(3): 10–5

Gefen A, Brienza D, Edsberg L et al (2019) *The etiology of pressure injuries. In: Prevention and Treatment of Pressure Ulcers/Injuries*. European Pressure Ulcer Advisory Panel (EPUAP), National Pressure Injury Advisory Panel (NPIAP) and the Pan Pacific Pressure Injury Alliance (PPPIA) (3rd edn) EPUAP-NPIAP-PPPIA: Westford MA, USA.

Gefen A, Kolsi J, King T, Grainger S, Burns M (2020) Modelling the cost-benefits arising from technology-aided early detection of pressure ulcers. *Wounds International* 11(1): 22–9

Gefen A, Ross G (2020) The subepidermal moisture scanner: the technology explained. *J Wound Care* 29(Sup2c): S10–S6

Gefen A, Ousey K (2020) Update to device-related pressure ulcers: SECURE prevention. COVID-19, face masks and skin damage. *J Wound Care* 29(5): 245–59

Gefen A, Soppi E (2020) What is new in our understanding of pressure injuries: the inextricable association between sustained tissue deformations and pain and the role of the support surface. *Wound Practice and Research* 28(2): 84–91

Oliveira AL, Moore Z, O Connor T, Patton D (2017) Accuracy of ultrasound, thermography and subepidermal moisture in predicting pressure ulcers: a systematic review. *J Wound Care* 26(5): 199–215

Padula WV, Delarmente BA (2019) The national cost of hospital-acquired pressure injuries in the United States. *Int Wound J* 16(3): 634–40

Peko Cohen L, Gefen A (2019) Phantom testing of the sensitivity and precision of a sub-epidermal moisture scanner. *Int Wound J* 16(4): 979–88

Peko L, Gefen A (2020) Sensitivity and laboratory performances of a second-generation sub-epidermal moisture measurement device. *Int Wound J* 17(3): 864–7

Ross G, Gefen A (2019) Assessment of sub-epidermal moisture by direct measurement of tissue bio-capacitance. *Med Eng Phys* 73: 92–9

Takahashi Y, Mizokami F, Isogai Z (2017) Palpation for pressure ulcers: examining the bony promi-nence and physical properties of the wound. *Int Wound J* 14(6): 1402–4

Predictive validity of Amit Jain's screening tool in estimating the risk of complications in diabetic foot — a retrospective cohort study

Authors
Amit Kumar C Jain and Apoorva HC

Aim: The aim of this study was to assess the new Amit Jain's linear foot test (LFT) screening tool (scored) in estimating the risk of developing complications in the foot in diabetes. **Method and materials:** All patients who were seen at Amit Jain's Institute of Diabetic Foot and Wound Care at Brindhavvan Areion Hospital, Bengaluru, India, were included in this study. The study period was from January 15, 2019 to July 15, 2019 and patients were followed until June 15, 2020. Statistical analysis was done using SPSS 25 and *P* value of less than 0.05 was considered significant. The study was approved by ethics committee. **Results:** Fifty-two patients were included in the study: 63.5% were males. Only 10 patients (19.23%) had diabetes of more than 20 years' duration. Around 84.6% had underlying neuropathy and 21.2% had non-palpable pulses. Jain's LFT screening tool was used to estimate the risk of developing complications in diabetic foot; 53.8% of the patients had a score of 2 and 71.2% belonged to high-risk category. Within the high-risk group, 27% of the patients developed complications within 1 year. The sensitivity of this score was 100% and area under curve was 0.704 showing that this scoring system is clinically useful. **Conclusion:** The new Amit Jain's scoring system for the LFT screening tool shows a good sensitivity and area under curve. Patients in the high-risk category are at significant risk of developing complications in the foot within 1 year and they should be followed up periodically. This new scoring to the screening tool increases the utility of the Amit Jain's triple assessment and opens further prospects for research of the tool.

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It is estimated that by 2045, there will be 628 million people living with diabetes (Abdisaa et al, 2020). Diabetes and its complications are growing rapidly globally, and the increase is higher in Asian and African countries, leading to huge burden on healthcare system (Rowley et al, 2017; Wang et al, 2018). One serious complication of diabetes is diabetic foot ulceration, which leads to an increase in morbidity and mortality, thereby decreasing the quality of life, especially after amputation (Abdisaa et al, 2020). Prior to ulceration, the feet of people with diabetes often have underlying problems, such as neuropathy, ischaemia or deformities.

Trauma to the insensate foot often leads to entry of bacteria (Zubair, 2020). Furthermore, loss of sensation leads to higher pressure areas on plantar aspects leading to callus formation and ulceration, which could lead to amputation (Mishra, 2017).

It is well known that 15% of patients with diabetes are likely to develop ulcers in the foot during their lifetime with 5% of people with diabetes developing foot ulcers annually and more than half of these foot ulcers going on to become infected (Alonso-Fernandex et al, 2014; Jain and Gopal, 2020). As many as 7–20% of these will result in some form of lower-limb amputation (Alonso-Fernandex et al, 2014).

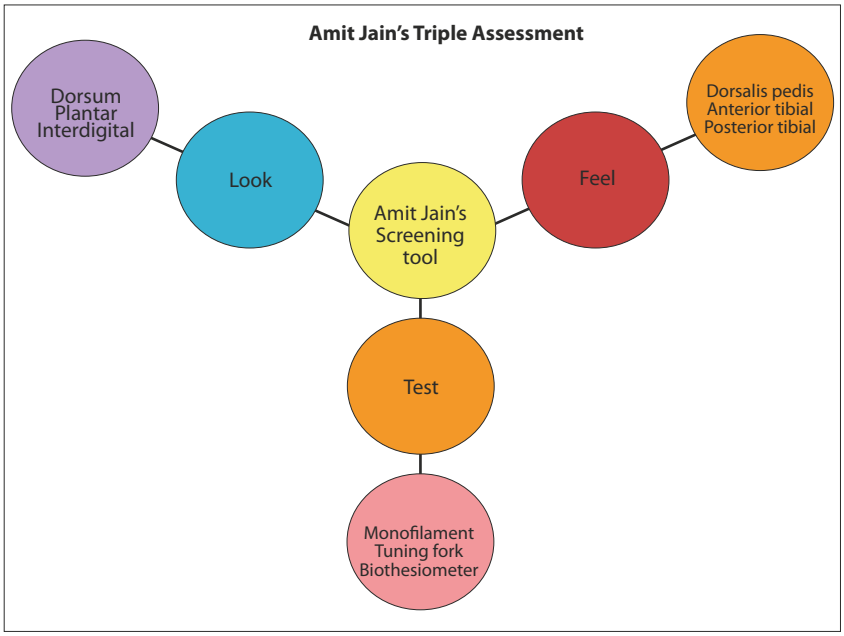

Figure 1 (above). Amit Jain's screening tool for diabetic foot.

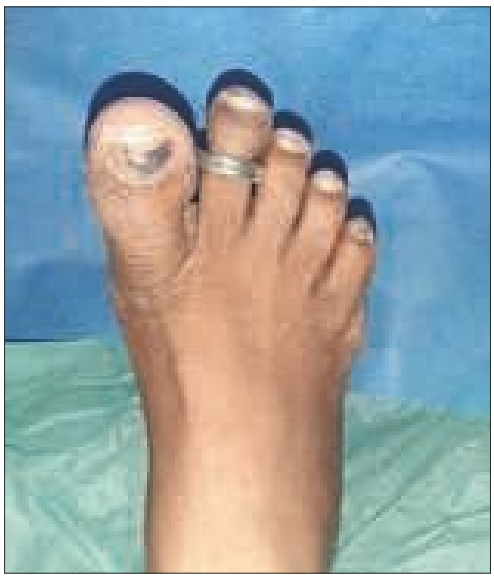

Figure 2 (right). Dorsum of the foot — Look component.

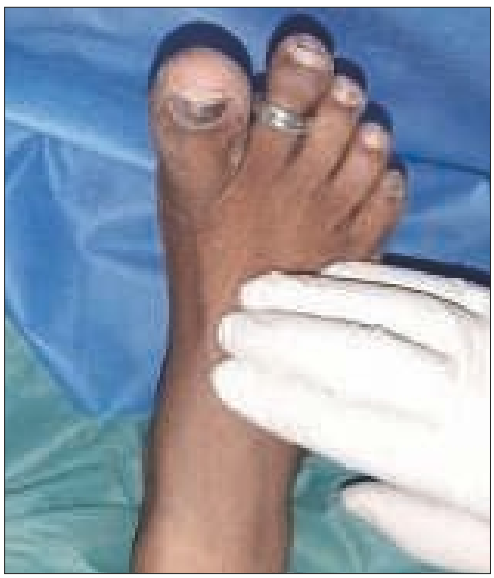

Figure 3 (right). Palpation of dorsalis pedis artery — Feel component.

In a recent study from India (Jain and Santosh, 2020), around 40% of diabetic foot patients presenting to hospital will require an amputation. The problem does not end here. These patients are prone for readmissions, recurrence of problem or re-amputations (Galea et al, 2009; Ang et al, 2013; Choi et al, 2014). It is well known that ulcer recurrence is high within 1 year after healing (Gale et al, 2009; Khalifa, 2018).

Foot amputations in people with diabetes can be prevented by identifying high-risk groups and this can be achieved through screening (Nanwani et al, 2019; Abdisaa et al, 2020; Jain and Gopal, 2020). Despite knowing that 75–80% of diabetic foot complications and amputations can be prevented by screening and education, there are many studies that show screening is omitted by some healthcare professionals (Jain and Gopal, 2020). A hospital-based study from Karachi, Pakistan, by Kumar et al (2016) showed that only 13.5% of the feet of people with diabetes were screened.

Various novel methods of foot evaluations/screening/campaign have been developed over years and they include comprehensive foot examination, 3-minute foot examination, Inlow's 60-second screening tool, simplified 60-second foot screen (Boulton, 2008; Sibbald et al, 2012, Kunhe et al, 2013; Miller et al, 2014; Stang et al, 2014; Jain, 2017).

Each of the diabetic screening tools has its own merits. The comprehensive foot examination and 3-minute foot exam are not screening methods, but are detailed foot evaluation methods and often require charts to remember. Inlow's 60-second screening tool and simplified 60-second foot screen also requires a chart to remember the parameters and often can take longer if performed by non-specialists and other healthcare professionals.

A new screening tool, known as Amit Jain's triple assessment for diabetic foot, was proposed by the authors recently *[Figure 1]*. It is also known as 'Amit Jain's 10–20 second screening tool/Linear foot test' (Santosh and Jain, 2018; Jain et al, 2018; Jain, 2020; Jain and Gopal, 2020). This screening tool can be easily performed by any healthcare professionals, including family physicians who are primary care givers. This screening tool has three components namely the Look, the Feel and the Test component.

The Look component aims to identify infection/ulcer and pre-ulcerative lesion like callus. The areas of the foot that needs to be seen are the dorsum *[Figure 2]*, interdigital/

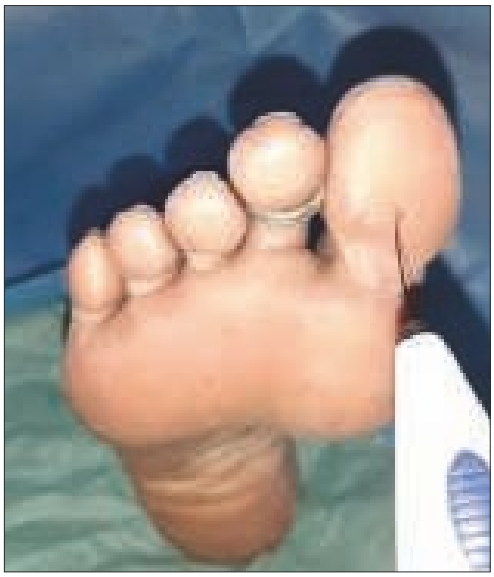

Figure 4. Monofilament testing — Test component.

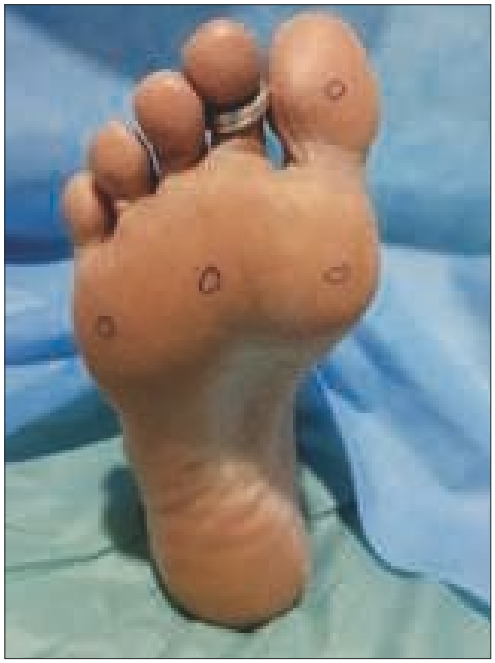

Figure 5. Common sites on foot for neuropathy testing.

web space and the plantar surface. The Feel component aims to assess the blood supply to the foot. One can palpate the dorsalis pedis/anterior tibial artery *[Figure 3]* and the posterior tibial artery. The Test component aims to assess the sensation of the foot addressing the neuropathic diabetic foot (Jain et al, 2018; Jain et al, 2019). One can use commonly suggested instruments like Semmes monofilament *[Figure 4]*, Tuning fork, vibratip and biothesiometer (Jain et al 2019). The monofilament test determines the touch sensation of the foot, whereas the tuning fork or the biothesiometer assesses the vibration sensation. One is advised to check at least three to four sites on the foot *[Figure 5]* and the commonly tested sites are the pulp of great toe, first and the fifth MTP region of the foot (Jain et al, 2019). A study by Santosh et al (2018) on the Amit Jain's screening tool revealed that only 7.7% of the feet of people with diabetes were screened, while just 6.2% were inspected, 1.5% pulses were checked and none of the patients had sensation assessed (Santosh et al, 2018).

Later, scores *[Table 1]* were added to each component of this new screening tool (Jain, 2020). This new Amit Jain's scoring system has a maximum score of 3. Patients with a score of 0 or 1 belong to low-risk categories, whereas those scoring 2 and 3 are in high-risk categories *[Figure 6]*. This study aimed to determine the predictive validity of this new Amit Jain's scoring system for diabetic foot screening.

Methods and materials

All patients who were seen or screened at Amit Jain's Institute for Diabetic Foot and Wound Care at Brindhavvan Areion hospital, Bengaluru, India, from January 15 to July 15, 2019 were included in this study and were followed until June 2020 (at the same centre) to determine whether or not there was an occurrence of new complications. Outpatient records, operation theatre register and emergency room records were reviewed. All the patients who underwent surgery from January to July 2019 were included in the study. Patients who operated elsewhere during the above period or were not followed up were not included. The study was approved by Institutional ethics committee (RRMCH-IEC/22/2020-21).

Demographic data collected included age, sex, diabetes duration, presence of comorbidities like hypertension, chronic kidney disease and ischaemic heart disease were collected from case notes, admission sheets, operation register and discharge summaries. The adequacy of foot circulation was checked clinically by palpating the pulses. Only in cases where foot oedema prevented pulses from being palpated was a handheld Doppler or duplex ultrasound used. The presence of neuropathy was determined with 10 g monofilament, vibratip or Biothesiometer. The authors usually use a combination of monofilament and vibratip and, in some cases, Biothesiometer. Patients were subsequently scored. All patients with scores of 0 and 1 were deemed low risk (Group A), while patients scoring 2 and 3 were considered high risk (Group B).

Statistical analysis

Both descriptive and inferential statistics were measured in this study. Descriptive statistics are reported using mean and SD for the

Table 1. Amit Jain's scoring system for the LFT screening tool.			
Parameters	**Description**		**Score**
Look	Any infection/ulcer or pre-ulcer causing pathology-like callus	No	0
		Yes	1
Feel	Pulses of foot – palpable or not	Yes	0
		No	1
Test	Sensation of the foot – present or not	Yes	0
		No	1
The maximum score is 3			

Figure 6. Risk categorisation of the new Amit Jain's scoring system.

normally distributed continuous variables, for the variables that are not normally distributed were median with 25th and 75th percentiles. Categorical variables were reported as number and percentage. Student t test (two tailed) has been used to find the significance of study parameters on continuous scale between two groups (Inter group analysis) on metric parameters. The Chi-square/Fisher Exact test has been used to find the significance of study parameters on categorical scale between two or more groups. Logistic regression analysis was performed to find the factors associated with the high-risk category. Adjusted odds ratio and 95% confidence interval was reported. The discriminative power of the prediction of score was assessed by calculating the area under the receiver operating characteristic (ROC) curves (AUC). Sensitivity, specificity, positive predictive and negative predictive values were reported. A *P* value less than 0.05 was considered statistically significant. All the analyses were performed using SPSS version 25.0 (IBM Corp-2017).

Results

A total of 52 patients were included in this pilot study. The mean age was 60.43 ± 11.27 years. Males accounted for the majority of the cases (63.5%). A total of 19.23% of patients had diabetes mellitus of more than 20 years' duration *[Table 2]*. No statistical significant difference in age, gender or duration of diabetes mellitus was found between the groups.

Comorbidities, such as hypertension, ischaemic heart disease or chronic kidney disease were present in 63.5% of the sample. Hypertension was common and seen in 53.8%, chronic kidney disease was seen in

Table 2. Patient demographics.				
Variables	**Number (*n*=52)**		**Total (percentage)**	***P* value**
	Group A (low risk)	**Group B (high risk)**		
Age (years)	60.73 ± 10.14	60.38 ± 11.96		0.184
Gender				
- Male	8 (53.5%)	25 (67.6%)	33 (63.5%)	0.334
- Female	7 (46.7%)	12 (32.4%)	19 (36.5%)	
Duration of diabetes mellitus (years)	13.8 ± 7.37	15.32 ± 7.98		0.852
<10 years	6 (40%)	12 (32.4%)	18 (34.62%)	0.756
11–20 years	7 (46.7%)	17 (45.9%)	24 (46.15%)	
>20 years	2 (13.3%)	8 (21.6%)	10 (19.23%)	

3.8% and 21.2% of patients had ischaemic heart disease. Using the three components, 71.2% of the patients had some lesions (Look component), 21.2% of patients did not have palpable pulses (Feel component) and 84.6% had underlying neuropathy (Test component) *[Table 3]*. The majority of the patients were in high-risk category (71.2%). A total of 53.8% of the patients had 2 as the highest score. Ten patients (19.2%) *[Table 4]* presented with some complications within the follow-up year. Four patients presented with ulceration, two with calluses, two with abscess, one wet gangrene and one with cellulitis. The authors compared the variables with diabetes duration as it is well known that diabetes of a long duration can result in neuropathy, as well as peripheral vascular disease.

No association was seen between risk categories, complications, the Look component and the Test component with duration of diabetes duration *[Table 5]*, although significant association was noted between the Feel component (palpable pulses) and diabetes duration (*P*=0.041). Only 18.2% of patients who had pulses absent had diabetes of less than 10 years' duration, whereas 45.5% of patients whose pulses were not palpable had diabetes of more than 20 years. Logistic regression analysis revealed that comorbidity presence was the only significant factor associated with the high-risk category. The presence of any comorbidity was 4.3 times [AOR = 4.3, 95% C.I. (1.01, 19.1)] more likely to be in the high-risk category as compared to patients with no comorbidity adjusted for age, gender and duration of diabetes.

Table 6 shows the sensitivity, specificity, positive predictive (PPV) and negative predictive values (NPV). None of the patients in the low-risk category developed complications whereas 10 patients (27%) in high-risk category developed complications within a year (*P*=0.046, significant). Based on the ROC curve analysis *[Figure 7]*, the Amit Jain's LFT score achieved AUC of 0.704. The

Table 3. Patient screening variables.		
Screening variables	**Number of patients (total=52)**	**Percentage (%)**
Look		
0	15	28.8
1	37	71.2
Feel		
0	41	78.8
1	11	21.2
Test		
0	8	15.4
1	44	84.6

Table 4. Patient variables.		
Variables	**Number of patients (total=52)**	**Percentage (%)**
Total scores		
Score 0	7	13.5
Score 1	8	15.4
Score 2	28	53.8
Score 3	9	17.3
Group		
Low-risk category	15	28.8
High-risk category	37	71.2
Complications within 1 year		
Yes	10	19.2
No	42	80.8

Table 5. Different patient variables with diabetes duration.				
Variables	**Diabetes duration**			***P* value**
	<10 years	**10–20 years**	**>20 years**	
Look				
0	5 (33.3)	6 (40)	4 (26.7)	0.674
1	13 (35.1)	18 (48.6)	6 (16.2)	
Feel				
0	16 (39)	20 (48.8)	5 (12.2)	0.041
1	2 (18.2)	4 (36.4)	5 (45.5)	
Test				
0	4 (50)	3 (37.5)	1 (12.5)	0.600
1	14 (31.8)	21 (47.7)	9 (20.5)	
Complications within 1 year				
Yes	2 (20)	5 (50)	3 (30)	0.461
No	16 (38.1)	19 (45.2)	7 (16.7)	
Risk category				
Low-risk	6 (40)	7 (46.7)	2 (13.3)	0.756
High-risk	12 (32.4)	17 (45.9)	8 (21.6)	

Table 6. Sensitivity, specificity, positive predictive (PPV) and negative predictive (NPV) values.							
Risk category	**Complications within 1 year**			***P* value**	**Sensitivity**	**Specificity**	**PPV**	**NPV**
	Yes	No	Total	0.046	100%	36%	27%	100%
Low-risk	0 (0)	15 (100)	15 (100)					
High-risk	10 (27)	27 (73)	37 (100)					

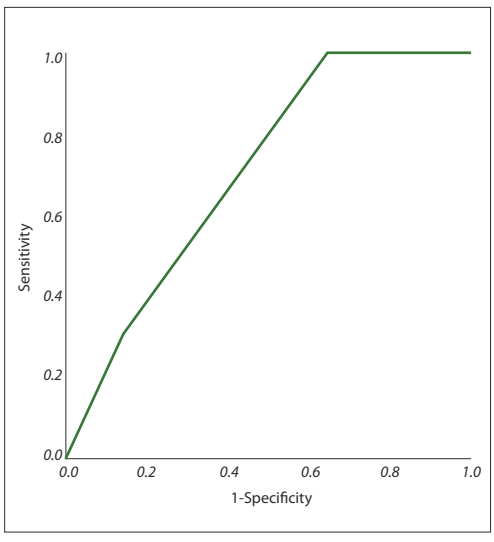

Figure 7. Receiver operating characteristic (ROC) curve for Amit Jain's LFT scoring.

predictive validity of the Amit Jain's LFT screening score shows that a score of 2 (AUC of the ROC was 0.704) and above can predict the complications within a year (*P*=0.047) and is clinically very useful. People in these category should be taught to take care of their feet to avoid the complications.

Discussion

No risk screening tool is effective if it is not done. The ease of using a tool makes it more likely to be used. The assessment of diabetic limbs should include an assessment of skin injury (for example, callus, ulceration), perfusion (pulses) and neuropathy. Early screening allows for education of the patient on how to avoid injury to the feet and how to inspect the foot daily. The tool tested in this study was easy to use and score. It also predicted the risk of complications of the diabetic foot accurately. In this study, we noticed that 27% of patients who were in the high-risk category [AJ score 2 and 3], developed some form of foot complications within 1 year. These complications collectively studied by us ranged from an ulcer to development of abscess, cellulitis, necrotising fasciitis, etc.

The recurrent problems will add huge financial burden to already financially squeezed patients with a diabetic foot/feet and the situation is worse if patient is uninsured and is in developing and underdeveloped countries. It is recommended by the authors that individuals in the high-risk category should be followed at least quarterly to semi-annually and those in the low-risk category should be followed semi-annually to annually in an attempt to reduce

diabetic foot complications.

The limitation of this study is that the sample size was small. Further, the authors did not study patients lost to follow-up.

Conclusion

The Amit Jain's LFT screening tool is a new simple screening tool for diabetic foot that addresses the triopathy efficiently and is quick to complete with minimum resources. The patients can be effectively categorised into the low-risk group and high-risk group. This new scoring system for screening has good predictive ability with sensitivity of 100%. Further studies are needed on this new LFT scoring system for diabetic foot screening. WINT

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References

Abdisaa D, Adugna T, Gerema U, Dereje D (2020) Prevalence of diabetic foot ulcer and associated factors among adult diabetic patients on follow-up clinic at Jimma Medica Centre, Southwest Ethiopia, 2019: an institutional based cross sectional study. *J Diabetes Res* 2020: 4106383

Alonso-Fernández M, Mediavilla-Bravo JJ, López-Simarro F et al (2014) Evaluation of diabetic foot screening in Primary Care. *Endocrinol Nutr* 61(6): 311–7

Ang CL, Lim YJ (2013) Recurrent admissions for diabetic foot complications. *Malays Orthop J* 7(2): 21–6

Boulton AJ, Armstrong DG, Albert SF, et al (2008) Comprehensive foot examination and risk assessment: a report of the task force of the foot care interest group of the American Diabetes Association, with endorsement by the American Association of Clinical Endocrinologists. *Diabetes Care* 31(8): 1679–85

Choi MSS, Jeon SB, Lee JH (2014) Predictive factors for successful limb salvage surgery in diabetic foot patients. *BMC Surg* 14: 113

Galea AM, Springett K, Bungay H et al (2009) Incidence and location of diabetic foot ulcer recurrence. *The Diabetic Foot Journal* 12(4): 181–6

Jain AKC (2017) Amit Jain's triple assessment for foot in diabetes - the simplest and the fastest new screening tool in the world. *IJMSCI* 4(6): 3015–9

Jain AKC (2020) Proposal of a scoring system to Amit Jain's screening tool for foot in diabetes. *SAR J Surg* 1(3): 17–9

Jain AKC, Apoorva HC, Kumar K (2019) Screening of diabetic foot through Amit Jain's triple assessment: A 10 to 20 second screening method. *Int J Orthod Sci* 5(2): 227–9

Jain AKC, Gopal S (2020) Comparing foot evaluation in hospitalized diabetic patients between surgeons, orthopedicians and physicians through Amit Jain's triple assessment. *East African Scholars J Med Sci* 3(5): 169–78

Jain A, Kumar K, Kumar H, Kumar S (2018) Amit Jain's triple assessment: a new screening method for the diabetic foot. *Diab Foot J Middle East* 4(1): 40–1

Jain AKC, Santosh MP (2020) To analyze type of surgery done, multi-disciplinary surgical procedure, antimicrobial used and post op care in patients with diabetic foot infections. *Int J Diab Research* 1(1): 23–7

Khalifa WA (2018) Risk factors for diabetic foot ulcer recurrence: A prospective 2-year follow-up study in Egypt. *Foot (Edinb)* 35: 11–5

Kuhnke JL, Botros M, Elliott J et al (2013) The case for diabetic foot screening. *Diabetic Foot Canada* 1(2): 8–14

Kumar D, Khan MU, Mobin A (2016) The awareness and practices of foot care in adult patients attending University hospital. *J Diabetes Metab* 7: 11

Miller JD, Carter E, Shih J et al (2014) The 3-minute diabetic foot exam. *J Fam Pract* 63(11): 646–56

Mishra SC, Chhatbar KC, Kashikar A, Mehndiratta A (2017) Diabetic foot. *BMJ* 359: j5064

Nanwani B, Shankar P, Kumar R, et al (2019) Risk Factors of Diabetic Foot Amputation in Pakistani Type II Diabetes Individuals. *Cureus* 11(6): e4795

Rowley WR, Bezold C, Arikan Y et al (2017) Diabetes 2030: Insights from Yesterday, Today and Future trends. *Popul Health Manag* 20(1): 6–12

Santosh MP, Jain AKC, Gopal S (2018) Determining foot evaluation done in diabetic inpatients admitted in medical wards and analyzing it through Amit Jain's triple assessment for foot in diabetes. *Int Surg J* 5(7): 2465–9

Sibbald RG, Ayello EA, Alavi A et al (2012) Screening for high risk diabetic foot: A 60 second tool. *Adv Skin Wound Care* 25(10): 465–70

Wang CY, Neil DL, Home P (2018) 2020 vision – An overview of prospects for diabetes management and prevention in the next decade. *Diabetes Res Clin Pract* 143: 101–12

Zubair M (2020) Prevalence and interrelationships of foot ulcer, risk-factors and antibioticresistance in foot ulcers in diabetic populations: a systematic review and meta-analysis. *World J Diabetes* 11(3): 78–89

The pathophysiological links between pressure ulcers and pain and the role of the support surface in mitigating both


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This article reviews the reported associations between the alleviation of sustained or excessive tissue deformation and mitigation of pressure ulcer (PU) risk or associated pain, with a specific focus on the role of the support surface. Three patient case studies are used to analyse relevant literature and demonstrate important links between aetiological factors for PUs, background diseases, perceptions of discomfort and pain, and the ability of an adequate support surface to provide relief. Taken together, the literature and case studies indicate that alleviation of sustained or excessive soft tissue deformation caused by weight-bearing forces — through adequate envelopment of the support surface — protects from PUs and also effectively relieves chronic pain.

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Pressure ulcers (PUs), or pressure injuries, result from sustained cell and tissue deformations (Gefen 2018, 2019; Gefen et al, 2019). Primary deformation-inflicted damage progresses over time and exacerbated by secondary inflammatory damage and tertiary ischaemic damage (Gefen 2018, 2019; Gefen et al, 2019). Tissue damage in PUs does not appear instantaneously but develops gradually from the cellular to the tissue level. It ultimately presents as skin breakdown or discolouration (typically purple or maroon marks) due to underlying tissue necrosis.

When lying in bed, the transfer of body weight forces to the support surface cause sustained soft tissue distortion and high concentrations of tissue stress, particularly under bony prominences where rigid and highly curved (almost 'sharp') bone surfaces come into contact with easily deformable soft (muscle, adipose or skin) tissues. High levels of tissue stress progressively damage the cytoskeleton, the complex protein scaffold that forms the structural framework of cells and supports the plasma membrane. Damage to the cytoskeleton leads to plasma membrane poration, which in turn compromises molecular transport across the cell membrane. The inability of a large number of cells to control molecular traffic causes collective loss of homeostasis, resulting in massive apoptotic cell death within minutes (Gefen 2008; Gefen and Weihs, 2016; Gefen et al, 2019, 2020). This triggers damaged and dead cells and nearby immune cells to release pro-inflammatory cytokines, such as interleukin-1α (IL-1α) and tumour necrosis factor-α (TNF-α), which activate and attract additional immune and tissue-repairing cells such as mast cells and fibroblasts (Soetens et al, 2019). The recruitment of immune and tissue-repairing cells is a normal phase in the body's response to localised cell and tissue damage and is primarily aimed at clearing cellular debris, neutralising potential pathogens and preparing for tissue regeneration.

However, in the context of PU aetiology, pro-inflammatory signalling can contribute to injury as local vasodilation and increased blood vessel permeability facilitate leukocyte extravasation, enabling immune cells to migrate from the circulatory system to the site of initial damage and resulting in leaky vasculature, causing plasma to build-up in the interstitial spaces, resulting in oedema (Traa et al, 2019). When constrained between a bony prominence and a support surface, which is often the case for bed-bound patients, the soft tissues cannot sufficiently expand in volume. This causes a

sharp rise in interstitial pressure, leading to further cell deformation and additional cell death (Gefen 2018, 2019; Gefen et al, 2019, 2020). In an effort to relieve rising interstitial pressure, reactive oxygen and nitrogen species may be released. These degrade and damage the extracellular matrix. Growing interstitial pressure may eventually obstruct the vasculature, inducing additional ischaemic damage. The three key aetiological factors that contribute to PUs — direct deformation damage (primary), inflammatory damage (secondary) and ischaemic damage (tertiary) — degrade and exacerbate the state of the cells and tissues (Gefen 2018, 2019; Gefen et al, 2019, 2020). Each is activated successively at a time and rate specific to the individual. A person's anatomy (bony prominences, soft tissue mass and composition) affects the extent of deformation-inflicted tissue damage. Their immune system function affects the extent and rate of accumulated inflammation-related damage and their cardiovascular system determines the magnitude and rate of ischaemic damage (Gefen 2018, 2019; Gefen et al, 2019, 2020). Exposure to sustained cell and tissue deformation is always the triggering event and driving factor in this cycle. The most effective intervention is to reduce exposure to sustained tissue deformation and high concentrations of tissue stress.

What makes a support surface effective in PU prevention?

The two most important biomechanical features determining the effectiveness of a support surface in reducing the risk of PUs for patients with impaired movement or sensory functions are immersion and envelopment (Levy et al, 2018; Call and Cheney, 2020; Call et al, 2020):

- Immersion is the depth to which a patient's body penetrates when placed on a support surface
- Envelopment is the ability of a support surface to conform around the patient's body.

Good envelopment is associated with low interface pressures and shear, since more of the body surface area is in contact with the support surface and the body weight loads are transferred more uniformly (Call and Cheney, 2020; Call et al, 2020). The larger the contact area for load transfer, the smaller the localised cell and tissue deformations and tissue stress concentrations. A support surface that continuously provides good envelopment regardless of patient body characteristics and position fulfils the primary requirement for being effective in PU prevention (Levy et al, 2018). Additional features affecting the sustained tissue loading conditions of a patient positioned on a mattress are the frictional properties of the skin-facing layer (which could potentially be the bedsheets or the mattress cover) and thermal properties of the support surface, which determine the microclimate at the body–mattress interface. Elevated skin temperatures may lead to perspiration, which causes adhesive friction resulting in elevated frictional forces on the skin and sustained shearing in underlying tissues (Schwartz et al, 2018; Zeevi et al, 2018). Skin temperature rise will also increase the metabolic rate and demands on skin and underlying tissues, making tissues more susceptible to ischaemic damage. Each 1°C rise in tissue temperature is associated with a 10–13% increment in oxygen consumption by the tissue's cells (Landsberg et al, 2009).

The links between PUs and pain

In contrast to measurable physiological signals – such as heart rate, blood pressure or core body temperature – pain is subjective and cannot be quantified in a strict sense. While noxious pain stimuli and the associated neural responses can be assessed from an electrophysiological (laboratory) perspective, the pain sensation itself ('the pain experience') is multifaceted and includes mental, psychological, emotional, cognitive and social elements, all of which are characteristic to the individual and specific to the time and circumstances (Upton and Solowiej, 2010). Accordingly, the pain experience can only be evaluated with a patient's cooperation and requires a patient-centred approach for interpretation (Crowe et al, 2019). Little information has been published on the relationship between PUs and pain and the role of the support surface in this regard. Studies have mentioned anecdotally that the type of support surface may be associated with improvement in reported discomfort or pain levels in patients at risk of PUs (Girouard et al, 2008; Gouin and Kiecolt-Glaser, 2011; Gleeson, 2016). However, individualised multifactorial subjective elements — including learned behaviours to cope with chronic pain — limit the validity of such work. Given the subjective nature of pain perception and need for a patient-centred approach, case reports reviewing the conditions and quality of life of individuals and documenting their relevant experience is useful, despite being qualitative rather than quantitative (Gefen and Soppi, 2020).

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Although the pain experienced by bed-bound individuals has non-physical elements, it typically includes noxious physical stimuli. Sustained tissue deformation activates peripheral sensory neurons (nociceptors) in the skin as well as the adipose, ligament, tendon and skeletal muscle tissues; these nociceptors transmit signals to the spinal and supra-spinal nuclei and, from there, to the medulla oblongata in the brainstem (Bechert and Abraham, 2009; Gold and Gebhart, 2020). Once nociceptive stimuli reach the brain, a process of pain modulation is activated: the body may decrease pain intensity by inhibiting the ascending transmission of pain impulses from the primary afferent neurons to the second-order neurons in the spinal cord (Bechert and Abraham, 2009). Pharmaceutical opioids that bind to receptors at the dorsal horn of the spinal cord can mimic or enhance pain modulation (Bechert and Abraham, 2009). The brain's primary somatosensory cortex is highly involved in the sensory aspects of pain, including localisation and discrimination of pain intensity (Bushnell et al, 1999). Damage to this specific region, eg due to a brain trauma or cerebrovascular accident, may impact the body's ability to modulate pain and cause somatosensory symptoms.

The central nervous system picks up and delivers pain signals, indicating potentially tissue-damaging events through nociceptors. This sensory perception is the first line of defence against PUs. Motor ability is needed to respond to discomfort or pain stimuli in a timely manner (through postural changes including micro-movements). These sensory and motor abilities distinguish healthy people from those at risk of developing PUs. Susceptibility to deformation-inflicted tissue damage can be due to high-level nerve injury, eg stroke or peripheral neuropathy.

Inflammation — a key factor in PU development — is very strongly related to pain. Pro-inflammatory cytokines contribute not only to the onset and maintenance of inflammation after localised mass cell death events but also to the development of pain by stimulating nociceptors (Kulmatycki and Jamali, 2007). IL-6 and TNF-α, which are associated with PU formation (Jiang et al, 2014; Kurose et al, 2015; Krishnan et al, 2017), also play important roles in pathological pain (Hess et al, 2011; Zhou et al, 2016; Gefen and Soppi, 2020). Inflammation lowers the threshold for pain perception in the central nervous system, leading to hyperalgesia (Reinold et al, 2005) and elevated concentrations of pro-inflammatory cytokines are neurotoxic (Czirr and Wyss-Coray, 2012; Brambilla, 2019), hence, PU-related inflammation aggravates the neural system.

'Inflammatory pain' is one of three primary contributors to the general pain sensation associated with exposure to sustained tissue deformation. The second is mechanical irritation resulting from increasing interstitial pressure on nociceptors as inflammatory oedema builds, causing direct 'nociceptive pain' (Fleckenstein et al, 2017; Gefen and Soppi, 2020). Direct mechanical loading on primary nerve endings when the skin breaks down, as occurs in category 2 or deeper PUs, also causes nociceptive pain (Bechert and Abraham, 2009). The third contributor to general pain is ischaemic (and acidotic) biochemical conditions in the soft tissues at and adjacent to the site of damage. These conditions may develop once oedema compromises blood perfusion, inducing 'ischaemic pain' (Gefen and Soppi, 2020). Nociceptors are further stimulated by the accumulation of lactic acid in ischaemic tissue regions, as hypoxic cells shift to an anaerobic metabolic pathway, lowering tissue pH, and by a rise in extracellular adenosine triphosphate (Inoue et al, 2005; Melani et al, 2005; Birdsong et al, 2010; Anitescu, 2018). Ischaemic pain can be amplified by the presence of sustained shear stresses in soft tissues distorted due to the force of body weight or an externally applied medical device. Such stresses may further obstruct the vasculature and aggravate biochemical tissue conditions (Linder-Ganz and Gefen, 2007). Multifactorial general pain, consisting of inflammatory, nociceptive and ischemic pain components, is therefore strongly coupled with PU development, in which inflammatory and ischaemic damage play a key role (Gefen, 2018, 2019; Gefen et al, 2019; Gefen and Soppi, 2020).

Reducing general pain typically improves the overall mental and physical conditions of at-risk patients, allowing them to better respond to (physically) or communicate (verbally) any changes or sensations that may indicate a PU is forming. With reductions in general pain, patients become more sensitive and responsive to localised discomfort or pain sensations relating to tissue damage and are able to sleep better, so they have greater stamina and coping ability. They are also likely to need lower doses of pain and sleep medications (which improves their cognitive state), as well as less strenuous care regimens. Reducing general pain is therefore pivotal in the treatment of patients at risk of PUs.

Box 1: Patient A case history.

Clinical background

Presentation: A 74-year-old female was admitted to the emergency department with right upper quadrant pain, nausea, vomiting and fever (39ºC). She was drowsy and unable to remain seated in bed. She had a flare up of long-standing psoriasis that was causing considerable pain. Oozing from the psoriasis and faecal incontinence resulted in her skin being constantly moist.
Blood cultures confirmed septicaemia.
Medical history: Hypothyroidism, myelodysplastic syndrome, cholecystectomy, psoriatic arthritis, obesity (110 kg) and limited mobility due to arthritis.

Interventions and clinical outcomes

Day 0: The patient had a high risk of skin breakdown based on a Waterlow score of 24 and clinical judgement. She was placed on an alternating pressure (three-cell cycle) mattress but complained about general discomfort and pain.
Day 3: Three areas of broken skin appeared on the right buttock/sacrum. These were assessed and identified as Category 2 pressure ulcers.
Day 6: The patient was transferred to a minimum tissue deformation (MTD) mattress with the aim of improving/maintaining current skin conditions. While on the MTD mattress, the patient felt comfortable and her pain was relieved.
Weeks 1–6: The patient continued to be nursed on the MTD mattress. Her general condition improved and the pressure ulcers begun to granulate, allowing her transfer to another hospital.

Case studies: a patient-centred approach

The case studies presented here were documented in interviews and clinical examinations; all three patients eventually used a powered, non-alternating, minimum tissue deformation (MTD) mattress (Thompson et al, 2008; Ahtiala et al, 2020; Gefen and Soppi, 2020). The MTD mattress has a double-cell structure and reactive air pressure adjustment technology that automatically maximises patient-specific body envelopment at all times. The case studies focus on patient perspectives, particularly in an aetiological context and in light of analysis of PU formation and pain pathways.

Patient A *[Box 1]*

Patient A had a number of factors that contributed to inflammation, and so her patient's risk of developing PUs.

Psoriasis is an inflammatory disease. Increased levels of IL-6 and TNF-α occur in the blood plasma of patients with active psoriasis (Grossman et al, 1989; Castells-Rodellas et al, 1992; Goodman et al, 2009; Yost and Gudjonsson, 2009; Kyriakou et al, 2014). These cytokines also induce inflammatory pathological pain (Hess et al, 2011; Zhou et al, 2016; Gefen and Soppi, 2020) and are associated with inflamation-related damage in PUs (Jiang et al, 2014; Kurose et al, 2015; Krishnan et al, 2017). Psoriasis flare ups are often associated with hyperalgesia; affected individuals are more sensitive to experimentally applied somatosensory stimuli than healthy controls (van Laarhoven et al, 2013).

Obesity causes low-grade inflammation. It results in the recruitment and activation of immune cell subsets in adipose tissues, which systemically increase IL-6 and TNF-α levels (Eder et al, 2009; Kern et al, 2018). Hypothyroidism and myelodysplastic syndrome are also associated with low-grade inflammation and overexpression of IL-6 and TNF-α (Taddei et al, 2006; Marchiori et al, 2015; Shi et al, 2019).

Patient A's psoriasis, obesity, hypothyroidism and myelodysplastic syndrome may have contributed to her inflammatory pain. Moreover, hypothyroidism is associated with impaired endothelium dysfunction and vasodilatation (Taddei et al, 2006; Marchiori et al, 2015), making her more susceptible to localised oedema during early-stage PU damage, leading to a considerable rise in interstitial pressures that would cause nociceptive pain.

The cyclic action of an alternating pressure mattress may have caused waves of high stress concentration in soft tissue under bony prominences in Patient A, stimulating local nociceptors to signal increases in inflammatory pain. This likely explains the general discomfort and pain she reported when placed on the alternating pressure mattress. The development of PUs must have aggravated her pain, as PUs activate both inflammatory and nociceptive pain pathways. MTD air-float technology does not induce the cyclic increases in localised interface pressures and shear caused by alternating pressure systems and MTD mattresses may therefore be advantageous in patients with inflammatory conditions that predispose to oedema.

Patient B *[Box 2]*

Patient B had herpes zoster. The most common complication of this condition — which is caused by reactivation of varicella-zoster virus — is postherpetic neuralgia, a neuropathic burning pain that occurs due to peripheral nerve damage. Neuropathic pain may mask localised sensations indicating PU formation, theoretically increasing PU risk. Tissue culture models of skin infected by varicella-zoster revealed >30-fold increased IL-6 levels compared to uninfected skin (Jarosinski et al, 2018). The virus also causes rapid and transient expression of TNF-α by macrophages (Paludan et al, 2001). Elevated IL-6 and TNF-α levels can generate or aggravate inflammatory pain, in turn inducing nociceptive pain.

Elastic solid support (spring-based or foam-based) surfaces, such as the spring mattress

Box 2: Patient B case history.

Clinical background

Presentation: A 78-year-old male with a body mass index of 16.6 admitted due to deterioration of underlying diseases, in particular herpes zoster that resulted in painful neuralgia. The patient also had a painful spontaneous compression fracture of the spine at his L1 vertebra.
Medical history: Severe chronic obstructive pulmonary disease with cardiac involvement, muscle atrophy and osteoporosis.

Interventions and clinical outcomes

Post discharge: The patient's wife was solely responsible for the care of her husband, who was completely bed-bound. The patient was nursed at home on a standard spring mattress. In addition to chronic pain, he suffered from disturbed and intermittent sleep, which affected his wife's sleep and overall quality of life. The patient was drowsy due to nighttime sedatives and pain management medications (delivered via drug-releasing patches), however his cognitive status was not impaired.
2 months: A minimum tissue deformation mattress was made available and the patient's general pain and pain due to the compression fracture diminished. The pain due to postherpetic neuralgia was still present. The patient's sleep improved as a result of his reduced pain levels, and his wife's sleep improved as a consequence.
6 months: The patient and his wife were very satisfied with the MDT mattress. The patient reported that the pain relief was persistent, which resulted in better quality of life and easier care, as moving in bed was not as painful as previously.

initially used by Patient B, are inherently inferior to air-cell-based support surfaces as they provide lower body envelopment, resulting in greater concentrations of tissue stress when compared to air-cell-based mattresses (Moysidis et al, 2011; Levy et al, 2014, 2015). The increase in body envelopment provided by the MTD mattress and associated decrease in localised soft tissue stress, therefore substantially reduced the inflammatory and nociceptive pain experienced by Patient B.

Patient C *[Box 3]*

Patient C is a classic example of a cerebrovascular accident damaging the primary somatosensory cortex in the brain, leading to loss of pain modulation capacity by the central nervous system. This damage explains her somatosensory symptoms and tactile hypersensitivity complaints.

As with Patient B, envelopment was lower and tissue deformations and stress concentrations greater on the commodity mattress than on the MTD mattress. Generally, the intensity and frequency of the trains of action potentials fired by stimulated nociceptors are proportional to tissue distortion levels (Eilers and Schumacher, 2005; Djouhri et al, 2006, 2012). Hence, the greater envelopment and reduced localised tissue distortions provided by the MTD air-float mattress translate to less chronic pain, especially in conditions where pain modulation is impaired, as in Patient C's case.

Summary and conclusions

Reducing general pain is a central objective in the management of patients at risk of developing PUs. The aetiological links between the PU cycle, which is triggered and driven by exposure to sustained cell and tissue deformation, and experience of pain, which is fed by inflammatory oedema and ischaemia (secondary and tertiary factors in PU aetiology), need to be considered. This article has analysed the complex interactions between PU aetiology and pain pathways, applying known and theoretical knowledge to the case histories of patients with inflammatory disease or neural damage, which are risk factors for PUs and chronic pain. Alleviation of sustained tissue deformation through good immersion and envelopment by the support surface, as with MTD air-float technology, therefore appears to protect against PUs and relieve chronic or general pain. WINT

References

Ahtiala M, Kivimäki R, Laitio R, Soppi E (2020) Effect of mattress deployment on pressure ulcer development: a real-world observational cohort experience. *Wounds Int* 11(1): 10–7

Anitescu M (2018) Ischemic pain. In: Cheng J, Rosenquist R (eds). *Fundamentals of Pain Medicine.* Springer: 141–51

Bechert K, Abraham SE (2009) Pain management and wound care. *J Am Col Certif Wound Spec* 1(2): 65–71

Birdsong WT, Fierro L, Williams FG et al (2010) Sensing muscle ischemia: coincident detection of acid and ATP via interplay of two ion channels. *Neuron* 68(4): 739–49

Brambilla R (2019) Neuroinflammation, the thread connecting neurological disease: cluster: "Neuroinflammatory mechanisms in neurodegenerative disorders". Acta Neuropathol 137(5): 689–91

Bushnell MC, Duncan GH, Hofbauer RK et al (1999) Pain perception: is there a role for primary somatosensory cortex? *Proc Natl Acad Sci U S A* 96(14): 7705–9

Call E, Cheney A (2020) Developing standard test methods for assessment of medical devices in the field of wound prevention and care. In: Gefen A. *Innovations and Emerging Technologies in Wound Care.* Academic Press: London

Call E, Tanner L, Cheney A et al (2020) Results of laboratory testing for immersion, envelopment, and horizontal stiffness on turn and position devices to manage pressure injury. *Adv Skin Wound Care* 33(10S Suppl 1): S11–22

Castells-Rodellas A, Castell JV, Ramirez-Bosca A et al (1992) Interleukin-6 in normal skin and psoriasis. *Acta Derm Venereol* 72(3): 165–8

Crowe M, Gillon D, McCall C, Jordan J (2019) "Pain takes over everything": the experience of pain and strategies for management. In: van Rysewyk S (ed). *Meanings of Pain.* Springer: Cham Switzerland; 59–76

Czirr E, Wyss-Coray T (2012) The immunology of neurodegeneration. *J Clin Invest* 122(4): 1156–63

Djouhri L, Koutsikou S, Fang X et al (2006) Spontaneous pain, both neuropathic and inflammatory, is related to frequency of spontaneous firing in intact C-fiber nociceptors. *J Neurosci* 26(4): 1281–92

Box 3: Patient C case history.

Background and underlying conditions

Patient C had cerebral palsy from birth that resulted in weakness on the left side of her body but was otherwise independent and able to walk. At the age of 21, she had a cerebrovascular accident with no known cause, which resulted in the need to use a wheelchair as she was unable to move her legs. After the stroke, the patient began to experience aching sensations in her lower extremities and numerous pain relievers were prescribed. She reported electric shock-like sensations below her knees that were triggered by objects in contact with her skin. These sensations were resistant to all treatments.
For 9 years the patient woke up tens of times each night, causing extreme exhaustion and fatigue. She slept in the same position at night on a commodity mattress for conventional home use.

Interventions and clinical outcomes

Patient C had the opportunity to test a minimum tissue deformation mattress. She has now used this mattress for the past 8 years, reporting that her pain levels have decreased and her quality of sleep is satisfactory. In particular, she has reported that she no longer wakes up during the night because of pain. The patient, who is currently 39 years old with a body mass index of 22.9, has never suffered from pressure ulcers.

Djouhri L, Fang X, Koutsikou S, Lawson SN (2012) Partial nerve injury induces electrophysiological changes in conducting (uninjured) nociceptive and nonnociceptive DRG neurons: possible relationships to aspects of peripheral neuropathic pain and paresthesias. *Pain* 153(9): 1824–36

Eder K, Baffy N, Falus A, Fulop AK (2009) The major inflammatory mediator interleukin-6 and obesity. *Inflamm Res* 58(11): 727–36

Eilers H, Schumacher MA (2005) Mechanosensitivity of primary afferent nociceptors in the pain pathway. In: Kamkin A, Kiseleva I (eds). *Mechanosensitivity in Cells and Tissues*. Academia: Moscow

Fleckenstein J, Simon P, König M et al (2017) The pain threshold of high-threshold mechanosensitive receptors subsequent to maximal eccentric exercise is a potential marker in the prediction of DOMS associated impairment. *PLoS One* 12(10): e0185463

Gefen A (2008) How much time does it take to get a pressure ulcer? Integrated evidence from human, animal, and in vitro studies. *Ostomy Wound Manage* 54(10): 26–35

Gefen A, Weihs D (2016) Cytoskeleton and plasma-membrane damage resulting from exposure to sustained deformations: a review of the mechanobiology of chronic wounds. *Med Eng Phys* 38(9): 828–33

Gefen A (2018) The future of pressure ulcer prevention is here: detecting and targeting inflammation early. *EWMA J* 19(2): 7–13

Gefen A (2019) How medical engineering has changed our understanding of chronic wounds and future prospects. *Med Eng Phys* 72: 13–8

Gefen A, Brienza D, Edsberg L et al (2019) The etiology of pressure injuries. In: *Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline*. 3rd Edition. European Pressure Ulcer Advisory Panel (EPUAP), National Pressure Injury Advisory Panel (NPIAP) and the Pan Pacific Pressure Injury Alliance (PPPIA)

Gefen A, Soppi E (2020) What is new in our understanding of pressure injuries: the inextricable association between sustained tissue deformations and pain and the role of the support surface. *Wound Practice and Research* 28(2): 84–91

Gefen A, Alves P, Ciprandi G et al (2020) Device-related pressure ulcers: SECURE prevention. *J Wound Care* 29(Suppl 2a): S1–52

Girouard K, Harrison MB, Van Den Kerkof E (2008) The symptom of pain with pressure ulcers: a review of the literature. *Ostomy Wound Manage* 54(5): 30–40, 42

Gleeson D (2016) Effectiveness of a pressure-relieving mattress in an acute stroke ward. *Br J Nurs* 25(20 Suppl): S34–8

Gold MS, Gebhart GF (2010) Nociceptor sensitization in pain pathogenesis. *Nat Med* 16(11): 1248–57

Goodman WA, Levine AD, Massari JV et al (2009) IL-6 signaling in psoriasis prevents immune suppression by regulatory T cells. *J Immunol* 183(5): 3170–6

Gouin JP, Kiecolt-Glaser JK (2011) The impact of psychological stress on wound healing: methods and mechanisms. *Immunol Allergy Clin Noth Am* 31(1): 81–93

Grossman RM, Krueger J, Yourish D et al (1989) Interleukin 6 is expressed in high levels in psoriatic skin and stimulates proliferation of cultured human keratinocytes. *Proc Natl Acad Sci U S A* 86(16): 6367–71

Hess A, Axmann R, Rech J et al (2011) Blockade of TNF-α rapidly inhibits pain responses in the central nervous system. *Proc Natl Acad Sci USA* 108(9): 3731–6

Inoue K, Tsuda M, Koizumi S (2005) ATP receptors in pain sensation: involvement of spinal microglia and P2X4 receptors. *Purinergic Signal* 1(2): 95–100

Jarosinski KW, Carpenter JE, Buckingham EM et al (2018) Cellular stress response to varicella-zoster virus infection of human skin includes highly elevated interleukin-6 expression. *Open Forum Infect Dis* 5(6): ofy118

Jiang L, Dai Y, Cui F et al (2014) Expression of cytokines, growth factors and apoptosis-related signal molecules in chronic pressure ulcer wounds healing. *Spinal Cord* 52(2): 145–51

Kern L, Mittenbühler MJ, Vesting AJ et al (2018) Obesity-induced TNFα and IL-6 signaling: the missing link between obesity and inflammation-driven liver and colorectal cancers. *Cancers* 11(1): 24

Krishnan S, Vodovotz Y, Karg PE et al (2017) Inflammatory mediators associated with pressure ulcer development in individuals with pneumonia after traumatic spinal cord injury: A pilot study. *Arch Phys Med Rehabil* 98(9): 1792–9

Kulmatycki KM, Jamali F (2007) Drug disease interactions: role of inflammatory mediators in pain and variability in analgesic drug response. *J Pharm Pharm Sci* 10(4): 554–66

Kurose T, Hashimoto M, Ozawa J, Kawamata S (2015) Analysis of gene expression in experimental pressure ulcers in the rat with special reference to inflammatory cytokines. *PLoS One* 10(7): e0132622

Kyriakou A, Patsatsi A, Vyzantiadis TA, Sotiriadis D (2014) Serum levels of TNF-α, IL-12/23p40, and IL-17 in plaque psoriasis and their correlation with disease severity. *J Immunol Res* 2014: 467541

Landsberg L, Young, JB, Leonard WR et al (2009) Do the obese have lower body temperatures? A new look at a forgotten variable in energy balance. *Trans Am Clin Climatol Assoc* 120: 287–95

Levy A, Kopplin K, Gefen A (2014) An air-cell-based cushion for pressure ulcer protection remarkably reduces tissue stresses in the seated buttocks with respect to foams: finite element studies. *J Tissue*

Viability 23(1): 13–23

Levy A, Kopplin K, Gefen A (2015) Adjustability and adaptability are critical characteristics of pediatric support surfaces. *Adv Wound Care (New Rochelle)* 4(10): 615–22

Levy A, Shoham N, Kopplin K, Gefen A (2018) The critical characteristics of a good wheelchair cushion. In: Romanelli M, Clark M, Gefen A, Ciprandi G (eds). *Science and Practice of Pressure Ulcer Management.* 2nd Edition. Springer-Verlag: London; 17–31

Linder-Ganz E, Gefen A (2007) The effects of pressure and shear on capillary closure in the microstructure of skeletal muscles. *Ann Biomed Eng* 35(12): 2095–107

Marchiori RC, Pereira LAF, Naujorks AA et al (2015) Improvement of blood inflammatory marker levels in patients with hypothyroidism under levothyroxine treatment. *BMC Endocr Disord* 15: 32

Melani A, Turchi D, Vannucchi MG et al (2005) ATP extracellular concentrations are increased in the rat striatum during in vivo ischemia. *Neurochem Int* 47(6): 442–8

Moysidis T, Niebel W, Bartsch K et al (2011) Prevention of pressure ulcer: interaction of body characteristics and different mattresses. *Int Wound J* 8(6): 578–84

Paludan SR, Ellermann-Eriksen S, Kruys V, Mogensen SC (2001) Expression of TNF-alpha by herpes simplex virus-infected macrophages is regulated by a dual mechanism: transcriptional regulation by NF-kappa B and activating transcription factor 2/Jun and translational regulation through the AU-rich region of the 3′ untranslated region. *J Immunol* 167(4): 2202–8

Reinold H, Ahmadi S, Depner UB et al (2005) Spinal inflammatory hyperalgesia is mediated by prostaglandin E receptors of the EP2 subtype. *J Clin Invest* 115(3): 673–9

Schwartz D, Magen YK, Levy A, Gefen A (2018) Effects of humidity on skin friction against medical textiles as related to prevention of pressure injuries. *Int Wound J* 15(6): 866–74

Shi X, Zheng Y, Xu L et al (2019) The inflammatory cytokine profile of myelodysplastic syndromes: A meta-analysis. *Medicine* 98(22): e15844

Soetens JFJ, Worsley PR, Bader DL, Oomens CWJ (2019) Investigating the influence of intermittent and continuous mechanical loading on skin through non-invasive sampling of IL-1α. *J Tissue Viability* 28(1): 1–6

Taddei S, Caraccio N, Virdis A et al (2006) Low-grade systemic inflammation causes endothelial dysfunction in patients with Hashimoto's thyroiditis. *J Clin Endocrinol Metab* 91: 5076–82

Thompson G, Bevins J, Hutchcox S, White R (2008) Examining the Carital Optima air-float mattress through patient experience and pressure mapping. *Wounds UK* 4(3): 72–82

Traa WA, van Turnhout MC, Nelissen JL et al (2019) There is an individual tolerance to mechanical loading in compression induced deep tissue injury. *Clin Biomech* 63: 153–60

Upton D, Solowiej K (2010) Pain and stress as contributors to delayed wound healing. *Wound Practice Res* 18: 114–22

van Laarhoven AI, Kraaimaat FW, Wilder-Smith OH et al (2013) Sensitivity to itch and pain in patients with psoriasis and rheumatoid arthritis. *Exp Dermatol* 22(8): 530–4

Yost J, Gudjonsson JE (2009) The role of TNF inhibitors in psoriasis therapy: new implications for associated comorbidities. *F1000 Med Rep* 1: 30

Zeevi T, Levy A, Brauner N, Gefen A (2018) Effects of ambient conditions on the risk of pressure injuries in bedridden patients-multi-physics modelling of microclimate. *Int Wound J* 15(3): 402–16

Zhou YQ, Liu Z, Liu ZH et al (2016) Interleukin-6: an emerging regulator of pathological pain. *J Neuroinflammation* 13(1): 14

Contribution of photonic therapies to the healing process of chronic wounds: case studies


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Chronic wounds represent an increasing public health issue, since their prevalence is quite high and have caused a major economic problem. In recent years, photonic therapies have emerged as new treatment options for wound healing. A photonic therapy is based on a transfer of energy through photons from a physical system to the wound, which results in observable and measurable modifications in the treated area.
This report describes two different photonic therapies in the care of 10 patients with chronic wounds of various aetiology not responding to standard treatment — blue light photobiomodulation and fluorescence biomodulation.

All types of wounds have the potential of becoming chronic if the complex process of cutaneous healing does not progress normally. Physiological wound healing involves a cascade of factors that are highly regulated, where multiple biological factors interplay (Clark, 1985; Mast and Schultz, 1996; Gurtner et al, 2008; Han and Ceilley, 2017). If the sequence of reparative events is altered due to an underlying disease, infections or metabolic deficiencies, the wound will likely become chronic, causing discomfort for the patient and generating a significant impact to the healthcare system (Han and Ceilley, 2017).

Conventionally, if wounds do not heal after 2 months they are defined as chronic (Adeyi, 2009). Chronic wounds are estimated to exist in 1–2% of the population (Werdin et al, 2008; Nussbaum et al, 2018). The most common chronic wounds are venous leg ulcers, diabetic foot ulcers, pressure ulcers and arterial ulcers. Other soft tissue injuries may also fail to heal, including surgical wounds and traumatic injuries (Werdin et al, 2008; Nussbaum et al, 2018).

Chronic wounds are expensive to treat and costs expand beyond local wound care to indirect social costs, such as pain, reduced, disability, distress and loss of productivity (Ma et al, 2014; Guest et al, 2017; Järbrink et al, 2017; Nussbaum et al, 2018). Due to the aging population and a rising incidence of chronic diseases, prevalence and costs associated with chronic wounds will probably further increase (Järbrink et al, 2017).

The use of light energy for promoting wound healing dates back to the late 19th century, with the use of blue and red light in the treatment of lupus vulgaris (cutaneous tuberculosis). In the late 1960s, low-dose laser treatments began to be used for wound healing.

Only recently has light energy for wound healing been revoluntionised with the introduction of high-efficiency light-emitting diodes (LEDs) due to their affordability, ease of use, and safety (Mosca et al, 2019).

One of the new generation physical therapies used in wound healing is photobiomodulation (PBM), a form of low dose light treatment. This was defined in 2014 by the North American Association for Light Therapy and the World Association for Laser Therapy as the following: "…A form of light treatment that utilizes non-ionizing forms of light sources, including lasers, light emitting diodes (LEDs), and broadband light, in the visible and infrared spectrum, involving a nonthermal process with endogenous chromophores eliciting photophysical (i.e. linear and nonlinear) and photochemical events at various biological scales. This treatment results in beneficial therapeutic outcomes including, but not limited to, the alleviation of pain or inflammation, immunomodulation, and promotion of wound healing and tissue regeneration" (Anders et al, 2015).

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Table 1. Patients treated with Blue Light PBM.					
Patient	**Number of ulcers**	**Aetiology**	**Comorbodities**	**Re-epithelialisation achieved**	**Number of treatments**
1	1	Post-traumatic	Diabetes	Healed	3
2	1	Post-traumatic	Diabetes, PAD	Healed	3
3	1	Stump dehiscence	Diabetes, hypertension	97%	21
4	1	Stump dehiscence	Diabetes	69%	10
5	2	Vascular	Hypertension, PAD	89%, 54%	10

Table 2. Patients treated with Fluorescence Biomodulation.					
Patient	**Number of ulcers**	**Aetiology**	**Comorbodities**	**Re-epithelialisation achieved**	**Number of treatments**
1	3	Stump dehiscence	Diabetes, PAD	Healed	18
2	1	Stump dehiscence	Diabetes	40%	8
3	1	Vascular	Hypertension	66%	20
4	1	Vasculitic	Diabetes	30%	8
5	1	Post-traumatic	Venous insufficiency	20%	12

The mechanisms of action of blue light photobiomodulation (PBM) are still not completely understood. It is recognised that for low-dose light treatments to have an effect on biological systems, the photons must be absorbed by molecular chromophores or photoacceptors. The candidates as principal photoacceptors are cytochromes involved in the respiratory chain on the mitochondrial membrane. Absorption of photons by cytochromes initiates a biochemical cascade that increase adenosine triphosphate (ATP), generating energy for cell metabolism (Prindeze et al, 2012).

Photobiomodulation has accumulated evidences of a positive action on all phases of wound repair, from inflammatory phase to remodeling phase. These beneficial effects include acceleration of wound healing, cellular and extracellular matrix proliferation, collagen production and granulation tissue formation (Prindeze et al, 2012).

The following is a report of the observations made on 10 patients suffering from ulcers of the lower limbs not responding to standard therapy who were treated with two different photonic therapies: blue light PBM and fluorescence biomodulation (FB). Blue light PBM is based on a direct transfer of energy from a light emitter to the patient, without the use of mediators (chemical additives or medicines), while FB is based on a topical light absorbing molecule gel that is applied to the affected area; an LED light source is used to illuminate the topical product that absorbs light and convert it into dynamic fluorescent energy.

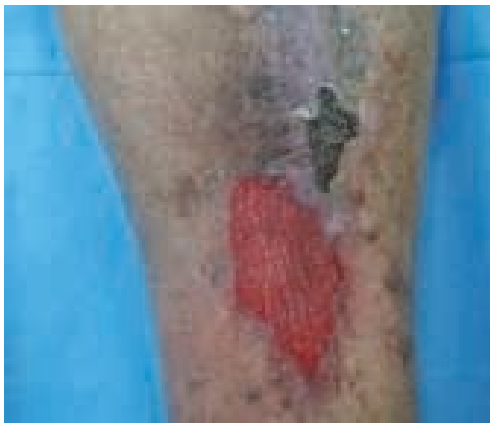
For the purpose of evaluating the effectiveness of the two photonic therapies, the percentage of reepithelialisation achieved over the observation period was measured.

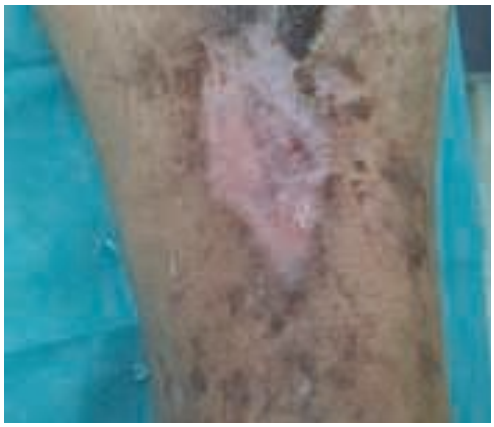
Materials and methods

The blue light PBM therapy was provided through a portable Class IIa Medical Device (EmoLED) equipped with LED sources that emit blue light within the range of 400–430 nm. The effects of blue light reported in preclinical studies and clinical observations are an anticipated transition of inflammation and a faster and better tissue regeneration (Cicchi et al, 2016; Magni et al, 2019; Marchelli et al, 2019; Mosti and Gasperini, 2018). The device does not come into contact with the lesion but must be kept at a distance of 4 cm from the wound bed. It emits blue light for 1 minute on a circular area measuring 5 cm in diameter, providing a uniform power density of 120 mW/cm^2, which corresponds to a fluence of 7.2 J/cm^2. For lesions that measured >5 cm, patients were exposed to multiple, 1-minute applications, in order to cover the entire wound area.

Fluorescence biomodulation was provided through the use of a photo-converter wound gel in conjunction with a LED lamp (LumiHeal). The topical gel contains specific chromophores and when excited with the LED lamp (410 to 470 nm), they release an ultrafast micropulsed emission of photons in the form of fluorescence;

Figure 1a. Patient 1. Traumatic skin ulcer on the left lower limb. (a, right) Prior to Blue Light PBM therapy. (b, far right) After 3 treatments with Blue Light.





the fluorescence's energy delivers wavelengths in the spectra of visible light, from 500 to 610 nm. In preclinical and clinical studies a beneficial effect on inflammation and stimulation of the healing process in a physiological manner have been observed (Ferroni et al, 2020; Nikolis et al, 2016; Romanelli et al, 2018; Scapagnini et al, 2019). The topical gel was obtained by mixing two products (vector gel and chromophores) and was applied to the wound bed after the mixture had been prepared. A 2-mm-thick layer of topical gel was applied to the area to be treated. The LED lamp was kept at a distance of 5 cm from the affected area and applied for 5 minutes on a lesion area that measured a maximum of 7.5 cm x 15 cm. Once the application was completed, the activating gel was removed and the skin was cleansed.

The use of both PBM with blue light and FB was complementary to conventional therapies and part of wound bed preparation.

Subjects and setting

Clinical observations were conducted for a maximum period of 4 months on 10 patients (five men and five women; average age 69.7 years) with ulcers of the lower limbs and diverse aetiologies, not responding to standard treatments. These 10 patients formed two groups: one group treated weekly with blue light PBM and the other treated with FB twice weekly. The chronic wounds were: stump dehiscences, post-traumatic ulcers, vascular ulcers and a vasculitic ulcer.

Outcome measures

The outcomes observed over the course of treatment were changes in the size of the wound surface area and level of pain measured by the Visual Analogue Scale. All 10 patients were mentally competent to express their pain using the VAS.

Results

All wounds observed responded to the photonic therapies, recording an increase of granulation tissue in the wound bed with a reduction of the wound's surface.

The wounds treated with blue light PBM had an average size at baseline of 30.5 cm^2 (median 32.4) and reached an average of 88.6% re-epithelialisation. *Table 1* reports results (reepithelialisation achieved) for each patient. A perceived intensity of ≥4 on the VAS was reported in three patients treated with blue light PBM at their first visit, indicative of pain presence. All three patients recorded a significant reduction in pain (93%) at the end of the treatment period. The blue light PBM treatment was well accepted by all five patients.

The wounds treated with FB had an average area at baseline of 30.5 cm^2 (median 25) and reached an average 51.2% reepithelialisation. *Table 2* reports results (reepithelialisation achieved) reached for each patient. A perceived intensity of pain ≥4 on the VAS was reported in all five patients treated with FB at their first visit. For four of these patients an important reduction of the symptom (56%) was recorded, while one patient reported no improvement at the end of the treatment period. No adverse events were recorded; two patients interrupted the therapy due to pain related to the treatment.

The authors outline four interesting cases here, chosen because of the interesting outcomes obtained, given the initial conditions.

The first patient was a 69-year-old male smoker with diabetes and peripheral arterial disease (PAD). The patient had undergone revascularization through angioplasty in both limbs. He presented three post-traumatic iatrogenic ulcers (from rubbing): one in the anterior tibial region of the left leg with a surface area of 48 cm^2 (6 x 8 cm), two in the anterior tibial region of the right leg with a surface area of 6

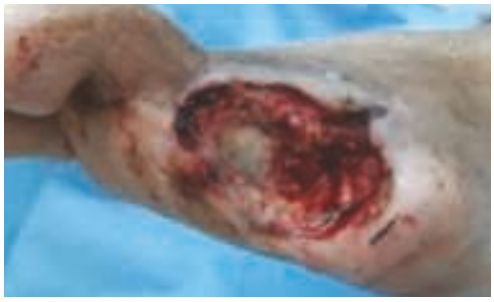
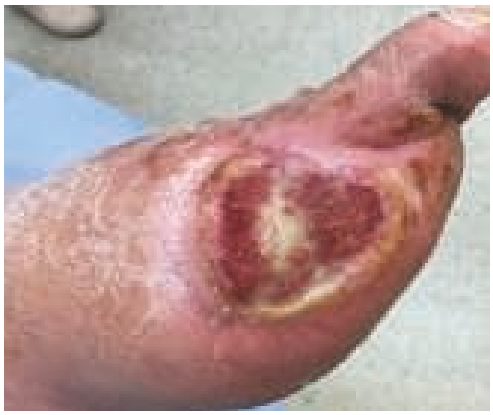


Figure 2. Patient 2. Stump wound dehiscence after toe amputation (fourth and fifth toes) of the left foot. (a, right) Prior to Blue Light PBM therapy. (b, far right) After 21 treatments with Blue Light.



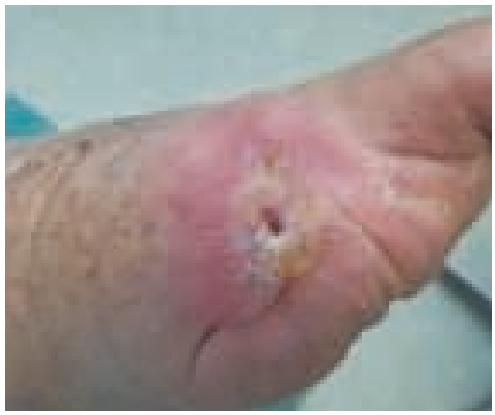


Figure 3. Patient 3. Dehiscence of stump after amputation of first toe on the left foot. (a, right) Prior to Fluorescence Biomodulation therapy. (b, far right) After 18 treatments with Fluorescence Biomodulation.

cm^2 (3 x 3 cm) and 12 cm^2 (4 x 3 cm). The wounds had been present for 12 weeks. Pain before treatment was reported as a 2-point score on the VAS. Healing was fully achieved after 3 treatments with blue light PBM. At the last visit, the wounds showed complete reepithelialisation *[Figure 1]* and the patient rated the pain with 0 points on the VAS.

The second patient was a 60-year-old man with hypertension and type II diabetes mellitus who took insulin on a regular basis. The patient presented a 12 week old wound dehiscence after toe amputation (fourth and fifth toes) of the left foot. The left limb was also previously revascularised through angioplasty.

The wound was quite extensive at baseline, with a surface area of 48 cm^2 (6 x 8 cm) and a lesion depth of 1.8 cm. The wound was characterized by a mixture of fibrin and granulation tissue. Pain assessment confirmed a high discomfort in the patient, with a score of 5 on the VAS. Blue light PBM treatment was performed once a week for 21 weeks. During this period, a significant improvement of the wound was observed, in concurrence with a reduction in lesion size and depth and a revitalization of the wound bed. At the end of the treatment period, a 97% reduction in lesion size and a 90% reduction in lesion depth were observed *[Figure 2]*.

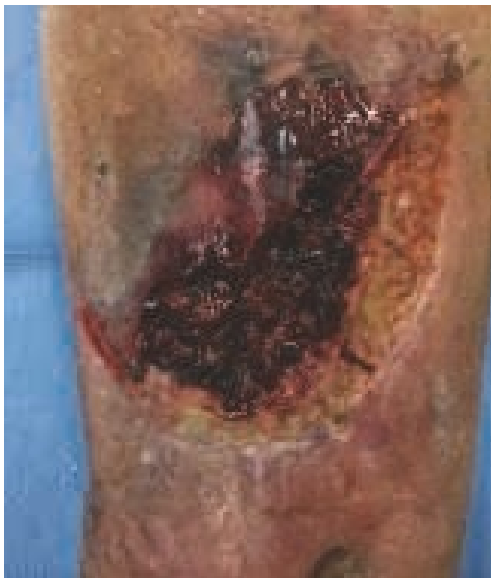
The third patient was a 73-year-old man with diabetes and PAD. The patient presented a wound dehiscence after amputation of the first toe of the left foot. The lesion had been present for 16 weeks. Before treatment, the lesion had a surface area of 18 cm^2 (4.5 x 4 cm), and the related pain was rated 4 on the VAS. After 18 treatments with FB the wound appeared healed, achieving complete re-epithelialization and the patient rated the pain with 0 points on the VAS *[Figure 3]*.

The fourth patient was a 78-year-old woman with diabetes and a vasculitic ulcer in the anterior tibial region of the right lower limb that had been present for 12 weeks. At the baseline visit, the wound had a surface area of 48 cm^2. The patient rated the associated pain with an 8-point score on the VAS.

Treatment was interrupted after the eighth application, since the patient complained of severe pain and a burning sensation. After eight treatments with FB, the lesion size had decreased by approximately 30% and the pain perceived by the patient measured six points on the VAS *[Figure 4]*.

Conclusions

To evaluate the contribution of photonic therapies to the healing process of chronic wounds, blue light PBM or FB was added to standard treatment in the management of unresponsive, hard-to-heal wounds of various aetiology in 10 patients. All wounds observed responded to the photonic therapies: a reduction of the wound size (88.6% with blue light PBM; 51.2% with FB) and pain was achieved with both therapies. However, the authors report anecdotally that blue light PBM therapy proved



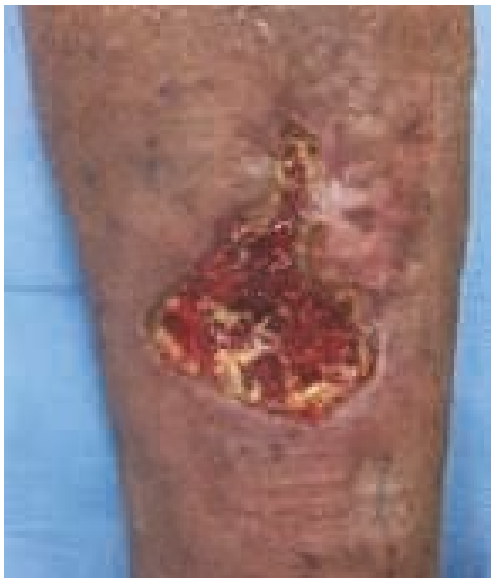


Figure 4. Patient 4. Vasculitic ulcer in the anterior tibial region of the right lower limb. (a, right) Prior to Fluorescence Biomodulation (FB) therapy (b, far right) After eight FB treatments, which were discontinued due to patient complaints of pain.

to be easier to administer and better tolerated by patients: the device is handy, the single treatment is fast (only 60 seconds light irradiation on wound surface) and all the patients accepted the therapy. Based on this reported experience, photonic therapies can contribute significantly to the healing of hard-to-heal chronic wounds. WINT

References

Adeyi A, Muzerengi S and Gupta I (2009) Leg Ulcers in Older People: A Review of Management. *BJMP* 2(3): 21–8

Anders JJ, Lanzafame RJ, Arany PR (2015) Low-level light/laser therapy versus photobiomodulation therapy. *Photomed Laser Surg* 33(4): 183–4

Cicchi R, Rossi F, Alfieri D, et al (2016) Observation of an improved healing process in superficial skin wounds after irradiation with a blue LED haemostatic device. *J Biophotonics* 9(6): 645–55

Clark RA (1985) Cutaneous tissue repair: basic biologic considerations. I. *J Am Acad Dermatol* 13(5 Pt1): 701–25

Ferroni L, Zago M, Patergnani S et al (2020) Fluorescent light Energy (FLE) acts on mitochondrial physiology improving wound healing. *J Clin Med* 9(2): 559

Guest JF, Ayoub N, McIlwraith T et al (2017) Health economic burden that different wound types impose on the UK's National Health Service. *Int Wound J* 14(2): 322–30

Gurtner GC, Werner S, Barrandon Y, Longaker MT (2008) Wound repair and regeneration. *Nature* 453(7193): 314–21

Han G, Ceilley R (2017) Chronic wound healing: a review of current management and treatments. *Adv Ther* 34(3): 599–610

Järbrink K, Ni G, Sönnergren H et al (2017) The humanistic and economic burden of chronic wounds: a protocol for a systematic review. *Syst Rev* 6(1): 15

Magni G, Tatini F, Bacci S et al (2019) Blue LED light modulates inflammatory infiltrate and improves the healing superficial wounds. *Photodermatol Photoimmunol Photomed* 36(2): 166–8

Ma H, O'Donnell TF Jr, Rosen NA, Iafrati MD (2014) The real cost of treating venous ulcers in a contemporary vascular practice. *J Vasc Surg Venous Lymphat Disord* 2(4): 355–61

Marchelli M, Perniciaro G, Granara D et al (2019) Photobiomodulation with Blue Light in non healing wounds: case series evaluation. *Wounds International* 10 (3): 63–7

Mast BA, Schultz GS (1996) Interactions of cytokines, growth factors, and proteases in acute and chronic wounds. *Wound Repair Regen* 4(4): 411–20

Mosca RC, Ong AA, Albasha O et al (2019) Photobiomodulation therapy for wound care: a potent, noninvasive, photoceutical approach. *Adv Skin Wound Care* 32(4): 157–67

Mosti G, Gasperini S (2018) Observations made on three patients suffering from ulcers of the lower limbs treated with Blue Light. *Chronic Wound Care Management and Research* 5: 23–38

Nussbaum SR, Carter MJ, Fife CE et al (2018) An economic evaluation of the impact, cost, and medicare policy implications of chronic nonhealing wounds. *Value Health* 21(1): 27–32

Nikolis A, Grimard D, Pesant Y et al (2016) A prospective case series evaluating the safety and efficacy of the Klox BioPhotonic System in venous leg ulcers. *Chronic Wound Care Management and Research* 3: 101–11

Prindeze NJ, Moffat LT, Schupp JW (2012) Mechanism of action for light therapy. A review of molecular interactions. *Exp Biol Med* 237(11): 1241–8

Romanelli M, Piaggesi A, Scapagnini G et al (2018) Evaluation of fluorescence biomodulation in the real-life management of chronic wounds: The EUREKA trial. *J Wound Care* 27(11): 744–53

Scapagnini G, Marchegiani A, Rossi G et al (2019) Management of all three phases of wound healing through the induction of fluorescence biomodulation using fluorescence light energy. *Proceedings Volume* 10863, 108630W

Werdin F, Tenenhaus M, Rennekampff HO (2008) Chronic wound care. *Lancet* 372(9653): 1860–2

Implementing the new Infection Management Pathway to optimise outcomes: real-world case series

Author:
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The Infection Management (IM) Pathway is a comprehensive, succinct, expert-endorsed, evidence-based pathway that can assist clinicians in the diagnosis and management of infection (Dowsett et al, 2020). This article describes the real-world experiences of a clinical team who have implemented the IM pathway into daily practice. They have formally evaluated three clinical cases. The IM pathway helped to guide diagnosis of infection, wound bed preparation, treatment and ongoing management of chronic wounds including the clarification of biofilm based wound care and management of local infection. The clinicians involved reported that the IM pathway was easy-to-follow and they felt more confident managing infected wounds with the support of the IM pathway.

Local infection and biofilm management continue to be challenges faced by clinicians caring for people with wounds. A recently published international survey (Dowsett et al, 2020) confirms this, underlining that the three biggest challenges faced by clinicians related to managing infected chronic wounds are:

1. Distinguishing between local infection and biofilm
2. Selecting the right treatment according to diagnosis
3. Fear of rapid deterioration due to systemic and spreading infection.

The survey reported that 67% of wound care clinicians recognise the different presentation of local infection and biofilm, however only 40% (*n*=119/298) manage the wounds differently in practice (Dowsett et al, 2020). Of the 60% of responders who did not follow a biofilm-specific pathway for management (*n*=180), 70% were non-wound care specialists and 56.5% were wound care specialists (*p*=0.041). This highlighted an educational opportunity to support and upskill non-wound care specialists to deliver consistent care, particularly in biofilm management.

Infection Management (IM) pathway

The recently published IM pathway was developed by an international group of experts using published guidelines and clinical evidence *[Figure 1]* to guide differential diagnosis of biofilm and local infection and appropriate early treatment intervention, thereby reducing unnecessary or incorrect antimicrobial use and delays in treatment. This should lead to better patient outcomes, appropriate use of antimicrobials and reduced costs through prompt management of wound complications before they progress, resulting in faster wound healing overall (Dowsett et al, 2020). The IM pathway was also developed as an aid to support non-wound care specialists *[Box 1]*.

Box 1. How the IM pathway can support non-wound care specialists and the wider clinical team.

- Simplifies the complexities of wound assessment, and provide a treatment plan based on the signs and symptoms of biofilm or infection present in the wound and the patient
- Prompts for re-assessment and evaluation of the treatment options if the wound is stalled and not responding to antimicrobial treatments
- Reduces variation in care and improves confidence by providing a consistent means of communication for wound infection terminology

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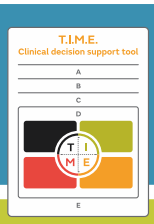
Declaration
This case series has been supported by Smith & Nephew.

A route to more effective infection management

Improve patient outcomes[1] with accurate decision making, a fast response and effective treatment choices



Start with following steps to undertake a comprehensive assessment[2]

- **A** **Assess** patient, wellbeing and wound
- **B** **Bring in** a multi-disciplinary team and informal carers to promote holistic patient assessment
- **C** **Control** and treat the underlying causes and barriers to wound healing
- **D** **Decide** appropriate treatment
- **E** **Evaluate** and reassess the treatment and wound management outcomes

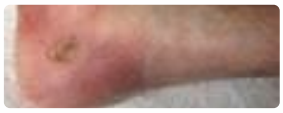
What clinical signs and symptoms of infection are present?

Biofilm[1,3-5]

- Antibiotic/antimicrobial treatment failure
- Recurrence of delayed healing on cessation of antibiotic treatment
- Delayed healing despite optimal wound/patient management
- Low level chronic inflammation
- Low level erythema
- Friable granulation
- Covert (subtle) signs of infection

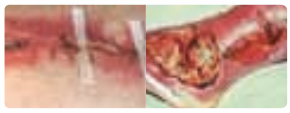
Covert (subtle)[1,3]

- Delayed wound healing
- Serous drainage with concurrent inflammation
- Hypergranulation
- Bleeding, friable granulation
- Epithelial bridging and pocketing in granulation tissue
- Wound breakdown & enlargement
- New or increasing pain
- Increasing malodour



Overt (classic)[1,3]

- Erythema
- Warmth
- Oedema/swelling
- Purulent discharge
- Pain
- Increasing malodour
- Delayed wound healing



Spreading or systemic infection[1,3]

- Spreading erythema, warmth
- May include cellulitis, crepitus
- Wound breakdown/dehiscence with or without satellite lesions
- Malaise/lethargy
- Loss of appetite
- Systemic inflammatory response
- Sepsis
- Organ dysfunction

Biofilm based wound care[4,5]

1. Repeated aggressive debridement and cleanse† as per local protocol
2. Manage suspected biofilm with **IODOSORB**◊ 0.9% Cadexomer Iodine Ointment / **IODOFLEX**◊ Cadexomer Iodine Dressing[7-9Ω]
3. Reassess at regular intervals as per local protocol and appropriate antimicrobials use. **Two weeks' minimum treatment – may need longer than overt local infection treatment due to persistent nature of biofilms**

Local wound infection management[1,3,6]

1. Debride and cleanse† as per local protocol
2. Manage local bioburden and infection with **ACTICOAT**◊ [10‡] Antimicrobial Barrier Dressing
3. Reassess at regular intervals as per local protocol and following **the two-week challenge principles[6]**

Spreading or systemic infection management

- Refer to appropriate specialist
- Tissue sample for culture and sensitivity
- Systemic antibiotics per local protocol

Have signs and symptoms of biofilm / covert infection resolved?

Yes

No

Conduct comprehensive reassessment using the A B C D E approach, manage host factors and refer to an appropriate specialist

Have signs and symptoms of local infection resolved?

No

Yes

Is the wound still stalled?

Yes – suspect biofilm

No

Use standard wound care (i.e. non-antimicrobial dressings) or advanced therapies until healing (follow local protocol)[5]

TWO-WEEK CHALLENGE[1,6∞]

Antimicrobial dressings are recommended to be used for a minimum of two weeks' duration. After two weeks, re-evaluate and either:

1. discontinue if signs and symptoms of infection have resolved,
2. continue with antimicrobial if wound is progressing but there are still signs and symptoms, or
3. consider an alternative antimicrobial and refer to an appropriate specialist if no improvement.

* No one sign or symptom can reliably confirm the presence of infection, and those with immunosuppression may not exhibit signs and symptoms of clinical infection.

† Cleanse wound and periwound skin thoroughly. Should an antiseptic cleanser be selected, the product's Instructions for Use (IFU) and soak time should be followed.

‡ Consider the use of **DURAFIBER**◊ **Ag Silver Gelling Fibre Dressing** for deep infected wounds.

Ω Unless iodine contraindicated.

∞ For very-high risk patients and wounds (e.g. osteomyelitis), it may be appropriate to use antimicrobial treatment for longer than the two-week challenge.

For detailed product information, including indications for use, contraindications, precautions and warnings, please consult the product's Instructions for Use (IFU).

References **1.** International Wound Infection Institute (IWII) Wound infection in clinical practice. Wounds International (2016). **2.** Moore Z, et al. J Wound Care 28(3):154-161 (2019). **3.** Weir D, Schultz G. Assessment and Management of Wound-Related Infections. In Doughty D & McNichol L (Eds.). Wound, Ostomy and Continence Nurses Society Core Curriculum: Wound Management (p. 156-180). 2016. Philadelphia: Wolters-Kluwer. **4.** Wolcott RD, et al. J Wound Care 19(2): 45–53 (2010). **5.** Schultz G, et al. Wound Repair Regen 25(5): 744–757 (2017). **6.** Ayello EA, et al. Wounds Int 1–24 (2012). **7.** Roche ED, et al. Int Wound J 1–10 (2019). **8.** Malone M, et al.. J Antimicrob Chemother 72, 2093–2101 (2017). **9.** Schwarzer S, et al J Infect 80(3):261-270 (2020). **10.** Gago M, Garcia F, Gaztelu V, Verdu J, Lopez P, Nolasco A. A comparison of three silver-containing dressings in the treatment of infected, chronic wounds. Wounds. 2008;20(10):273-278.

Photographs (from left to right) courtesy of Kerlyn Carville, Kevin Woo, and Henri Post.

Figure 1. The Infection Management Pathway (Dowsett et al, 2020).

Using the IM pathway in the real-world

A case series was conducted to evaluate the effectiveness of the IM pathway in supporting clinicians to deliver improved patient outcomes at two chronic care hospitals in Toronto, Canada.

The clinical team involved in this series were an engaged group of eight non-wound care specialists who were selected to participate due to their keenness to make a difference to patients, and to reinforce and validate their own experience in wound care. The non-wound care specialists were introduced to the IM pathway by the wound care specialist (KW), this included detailed discussion of the signs and symptoms associated with wound infection and suspected biofilm.

Prior to implementing the IM pathway into practice, the clinical team discussed what they perceived to be their biggest challenges surrounding the management of wound infection:

- When is a wound infected and what does this mean?
- How is infection diagnosed?
- When to swab a wound?
- How to treat and manage wound infection?

Alongside local protocols and guidelines, the IM pathway was used by the non-wound care specialists at initial patient assessment and at each subsequent review to provide consistent guidance on the following:

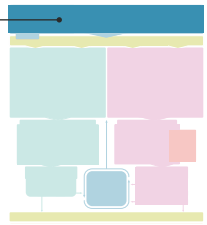
- Infection diagnosis
- Differentiation between local infection and biofilm
- Wound bed preparation
- Dressing selection.

Three patients were monitored and reviewed for at least 1 month. Wound parameters such as wound size, condition of the wound bed, wound progression and the degree to which the wound management goals had been achieved were recorded. Wound pain was measured on the visual analogue scale (VAS; 0=no pain, 10=unbearably pain).

The first patient case (case 1) is reported in detail and illustrates step-by-step each section of the pathway and how it helped the clinical team to identify when management needed to shift from **local infection management** to **biofilm based wound care (BBWC)**. *Table 1* describes the progression of this wound. A summary of the experiences using the IM pathway for two patients with local infection and biofilm are shown in *Table 2* and *Table 3*, respectively.

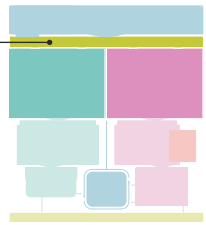
Case 1: Infected haematoma to the lower leg

Holistic assessment



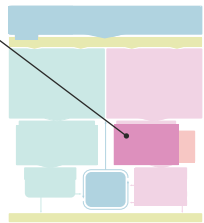
A female patient in her early 60s, presented with a traumatic wound that had begun to blister on the lateral gaiter area of the left leg 5 days post-injury. The patient had diabetes and lymphoedema. She was referred to the acute facility because of concerns with compartment syndrome. The wound initially appeared to be progressing to healing, and was treated with daily enzymatic debridement and topical antimicrobials.

What clinical signs and symptoms are present?



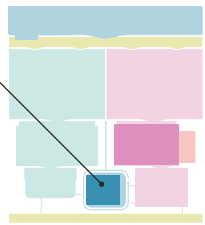
On day 15 post-injury, the wound was formally assessed using the IM pathway. The clinical signs and symptoms of local infection listed in the IM pathway were present, particularly, extensive friable tissue.

Local wound infection management



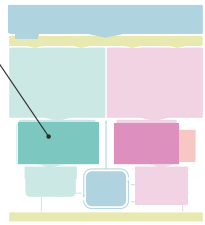
Therefore, following the IM pathway, local wound infection management was initiated. The wound was debrided using a curette and cleansed with saline as per local protocol and ACTICOAT™ FLEX 3 Antimicrobial Barrier Dressing was used to dress the wound along with a secondary dressing.

Reassessment



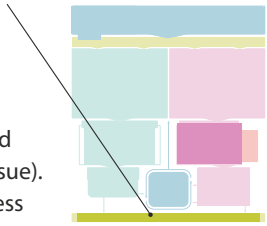
At Day 21 (7 days later), the signs of local infection had resolved, but the wound was not progressing. Following the IM pathway, this triggered a comprehensive reassessment using the 'ABCD and E' approach. The clinical signs and symptoms of biofilm and covert (subtle) were present, and biofilm was suspected. The clinician shifted to the right-side of the IM pathway and commenced BBWC.

Biofilm based wound care



Over 4 weeks, BBWC was conducted with frequent aggressive sharp debridement, cleansing and the use of IODOSORB™ as an effective topical antimicrobial against biofilm (Malone et al, 2017; Schultz et al, 2017; Roche et al, 2019; Schwarzer et al, 2020). IODOSORB™ Powder was changed every 2 days due to a high volume of exudate. A foam dressing (ALLEVYN™ Life) was applied as a secondary dressing, and two-layer short-stretch, inelastic high-level compression was applied to manage the oedema.

Standard care



The wound reduced in size over 4 weeks, and the wound bed composition improved (100% granulation tissue). The wound became less painful and the patient was pleased with progress. The clinical signs and symptoms of biofilm had resolved, so on day 43, PICO™14 Single Use Negative Pressure Wound Therapy (sNPWT) System was initiated to facilitate healing, reduce dressing change frequency under compression and accelerate wound closure.

Table 1. Case 1: Infected haematoma to the lower leg.

Before formal assessment with the IM pathway

5 days post-injury, on referral to wound care team

11 days post-injury

Post debridement

During daily enzymatic debridment

Formal assessment with the IM pathway commenced

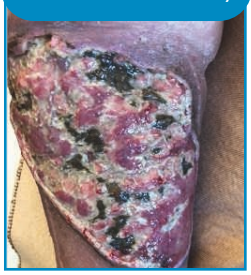
Wound condition	Clinical indicators	Treatment plan & rationale
Day 15 – initiated local wound infection management  **Size:** 24 cm (length) x 15 cm (width) **Wound bed composition:** 25% granulation tissue 75% slough and no-viable fibrinous tissue	**Overt (classic) infection** • Erythema • Warmth • Oedema/swelling • Purulent discharge • Pain (7 on the VAS) • Increasing malodour • Delayed wound healing.	**Local wound infection management** • Debrided with curette and cleansed with saline as per local protocol. • Managed local bioburden and infection with ACTICOAT FLEX™ 3 (Secondary dressing: ALLEVYN™ Life). • Reassessed regularly as per local protocol and following two-week challenge principles (Ayello et al, 2012).
Day 21 (6 days of ACTICOAT™ treatment)  **Size:** 24 cm (L) x 15 cm (W) **Wound bed composition:** 30% granulation tissue 40% sloughy 30% necrotic tissue	**Biofilm** • Delayed healing despite optimal wound management with ACTICOAT™ FLEX 3 • High exudate levels • Friable hypergranulation • Wound breakdown and enlargement • Low level chronic inflammation. **Overt (classic) infection** • Increasing pain (8 on the VAS) • Malodour.	**BBWC** • Aggressive sharp debridement and cleanse with saline as per local protocol. • Mangaged suspected biofilm with IODOSORB™ Powder (Secondary dressing: ALLEVYN™ Life). • Reassessed regularly as per local protocol and following two-week challenge principles. • High compression was applied with a two-layer, short-stretch, inelastic compression system. • Analgesia was prescribed (hydromorphone hydrochloride).

Table 1 (cont.) Case 1: Infected haematoma to the lower leg.

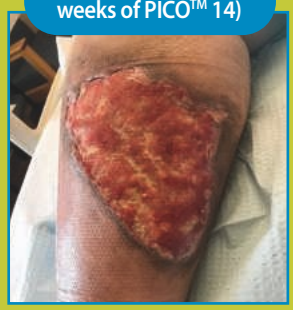
Wound condition	Clinical indicators	Treatment plan & rationale
Day 28 (7 days of IODOSORB™ treatment)  **Size:** 23.5 cm (L) x 14 cm (W) **Wound bed composition:** 60% granulation tissue 40% slough	**Covert (subtle) signs of infection** • High exudate levels • Pain reduced (6 on the VAS).	**BBWC** • There were no treatment changes as there were positive signs of progression to healing. • Antimicrobial therapy was continued for a minimum of 2 weeks, according to the two-week challenge (Ayello et al, 2012).
Day 35  **Size:** 22 cm (L) x 13.5 cm (W) **Increased granulation tissue:** 70% granulation tissue 30% slough	**Covert (subtle) signs of infection** The wound had reduced in size and more granulation tissue had developed.	**BBWC** • There were no treatment changes as there were positive signs of progression to healing. • The aim was to reassess in 7 days with aim to stop antimicrobial treatment.
Day 43  **Size:** 20 cm (L) x 12 cm (W) **Increased granulation tissue:** 80% granulation tissue 20% slough	**The signs and symptoms of biofilm and covert infection had resolved.**	Stepped-up treatment and initiated single-use NPWT with PICO™ 14 Single Use Negative Pressure Wound Therapy System for 2 weeks.
Day 64 (After 2 weeks of PICO™ 14)  **Size:** 20 cm (L) x 12 cm (W) **Increased granulation tissue:** 95% granulation tissue 5% yellow fibrin **Treatment plan & rationale:** Treatment was stepped-down to standard care with foam dressings to support moist wound healing		

Table 2. Case 2: Locally infected pressure ulcer to the trochanter area.

The patient was a 75-year-old male, who had Parkinson's Disease and anemia and had previously received cancer treatment. He was referred from ICU with a stalled Category 4 pressure ulcer on the right trochanter area present for over 6 months. The wound had previously been treated with an antimicrobial ribbon and foam dressing. The presence of osteomyelitis and deep infection involving the bony tissue was confirmed with X-ray and MRI; therefore, systemic antibiotics (pipecillin with tazobactam) were administered.

On Day 0, the clinical signs and symptoms of overt local infection and spreading or systemic infection were present. Therefore, local infection wound management was commenced – sharp debridement and cleansing with sterile water as per local protocol. The bioburden and local infection was managed with ACTICOAT™ FLEX 3 Antimicrobial Barrier Dressing in conjunction with antibiotics to treat the osteomyelitis to prevent sepsis. The wound was offloaded using an air mattress and frequently re-positioning the patient. The patient and wound were reassessed weekly for progress and the signs and symptoms of infection following the two-week challenge principles (Ayello et al, 2012). After the 4-week period when the IM pathway was used, the wound had reduced in size, granulation and epithelial tissue had developed, and the patient was in less pain.

Wound condition	Clinical indicators present	Treatment plan & rationale
Day 0  **Size:** 4.5 cm (length) x 4.5 cm (width) x 2 cm (depth) **Wound bed:** 60% granulation tissue 40% sloughy	**Overt (classic) infection** • Erythema • Warmth • Oedema/swelling • Purulent discharge • Pain (7 on the VAS) • Increasing malodour • Delayed wound healing. **Spreading or systemic infection** • Spreading erythema • Cellulitis • Crepitus • Malaise • Loss of appetite.	**Local infection management** • Sharp debridement and cleansed with sterile water as per local protocol. • Managed local bioburden and infection with ACTICOAT™ FLEX 3 (Secondary dressing: ALLEVYN™ Gentle Border). • Systemic antibiotics commenced (pipecillin with tazobactam). • Offloaded the wound with air mattress and repositioning.
Day 7  **Size:** 5 cm (L) x 4.5 cm (W) x 3 cm (D) **Improved wound bed composition:** 70% granulation tissue 30% sloughy	**Overt (classic) infection** The wound remained highly exuding requiring daily dressing changes, malodourous, but less painful (5 on the VAS) and improved condition of the wound bed. **Spreading or systemic infection** Fewer signs of spreading infection.	• There were no treatment changes as there were positive signs of progression to healing. • Analgesia was prescribed (hydromorohone hydrochloride).
Day 11  **Size:** 4.8 cm (L) x 4.5 cm (W) x 3 cm (D) **Improved wound bed composition:** 90% granulation tissue 10% sloughy	**Overt (classic) infection** The wound was improving, but there were still signs and symptoms of infection. The wound remained highly exuding, malodourous and the patient was in moderate pain (5 on the VAS).	• There were no treatment changes as there were positive signs of progression to healing. • Analgesia continued.
Day 17  **Size:** 3.5 cm (L) x 3.5 cm (W) x 2 cm (D) **Improved wound bed composition:** 100% granulation tissue	**Overt (classic) infection** The wound remained highly exuding and required daily dressing changes, but it was a thinner consistency and lighter in colour. The wound odour had improved and the wound was less painful for the patient (4 on the VAS).	• There were no treatment changes as there were positive signs of progression to healing. • Analgesia continued.

Table 3. Case 3: Chronic, non-healing pressure ulcer with suspected biofilm.

This patient was a 74-year-old man who was referred from ICU with a stalled wound present for 4 months. He had a complex medical history including coronary artery disease, diabetes, hypertension, end-stage renal disease (ESRD), stroke and anaemia. Previous wound treatment included systemic antibiotics for osteomyelitis, local silver wound dressings and foam dressings.

The patient presented with delayed healing despite optimal wound and patient management, so the patient and wound were assessed using the IM pathway. The signs and symptoms of infection were suggestive of biofilm, so biofilm based wound care (BBWC) was commenced. The wound was cleaned of devitalised tissue with frequent, aggressive mechanical debridement with monofilament pads and sharp debridement with curette, followed by saline to cleanse as per local protocol. IODOSORB™ Ointment was selected to manage the suspected biofilm, covered with ALLEVYN™ Gentle Border Dressing. After 1 week, the antimicrobial was changed to IODOSORB™ Powder so as to better absorb moisture from the wound. The wound was reassessed at regular intervals, and IODOSORB™ was continued beyond 2 weeks due to ongoing improvement and the persistent nature of the biofilm. Over a 4-week period when the IM pathway was used, the wound reduced in size and the composition of the wound bed improved from 50% slough and 50% granulation tissue to 95% granulation tissue and 5% epithelialisation tissue. The clinical indicators of biofilm were resolved and treatment was stepped down to standard care.

Wound condition	Clinical indicators present	Treatment plan & rationale
Day 0  **Size:** 7 cm (length) x 6 cm (width) x 0.4 cm (depth) **Wound bed composition:** 50% granulation tissue 50% sloughy	**Biofilm** • Delayed healing despite optimal management. • Recurrence of delayed healing on cessation of antibiotics. **Covert (subtle) signs of infection** • Serous drainage with concurrent inflammation, hypergranulation, bleeding, friable granulation, wound breakdown/enlargement, increasing odour. • High exudate levels. • Pain (4 of the VAS).	**BBWC** • Repeated, aggressive mechanical debridement with monofilament pad and sharp debridement with curette. • Wound was cleansed as per local protocol. • Managed suspected biofilm with IODOSORB™ Ointment (Secondary dressing: ALLEVYN™ Gentle Border). • Reassessed regularly as per local protocol and following two-week challenge principles (Ayello et al, 2012).
Day 7  **Size:** 7 cm (L) x 4 cm (W) x 0.2 cm (D) **Wound bed composition:** 70% granulation tissue 30% sloughy	**Covert (subtle) signs of infection** There remained high exudate levels, but the wound bed comprised of more granulation tissue and the edges were becoming flatter. The wound was less painful (2 on the VAS).	• Debridement and cleansing continued as before. • IODOSORB™ Powder was selected to absorb moisture from the wound. (Secondary dressing: ALLEVYN™ Gentle Border).
Day 13  **Size:** 6 cm (L) x 4 cm (W) x 0.2 cm (D) **Wound bed composition:** 100% granulation tissue	**Covert (subtle) signs of infection** All the slough was removed, and there was still some bleeding friable tissue.	• There were no treatment changes as there were positive signs of progression to healing. • Antimicrobial therapy was continued for a minimum of 2 weeks, according to the two-week challenge (Ayello et al, 2012).
Day 17  **Size:** 6 cm (L) x 4 cm (W) x 0.2 cm (D) **Wound bed composition:** 95% granulation tissue 5% epithelialisation tissue	**Covert (subtle) signs of infection** There were some signs of covert infection present: High exudate, serous drainage with concurrent inflammation, hypergranulation, bleeding friable granulation. The wound was no longer painful and epithelialised tissue was present on the wound bed.	• There were no treatment changes as there were positive signs of progression to healing. • Planned to review in 3 days and step down to a hydrofiber dressing once biofilm resolved.

Box 2. Feedback from the clinical team.

"Very helpful, easy to use and follow"

"Clear, straight forward"

"Precise, to the point, not lengthy"

"Now I understand/ know the signs [of wound infection] to look for"

Feedback on the IM pathway

The group of eight non-wound care specialists who used the IM pathway strongly agreed that the tool enhanced their confidence as a non-specialist caring for patients with underlying co-morbidities and very complex wounds *[Box 2]*. On a practical level, the IM pathway was straight forward, and easy to use and follow; it was "precise, to the point and not lengthy". The non-specialists also reported that the IM pathway helped them to communicate effectively and provide consistent evidence-based care in a setting where patients are often treated by a number of different clinicians.

The IM pathway provided a clear, systematic approach that facilitated differentiation between overt local infection and biofilm, and aided understanding of the different approaches to treatment. In doing so, the IM pathway simplified dressing choice and eased decision making. The group reported that they still occasionally required support and assistance from a wound care specialist for complex patients and hard-to-heal infected wounds, but that they were able to understand the rationale for the care they were providing and seek early help when infection was suspected to avoid delay in treatment.

Learnings from this case series

There are opportunities to produce the IM pathway in different formats to aid accessibility, i.e. digitally and in large posters or pocket-sized reference guides. The non-specialists identified that continued learning, including a glossary of some of the key clinical descriptors referenced in the IM pathway, would be beneficial in the future. In this way, the IM pathway can be used as a support tool for specialists to work alongside non-specialist colleagues to improve confidence and aid learning.

Other centres and teams are now implementing the IM pathway. For further information and support, visit: https://www.smith-nephew.com/key-products/advanced-wound-management/infection-

Conclusion

The need for differential diagnosis of biofilm and local infection and effective and appropriate antimicrobial use is well-known, but it is not always easily applied to practice. An evidence-based pathway can simplify guidelines, provide consistency in practice, support appropriate antimicrobial use and build confidence among non-specialists.

This real-world case series shows that the IM pathway is a one-stop tool that can:

- Improve the confidence of the clinical team when managing and discussing wound infection
- Encourage clinicians to seek help early when infection is suspected
- Help guide clinicians to make an accurate diagnosis
- Provide appropriate and effective solutions for patients with wounds with local infection and suspected biofilm.

WINT

References

Ayello EA et al (2012) *International Consensus. Appropriate Use of Silver Dressings in Wounds. An Expert Working Group Consensus.* London: Wounds International

Dowsett C et al (2020) A route to more effective infection management: The Infection Management Pathway. *Wounds International* 11(3): 50–57

Malone M et al (2017) Effect of cadexomer iodine on the microbial load and diversity of chronic non-healing diabetic foot ulcers complicated by biofilm *in vivo*. *J Antimicrob Chemother* 72: 2093–101

Roche ED et al (2019) Cadexomer iodine effectively reduces bacterial biofilm in porcine wounds *ex vivo* and *in vivo*. *Int Wound J* 1–10

Schultz G et al (2017) Consensus guidelines for the identification and treatment of biofilms in chronic nonhealing wounds. *Wound Repair Regen* 25: 744–57

Schwarzer S et al (2020) The efficacy of topical agents used in wounds for managing chronic biofilm infections: A systematic review. *J Infect* 80(3):261–70

The impact of psychological factors on wound healing


Authors: *Gerry Hussey and Trudie Young*

The links between the mind and the body have long been explored, and evidence demonstrates this can have a direct effect on wound healing (Wynn and Holloway, 2019). Cole-King and Harding (2001) established the link between anxiety and depression and wound healing: patients scoring in the top 50% of total Hospital Anxiety and Depression Scale (HADS) scores were four times more likely to have delayed healing than those scoring in the bottom 50%. In addition, the psychological toll of living with a chronic wound can also impact on quality of life. In an international webinar broadcast on November 5, 2020 and available to watch on demand on Wounds International TV, Gerry Hussey and Trudie Young explored how effectively managing the associated stress of living with a chronic wound can positively impact patient wellbeing and enhance wound healing. This webinar included two cases, which provide practical examples of appropriate wound care product selection in different care settings. In the cases selected, 3M products have been used to manage the chronic condition and help improve patient wellbeing and quality of life.

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Patients with a chronic wound usually have multiple underlying comorbidities, which are more complex to address than the wound itself. In some cases, they may have undergone a long-term process of trying different therapies that haven't worked. For these patients, there is a lack of certainty as to whether their wound will heal, as progress can be so slow that they lose hope. On the other hand, some patients can become complacent and accept the wound as part of their 'new normal', with the belief that it may never heal. For both patient groups, they may experience pain, stress, social isolation, loss of self-esteem and an inability to carry out activities of daily living.

As such, psychological tools are necessary to fight the ongoing frustration of a long-term chronic state and should be used by clinicians in order to engage patients in their own care, and optimise their mindset around their healing journey. By focusing on communication and getting to know patients, we can begin to understand their individual needs, worries and concerns. Positivity can help to boost overall wellbeing and have a tangible effect on the body: this can be reflected by the words clinicians use — i.e. taking a more positive slant — which is a practical method to engage patients and help build a therapeutic relationship.

The importance of patient wellbeing

The field of performance psychology and coaching centres around the links between the mind and the body – i.e. the idea that our thoughts and stress levels have a physical impact on the body. This field can be extrapolated into wound healing and patient wellbeing. Considering each of the factors that contribute to a patient's wellbeing may help to identify how patients can be supported holistically – for example, using appropriate dressings to reduce pain levels could potentially minimise stress.

Stress management is not a one-off intervention and recommendations for managing stress in patients with a chronic wound are needed *[Table 1]*. An holistic team approach to wound management is advised, that accounts for stress and psychological

Table 1. Recommendations for managing stress in patients with a chronic wound	
Recommendation	**Key message**
Get to know the patient	Establishing a good rapport with patients can help to create a close and trusting environment – they are more likely to be honest about their symptoms
Communicate effectively	Using positive language can help to build patient understanding, safety and satisfaction
Help the patient achieve a positive mindset	If patients can achieve a positive mindset by replacing internal discouraging and negative thoughts and maintaining an inner sense of belief, focus and passion, this will help them through their wound healing journey
Encourage a healthy diet	A balanced diet helps to keep the immune system healthy and strong and improves wound healing
Encourage meditation or controlled breathing	Using these techniques can help patients gain a new perspective on stressful situations, focus on the present and reduce negative emotions

factors as potential causes of delayed wound healing. Clinicians should also be aware of any other sources of anxiety that may be associated with stalled wound healing, such as self-image, odour, social isolation, debility and disruption of daily activities (Price et al, 2008; Woo et al, 2008; Woo, 2010).

The following strategies are recommended to aid identification and optimisation of stress-related factors (adapted from Woo, 2010):

- Engage patients by talking openly about their concerns relating to wound care
- Encourage patients to actively participate in their assessment and treatment plan
- Empathise with the individual living with a chronic wound
- Educate patients by explaining procedures and how they are performed, helping to dispel any myths and misconceptions that may be causing anxiety
- Look at the whole patient, and any factors that may be affecting their wound healing beyond the physical.

Table 2. The four phases of wound healing (Stacey, 2016)				
Phase	**Timeframe**	**Cells involved**	**Function**	**Cellular and biophysical events**
Haemostasis	Instant	Platelets	Clotting to prevent blood loss	Vascular constriction, Platelet aggregation, degranulation, Thrombus formation
Inflammation	1-4 Days	Monocytes, Lymphocytes, Neutrophils, Macrophages	Phagocytosis	Neutrophil infiltration, Monocyte infiltration, Lymphocyte infiltration
Proliferation	4-12 Days	Lymphocytes, Macrophages, Angiocytes, Neutrophils, Fibroblasts, Keratinocytes	Wound bed filling, Wound closure	Re-epithelialisation, Angiogenesis, Collagen synthesis
Maturation	21+ Days	Fibrocytes	Develop tensile stength	Collagen remodelling, Vascular maturation, Regression

The physiological impact of stress

Stress has many definitions, but for the purposes of this paper, can be defined as 'a process whereby environmental demands exceed a person's individual perceived ability to cope, resulting in behavioural and physiological changes' (Cohen et al, 1997). Stress can be subdivided into two distinct types: acute stress, resulting from a short traumatic experience, and chronic stress, associated with long-term issues, which could include social or personal factors or disease progression in the case of wounds or comorbidities (Segerstrom and Miller, 2004).

Stress can affect physiological and behavioural changes (e.g. poor diet, little exercise, smoking or alcohol use), which may lead to an increase in inflammatory markers and wound healing time (Christian et al, 2006; Gouin and Kiecolt-Glaser, 2011).

The wound healing process

The stages of normal wound healing proceed in an automated fashion and follow four processes: haemostasis, inflammation, proliferation and maturation, see *Table 2* (Stacey, 2016). However, these processes are susceptible to interruption due to local

and systemic factors, including stress. Within a systematic and holistic assessment and treatment plan, if healing does not progress as suspected, stress should be considered as a possible factor (Gouin and Kiecolt-Glaser, 2011).

Stress and the mechanisms of healing

Wound healing requires pro- and anti-inflammatory cytokines, with the suppression of pro-inflammatory cytokines having an adverse effect on the inflammatory stage of healing. In particular, chronic stress has been found to cause abnormal extension of the inflammatory response, with measurable increases in inflammatory cytokines, disrupting the normal wound healing phases and prolonging wound healing times (Christian et al, 2006; Walburn et al, 2009). Glucocorticoids cause delayed wound healing by suppressing the systemic release of pro-inflammatory cytokines, which are required for the wound healing process (Kato et al, 2017), such as interlukin-1, interlukin-6, interlukin-8, tumour necrosis alpha and keratinocyte growth factor.

Stress and the immune system

Stress can negatively impact immunity (Morey et al, 2015). The immune system comprises cells, proteins, organs and tissues that work to protect and fight off bacteria and viruses. During acute stress, certain cells are mobilised into the bloodstream, preparing the body for injury or infection as part of the 'fight or flight' response. This response can last a matter of minutes and increases blood levels of pro-inflammatory cytokines. These increased levels can also be linked to chronic stress, which may last days or years and can dysregulate the immune system and increase the risk for chronic diseases (Morey et al, 2015).

Enabling the patient to understand the relationship between stress and the immune system and what enables a wound to heal can have a significant effect in improving outcomes.

Wound-specific stressors

Literature contains numerous examples of factors known to cause stress to a patient living with a chronic wound: these are known as wound-specific stressors. These include physical stressors, which can delay wound healing, and psychological stressors, which can impair an individual's quality of life and impact the wound healing process. Pain has also been established as a key cause of delayed healing due to the associated inflammatory responses, as well as psychosocial impacts that may include behavioural changes secondary to pain-related stress (Snyder, 2006). Chronic wound-related pain constitutes a psychological stressor that triggers the hypothalamic-pituitary-adrenal axis, promoting the production of glucocorticoid (cortisol) and vasopressin (McGuire et al, 2006). This has been associated with greater perceived stress and subsequent delayed healing (Ebrecht et al, 2004). Increased levels of stress and heightened anxiety have been linked with a lower pain threshold, as the person may become more vigilant of somatic signals: this can result in a vicious cycle of pain, stress/anxiety, and worsening of pain (Woo, 2010). Relatedly, the anticipated effect of pain has been demonstrated to intensify the actual pain experienced during a dressing change (Woo, 2010).

Snyder (2006) also identified odour and body image issues as major sources of stress in patients with a wound. The inability to carry out activities of daily living was also found to cause secondary social isolation and feelings of hopelessness. Cole-King and Harding (2001) recommended further investigation into behavioural and pharmacological interventions, to reduce the level of anxiety and depression in patients with potentially stress-induced delays in healing. In individuals experiencing pain that cannot be managed by medication (e.g. painful diabetic neuropathy) — psychological interventions may be necessary.

Monitoring stress

While stress can be difficult to measure (Wynn and Holloway, 2019), various methods have been suggested. Biomarkers such as cholesterol, blood pressure and body mass index may help to guide identification and management of stress, and provide a broad picture of an individual's health. Cortisol and interlukin-6 levels may also be checked, although these are not always routine tests.

Looking beyond the physical

A healthy mindset is a key component of a healthy body and attention should be paid to how an individual views themselves. If clinicians look only at the physical factors, they may miss underlying psychological and emotional factors that are affecting the

Figure 1. Coban 2 Lite Two-Layer Compression System.

Case study 1. Living with a chronic venous leg ulcer *(Courtesy of Melinda Brooks, Nurse Practitioner, Melbourne, Australia).*

Background: In October 2019, Jack presented with a chronic venous ulcer on his left lateral calf, which had been present for 3 months. The wound was small, measuring 1.5cm x 1.0cm, with partial-thickness tissue loss and significant oedema in the lower limb, mainly due to his comorbidities. These included cardiac failure, sedentary lifestyle due to limited mobility and mild peripheral arterial disease. The wound was impacting significantly on Jack's quality of life. It was painful, reduced his mobility and prevented him from carrying out activities of daily living. Due to his cardiac issues, Jack had many episodes of feeling unwell and would spend stints in hospital.

Treatment: Treatment initially commenced with a tubular form, tight compression system to allow ease of application for staff in his nursing home; however, this led to high levels of exudate, further maceration and skin breakdown. The wound increased significantly in size, measuring 6cm x 4cm. The decision was made to use a super-absorbent dressing and 3M™ Coban™ 2 Lite Two-Layer Compression System *[Figure 1]* to provide consistent compression to reduce the lower-leg oedema. Jack was involved in the decision-making process; potential complications, such as shortness of breath, were discussed to ensure he would be comfortable with the system. Two nurses were educated on how to apply the compression system safely to ensure continuity of care and avoid trauma to the tissues and limb.

Results: Coban 2 Lite Two-Layer Compression System was comfortable, lightweight and the compression therapy effectively reduced limb size. The wound progressed well and healed in a reasonable timeframe, despite Jack's complex comorbidities. Jack had peace of mind that the goals set out at the beginning of care had been achieved, which were to heal the wound as quickly as possible, reduce pain and improve quality of life.

Figure 2. Coban 2 Two-Layer Compression System.

Case study 2. Living with lymphoedema *(Courtesy of Síle Dillon)* .

Background: Síle is a 39-year-old lymphoedema patient. In 2015, she was diagnosed with cervical cancer and underwent a radical hysterectomy, followed by 29 rounds of radiotherapy and six rounds of chemotherapy. Secondary to cancer treatments, Síle developed lymphoedema, which presented in her leg a year after treatment and caused extreme swelling from hip to toe. The effects of this disease on her daily life — personal and social — were devastating. Whereas Síle previously enjoyed wearing high heels, dresses, fancy leggings and skinny jeans, with her swollen leg, she had to switch to runners a size bigger to fit her swollen foot, and wide leg trousers to accommodate her swollen limb. As a family, they had enjoyed long walks and attending football matches, but this was no longer possible as Síle was unable to walk as fast or as far. Síle also had to leave her job as she was unable to be on her feet without pain and uncontrollable swelling.

Treatment: Beginning in 2016, Síle and her team worked together to help find her relief from her condition and improve her quality of life. Everything was tried from compression stockings to a revolutionary new lymphatic pump, which Síle currently uses for an hour, up to three times a day, to help massage and displace the fluid in her leg. She also tried multi-layer bandaging and manual lymphatic drainage; however, this was incredibly painful and showed no results. A 3M representative introduced Síle to 3M™ Coban™ 2 Two-Layer Compression System — a bandaging system which changed her life *[Figure 2]*. It didn't slip, it felt light and supportive, plus conformed to her leg everywhere it was needed. Síle could walk without pain and after a few weeks, could even get back into a pair of wide leg jeans with her bandages on. Treatment continued for four months, by which point Síle had definition again and was able to see her ankle and knee, which brought tears to her eyes.

Results: Coban 2 Two-Layer Compression System has been life changing. Since March 2020, Síle has used the product intermittently to help control the build-up in her limb, along with compression garments and a lymphatic pump. It has given Síle back some confidence and made things possible again, like walking the dog, going to football matches — even getting dressed and putting on socks and shoes. Although lymphoedema is a lifelong condition with no cure, she is grateful to have Coban 2 Two-Layer Compression System as part of her therapy.

patient, their wellbeing and quality of life. Clinicians can advise patients on what the healing process looks like, how to help heal their wound and how to change their dressing, as well as helping to identify factors that motivate and encourage patients to engage and continue participation in their care.

However, patients can lose their 'why' (motivation and passion) when living with a chronic wound. It is vital for clinicians to understand this 'why?' to increase resilience and provide coping strategies, which can positively influence patient wellbeing and a positive mindset. Therefore, clinicians should provide support, hope and effective ways of adjusting to the new reality of their situation.

In assessing patients, it is important to look beyond the physical body and focus on the psychological factors which may be affecting patient quality of life and wound progression, such as:

- Sense of self/identity – a patient may feel they no longer know who they are and have lost a sense of self or identity
- Self-confidence — a patient may no longer have the confidence to carry out activities of daily living and wish to hide away from social situations
- Future dreams — a patient may feel they have lost sight of future dreams and that they are no longer attainable
- Sense of hope — a patient may feel hopelessness and discouragement as the wound is not progressing as expected
- Meaning — a patient may feel life no longer has any meaning and that they are simply surviving, rather than living
- Self-belief — a patient may have a low opinion and be overly critical of themselves.

Ultimately, it is about giving the patient confidence — accepting that they may lose this along the way — and helping them to see what the future could look like. With every positive and encouraging interaction between clinician and patient, the goals set out at the beginning of care can be achieved: to optimise wound healing and patient wellbeing.

It is also necessary for clinicians to identify what patients view as a stressor and subsequently include interventions in treatment plans, which will effectively manage the psychological factors contributing to delayed wound healing. Essentially, good wound care should involve an individualised and holistic approach, taking into account and actively optimising the links between the mind and the body.

Conclusion

This article explores the impact of psychological factors on wound healing and how clinicians can improve their practice by considering the whole patient including the body, the mind and the wound. Understanding the importance of patients' wellbeing, the effect of stress on wound healing and the psychological impact of living with chronic wounds can help to optimise wound healing for each individual patient. WINT

References

Christian LM, Graham JE, Padgett DA et al (2006) Stress and wound healing. *Neuroimmunomodulation* 13(5–6): 337–46

Cohen S, Kessler RC, Underwood Gordon L (1997) *Measuring Stress: A Guide for Health and Social Scientists*. Oxford University Press, New York

Cole-King A, Harding KG (2001) Psychological factors and delayed healing in chronic wounds. *Psychosomatic Medicine* 63(2): 216–20

Ebrecht M, Hextall J, Kirtley LG et al (2004) Perceived stress and cortisol levels predict speed of wound heating in healthy male adults. *Psychoneuroendocrinology* 29(6): 798–809

Gouin J-P, Kiecolt-Glaser JK (2011) The impact of psychological stress on wound healing: Methods and mechanisms. *Immunol Allergy Clin North Am* 31(1): 81–93

Kato T, Khanh VC, Sato K et al (2017) SDF-1 improves wound healing ability of glucocorticoid-treated adipose tissue-derived mesenchymal stem cells. *Biochem Biophys Res Commun* 493(2): 1010–7

McGuire L, Heffner K, Glaser R, et al (2006) Pain and wound healing in surgical patients. *Ann Behav Med* 31(2): 165–72

Morey JN, Boggero IA, Scott AB, Segerstrom SC (2015) Current directions in stress and human immune function. *Curr Opin Psychol* 5: 13–7

Price PE, Fagervik-Morton H, Mudge EJ et al (2008) Dressing-related pain in patients with chronic wounds: an international patient perspective. *Int Wound J* 5(2): 159–71

Segerstrom SC, Miller GE (2004). Psychological stress and the human immune system: a meta-analytic study of 30 years of inquiry. *Psychological Bulletin* 130(4): 601–30

Snyder RJ (2006) Venous leg ulcers in the elderly patient: associated stress, social support, and coping. *Ostomy Wound Manage* 52(9): 58–66, 68

Stacey M (2016) Why don't wounds heal? *Wounds International* 7(1): 16–21

Walburn J, Vedhara K, Hankins M et al (2009) Psychological stress and wound healing in humans: A systematic review and meta-analysis. *J Psychosom Res* 67(3): 253–71

Woo KY (2010) Wound-related pain: Anxiety, stress and wound healing. *Wounds UK* 6(4): 92–8

Woo KY, Harding K, Price P, Sibbald G (2008) Minimising wound-related pain at dressing change: evidence-informed practice. *Int Wound J* 5(2): 144–57

Wynn M, Holloway S (2019) The impact of psychological stress on wound healing: a theoretical and clinical perspective. *Wounds UK* 15(3): 20–7

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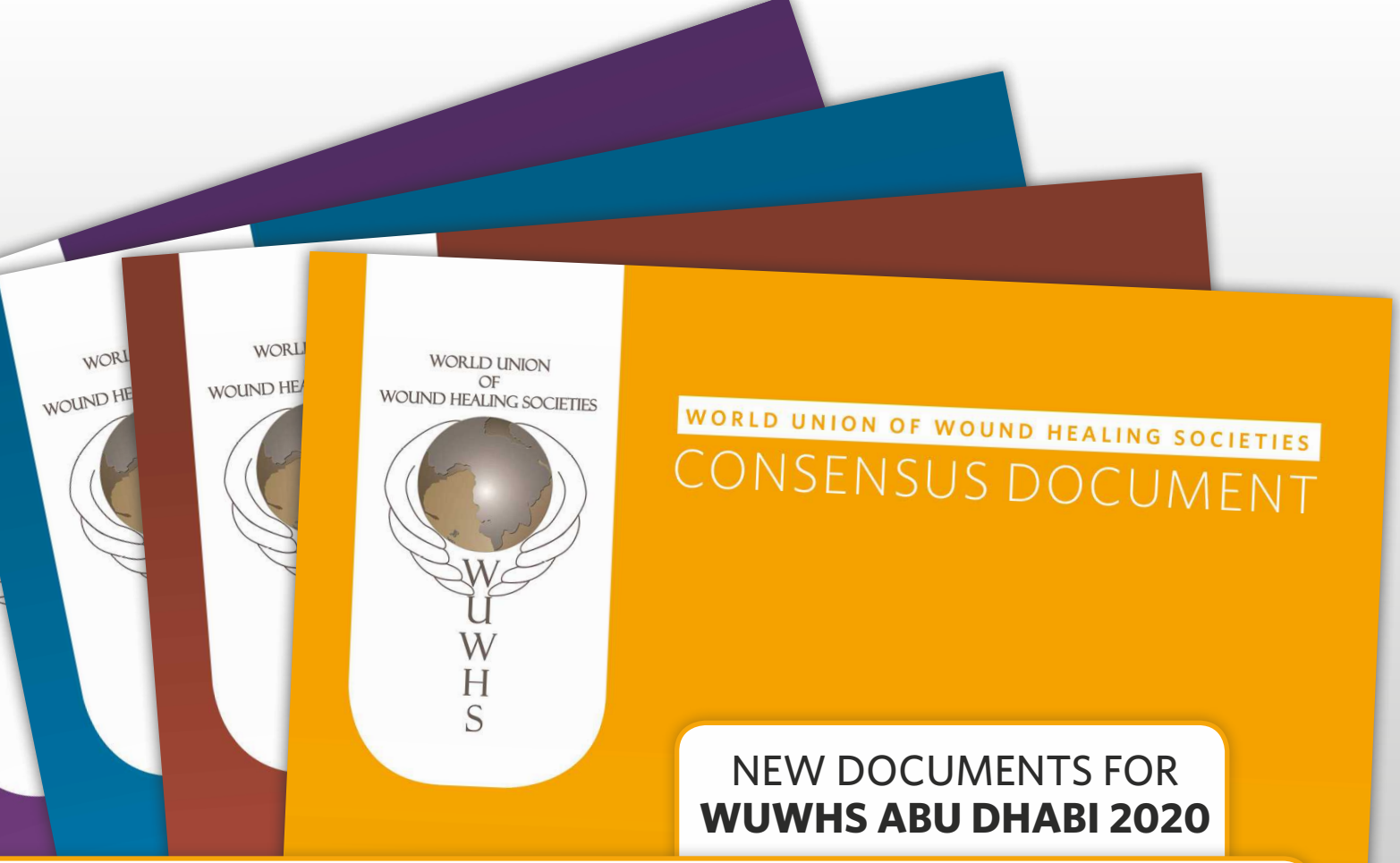

NEW DOCUMENTS FOR **WUWHS ABU DHABI 2020**

WORLD UNION OF WOUND HEALING SOCIETIES

WUWHS

POSITION DOCUMENT: THE ROLE OF NON-MEDICATED DRESSINGS FOR THE MANAGEMENT OF WOUND INFECTION

POSITION DOCUMENT: EVIDENCE IN WOUND CARE

CONSENSUS DOCUMENT: OPTIMISING WOUND CARE THROUGH PATIENT ENGAGEMENT

CONSENSUS DOCUMENT: WOUND BED PREPARATION, USING TIME CLINICAL DICISION SUPPORT TOOL IN PRACTICE

Wounds INTERNATIONAL

Silicone therapy for the treatment and prevention of problematic scars: a practical guideline


Authors: Corrado Maria Durante and Sander Kant

Annually, about 100 million people worldwide develop a scar (Sund, 2000). Most wounds heal without problems; however, a proportion of people form raised, problematic, painful, itchy, or red scars. Historically, and more recently, it is estimated that about 40 to 70% of all patients that undergo surgery develop hypertrophic scars as a result (Deitch, 1983; Murray and Pinnel, 1992; Sund, 2000). After a rapid growth phase for up to 6 months, these scars regress slowly over a period of multiple years (Kant et al, 2019; Gauglitz et al, 2011).

The most common types of problematic scars are atrophic, hypertrophic and keloid scars. Hypertrophic scars are broad and elevated and, therefore, can be conspicuous. While hypertrophic scars grow within the borders of the original wound and eventually become smaller, keloids grow beyond the original wound borders, do not become smaller on their own, and are difficult to treat (Limandjaja et al, 2020).

Also, keloids tend to cause more discomfort, itchiness and sometimes pain when compared to hypertrophic scars. The incidence of keloid scars is 6 to 16% in individuals with dark skin (Niessen et al, 1999); in individuals with lighter skin, they occur les frequently. It can sometimes still be difficult to determine whether a scar is hypertrophic or keloid (Limandjaja et al, 2020).

In both keloid and hypertrophic scars, there is a derailment of the normal wound healing cascade, and an upregulation of collagen synthesis, deposition, and accumulation. An important and convenient non-invasive first-line strategy in the treatment and prevention of hypertrophic and keloid scarring is silicone treatment (Neligan et al, 2013). Silicone therapy can both prevent problematic scar formation, accelerate the maturation phase and relieve symptoms such as itch and pain (Neligan et al, 2013). However, there are still some uncertainties about the mechanism of action, the clinical effects, and the optimal duration of silicone therapy. This article aims to offer a practical guideline for medical professionals for the use of silicone therapy in scars.

What are silicones?

Silicones that are used for scar therapy are elastomers. They can have a solid rubber-like appearance, or they can have a more liquid, gel-like form. The matter of cross-linking of the elastomers determines the consistency of the silicone material (Berman et al, 2007).

Mechanism of action

One of the primary benefits of silicone therapy is increased hydration of the skin. By occluding the skin with silicones, trans-epidermal water loss (TWL) via evaporation in the skin decreases. In this manner, fresh scar tissue will be provided with optimal moisture levels. As a result, the appearance of scars improves: they become lighter, more pliable, and they flatten (Berman et al, 2007).

Indications for the use of silicones

Silicone scar therapy can be used for the treatment of hypertrophic and keloid scars caused by surgery, burns, and other trauma. Those are raised, thickened, red or dark-coloured scars that can be itchy and painful, or cause aesthetic issues that may affect the individual. These types of problematic scars are also known to cause a significant impairment on patient quality of life (Bock et al, 2006). Keloid scars in particular have a more aggressive growth pattern, where they extend over the original wound.

Silicones are an easy-to-use local, well-tolerated first-line therapy for these problematic scars. They also have a preventative value in the

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treatment of scars: they can be useful in patients with an increased risk of developing problematic scars, as well as being advised for use post-surgery on certain high-risk areas on the body.

It should be noted that a patient with hypertrophic scars after severe (deep) burns should be admitted to a specialised burn centre, as additional therapy is presumably necessary in such cases.

PREVENTION OF PROBLEMATIC SCARS

Excessive scar tissue can have far-reaching consequences and the impact of problematic scars on quality of life can be extensive. Scars can cause functional, psychological, symptomatic and cosmetic complaints (Bock et al, 2006; Gibson et al, 2018; Nitescu et al, 2012). Wounds that are closed under tension, or wounds that have had prolonged healing time, are at risk of resulting in hypertrophic scars.

Therefore, appropriate surgical techniques and adequate wound care are important in the prevention of problematic scarring, especially in traumatic wounds. Nevertheless, there are areas on the human body where scars are at an increased risk of developing hypertrophy, even if adequate wound care is applied. The main areas that are associated with poor-quality scars are the chest, the lower face, the upper back, ears, neck, and shoulders. An untreated hypertrophic scar is in most cases still hypertrophic after one year (Mahdavian Delavary et al, 2012). Young age is also a risk factor for hypertrophic scar development (Lawrence et al, 2012). Furthermore, hypertrophic scars in younger patients tend to regress slower when compared to older patients (Kant et al, 2019). Therefore, younger patients are at risk for having hypertrophic scars for a prolonged period.

Patients who have had hypertrophic or keloid scars in the past are also at an elevated risk of developing problematic scars. Also, patients with dark skin complexions are more prone to developing problematic scars, especially when it comes to keloid scars. In the aforementioned 'risk groups', silicones are effective in preventing the formation of hypertrophic scars (Lawrence et al, 2012). Silicone therapy (both gels and sheets) has proven to outperform other locally applied agents such as Vaseline and onion extract cream in post-operative scar prevention (Hsu et al, 2017).

Gels or sheets?

The clinical effects of silicone gels are a less studied subject, when compared to silicone gel sheets. However, there is clinical evidence that shows silicone gels are effective in accelerating the maturation time and in reducing the hypertrophy rate of fresh post-surgical scars as well (Wang et al, 2020). Moreover, silicone gels and sheets seem to exert similar clinical effects in the prevention of problematic scars (Signorini and Clementoni, 2007; Lin et al, 2018). Silicone gels are invisible when dried, and therefore they are an attractive option for scars in visible areas, especially on the face. Some silicone sheets require fixation with adhesive tape, where silicone gels do not.

Clinical effects of silicone therapy

Silicone sheets have proven to result in reduction of thickness, erythema, pain, itchiness, and pliability of hypertrophic scars (Chang et al, 2018). See cases 1 and 2, which show the clinical effects of both silicone gel and sheets (BAPSCARCARE GEL and BAPSCARCARE T) on a keloid scar on the right external malleolus after an accident and on a hypertrophic scar on the forearm after surgery.

In combination with compression therapy

Compression therapy is, next to silicone scar therapy, also one of the most widely used and studied tools in the treatment of severe problematic scars, predominantly after burns. Compression garments require correct fitting, where adequate pressure underneath the garment should be reached. It can be challenging to maintain the patient's compliance to compression therapy. Combined use of compression and silicones has demonstrated more positive effects in some studies than either of those individual therapies alone (Li-Tsang et al, 2006), although one study showed silicone monotherapy to be more effective than combined therapy (Steinstraesser et al, 2011). When problematic scars result from deep dermal burns and are more severe, the patient should be referred to a specialised burn care unit for alternative and (frequently) combined scar therapy.

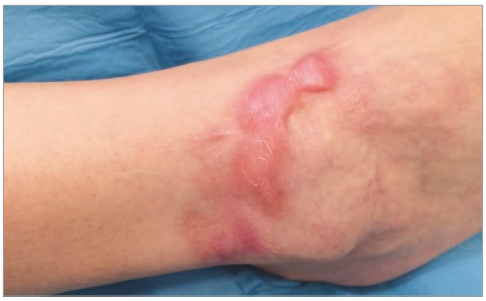
PRACTICAL GUIDELINES

How to use silicones on scars

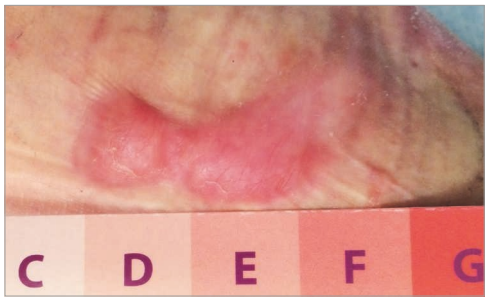
The silicone gel or sheet should be applied to the scar, extending approximately 1–2cm beyond the scar margins. When using silicone gel, it should be applied twice daily and the patient should wait until the gel has dried before putting clothes on that cover the area. Some silicones sheets and gels also contain adequate

Case 1. Keloid scar after road trauma.

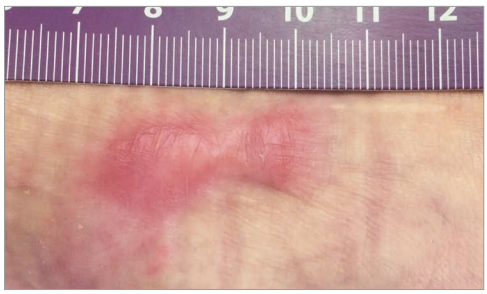
Patient age	38 years
Gender	Female
Cause	Soft tissue loss on the right external malleolus after accident
Why scar treatment?	Keloid scar
Start scar treatment	3 months after accident
Type of therapy	7 months BAPSCARCARE T (during the night) in combination with BAPSCARCARE gel (during daytime)



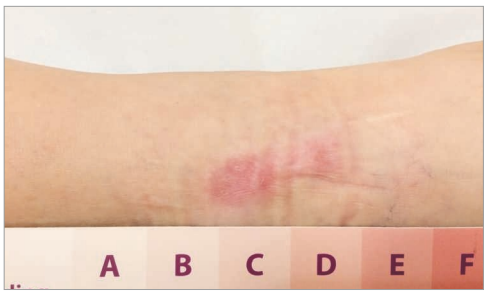
3 months after accident, start of therapy



2 months after start of therapy



3 months after start of therapy



Further treatment with BAPSCARCARE gel and sheets (T)

Conclusions of the medical team

- Significantly reduced thickness
- Improved vascularity
- Improved pliability of the skin.

Patient experience

- Improved overall appearance of the scar
- Both BAPSCARCARE T and BAPSCARCARE gel are easy to apply
- BAPSCARCARE gel is invisible and non-sticky after application
- Choice for using gel during the day because of wet environment (patient works as fitness instructor).

Case study: Prof. C.M. Durante MD, Rome, Italy

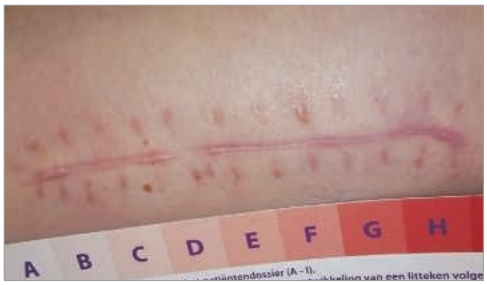
UV protection, so the skin that is covered can safely be exposed to sunlight.

Therapy duration: when to start?

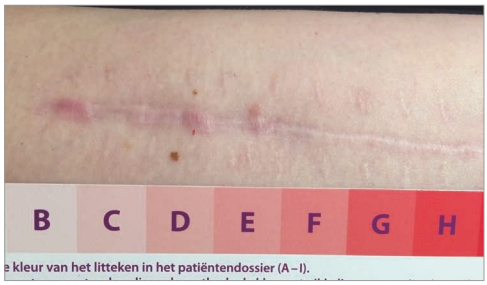
In patients at increased risk of hypertrophic or keloid scarring — and in patients who have previously developed an abnormal or problematic scar – silicone therapy should start when full re-epithelialisation of the wound is reached, within about 2 weeks of wound closure. Scar hypertrophy develops in most cases (96%) within a 3-month period after surgery, as shown in a study by Mahdavian Delavary et al (2012); therefore scar therapy should start in the early phases of healing, highlighting the importance of routine scar assessment after surgery. Nevertheless, silicone treatment has also proven to be effective in scars that have been present for more than 12 months (Wiseman et al, 2019). However, it is believed that optimal results will be seen when silicones are applied to scars that are still immature: when they are red, thickened, and cause clinical symptoms like itchiness and pain. This period of immaturity can last for over a year.

Case 2. Surgical intervention.

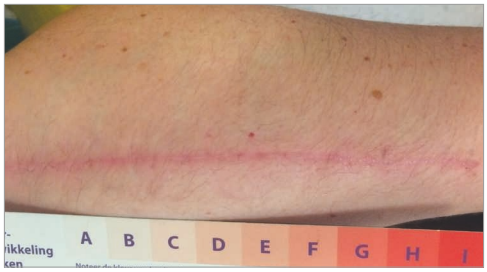
Patient age	38 years
Gender	Female
Cause	Multiple fractures of the right forearm, surgery to ensure realignment (plates)
Why scar treatment?	Early stage hypertrophic scar development
Start scar treatment	7 weeks post surgery
Type of therapy	4 months BAPSCARCARE T in combination with BAPSCARCARE gel



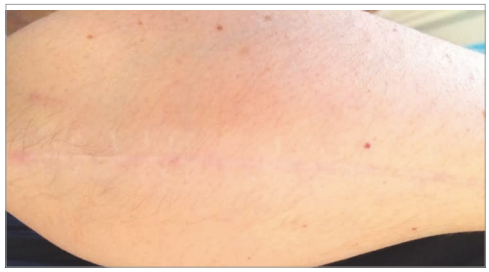
Anterior view: 7 weeks after surgery, start of therapy.



Anterior view: 4 months after start of therapy.



Posterior view: 7 weeks after surgery, start of therapy.



Posterior view: 4 months after start of therapy.

Conclusions of the medical team

- Significantly reduced vascularity (redness)
- Less pigmentation
- Improved flexibility of the skin
- Reduced scar thickness
- Advised to continue the therapy
- Combining the silicone sheet with the silicone gel, results in a higher compliance.

Patient experience

- Improved overall appearance of the scar
- Both BAPSCARCARE T and BAPSCARCARE gel are easy to use.

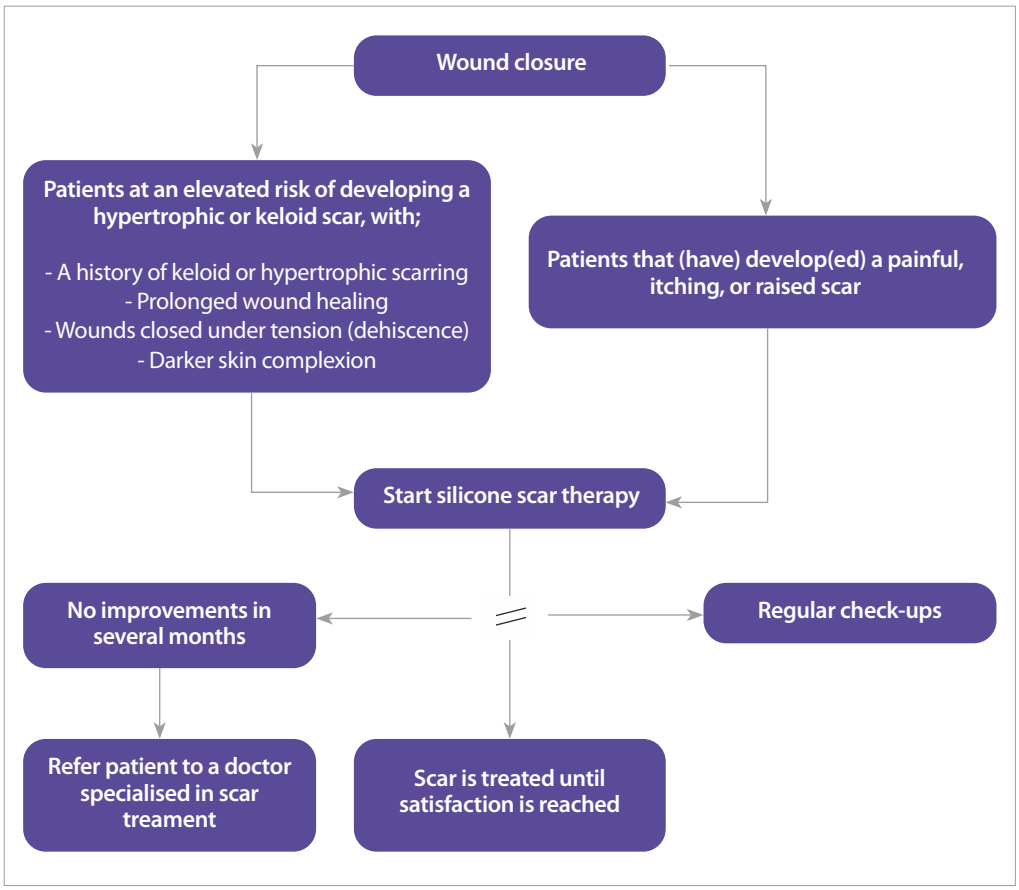
Case study: Prof. C.M. Durante MD, Rome, Italy

Therapy duration

Silicone products should ideally be worn for between 12 and 24 hours a day, but significant improvement in problematic scars has also been observed when therapy is maintained for at least 4 hours per day (Wittenberg et al, 1999). Because silicone scar therapy is well-tolerated in general, building up to a daily duration of 24 hours is advised to maximise the beneficial effects of silicones on scars. Silicone sheets that do not require daily rinsing can be applied immediately for a long time duration.

In general, total therapy duration — for both hypertrophic and keloid scars — should be at least 2 to 3 months, while a treatment period of 6 months can prevent recurrence (Berman et al, 2007; Wittenberg et al, 1999; Westra et al, 2016; Gold et al, 2014; Lyle and Plastic Surgery Educational Foundation DC, 2001). In cases where scars stay in the immature phase for a prolonged period, the total treatment period can in some cases be longer than 6 months. When the treated scar doesn't show any improvement over several months, the patient

Figure 1. Scar treatment algorithm.



should be referred to a board-certified plastic surgeon or dermatologist to consider additional scar therapy. *Figure 1* displays a proposed scar treatment algorithm.

Adverse effects

Potential adverse effects that can occur from silicones are mild, and they are mainly associated with silicone gel sheets. These can include itchiness, skin rash, maceration of the skin, and malodour. These symptoms can be resolved easily by a temporary break from treatment (Nikkonen et al, 2001). A steady build-up phase of the silicone sheet is therefore advised in order to ascertain whether the product is well tolerated on the skin.

Rinsing

In order to minimise potential adverse effects, proper hygiene and a structured washing routine are necessary when using silicone sheets. Patients should wash the silicone sheet and area of skin being treated once a day, with hypoallergenic soap and clear warm water, and it should be air-dried or patted dry with a lint-free cloth. There are also silicone products that do not require daily rinsing; for example, the silicone product BAPSCARCARE T (BAP Medical, The Netherlands).

SUMMARY

- Silicones are an easy-to-use and well-tolerated first-line treatment option for both prevention and management of hypertrophic or keloid scars.
- Silicones should be applied as a preventative measure directly after wound re-epithelisation in high-risk patients: those who have previously experienced hypertrophic or keloid scarring, patients with dark skin complexion, young patients, patients with problematic wound healing, and patients with wounds in high-risk areas.
- In patients who develop red, raised, painful, or itchy scars, silicones should be applied early (between 2 weeks and 3 months) and as a first-line measure. The same advice applies for patients who already have developed a scar with one of the aforementioned characteristics. Therapy duration should be at least 3 months, for a minimum of 12 hours daily.
- Employing a steady build-up phase, plus daily rinsing of the skin and the silicone sheet (for most silicone products), is important to minimise possible adverse effects.

References

Berman B, Perez OA, Konda S et al (2007) A review of the biologic effects, clinical efficacy, and safety of silicone elastomer sheeting for hypertrophic and keloid scar treatment and management. *Dermatologic Surgery* 33: 1291–302; discussion 302–3

Bock O, Schmid-Ott G, Malewski P, Mrowietz U (2006) Quality of life of patients with keloid and hypertrophic scarring. *Arch Dermatol Res* 297: 433–8

Chang CS, Wallace CG, Hsiao YC et al. (2018). Clinical evaluation of silicone gel in the treatment of cleft lip scars. *Sci Rep* 8: 7422

Deitch EA, T M Wheelahan, M P Rose et al (1983) Hypertrophic burn scars: analysis of variables. *J Trauma* 23: 895–8

Gauglitz GG, Korting HC, Pavicic T et al (2011) Hypertrophic scarring and keloids: pathomechanisms and current and emerging treatment strategies. *Mol Med* 17: 113–25

Gibson JAG, Ackling E, Bisson JI et al (2018) The association of affective disorders and facial scarring: Systematic review and meta-analysis. *J Affect Disord* 239: 1–10

Gold MH, McGuire M, Mustoe TA et al (2014) Updated international clinical recommendations on scar management: part 2--algorithms for scar prevention and treatment. *Dermatologic Surgery* 40: 825–31

Hsu KC, Luan CW, Tsai YW (2017) Review of silicone gel sheeting and silicone gel for the prevention of hypertrophic scars and keloids. *Wounds* 29: 154–8

Kant S, van den Kerckhove E, Colla C et al (2019) Duration of scar maturation: Retrospective analyses of 361 hypertrophic scars over 5 years. *Adv Skin Wound Care* 32: 26–34

Lawrence JW, Mason ST, Schomer K, Klein MB (2012) Epidemiology and impact of scarring after burn injury: a systematic review of the literature . *Journal of Burn Care & Research* 33(1):1 36–46

Li-Tsang CW, Lau JC, Choi J et al (2006) A prospective randomized clinical trial to investigate the effect of silicone gel sheeting (Cica-Care) on post-traumatic hypertrophic scar among the Chinese population. *Burns* 32: 678–83

Limandjaja GC, Belien JM, Scheper RJ et al (2020) A study looking at the differences between hypertrophic scars and keloid scars. *British Journal of Dermatology* 182 974–86

Lin YS, Ting PS, Hsu KC (2018) Does the form of dressings matter? A comparison of the efficacy in the management of postoperative scars between silicone sheets and silicone gel: a randomized controlled trial. *Medicine* 97: e11767

Lyle WG, Plastic Surgery Educational Foundation DC (2001) Silicone gel sheeting. *Plastic and Reconstructive Surgery* 107: 272–5

Mahdavian Delavary B, van der Veer WM, Ferreira JA, Niessen FB (2012) Formation of hypertrophic scars: evolution and susceptibility. *J Plast Surg Hand Surg* 46: 95–101

Murray CJ, Pinnel SR (1992) Keloids and excessive dermal scarring. In: Cohen IK, Diegelmann RF, Lindblad WJ, editors. Wound Healing, Biochemical and Clinical Aspects. Saunders Elsevier; Philadelphia. pp. 500-9

Neligan P (2013) Chapter 16: Scar prevention, treatment, and revision. Plastic Surgery, Volume 1: Principles. pp. 297–318

Niessen FB, Spauwen PH, Schalkwijk J, Kon M (1999) On the nature of hypertrophic scars and keloids: a review. *Plast Reconstr Surg* 104: 1435–58

Nikkonen MM, Pitkanen JM, Al-Qattan MM (2001) Problems associated with the use of silicone gel sheeting for hypertrophic scars in the hot climate of Saudi Arabia. *Burns* 27: 498–501

Nitescu C, Calota DR, Stancioiu TA et al (2012) Psychological impact of burn scars on quality of life in patients with extensive burns who received allotransplant. *Rom J Morphol Embryol* 53: 577–83

Signorini M, Clementoni MT (2007) Clinical evaluation of a new self-drying silicone gel in the treatment of scars: a preliminary report. *Aesthetic Plast Surg* 31: 183–7

Steinstraesser L, Flak E, Witte B et al (2011) Pressure garment therapy alone and in combination with silicone for the prevention of hypertrophic scarring: randomized controlled trial with intraindividual comparison. *Plast Reconstr Surg* 128(4): 306e–313e

Sund B (2000) New developments in wound care, vol. 86, PJB Publications CBS, London. pp. 1–255

Wang F, Li X, Wang X, Jiang X (2020) Efficacy of topical silicone gel in scar management: A systematic review and meta-analysis of randomised controlled trials. *International Wound Journal*

Westra I, Pham H, Niessen FB (2016) Topical silicone sheet application in the treatment of hypertrophic scars and keloids. *J Clin Aesthet Dermatol* 9: 28–35

Wiseman J, Ware RS, Simons M et al (2019) Effectiveness of topical silicone gel and pressure garment therapy for burn scar prevention and management in children: a randomized controlled trial. *Clinical Rehabilitation* 1: 120–131

Wittenberg GP, Fabian BG, Bogomilsky JL et al (1999) Prospective, single-blind, randomized, controlled study to assess the efficacy of the 585-nm flashlamp-pumped pulsed-dye laser and silicone gel sheeting in hypertrophic scar treatment. *Arch Dermatol* 135: 1049–55

Advancing practice in holistic wound management: a consensus-based call to action

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Marcelo Ruettimann Liberato de Moura, Caroline Dowsett, Kimberly Bain and Mark Bain

Wound care consumes extensive healthcare resources (Cornforth, 2013; Corbett and Ennis, 2014; Dowsett et al, 2015; Guest et al, 2015) and burdens patients and society with hidden costs, such as pain, social isolation, employment loss and depression (Cornwell and Schmitt, 1990; Dowsett, 2009; European Wound Management Association, 2009; Price and Krasner, 2012). A group of researchers undertook a modified Delphi process to build a consensus among 85 international wound care specialists on how to assess and treat chronic wounds, including how to embed evidence-based holistic wound management into clinical practice. Consensus was reached on the importance of conducting holistic wound management by assessing and treating the patient, based on their history and individual needs, assessing and treating the wound, based on a continuous and comprehensive wound assessment process, and assessing and considering the wound care environment.

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Conflict of Interests:
Each of the Authors have acted as consultants for Coloplast in the past, as well as other health care suppliers and companies
Ethical Principles:
The authors warrant that this manuscript is their original work, has not been published before and is not being considered for publication by another publisher.
Ethics Approval:
This research did not require ethical approval. It did not include patients, or patient data. Only the opinions of health care providers were gathered, and that information was only gathered directly from the providers, who consented to the process and the information collected.

Author details on p71

Eighty-five wound care specialists from 19 countries took part in a consensus process that spanned four months, ending in November 2019. The process included both traditional Delphi surveys, as well as virtual and face-to-face facilitated dialogues (Keast et al, 2020). The result was a consensus on best practices in chronic wound care and how to translate those best practices into effective patient care. This fourth article, in a four-part series, focuses on holistic wound management with the ultimate goal of increasing quality of care and reducing wound healing time.

Holistic wound management has been a topic of investigation and research for many years, often under the guise of holistic wound assessment, patient quality of life, patient empowerment, multidisciplinary wound care or patient-centred wound care. However, while some attention has been placed on holistic wound management, the emphasis is still focused on the biological factors influencing the wound's healing progression (Hopkins, 2001; Hollinworth and Hawkins, 2002; Benbow, 2006; European Wound Management Association [EWMA], 2008).

It is a generally accepted principle that the clinician's aim should be to reduce wound healing time (Price and Harding, 2004) by addressing all factors that promote healing (London, 2007; Ousey and Cook, 2013; Dowsett, 2018). Holistic wound management identifies and deals with the causative or contributory elements that could delay healing by recognising the complex combination of factors, both inside and outside the wound, that affect healing progression (EWMA, 2008; Ousey and Cook, 2012; Cornforth, 2013; Benbow, 2016; Wounds UK, 2018).

Identifying patient and wound factors that require intervention, using a holistic assessment process, enables the clinician to work with the patient to optimise their wound healing potential, through effective local wound care and by reducing risks of infection and other complications (Ousey and Cook, 2011; International Wound Infection Institute [IWII], 2016; Wounds UK, 2018).

Holistic wound management considers the 'whole patient', not the 'hole in the patient' (Hampton and Collins, 2004; Wounds UK, 2018).

This requires the clinician to document a holistic patient assessment before undertaking an assessment of the wound itself (Keast et al, 2004; Atkin, 2013; Benbow, 2016; Coleman et al, 2017). A holistic patient assessment should include:

- Detailed history taking:
  - About patient's current and past medical history — nutrition, smoking, mobility, dexterity, medication history, previous wounds, allergies, comorbidities, medications, etc (Williams and Leaper, 2000; EWMA, 2008; World Union of Wound Healing Societies [WUWHS], 2008; Ousey and Cook, 2011; Cornforth, 2012; Wounds UK, 2012; Wounds International, 2012; McRobert, 2013; Corbett and Ennis, 2014; Sibbald et al, 2014)
  - About patient's psychological, social and spiritual history and current status — i.e. anxiety, depression, body image, coping challenges, social isolation, support network, family, quality of life, etc (Beck et al, 1993; Tare, 2002; EWMA, 2008; Wounds International, 2012; Wounds UK, 2012; Corbett and Ennis, 2014; Erfurt-Berge et al, 2019; WUWHS, 2019)
  - Assessment of the wound care environment, including access to specialised health services (Cardozo, 2003; Wounds International, 2012; Wounds UK, 2012; IWII, 2016; Murphy et al, 2020)
- Physical assessment of patient — respiration, blood pressure, heart sounds, skin assessment, etc (EWMA, 2008; WUWHS, 2008; Ousey and Cook, 2011; Wounds International, 2012)
- Wound assessment — assessing the wound bed, the wound edges, the periwound skin and patient pain levels (Reddy et al, 2003; Barrett, 2007; Green and Jester, 2009; Ousey and Cook, 2011; Corbett and Ennis, 2014; Dowsett et al, 2019; Stolt et al, 2019).

Holistic wound management, requires the clinician to consider how the factors identified during the holistic patient assessment could increase the risks of delayed wound healing and then to develop a care plan to reduce those risks and heal the wound (EWMA, 2008; Wounds UK, 2016; Wounds UK, 2018). Understanding the relationship between the patient, the wound and the environment is key to developing an effective holistic management plan (Brown, 2015; Wounds UK, 2018). This requires a dynamic and continuous re-assessment process (Wounds International, 2012; Wounds UK, 2012; Cornforth, 2013; Wounds UK, 2018) utilising the expertise of a multidisciplinary team (Teare, 2002; Cornforth, 2012; McKenzie, 2011; Ousey and Cook, 2011). Development of the holistic wound management plan should be conducted in partnership with all members of the care team and the patient (Jordan et al, 2002; Corbett and Ennis, 2014; Nazarko, 2015; WUWHS, 2019). Evidence suggests that involving patients directly in their care planning and treatment decisions improves patient concordance, as well as healthcare outcomes (Solowiej et al, 2010; Corbett and Ennis, 2014).

Methodology

This project utilised a Modified Delphi Process that combines the rigor and validation of the traditional scientific Delphi method with professionally facilitated virtual and face-to-face collaborative processes (Bain and Hansen, 2020; Keast et al, 2020). Eighty-seven wound care specialists across 19 countries were sent a series of surveys on chronic wound care. Eighty-four of the survey participants then met in Denmark in November 2019 for a facilitated face-to-face dialogue. The group reviewed the survey results, discussed the latest research and best practices identified in the literature and shared their clinical experience.

The face-to-face interactive dialogue was designed as a round-robin iterative process to gather the views and ideas of all participants and to allow time for participants to build their collective intelligence and have in-depth discussions with international colleagues about their ideas (Keast et al, 2020). Eight stations were situated along what was called the 'Road to Consensus'. Each station had a topic, a summary of the relevant research and a series of open-ended questions to guide group discussions. After the participant groups cycled through each of the eight stations, the ideas generated were transcribed and thematically grouped by the facilitators, which led to the consensus on best practices in chronic wound care. The consensus results were presented back to participants who validated the results over a 30-day review period following the event.

Participants

Participants were qualified wound care specialists. Forty-five percent of participants had more than 20 years' experience and 86% had more than 10 years' experience. Eighteen percent of participants reported that their practice is 100% wound care. Participants were multidisciplinary and included: doctors (29%), nurse specialists (61%) and other healthcare professionals (10%).

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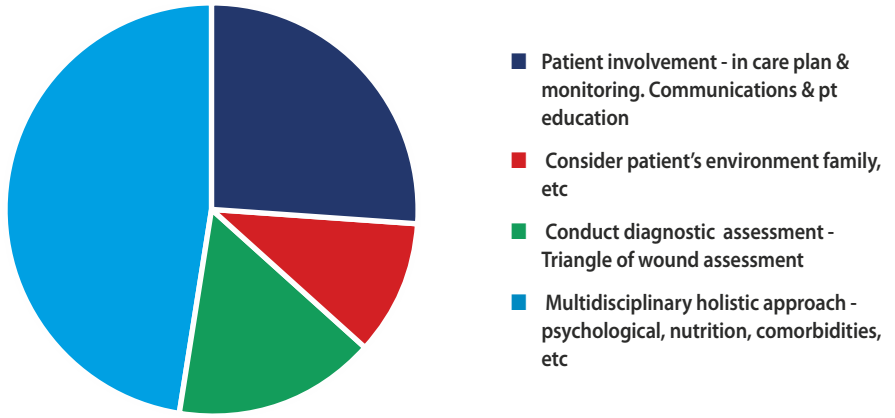
Figure 1. Best Practices in Holistic Wound Management.



Results

Participants reached agreement on the importance of holistic wound management and developed recommendations on how to develop an effective holistic wound management plan. Consensus was reached on the top four best practices in holistic wound management *[Figure 1]*.

The most important best practice in the holistic wound management recommended was utilising a multidisciplinary approach to assessing the whole patient. This included considering:

- Comorbidities and deteriorating conditions
- Lifestyle risk factors, such as smoking, sedentary lifestyles a alcohol/substance abuse
- Nutrition and obesity
- Vascular problems
- Dermatological complications such as allergies to adhesives
- Sociological issues, such as income instability/employment, housing, social network, social isolation and overall quality of life
- Psychological issues, such as depression, anxiety, etc
- Clinical history, such as previous wounds and diseases, allergies to medications, etc
- Current medications and medication history
- Age
- Mobility and dexterity.

Participants agreed that a multidisciplinary approach requires coordination among all care providers, as well as referral to specialist (i.e. dieticians, occupational therapists, diabetic educators, mental health service providers, surgeons, etc) as necessary.

The second-best practice recommended was involving the patient in care planning, treatment, and monitoring, through continuous communication and patient education. Four methods of empowering patients were identified, each were acknowledged as equally important in increasing patient concordance with the care plan and in increasing healing progression *[Figure 2]*. The four methods were:

- involve patients and caregivers in decision-making — work with patients to find solutions, consider the patient as a partner

Figure 2: Best Practice for empowering patients, increasing adherence to care plans and increasing health outcomes.

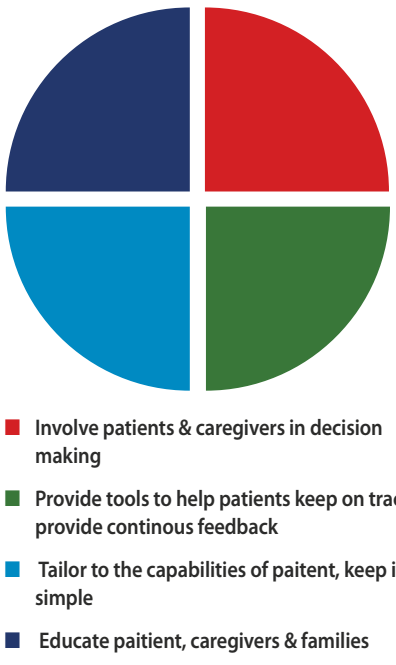
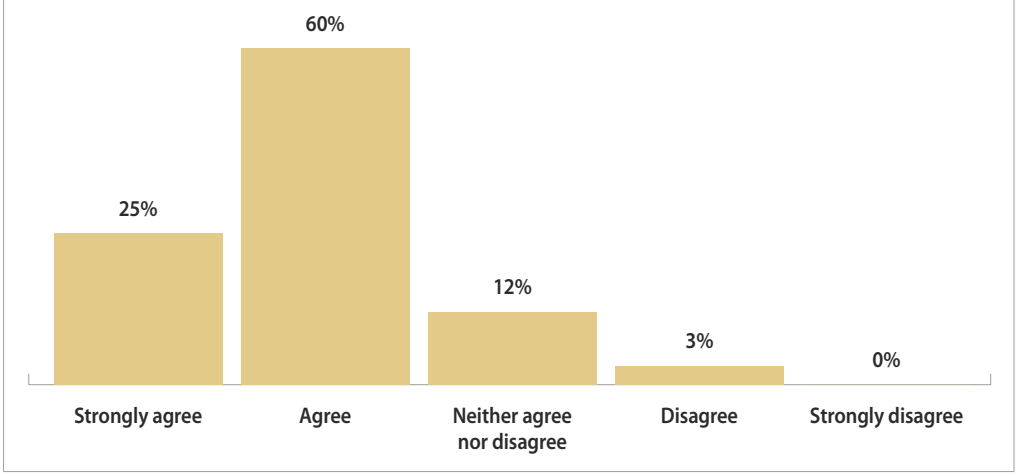


Figure 3. The acceptable indicator of effective wound healing progression is a reduction of the wound area of 20–40% in 4 weeks.



in care planning, accept patients' wishes, recognise and discuss patients' economic and social realities, listen to the patient, encourage patient ownership of their own health outcomes
- educate patients, caregivers and family members — on wound aetiology, on hygiene, on rationale behind care plan decisions, on effective dressing changes, using multiple delivery methods (demonstrations, pictures, pamphlets, videos etc), follow-up and test for understanding
- tailor communications to the capabilities of the patient — keep the message simple, use effective adult learning strategies, offer clear self-management pathway, empathise and empower
- provide tools to help keep patients on track and concordant with their care plan and provide continuous monitoring of progress and feedback — set mutual goals, encourage active accountability, give patients a copy of the care plan, provide patient diary or other tracking tools, offer help and relief strategies.

The third-best practice recommended was to conduct a holistic wound assessment. Agreement was reached on the following critical factors that must be considered when assessing the wound:
- assess the wound aetiology, or the cause of the wound
- assess the physical wound using a validated tool like the Triangle of Wound Assessment, that considers the wound bed, the wound edge and the periwound skin
- pain levels
- exudate level, colour and amount
- wound bioburden
- the wound's location
- the wound's history, duration, measurement and healing progression.

When asked what the acceptable indicator of effective wound healing progression is, 85% of participants agreed that a reduction in wound area of 20–40% in 4 weeks indicates an effective wound-healing progression *[Figure 3]*.

The fourth best practice recommended was considering the wound care environment. This included consideration of:
- the patient's home environment — hygiene, access to clean water, privacy, accessibility, etc
- the patient's family and support network — what supports are available to change dressings, follow and monitor the care plan, what emotional support the patient can draw on within their family/community, caregiver abilities, etc
- the healthcare system in which the care is given.

Conclusions

While there is a great deal of evidence that holistic wound management leads to better health outcomes and decreases wound healing time, the prevalence of non-healing wounds continues to be a global problem. This project brought together wound care specialists from across 19 countries to develop a consensus on how healthcare providers should assess and treat wounds to promote effective wound healing. The consensus reached, offers recommendations to all health care providers on how to translate the evidence into clinical practice and decrease the number of days with wounds.

The consensus process concluded that the best practices in holistic wound management

are:

- Conduct a holistic patient and wound assessment that includes: Sibbald et al, 2014)
  - an assessment of patient's medical, psychological and social history and current situation
  - a physical assessment of the patient
  - an assessment of the wound
- Utilise a multidisciplinary holistic approach — psychological, psychosocial, nutritional, comorbidities, etc
- Include the patient in the development and monitoring of the care plan and engage in continuous patient communication and patient education
- Conduct a diagnostic assessment of the wound using a validated assessment tool like the Triangle of Wound Assessment, at every dressing change and at least once per week
- When developing the care plan consider the wound care environment, the patient's environment, family situation, etc.

The consensus reached emphasised the importance of all members of the care team considering a wider range of factors than simply the biology of the wound. Taking a holistic approach to wound care assessment and management will help healthcare professionals consider all the factors that affect wound healing. Considering all of these factors will significantly impact the patient experience, will influence the patients' quality of life, and will positively impact healing time. Shifting our approach to holistic wound assessment and management will help us reach the goal of fewer days with wounds. WINT

References

Atkin L (2013) Wound assessment in primary care. *Nurs Pract* (72): 63–6

Bain K, Hansen AS (2020) Strengthening implementation success using large-scale consensus decision-making - A new approach to creating medical practice guidelines. *Eval Program Plann* 79: 101730

Bale S, Jones V (2006) *Wound Care Nursing: A Patient-centred Approach*. Mosby, Edinburgh

Barrett CM, Teare JA (2000) Quality of life in leg ulcer assessment: patients' coping mechanisms. *Br J Community Nurs* 5(11): 530, 534, 536, 538, 540

Barrett S (2007). 'Heal not Hurt': piloting an initiative on wound pain assessment. *Br J Community Nurs* 12(6): S18–21

Williams SR, Beck CR, Rawlins RP (1993) *Mental Health - Psychiatric Nursing, A Holistic Life-Cycle Approach*. Mosby, London

Benbow M, Stevens J (2010) Exudate, infection and patient quality of life. *Br J Nurs* 19(20): S30–6

Benbow M (2016) Best practice in wound assessment. *Nurs Stand* 30(27): 40–7

Benbow M (2006) Holistic assessment of pain and chronic wounds. *J Comm Nurs* 20: 24–8

Brown A (2015) The principles of holistic wound assessment. *Nurs Times* 111(46): 14–6

Cardozo M (2003) A Case study of holistic wound management in intensive care. *Br J Nurs* 12(11 Suppl): S35–7, S40–2

Coleman S, Nelson EA, Vowden P et al (2017) Development of a generic wound care assessment minimum data set. *J Tiss Viabil* 26(4): 226–40

Corbett LQ, Ennis WJ (2014) What do patients want? Patient preference in wound care. *Adv Wound Care* 3(8): 537–543

Cornforth A (2013) Holistic wound assessment in primary care. *Br J Community Nurs*. Suppl: S28–S34

Cornwell C, Schmitt M (1990) Perceived health status, self-esteem and body image in women with rheumatoid arthritis or systemic erythematosus. *Res Nurs Health* 13(2): 99–107

Detillion CE, Craft TK, Glasper ER et al (2004) Social facilitation of wound healing. *Psychoneuroendocrinology* 29(8): 1004–11

Dowsett C, Swanson T, Karlsmark T (2019) Focus on the Triangle of Wound Assessment – addressing the gap challenge and identifying suspected biofilm in clinical practice. *Wounds International* 10(3): 16–21

Dowsett C, von Hallern B, Moura MRL (2018) Meeting report: The gap challenge in clinical practice – how do you manage it? *Wounds International* 9(3): 60–5

Dowsett C, Gronemann M, Harding K (2015) Taking wound assessment beyond the edge. *Wounds International* 6(1): 19–23

Dowsett C (2009) Use of TIME to improve community nurses' wound care knowledge and practice. *Wounds UK* 5(3): 14–21

Erfurt-Berge C, Ronicke M, Richter-Schmidinger T et al (2019) Quality of life assessment in family members of patients with chronic wounds. *Eur J Dermatol* 29(5): 484–9

European Wound Management Association (2008) *Position Document: Hard-to-Heal Wounds: A Holistic Approach*. Available at: http://bit.ly/3q1h3mx (accessed 26.11.2020)

Franks PJ, Moffatt CJ (1998) Who suffers most from leg ulceration? *J Wound Care* 7(8): 383–5

Franks PJ, Bosanquet N, Connolly M et al (1995) Venous ulcer healing: effect of socioeconomic factors in London. *J Epidemiol Community Health* 49(4): 385–8

Green J, Jester R (2009) Health-related quality of life and chronic venous leg ulceration: part 1. Br J Comm Nurs 14(12): S12–7

Hampton S, Collins F (2004) *Tissue Viability*. Whurr, London

Harlow P, Poyner T, Finlay AY, Dykes PJ (2000) Impaired quality of life of adults with skin disease in primary care. *Br J Dermatol* 143(5): 979–82

Hollinworth H, Hawkins J (2002) Teaching nurses psychological support of patients with wounds. *Br J Nurs* 11(suppl): S8–18

Hopkins S (2001) Psychological aspects of wound healing. NTplus. *Nurs Times* 97(48): 57–8

International Wound Infection Institute (2016) *Wound Infection in Clinical Practice*. Wounds International, London

Jordan JL, Ellis SJ, Chambers R (2002). Defining shared decision making and concordance: are they one and the same? *Postgrad Med J* 78 (921): 383–4

Keast D, Bain K, Hoffmann C et al (2020) Managing the gap to promote healing in chronic wounds - an international consensus. *Wounds International* 11(3): 58–63

Acton C (2007) The holistic management of chronic wound pain. *Wounds UK* 3(1): 61–9

Keast D, Bowering K, Evans W et al (2004) MEASURE: a proposed assessment framework for developing best practice recommendations for wound assessment. *Wound Repair Regen* 12(Suppl 3): S1–17

Kiecolt-Glaser JK, Loving TJ, Stowell JR et al (2005) Hostile marital interactions, proinflammatory cytokine production, and wound healing. *Arch Gen Psychiatry* 62(12): 1377–84

London F (2007) Teaching patients about wound care. *Home Healthcare Nurse* 25(8): 497–500

Mckenzie H (2011) Wound care in not holistic patient care. *Home Healthcare Nurse* 29(4): 259–60

McRobert J (2013) Smoking and its effects on the healing process of chronic wounds. *Br J Community Nurs* (Suppl): S18, S20–3
Morison M (2004) A framework for patient assessment and care planning. In: Morison M, Ovington L, Wilkie K (2004) *Chronic Wound Care: A Problembased Learning Approach*. Mosby, Edinburgh
Muldoon M (1998) What are quality of life measurements measuring? *BMJ* 316(7130): 542–5
Murphy C, Atkin L, Swanson T et al (2020) International consensus document. Defying hard-to-heal wounds with an early antibiofilm intervention strategy: wound hygiene. *J Wound Care* 29(Suppl 3b): S1–28
Nazarko L (2015) Advance in wound debridement techniques. *Br J Community Nurs* Suppl Community Wound Care: S6, S8
International consensus (2012) Optimising wellbeing in people living with a wound. An expert working group review. Wounds International, London. Available at: https://www.woundsinternational.com/resources/details/international-consensus-optimising-wellbeing-in-people-living-with-a-wound (accessed 26.11.2020)
Ousey K, Cook L (2013) Optimising the patient journey made easy. *Wounds UK* 9(2): 1–6
Ousey K, Cook L (2012) Wound Assessment Made Easy. *Wounds UK* 8(2): 1–4
Ousey K, Cook L (2011) Understanding the importance of holistic wound assessment. *Practice Nurs* 22(6): 308–14
Price P, Krasner DL (2012) Health-related quality of life and chronic wounds: evidence and implications for practice. In: Krasner DL, Rodeheaver GT, Sibbald RG, Woo KY (eds.) *Chronic Wound Care: A Clinical Source Book for Healthcare Professionals*. HMP Communications, Malvern, PA
Price P, Harding K (2004) Cardiff Wound Impact Schedule: the development of a condition-specific questionnaire to assess health-related quality of life in patients with chronic wounds of the lower limb. *Int Wound J* 1(1): 10–17
Reddy M, Keast D, Fowler Y et al (2008) Pain in pressure ulcers. *Ostomy Wound Manage* 49(4A Suppl): 30–5
Sibbald RG, Ovington LG, Ayello EA et al (2014) Wound bed preparation 2014 update: management of critical colonization with a gentian violet and methylene blue absorbent antibacterial dressing and elevated levels of matrix metalloproteases with an ovine collagen extracellular matrix dressing. *Adv Skin Wound Care* 27(3 Suppl 1): 1–6
Solowiej K, Mason V, Upton D (2010) Psychological stress and pain in wound care, part 3: management. *J Wound Care* 19(4): 153–5
Stephen-Haynes J (2010) Professional accountability and outcomes in tissue viability. *Br J Community Nurs* 15(Suppl 8): 29
Stolt M, Hjerppe A, Hietanen H et al (2019) Local treatment of pressure ulcers in long-term care: a correlational cross-sectional study. *J Wound Care* 28(6): 409–15
Williams L, Leaper D (2000) Nutrition and wound healing. *Clinical Nutritional Update* 5(1): 3–5
Teare J, Barrett C (2002) Using quality of life assessment in wound care. *Nurs Standard* 17(6): 59–68
World Union of Wound Healing Societies (2019) *Consensus Document. Wound Exudate: Effective Assessment and Management*. Wounds International, London
World Union Wound Healing Societies (2004) *Principles of Best Practice: Minimising Pain at Wound Dressing-related Procedures. A Consensus Document*. MEP Ltd, London
World Union of Wound Healing Societies (2008) *Principles of Best Practice: Diagnostics and Wounds. A Consensus Document*. MEP Ltd, London
Wounds International (2012) International Consensus: Optimising Wellbeing in People Living with a Wound. Available at: https://bit.ly/2KMukPX (accessed 26.11.2020)
Wounds UK (2018) Best Practice Statement: Improving Holistic Assessment of Chronic Wounds. Wounds UK, London. Available at: https://bit.ly/3m8FmfW (accessed 26.11.2020)
Ousey K, Cook L (2012) Wound assessment made easy. *Wounds UK* 8(2): 1–4
Yang EV, Bane CM, MacCallum RC et al (2002) Stress-related modulation of matrix metalloproteinase expression. *J Neuroimmunol* 133(1–2): 144–50

Non-medicated wound dressings in managing infected wounds and wounds with biofilms



Authors (clockwise from top left): *Karen Ousey, Tomasz Banasiewicz and Hans Smola*

Antimicrobial resistance is a global issue that is present in wound care, in part, due to the inappropriate use or overuse of dressings containing antimicrobials. As a result, the World Union of Wound Healing Societies (WUWHS) and a group of experts in the field of wound care collaborated on a Position Document titled "The Role of Non-medicated Dressings for the Management of Wound Infection" (WUWHS, 2020). The Position Document highlights the impact that the misuse and overuse of topical and systemic antimicrobials have on antimicrobial resistance worldwide. Non-medicated wound dressings (NMWDs) are an alternative to dressings that containing active antimicrobials, and are suitable for wounds at risk of infection and where biofilm is suspected. A webinar supported by Hartmann AG was broadcast on September 15, 2020 at the WUWHS 2020 online conference to launch the Position Document. The session covered the practical aspects of treating infection, inflammation and biofilm within antimicrobial stewardship practices to reduce the burden of antimicrobial resistance. The symposium closed with practical guidance for when and how to use NMWDs in practice, including case examples.

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One of the biggest challenges facing clinicians today is non-healing, chronic wounds. Traditionally, treatment for wound infection and biofilm — and for managing the risk of infection — has included topical antimicrobials or systemic antibiotics.

A new WUWHS 2020 Position Document titled "The Role of Non-medicated Dressings for the Management of Wound Infection" raises awareness of the misuse and overuse of antimicrobials (including antibiotics and dressings containing antimicrobial substances). The Position Document comprises three articles, which aim to provide guidance on:

- The characteristics and role of non-medicated wound dressings (NMWDs), and how they can be used to help combat antimicrobial resistance (AMR)
- The role of NMWDs in the prevention and management of infected wounds
- Clinical evidence to support the use of NMWDs.

In the webinar, Prof. Karen Ousey, Prof. Dr. Tomasz Banasiewicz and Dr. Hans Smola described the rationale for developing the new Position Document and summarised the key outcomes of the Position Document.

Antimicrobial resistance in wounds

AMR is an umbrella term for the overuse of antibiotics, antiseptics and antimicrobials, including medicated wound dressings. Medicated dressings are defined as dressings that contain an antimicrobial, such as silver or iodine. Medicated dressings kill bacteria in a variety of direct antibiotic–bacteria interactions (e.g. inhibition of DNA replication, inhibition of cell wall synthesis). However, bacteria can become resistant to medicated dressings, and so they the dressings lose their efficacy (Bjarnsholt et al, 2007).

AMR is a severe, global concern, and there is a growing rise in number of bacterial pathogens resistant to available therapeutic antimicrobial agents. The World Health Organization (WHO, 2019) have identified that AMR is one of the 10 biggest threats to health. AMR is not a new concept; the past 10 years have seen the publication of many national and international documents that aim to identify the causes of

AMR and suggest ways to reduce the threat (e.g. WHO, 2019).

Prof. Karen Ousey set the scene by outlining the latest global facts and figures on AMR. If nothing is done to reduce the burden of AMR, by 2050 there could be 10 million deaths attributed directly to AMR, costing £66 trillion (O'Neill, 2014). This amount exceeds the cost of cancer treatment. There is currently no published guidance for prudent antimicrobial therapy in infected wounds, so how do we manage AMR in wound care?

Antimicrobial stewardship practices

Antimicrobial stewardship practices focus on infection prevention and control, accurate infection and biofilm diagnosis and the appropriate use of antimicrobial and antibiotic treatments to avoid treatments becoming ineffective (Bjarnsholt et al, 2007; Uchil et al, 2014; Phillips et al, 2015).

Everyone within the multidisciplinary wound care team plays a part in antimicrobial stewardship (i.e. nurses, family doctors, pharmacists, medical staff in acute settings, wound care specialists, infection and prevention control teams). Clinicians also have a responsibility to educate and encourage supported care and the role that patients and carers can play in antimicrobial stewardship (e.g. antibiotics or a medicated wound dressing are not always necessary and the importance of hygiene and effective regular hand washing).

Non-medicated wound dressings

NMWDs are currently defined as wound dressings that do not contain any active pharmaceutical component but reduce bioburden and bacterial load via alternative methods (WUWHS, 2020). NMWDs sequester and kill bacteria based on physical mechanisms and chemical interactions, without the need for topical antimicrobials or antibiotics.

Examples of NMWDs include hydrogels, hydrocolloids, super-absorbent polymers (SAPs) dressings, carboxymethylcellulose (CMC), dialkylcarbamoylchloride (DACC) and hydro-responsive wound dressings (HRWDs). NMWDs are important for the treatment of both acute and chronic wounds, as they remove and sequester bacteria from the wound bed to help manage infection and bioburden. The antimicrobial mode of action of NMWDs involves multiple steps taking place in a coordinated manner:

1. **Debridement:** disruption of devitalised tissue
2. **Absorption**: uptake of microorganisms
3. **Sequestration:** microorganisms drawn in and locked away
4. **Retention:** microorganisms held and immobilised within the wound dressing core
5. **Removal:** microorganisms are easily removed when the dressing is removed from the wound

Each of these mechanisms is individually able to reduce bacterial numbers *[Figure 1]*.

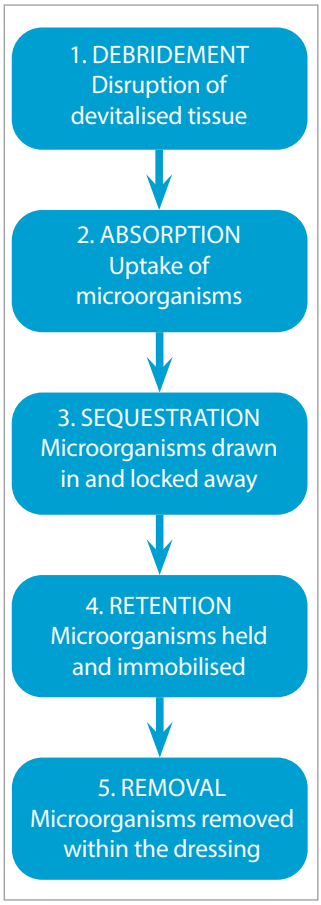


Figure 1. Mechanism of action of NMWDs for infection prevention and management (WUWHS, 2020).

Understanding the cause of wound chronicity

Patients with chronic wounds require a unique, multi-facted approach to manage their wounds, including management of the wound bed, surrounding tissue and optimisation of the patient's status (i.e. nutritional condition, management of other comorbidities and cause of the wound). Therefore, is impossible to create a 'one-size-fits-all' approach.

However, standardisation offers the opportunity to reduce variation in assessment and management. Algorithms such as T.I.M.E. (Tissue, Inflammation/Infection, Moisture, Edge/Epithelialisation) offer a treatment path to follow for wound bed assessment and preparation (Schultz et al, 2003; Moore et al, 2019).

Previous studies have shown that 78-100% of chronic wounds are likely to contain biofilm, so the existence of a biofilm should always be considered in a wound that is not healing (Hogsberg et al, 2011; Malone and Swanson, 2017; Schultz et al, 2017). However, it is very important to remain aware that bacteria are never the primary cause of a chronic non-healing wound. Patient factors, such as diabetes, peripheral vascular disease, peripheral neuropathy, trauma and increased plantar pressure may be the main cause of chronicity. Therefore, biofilms and wound chronicity cannot be managed by dressings alone; a standardised approach is necessary for consistency and to reduce variation in practice. Prof. Banasiewicz put forward an *aide memoire* to identify and manage chronicity using the T.I.M.E. acronym *[Box 1]*.

Effective use of systemic antibiotics

Systemic antibiotics are usually only indicated for clinical signs and symptoms of systemic infection or sepsis caused by planktonic bacteria. The overall picture suggests that high proportion of patients receive antibiotics for infection. In a review study of Canadian hospitals of over 4000 patients, a third received antimicrobials: 73.3% for therapeutic use, 14.2% for medical prophylaxis and 8.2% for surgical

Box 1. Identifying and managing chronicity using the T.I.M.E. acronym.

- **Think!** – Assess the primary reason of chronicity, then treat
- **Infection/inflammation recognition** – Local tools are available to identify the signs and symptoms of infection and inflammation
- **Microbiology** – Knowledge and understanding of the biofilm bacterial communities will guide appropriate care. Commonly used approaches to analysis DNA include 16S ribosomal RNA (rRNA) sequencing, whole genome (shotgun) sequencing and RNA transcriptomics.
- **Effective use of appropriate treatments and duration** – Consider NMWDs, and whether systemic antibiotics or medicated dressings are required.

prophylaxis (Frenette et al, 2020). Acute infections are relatively easy to treat compared to biofilm as most antibiotic agents act on metabolic pathways in active bacterial cells. When these therapies are employed against biofilm microorganisms that differ markedly in both physiology and activity, antibiotics typically fail to eradicate biofilm (Lebeaux et al, 2014).

Administration of a single antibiotic (even a broad-spectrum agent) will often not eradicate the biofilm microorganisms because:

- The antibiotic level at the site of infection is insufficient: biofilms have been found to withstand antimicrobial concentrations 100 to 1,000 times higher than that of planktonic microbes.
- Bacteria in the biofilm are slow growing or can be dormant.
- Bacteria in the biofilm are encapsulated in a protective matrix called extracellular polymeric substance (EPS), which helps biofilm resist antimicrobial treatments (WUWHS, 2020). The antibiotic is inactivated by accumulated enzymes in the biofilm matrix – produced by other resistant species growing alongside the pathogen (associated resistance) (Lebeaux et al, 2014).

This leads to a perceived notion that higher levels of antibiotics are required to actively combat the microorganisms within the biofilm, leading to frequently inappropriate treatment.

Instead of using antibiotics or antimicrobial agents, biofilms can be destroyed or removed by creating a hostile environment for the bacteria and removing the biofilm and the infected tissue. If a wound has excessive non-productive inflammation, infection or suspected biofilm, then NMWDs can be considered as an alternative to antimicrobial dressings. If necessary, NMWDs can be used in conjunction with other antimicrobial agents to aid in the overall management of the infection and contribute to reducing the level of bacterial bioburden.

Guidelines from the WUWHS (2020) Position Document exist on how to use NMWDs for the management of excessive inflammation, wound infection and biofilm *[see Figure 2]*.

How to use NMWDs for infected wounds or wounds at risk of infection

The clinical signs and symptoms of wound infection are well-established and are a guide for treatment (e.g. erythema, swelling, local and systemic hyperthermia, pain, odour). Treatment often includes debridement, plus antimicrobial treatment agents with or without topical agents. However, it can be challenging to decide when to initiate systemic antibiotics, and it can be a subjective decision based on the experience and speciality of the clinician (Olen and Forssell, 2013). Prof. Hans Smola described how understanding the mechanism of infection and inflammation makes the decision less subjective.

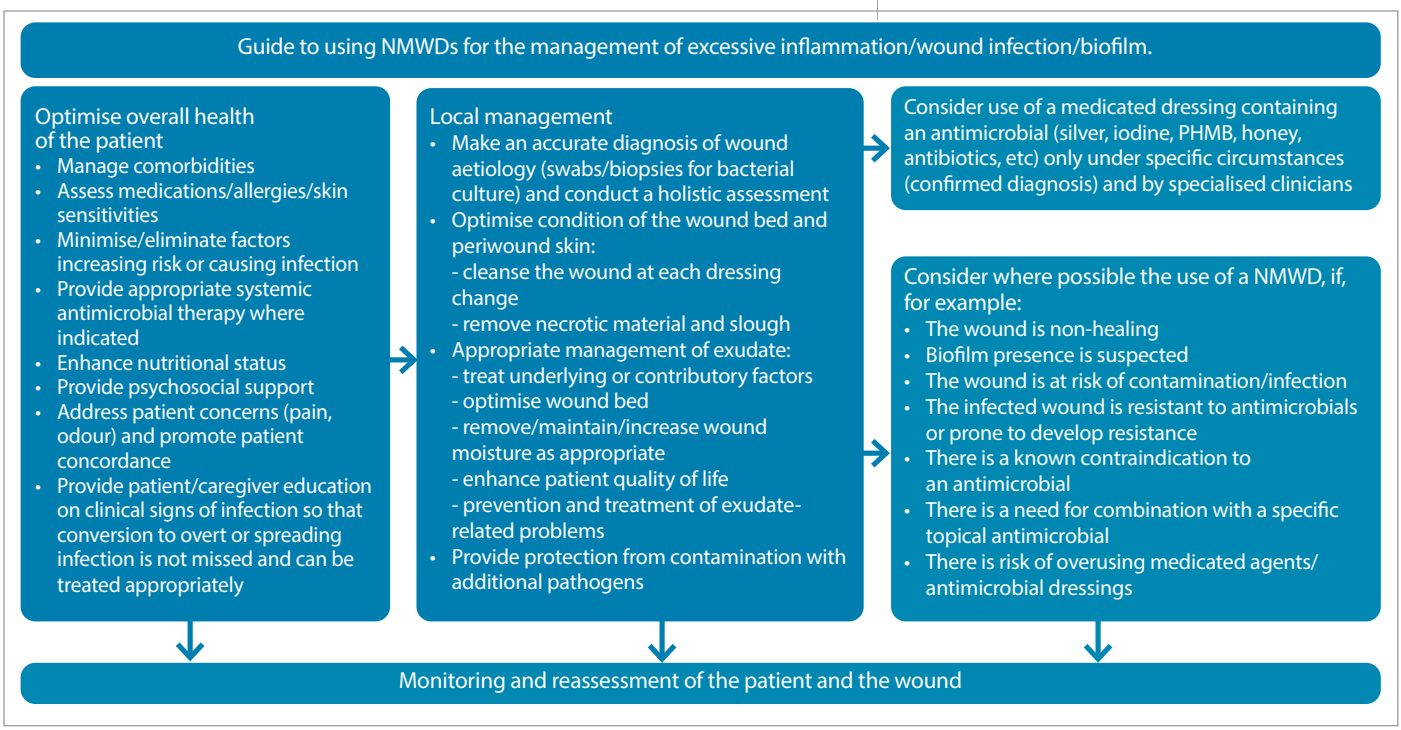


Figure 2. Factors to consider when using NMWD for the management of excessive inflammation, wound infection and biofilm (WUWHS, 2020)

Table 1. The cell signalling mediators and the impact of non-medicated wound dressings at each stage of wound healing.

Stages of healing:	Debridement	Wound bed preparation	Granulation tissue	Epithelialisation
	Necrosis / Autolytic debridement / Inflammation / Granulation tissue formation / Epithelialisation			
Associated cell signalling mediators	• DAMPs • PAMPs • Inflammatory mediators • Ischaemic mediators	• Inflammatory mediators • Infection/PAMPs	• Connective tissue synthesis • Cell proliferation and motility	• Cell motility and proliferation
Impact of NMWDs on the wound	Removal of wound healing inhibitors	Shift the local wound environment towards granulation tissue build-up	Prevent damage to the granulation tissue, provide optimal healing conditions	Protect the wound bed and prevent wound damage
Impact of NMWDs on wound progression	Move away from inflammation	Move towards a synthetic mesenchyme	Maintain a productive granulation tissue	Boost epithelialisation

Understanding the mechanism of infection and inflammation

Bacteria produce metabolites that stimulate inflammatory cells that produce mediators that initiate inflammation (Kawal et al, 2010). The clinical signs and symptoms observed are trigged by the host immune response and are not caused by the bacteria or their metabolites directly. Necrotic tissue also releases components that stimulate the immune reactions and can mimic an infection, can make identification of infection and inflammation difficult. *Figure 3* illustrates the cascade of inflammation, which can be initiated by bacteria or necrotic tissue.

Pathogen-associated molecular patterns (PAMPs) kill bacteria, and damage-associated molecular patterns (DAMPs) degrade tissue.

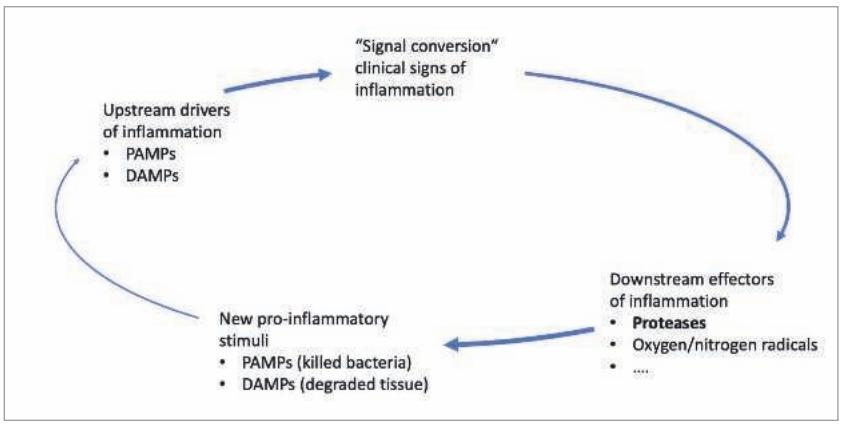


Figure 3. Cascade of inflammation.

PAMPs and DAMPs are upstream drivers of inflammation and trigger the immune response into producing the clinical signs of inflammation. A cascade of downstream-standardised effects of inflammation is triggered by the breakdown tissue via proteases and reactive oxygen or nitrogen species. The metabolised tissue releases the pro-inflammatory stimuli (DAMPS and PAMPs) and the cycle continues with the potential for relapse of chronic inflammation.

Table 1 shows the cell signalling mediators and the impact of non-medicated wound dressings at each stage of wound healing. Understanding the mechanism of inflammation can identify how to move the wound to healing and stop the inflammation cycle. The body mounts its own autolytic debridement to remove drivers of the inflammatory response, but this can be assisted with surgical debridement and the use of dressings. NMWDs can support wound bed preparation and prevent damage at the granulation tissue and epithelisation stage.

Role of NMWDs in infected or at-risk wounds

NMWDs such as HRWDs (e.g. HydroClean®, Hartmann AG) do not contain any active antimicrobial agent, instead Ringer's solution is released by the dressing to help soften devitalised tissues and cleanse the wound. HRWDs support autolytic debridement,

stimulate normalisation of wound environment and inactivate excess matrix metalloproteases (MMPs), inducing the progression to granulation. This occurs through the "rinsing motion" of the wound dressing itself. Bacteria-containing exudate is absorbed and bound into the absorbent core of the dressing and is retained by the dressing. The wound bioburden is reduced by removal of the bound bacteria at each dressing change. They are ideal for patients with infected wounds or wound that are at-risk of infection as they effectively eradicate bacteria with a physical mode of action, while not inducing microbial resistance.

NMWDs such as super-absorbent polymer (SAP) dressings (e.g. Zetuvit Plus Silicone/Border®, Hartmann AG) also do not contain any active antimicrobial agent. SAPs have been shown to inhibit MMP activity in chronic wounds by binding and locking the protein within the particles and blocking associated co-factors, such as calcium, magnesium and zinc (Eming et al, 2008). SAPs are small granules that absorb and bind bacteria and MMPs, thus contributing to undisturbed wound healing. Chronic wounds treated with SAP-containing dressings had a 36% increase in granulation tissue after 14 days compared to wounds treated with amorphous hydrogel, which had a 14.5% increase in granulation tissue (p=0.0005; Humbert et al, 2014).

SAP-containing dressings are ideal for exuding wounds at-risk of infection as they effectively absorb and retain the exudate containing wound healing inhibitors and bacteria by a physical mode of action, while not inducing bacterial resistance.

Using NMWDs in practice - Case studies

Two cases presented by Prof. Banasiewicz illustrated that there are many approaches to treating the patient and wound depending on the individual characteristics. Cases studies included in this article illustrate the combined approach of NMWDs, medicated wound dressings, antiseptics, negative pressure wound therapy (NPWT) to encourage wound healing.

Case 1. Septic and necrotic venous leg ulcer

This patient had a venous leg ulcer that had been present for 4 month, which had become septic and necrotic. Systemic antibiotics had been ineffective, likely due to the ischaemic tissue in the lower limb, which was suggestive of biofilm. The aim of treatment was to create a hostile environment so the biofilm communities could not thrive. The wound was extensively debrided in surgery *[Figure 3]*. NPWT with instillation using an antiseptic solution was combined with NWMDs for 2 weeks; the dressing was changed twice a week *[Figure 4]*. Zetuvit Plus Silicone® was used while there were high levels of exudate. Once the wound began to develop granulation tissue, the dressing was changed to a HRWD (HydroClean®). A skin graft was performed. The dressing regimen included Zetuvit Plus Silicone®. *Figure 5* shows the wound after 3 weeks. The patient was discharged 5 weeks after the skin graft. The total length of treatment was 12 weeks from the first surgical intervention.

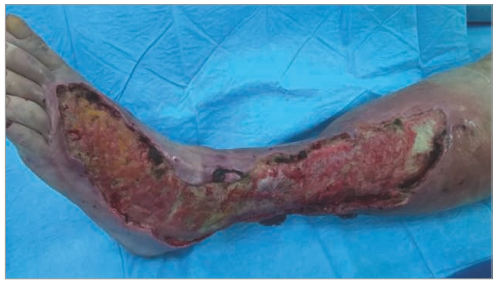


Figure 3. After extensive surgical debridement.

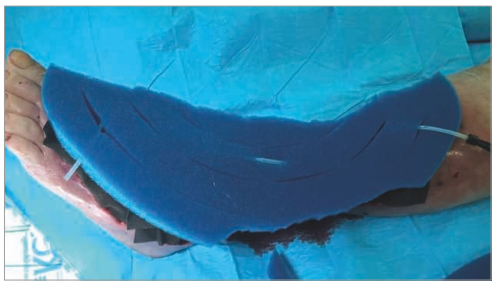


Figure 4. Application of NPWT.

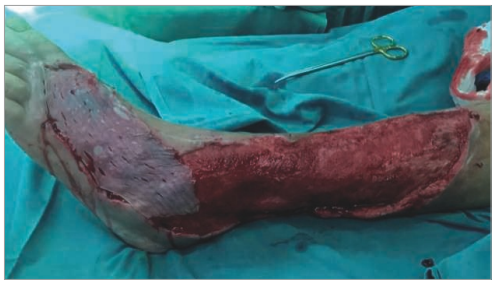


Figure 5. 3 weeks after skin graft was performed.

Case 2: Ambulatory patient with a chronic leg ulcer

The patient had a chronic leg ulcer and was ambulatory, so it was important to not limit their mobility during treatment *[Figure 6]*. The aim was to clean the wound, remove exudate, and absorb and sequestrate the bacteria. Following thorough physical debridement, a HRWD (HydroClean®) was used for 2 weeks to cleanse, debride, deslough the wound bed *[Figure 7]*. Then a SAP dressing (Zetuvit Plus Silicone®/Border) in combination with

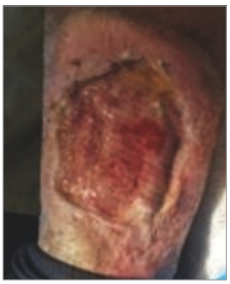


Figure 6. Leg ulcer at day 0.

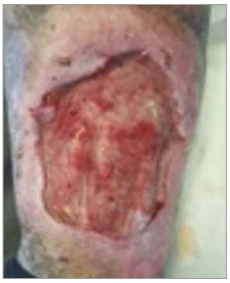


Figure 7. Leg ulcer at day 7.

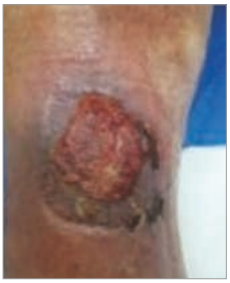


Figure 8. Leg ulcer at week 3.

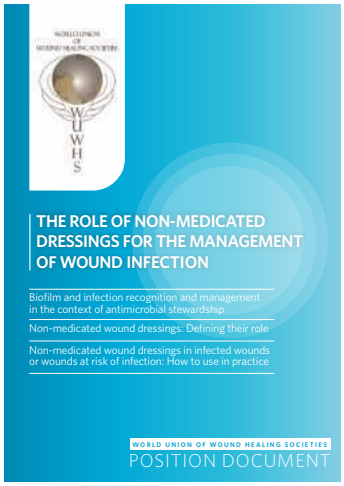
This meeting report has been supported by an unrestricted educational grant by HARTMANN AG

Octenillin® gel (Schülke) were used to provide a moist wound healing environment *[Figure 8]*. The patient's wound healed fully after 2 months.

Summary

Diagnosing wound infection can be challenging for many clinicians. There is evidence to suggest that systemic antibiotics and antimicrobial dressings are prescribed unnecessarily. NMWDs, such as HydroClean® and Zetuvit Plus Silicone®/Border, offer a treatment option that does not impact on microbial resistance.

Many patients and healthcare systems could benefit from a more tailored individualistic approach, reserving antimicrobial therapy for correctly diagnosed local infection. The new WUWHS Position Document offers innovative perspectives and new clarity on the role of NMWDs, and how they can be used to help combat AMR in wounds. Deployment of more frequent wound debridement/cleansing and using dressings without an active ingredient, such as NMWDs, offer an ideal option in the drive to promote antimicrobial stewardship. WINT



Download the Position Document at: https://www.woundsinternational.com/resources/details/the-role-of-non-medicated-dressings-for-the-management-of-wound-infection

References

Bjarnsholt T et al (2007) Silver against *Pseudomonas aeruginosa* biofilms. *APMIS* 115: 921–8

Eming S et al (2008) The inhibition of matrix metalloproteinase activity in chronic wounds by a polyacrylate superabsorber. *Biomaterials* 29: 2932–40

Frenette C et al (2020) The 2017 global point prevalence survey of antimicrobial consumption and resistance in Canadian hospitals. *Antimicrob Resist Infect Control* 9: 104

Høgsberg T et al (2011) Success Rate of Split-Thickness Skin Grafting of Chronic Venous Leg Ulcers Depends on the Presence of *Pseudomonas aeruginosa*: A Retrospective Study. *PLOS ONE* 6(5): e20492

Humbert et al (2014) Protease-modulating polyacrylate-based hydrogel stimulates wound bed preparation in venous leg ulcers – a randomized controlled trial. *J Eur Acad Dermatol Venereol* 28: 1742–50

Kawai T et al (2010) The role of pattern-recognition receptors in innate immunity: update on Toll-like receptors. *Nat Immunol* 11: 373–84

Lebeaux D et al (2014) Biofilm-related infections: bridging the gap between clinical management and fundamental aspects of recalcitrance toward antibiotics. *Microbiol Mol Biol Rev* 78(3): 510–43

Moore Z et al (2019) TIME CDST: an updated tool to address the current challenges in wound care. *J Wound Care* 28: 154–61

Malone M, Swanson T (2017) Biofilm-based wound care: the importance of debridement in biofilm treatment strategies. *Br J Community Nurs* 22: S20–S25

O'Neill J (2014) *Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations.* Available at: https://amr-review.org/sites/default/files/AMR%20Review%20Paper%20-%20Tackling%20a%20crisis%20for%20the%20health%20and%20wealth%20of%20nations_1.pdf (accessed 12.10.20)

Schultz G et al (2003) Wound bed preparation: a systematic approach to wound management. *Wound Repair Regen* 11(1): S1-S28

Schultz G et al (2017) Consensus guidelines for the identification and treatment of biofilms in chronic nonhealing wounds. *Wound Repair Regen* 25: 744–57

Phillips P et al (2015) Antimicrobial dressing efficacy against mature *Pseudomonas aeruginosa* biofilm on porcine skin explants. Int Wound J 12: 469–83

Uchil RR et al (2014) Strategies to combat antimicrobial resistance. *J Clin Diagn Res* 8(7): ME01–ME4

World Health Organization (2019) *Ten Threats to Global Health in 2019.* WHO, Geneva, Switzerland. Available at: https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019 (accessed 01.10.20)

World Union of Wound Healing Societies (2020) *The Role of Non-medicated Dressings for the Management of Wound Infection.* London: Wounds International. Available at: www.woundsinternational.com

Preventing and treating infection in wounds: translating evidence and recommendations into practice

Authors:
Terry Swanson, Dr. David Keast, Kimberly Bain and Mark Bain

Infected wounds are slower to heal than non-infected wounds and are a growing problem for both patients and healthcare systems (Guest et al, 2015; Wounds UK, 2017). A group of researchers undertook a modified Delphi process to build a consensus among 85 international wound care specialists on how to prevent, identify and managed chronic wound infections. Consensus was reached on when and how to assess chronic wounds, the warning signs of infection, prevention strategies, management of infection and biofilms, and when to refer a patient to a wound care specialist.

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Conflict of Interests:
Each of the Authors have acted as consultants for Coloplast in the past, as well as other health care suppliers and companies.
Ethical Principles:
The authors warrant that this manuscript is their original work, has not been published before and is not being considered for publication by another publisher.
Ethics Approval:
This research did not require ethical approval. It did not include patients, or patient data. Only the opinions of health care providers were gathered, and that information was gathered directly from the providers, who consented to the process and the information collected.

Author details on p83

Eighty-five wound care specialists from 19 countries took part in a consensus process that spanned 4 months, ending in November 2019. The process included traditional Delphi surveys, as well as virtual and face-to-face facilitated dialogues (Keast et al, 2020). The result was a consensus on best practices in chronic wound care and how to translate those best practices into effective bedside care for patients. This, the third article in a four-part series, focuses on how to prevent and treat wound infections with the ultimate goal of reducing healing time.

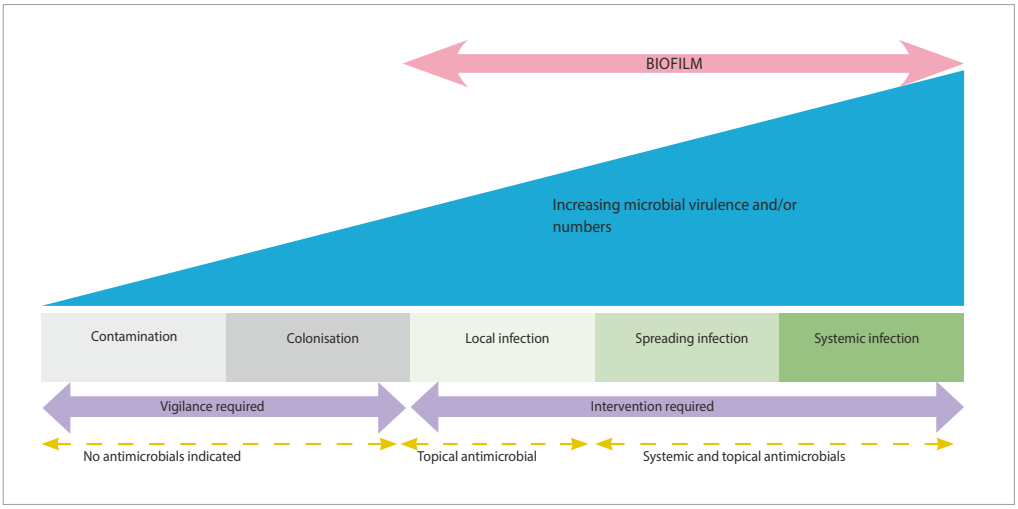
Microbial burden in wounds has been a topic of research and investigation for many years. Chronic and acute wounds are different. Acute wounds follow an orderly repair process (Swanson et al, 2015). In contrast, chronic wounds are slower to heal, usually remaining in an inflammatory state with high microbial loads (Scali and Kunimoto, 2013). Chronic wounds in this consensus process were defined as nonhealing wounds, that have healing potential, and have not healed within 4 weeks.

It is generally agreed that a holistic wound assessment is needed to determine the risk of infection (Keast et al, 2014; Swanson et al, 2014; Wounds UK, 2018; Dowsett et al, 2019) and that proactive wound management is needed to prevent infection (Keast et al, 2014; Swanson et al, 2015; International Wound Infection Institute [IWII], 2016; World Union of Wound Healing Societies [WUWHS], 2016). Where the risk of infection is high, but the signs and symptoms of spreading infection are absent, the goal of treatment should be to prevent escalation of infection through therapeutic cleansing, debridement, moisture balance and exudate management (Swanson et al, 2014; Dowsett and Muenter, 2020).

The presence of microorganisms in a wound does not necessarily mean that the wound is infected (European Wound Management Association, 2005; Moore and Strapp, 2015). The bacterial status of wounds continuously changes depending on local, environmental and systemic factors (WUWHS, 2008). Wound infection was defined by international consensus in 2016 as "the invasion of a wound by proliferating microorganisms to a level that invokes a local and/or systemic response in the host. The presence of microorganisms within the wound causes local tissue damage and impedes wound healing" (IWII, 2016). In wounds exhibiting signs and symptoms of local infection, the immediate treatment goal should be to reduce the bioburden within the wound (Swanson et al, 2014).

The transition from non-infected to infected wounds is often gradual. Identifying infection in chronic wounds can be challenging for clinicians who may be required to rely on a range of signs and symptoms depending on the wound aetiology, comorbidities, wound

Figure 1. IWII Wound Infection Continuum (reproduced with permission).



location and the patient's overall health and wellbeing (EWMA, 2005). A wound's microbial balance has been conceptually described by IWII (2016) as a continuum or a gradual increase in the number and virulence of microorganisms and the response those organisms invoke in the host. As the microbial virulence, numbers and pathogenic action increases, the wound infection moves from contamination through colonisation, local infection, spreading infection to systemic infection *[Figure 1]*. While progress in laboratory testing has been made, most clinicians do not have access to modern microscopy tests that identify the causative organism of infections, such as biofilm. Therefore, a wound infection must be diagnosed using clinical signs and symptoms, followed by a wound culture that may assist in identifying the causative organisms and resistant species to antibiotics that were commenced.

The classic signs and symptoms of wound infection include inflammation, new or increasing pain, increased malodour, local heat, swelling, advancing redness and purulence (WUWHS, 2008; Swanson et al, 2014; IWII, 2016). Increased exudate or exudate that has become purulent can be signs that the microbial burden in the wound may be stalling the wound's healing progression in the inflammatory phase (WUWHS, 2008; Swanson et al, 2015). In wounds where infection is suspected, the healthcare provider's immediate treatment goal must be to reduce the bioburden in the wound by therapeutic cleansing of the wound at each dressing change and through aggressive debridement of surface substance and underlying non-viable or unhealthy tissue to disrupt microbial burden and suppress biofilm regrowth (WUWHS, 2008; Swanson et al, 2014; WUWHS, 2019).

A holistic wound management approach and patient education about aseptic wound management is also critical for effectively treating wound infections (IWII, 2016; Moura et al, 2020). Monitoring progress and continual reassessment are important to evaluate the progression of the wound against the treatment goals, and a multidisciplinary approach, coupled with a treatment pathway that enables timely referral to specialists, is important for optimal outcomes (Ousey and Atkin, 2013; Swanson et al, 2014).

The role that biofilm plays in the development of infection, inflammation and in the delay of wound healing is generally accepted (Dowsett et al, 2019). Biofilms are described as microorganisms embedded in a thick, slimy barrier of sugars and proteins that acts as a barrier that shields microorganisms from the patient's natural immune system and from many antimicrobial agents (Keast et al, 2014). The seminal IWII 2016 International Consensus: Principles of Best Practice, defines biofilms as "a structured community of microbes with genetic diversity and variable gene expression (phenotype) that creates behaviours and defences used to produce unique infections (chronic infection)".

Biofilms are characterised by significant tolerance to antibiotics and biocides, while remaining protected from host immunity. Biofilm can develop within 2–4 days of initial colonisation, and become very tightly attached to extracellular matrix components or the wound bed, making them difficult to remove by surface irrigation or superficial debridement (Phillips et al, 2010; Swanson et al, 2014; Schultz et al, 2017). There is evidence that suggests biofilm is present in the majority of chronic wounds (Keast et al, 2014; WUWHS, 2016; Johani et al, 2017; Malone et al, 2017).

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Therapeutic wound cleansing at every dressing change and ongoing aseptic management, as well as conservative sharp and mechanical debridement are critical to effective biofilm management (Rodeheaver and Ratliff, 2007; WUWHS, 2008; Wolcott et al, 2010; Keast et al, 2014; IWII, 2016; WUWHS, 2019). Biofilms appear to 'recur' despite repeated attempts at antibiotic therapy (Keast et al, 2014). Biofilm eradication is difficult and almost impossible with a single structure approach. Multiple modalities are required to disrupt, decrease, and prevent reformation of biofilms.

The IWII 2016 consensus document recommends at least four steps are required: therapeutic cleansing, debridement, after debridement cleansing/care, antimicrobial dressings, and if spreading, systemic antimicrobials. An international consensus document in 2020, recommends an early antibiofilm intervention strategy through therapeutic cleansing, debridement, cleansing the edges and topical antimicrobials (Murphy et al, 2020). Evidence suggests that after appropriate wound bed preparation, applying topical antimicrobials to the wound helps reduce biofilm reformation and protects the wound from contamination by other microbes (Wolcott et al, 2010; IWII, 2016; Percival, 2017; Schultz et al, 2017; Wounds UK, 2017; WUWHS, 2019).

The best strategy for biofilm management is, therefore, the 'clean and cover' approach, which relies on the use of antimicrobial dressings between debridements to reduce the ability of planktonic bacteria to re-establish a biofilm (Keast et al, 2014). Both silver and iodine releasing dressings have been shown to kill biofilm bacteria (Akiyama et al, 2004; Percival et al, 2008; Phillips et al, 2015). The efficacy is influenced by time of exposure, number of applications, moisture level and agent formulation (Phillips et al, 2013).

Methodology

Consensus building is based on the belief that when people think together, they can make better decisions (Bain and Hansen, 2020). This project utilised a Modified Delphi Process that combines the rigour and validation of the traditional scientific Delphi method with professionally facilitated virtual and face-to-face collaborative processes (Keast et al, 2020). Eighty-seven wound care specialists across 19 countries were sent a series of surveys on chronic wound care, including specific questions on best practices in the prevention and treatment of infection and biofilms, based on literature review evidence. Eighty-four of the survey participants then met face-to-face for 2 days to review the survey results and finalise their consensus.

Participants

Participants were qualified wound-care specialists:

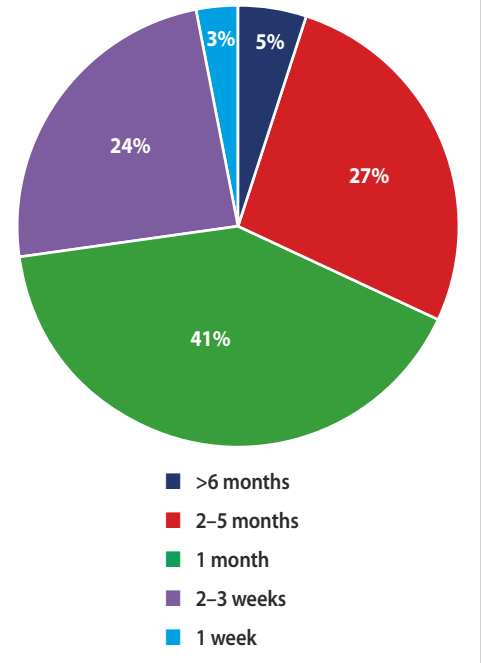
- 86% had more than 10 years of wound care experience
- 18% of participants reported that their practice is 100% wound care, with the average across all respondents being 65% of their total clinical practice being wound care
- Participants included: doctors (29%), nurse specialists (61%) and other healthcare professionals (10%)
- Participants reported that 65% of the wounds they treat are chronic wounds
- Participants reported that on average 44% of the wounds they treat are infected.

Survey results

Eighty-seven wound care specialists were surveyed in September and October 2019. The first survey had an 82% response rate and the second survey had a 71% response rate.

When asked how much longer, in their experience, wounds took to heal because of the existence of infection or biofilm, 73% of

Figure 1: Added wound healing time due to infection.



respondents reported that healing time was extended by 4 weeks or more *[Figure 1]*. A total of 82% of respondents agreed that the presence of bacteria in wounds is one of the biggest factors that delays healing. Regarding biofilm, 95% of respondents agreed that biofilm in a chronic wound can cause infection and delay healing.

When conducting a wound assessment, 91% of respondents indicated that they always examine the wound bed for signs of infection. Ninety-eight percent of respondents indicated that assessing the wound at each dressing change provides an opportunity to diagnose and treat a wound infection in the early stages and decreases the potential of limb- or life-threatening infections. When asked what they look for when assessing the level of bioburden in a wound, respondents indicated amount, odour and colour of exudate (88%), inflammation of the wound edge and periwound skin (85%), and increased pain levels (75%).

Ninety-eight percent of respondents agreed that one of best ways to decrease the risk of infection and the development of biofilm in chronic wounds is to manage the gap or dead-space between the wound bed and the dressing. Management of wound bioburden was identified as one of the top three most important critical success factors in managing chronic wounds. Eighty-seven percent of respondents agreed or strongly agreed that managing biofilm is an important step in preventing spread and systemic infection. When asked to rank in order of importance, factors considered when choosing the best dressing choice for patients, respondents identified wound bed assessment, prevalence of bacteria in the wound, amount of exudate and presence of biofilm as the top-four risk factors *[Table 1]*.

When treating an infected wound, respondents indicated the two most effective ways to prepare the wound bed are debridement and therapeutic irrigation. Forty percent of respondents indicated they always or usually debride the wound before applying a dressing and the most popular debridement methods reported were surgical sharp (79%), autolytic (63%) and mechanical (54%). Eighty-three percent of survey respondents indicated that once the wound bed is prepared the best way to fill the gap for wounds that are up to 2 cm deep is to use a dressing that conforms to the wound bed.

Consensus results

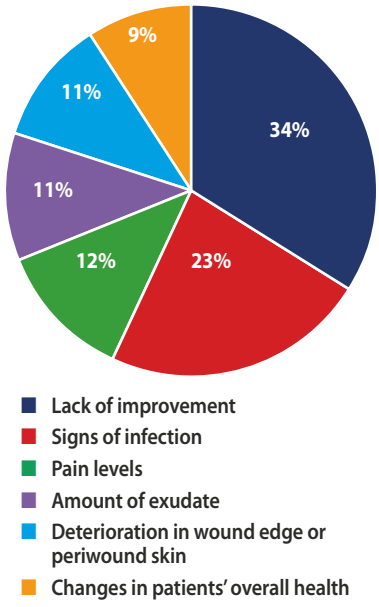
Eighty-four of the wound specialists surveyed met in Denmark in November 2019 for a 2-day facilitated face-to-face dialogue. Consensus was reached on a number of recommendations on how to prevent and management infection and biofilm. Consensus was achieved when more than 80% of participants agreed AND no participants disagreed with a recommendation (i.e. 100% of participants either agreed with or agreed to support a recommendation).

Eighty-two percent of participants agreed that chronic wounds should be assessed at least once per week, with 23% of those indicating

Table 1. Importance of factors in determining best dressing choice for patients.

Rank	
1st	Wound bed assessment
2nd	Prevalence of bacteria in the wound
3rd	Amount of exudate
4th	Occurrence of biofilm in the wound
5th	Amount of dead-space in the wound
6th	Assessment of periwound skin
7th	Frequency of dressing changes
8th	Availability of resources
9th	Patient's body profile and activity level
10th	Patient's capacity to engage in effective self-care
11th	Patient preferences

Figure 2. What warning signs should healthcare providers watch for when assessing a chronic wound?



assessment should happen at every dressing change. Participants also agreed that the warning signs that healthcare providers should be looking for when assessing a chronic wound are: lack of improvement; signs of infection; pain levels; amount of exudate; deterioration of wound edge or periwound skin; and changes to the patient's overall health and wellbeing *[Figure 2]*.

Consensus was reached on how to prevent infections in chronic wounds. It was agreed that the best prevention strategies are:

- Effective debridement and wound cleansing
- Managing exudate by managing the gap between the wound bed and the dressing
- Assessing wound bioburden at each dressing change using the IWII Wound Infection Continuum (IWII, 2016)
- Promoting a sterile environment through hand washing, antiseptic use, and ongoing patient education; and
- Continuous antimicrobial stewardship.

Participants also agreed that the best ways to prepare the wound bed to prevent or treat infection were debridement and therapeutic cleansing, followed by using a dressing with antimicrobial properties for local infections and the use of systemic antibiotics, appropriate for the type and level, for spreading and systemic infections. When asked what active components in dressings are best used to treat local infections, participants recommended, in rank order:

1. Silver
2. PHMB (Polyhexamethylene Biguanide)
3. Honey
4. Iodine

Consensus was also reached on what factors should prompt health care providers to refer a patient to a wound-care specialist. When one or more of the following factors is present, it was recommended that the patient be referred to a wound care specialist:

- Worsening of wound condition observed by increase in wound size, odour, pain or exudate (i.e. a treatment plan was established and followed but the wound is not healing or is deteriorating)
- There is a lack of wound healing progression within 14 days
- There is suspicion of, or signs of, systemic infection or biofilm
- Comorbidities and other complications (i.e. diabetes, elevated C-Reactive Proteins, underlying structures like exposed bone or tendons, aetiology of wound is not known).

Regarding biofilm, consensus was reached on best practices to prevent biofilms, what to look for when assessing the presence of biofilm and what healthcare providers should do if biofilm is suspected in a chronic wound. Best practices in preventing biofilm development were identified as:

- Debridement
- Therapeutic Cleansing
- Antimicrobial choices and stewardship, and
- Managing the gap between the wound bed and the wound dressing.

When assessing a wound for presence of biofilm, it was recommended that healthcare providers look for the following:

- Delay in healing progression
- Complications, such as bleeding, discolouration, granulation and fragile tissue
- Excessive amounts of exudate or grey film in the wound
- Odour; and
- Changes in the patient's overall wellbeing or quality of life.

When biofilm is suspected it is recommended that healthcare providers do the following:

1. Debride and clean the wound;
2. Employ antimicrobials and/or NPWT (negative pressure wound therapy);
3. Change the dressing type or dressing frequency;
4. Perform diagnostic tests or refer to a wound care specialist;
5. Manage the gap or dead-space between the wound bed and the dressing.

Participants also agreed that the best dressing choice for wounds down to 2 cm deep is a dressing that conforms to the wound bed.

Conclusions

The prevalence of non-healing wounds continues to be a global problem. Evidence is mounting about the importance of prevention and treatment of infection in wound care and there is growing evidence that biofilm is detrimental to wound healing. This project brought together wound care specialist from across 19 countries to develop a consensus on how healthcare providers should prevent, identify, and treat infection and biofilm in chronic wounds. The consensus reached was that managing the gap or the dead-space between the wound bed and the dressing is one of the best ways to prevent infection and detrimental biofilm development in chronic wounds.

The consensus process concluded that the prevention of infection and biofilm development should always be a goal of

wound care. If the wound bioburden reaches a point where it begins to delay wound healing, then immediate action should be taken to reinvigorate the wound healing progression, hence reducing costs and morbidity. The choices that healthcare professionals make regarding the prevention and treatment of wound infection and biofilm will significantly impact the patient experience, will influence the patients' quality of life, will impact the healing time and will have significant impact of costs to the healthcare system. The healthcare providers' outcome goal should always be fewer days with wounds and prevention of infection and the treatment of wound bioburden is one of the best ways to achieve that outcome. WINT

References

Akiyama H, Oono T, Saito M, Iwatsuki K (2004) Assessment of cadexomer iodine against Staphylococcus aureus biofilm in vivo and in vitro using confocal laser scanning microscopy. *J Dermatol* 31(7): 529–34

Bain K, Hansen AS (2020) Strengthening implementation success using large-scale consensus decision-making - A new approach to creating medical practice guidelines. *Eval Program Plann* 79: 101730

Dowsett C, Muenter C, Bain K, Bain M (2020) Closing the gap between the evidence and the bedside: A consensus report on Exudate Management. *Wounds International* 11(3): 64–8

Dowsett C, Swanson T, Karlsmark T (2019) A Focus on the Triangle of Wound Assessment – addressing the gap challenge and identifying suspected biofilm in clinical practice. *Wounds International* 10(3): 16–21

European Wound Management Association (2005) *Position Document: Identifying Criteria for Wound Infection.* MEP Ltd, London. Available at: http://www.cslr.cz/download/English_pos_doc_final.pdf (accessed 24.11.2020)

Guest JF, Ayoub N, McIlwraith T et al (2015) Health economic burden that wounds impose on the National Health Service in the UK. *BMJ Open* 5(12): e009283

International Wound Infection Institute (IWII) Wound infection in clinical practice. Wounds International 2016

Johani K, Malone M, Jensen S et al (2017) Microscopy visualisation confirms multi-species biofilms are ubiquitous in diabetic foot ulcers. *Int Wound J* 14(6): 1160–9

Keast D, Bain K, Hoffmann C et al (2020) Managing the Gap to promote Healing in Chrinic Wounds – An International Consensus. *Wounds International* 11(3): 58–63

Keast D, Swanson T, Carville K et al (2014) Ten Top Tips: Understanding and managing wound biofilm. *Wounds International* 5(2): 20–4

Malone M, Bjarnsholt T, McBain AJ et al (2017) The prevalence of biofilms in chronic wounds: a systematic review and meta-analysis of published data. *J Wound Care* 26(1): 20–5

Moore Z, Strapp H (2015) Managing the problem of excess exudate. *Br J Nurs* 24(15): S12–7

Moura MRT, Dowsett C, Bain K, Bain M (2020) Advancing practice in holistic wound management: a consensus-based call to action. *Wounds International* 11(4): 70–5

Murphy C, Atkin L, Swanson T et al (2020) International consensus document. Defying hard-to-heal wounds with an early antibiofilm intervention strategy: wound hygiene. *J Wound Care* 29(Suppl 3b): S1–28

Ousey K, Atkin L (2013) Optimising the patient journey Made Easy. *Wounds UK* 9(2) 1–6

Ousey K, Cook L (2012) Wound assessment made easy. *Wounds UK* 8(2): 1–4

Penhallow K (2005) A review of studies that examine the impact of infection on the normal wound-healing process. *J Wound Care* 14(3): 123–6

Persival SL (2017) Importance of biofilm formation in surgical infection. *BLS Society* 104(2): 85–94

Percival SL, Bowler P, Woods EJ (2008) Assessing the effect of an antimicrobial wound dressing on biofilms. *Wound Repair Regen* 16(1): 52–7

Phillips PL, Yang Q, Davis S, et al (2015) Antimicrobial dressing efficacy against mature Pseudomonas aeruginosa biofilm on porcine skin explants. *Int Wound J* 12(4): 469–83

Phillips PL, Yang Q, Schultz GS (2013) The effect of negative pressure wound therapy with periodic instillation using antimicrobial solutions on Pseudomonas aeruginosa biofilm on porcine skin explants. *Int Wound J* 10(1): 48–55

Phillips PL, Wolcott RD, Fletcher J, Schultz GS (2010) Biofilms Made Easy. *Wounds International* 1(3): 1–6

Rodeheaver GT, Ratliff CR (2007) Wound cleansing, wound irrigation, wound disinfection. In: Rodeheaver GT et al (eds.) *Chronic Wound Care: A Clinical Source Book for Healthcare Professionals*. HMP Communications, Malvern, PA: pp331–42

Scali C, Kunimoto B (2013) An update on chronic wounds and the role of biofilms. *J Cutan Med Surg* 17(6): 371–6

Schultz G, Bjarnsholt T, James GA et al (2017) Consensus guidelines for the identification and treatment of biofilms in chronic nonhealing wounds. *Wound Repair Regen* 25(5): 744–57

Swanson T, Keast D, Cooper R et al (2015) Ten Top Tips: identification of wound infection in a chronic wound. *Wounds International* 6(2): 22–7

Swanson T, Grothier L, Schultz G (2014) *Wound Infection Made Easy*. Wounds International, London.

Wolcott RD, Kendra P, Rumbaugh GJ et al (2010) Biofilm maturity studies indicate sharp debridement opens a time-dependent therapeutic window. *J Wound Care* 19(8): 320–8

World Union of Wound Healing Societies (2019) *WUWHS Consensus Document: Wound Exudate: Effective Assessment and Management*. Wounds International, London. Available at: https://bit.ly/3692LbN (accessed 24.11.2020)

World Union of Wound Healing Societies (2016) *Position Document: Management of Biofilm*. Wounds International, London. Available at: https://bit.ly/3l3k1mU (accessed 24.11.2020)

World Union of Wound Healing Societies (2008) *Wound Infection in Clinical Practice. A WUWHS International Consensus*. London, MEP Ltd. Available at: https://bit.ly/39ixa9x(accessed 24.11.2020)

Wounds UK (2018) *Best Practice Statement: Improving Holistic Assessment of Chronic Wounds*. Wounds UK, London. Available at: https://bit.ly/3fBggDY (accessed 24.11.2020)

Wounds UK (2017) *Best Practice Statement: Making Day-to-Day Management of Biofilm Simple*. Wounds UK, London. Available at: https://bit.ly/2JdBnjG (accessed 24.11.2020)

Wounds digest

In this section, a brief synopsis is presented of a range of recently published articles that may be of interest to healthcare professionals working in the wound care setting. The aim of this round-up is to provide an overview, rather than a detailed summary and critique, of the research papers selected. Full references are provided should you wish to look at any of the papers in more detail.

1 The sorptivity and durability of gelling fibre dressings tested in a simulated sacral pressure ulcer system

Readability	✔	✔	✔	✔	
Relevance to daily practice	✔	✔	✔	✔	
Novelty factor	✔	✔	✔		

- Factors that have been identified as affecting wound-dressing performances, include exudate viscosity, flow resistance due to gravity and bodyweight loads, and the level of which is related to the body position.
- The authors focussed their attentions on two dressing properties, namely sorptivity (a dressing's ability to transfer exudate away from the wound bed through capillary) and durability (a dressing's ability to maintain their integrity over time and during their removal). In order to effectively measure these properties, the development of new laboratory tests was required.
- A computer-controlled phantom was developed to compare the performances of Exufiber (Mölnlycke Health Care) and an alternative market-leading dressing on an exuding sacral pressure ulcer. Weight tests were used to determine sorptivity, while durability was measured through tensile tests of the dressings.
- The Exufiber dressing was found to offer three times higher sorptivity and better durability than the alternative dressing. In addition, the Exufiber dressing was found to offer approx. five times greater strain energy than the alternative before failure occurred.
- In conclusion, this research opens the door for further quantitative, standardised testing of dressings in all aspects of exudate management.

Lustig A, Alves P, Call E et al (2020) The sorptivity and durability of gelling fibre dressings tested in a simulated sacral pressure ulcer system. *Int Wound J* doi: 10.1111/iwj.13515. Online ahead of print

2 Can photons pass through primary coatings used to treat cutaneous wounds?

Readability	✔	✔	✔	✔	
Relevance to daily practice	✔	✔	✔	✔	
Novelty factor	✔	✔	✔		

- The authors set out to determine whether or not the transmittance spectrum of primary dressings, which is commonly used in the treatment of cutaneous wounds, means that they should be removed during photobiomodulation.
- Seventeen dressings were spectroscopic analysed using a spectrophotometer. A piece of each dressing was enclosed in a quartz cuvette and the transmittance of each dressing was measured from 350–950 nm. A transmittance table was then created based on the main wavelengths used in photobiomodulation.
- Six dressings were found to have a transmittance greater than 50% in most of the spectral range. These were: Supriderme, Membracel, Cuticell Contact, UrgoTul, Tegaderm, and Opsite Flexigrid. The results suggested that these dressings may remain on wounds during irradiation.
- When lasers or LED lights are used to treat wounds, it may not always be necessary to remove the primary dressing. There are hopes that this research will increase the effectiveness of both photobiomodulation and primary dressings in the future, as well as decrease patient discomfort.

Barbosa da Silva S, Salani R, de Cássia Ferreira R et al (2020) Can photons pass through primary coatings used to treat cutaneous wounds? *Adv Skin Wound Care* doi: 10.1097/01.ASW.0000721440.25562.a3. Online ahead of print

3 Dehydrated human amnion chorion membrane as treatment for pediatric burns

Readability	✔	✔	✔	✔	
Relevance to daily practice	✔	✔	✔		
Novelty factor	✔	✔	✔	✔	

- A lack of adequate care when treating burns in the paediatric population can cause lifelong functional loss and disfigurement. A focus on alternative skin substitutes, such as allografts, has gained traction in recent times when treating burns, given that the use of split-thickness skin autografts, which are the current standard of care for deep partial and full-thickness burns, is associated with considerable morbidity.
- This article involves a case series of 30 children with different types of burns that were treated with dehydrated human amnion chorion membrane (dHACM). Treatment with dHACM was found to have a highly effective healing rate, which was comparable to split-thickness skin grafts with less rate of hypertrophic scar and contracture.
- Although dHACM has a higher upfront cost than split-thickness skin autografts, the treatment of patients presenting with small- to moderate-sized burns with dHACM decreases downstream costs, while avoiding the need and associated cost of transferring patients to higher level centres of care.
- The authors found that dHACM provides an effective alternative to split-thickness skin grafting when treating partial and full-thickness paediatric burns.

Ahuja N, Jin R, Powers C et al (2020) Dehydrated human amnion chorion membrane as treatment for pediatric burns. *Adv Wound Care (New Rochelle)* 9(11): 602–11

4 Effectiveness of ultrasonic debridement on reduction of bacteria and biofilm in patients with chronic wounds: a scoping review

Readability	✔	✔	✔		
Relevance to daily practice	✔	✔	✔	✔	
Novelty factor	✔	✔	✔		

- Infection control and removal of the biofilm in chronic wounds are crucial in chronic wounds due to these hard-to-heal wounds having a high risk of infection and at risk of the formation biofilms.
- Ultrasonic debridement has been developed in recent years aimed at reducing infection and promoting chronic wound healing. The authors undertook a scoping review to evaluate the effectiveness of ultrasonic debridement when treating these wounds. A database search identified 1,021 articles, with nine papers eligible for inclusion.
- Non-contact devices were found to be effective in the healing of chronic wounds due to their ability to reduce the inflammatory response, but they did not significantly change bacterial load.
- On the other hand, ultrasonic debridement devices that require direct contact with the wound were found to promote wound healing by reducing biofilm or bacterial load.
- It was found that the optimum settings for ultrasonic debridement using a non-contact device were relatively steady, but the settings for devices that require direct contact were found to be relatively diverse.

Kataoka Y, Kunimitsu M, Nakagami G et al (2020) Effectiveness of ultrasonic debridement on reduction of bacteria and biofilm in patients with chronic wounds: a scoping review. *Int Wound J* doi: 10.1111/iwj.13509. Online ahead of print

5 Use of the ankle-brachial index combined with the percentage of mean arterial pressure at the ankle to improve the prediction of all-cause mortality in type 2 diabetes mellitus: an observational study

Readability	✔	✔	✔	✔	
Relevance to daily practice	✔	✔	✔		
Novelty factor	✔	✔	✔	✔	

- The ankle-brachial index (ABI) is a simple noninvasive method to screen peripheral artery disease (PAD). The authors hypothesised that by using ABI in conjunction with the percentage of mean arterial pressure (%MAP), this would improve the prediction of mortality.
- For this study, data from patients with type 2 diabetes who had undergone ABI and %MAP measurements at the authors' hospital were retrospectively collected. The cohort was split into four groups according to their ABI and %MAP values, after which the indices were examined to determine whether or not they were associated with mortality.
- The authors called upon 5,569 patients to the study and during the follow-up period (median was 22.9 months), 266 of the enrolled patients died, equating to 4.8%. Mortality prediction was found to be significantly more effective through the combination of ABI and %MAP.
- The study concluded that the use of %MAP alongside ABI can significantly improve the prediction of all-cause mortality in those with type 2 diabetes.

Li Y-H, Sheu WH-H, Lee I-Te (2020) Use of the ankle-brachial index combined with the percentage of mean arterial pressure at the ankle to improve the prediction of all-cause mortality in type 2 diabetes mellitus: an observational study. *Cardiovasc Diabetol* 19(1): 173

6 Evaluation of a novel three-dimensional wound measurement device for assessment of diabetic foot ulcers

Readability	✔	✔	✔	✔	
Relevance to daily practice	✔	✔	✔		
Novelty factor	✔	✔	✔	✔	

- Despite the fact that initial wound measurement and regular monitoring of diabetic foot ulcers (DFUs) is crucial to establish a treatment plan, there is currently no standardised, universally accepted, assessment method to characterise DFUs in a quick, reliable and quantitative way. Therefore, the authors set out to assess a novel topographic imaging system used in the assessment of DFUs.
- It was the WoundVue system that was assessed for this study, with 57 diabetic foot wounds seen from patients in a multidisciplinary foot clinic included. These wounds were photographed from two different angles and distances by using the WoundVue camera, with wound area, volume, and maximum depth all measured. Of these, 31 had their area calculated by using the established Visitrak™ system, with results from both systems examined.
- The average percentage differences by using the WoundVue from different angles for assessment of different sizes and shapes of wounds were: 2.9% (95% confidence interval [CI]: 0.3-5.4), 12.9% (95% CI: 9.6-35.7), and 6.2% (95% CI: 2.3-14.7) for area, maximum depth, and volume, respectively.
- To the authors' knowledge, this is the first human trial evaluating this novel 3D wound measurement device, which has the potential to be a valuable adjunct in diabetic foot wound care going forward.

Pena G, Kuang B, Szpak Z et al (2020) Evaluation of a novel three-dimensional wound measurement device for assessment of diabetic foot ulcers. *Adv Wound Care (New Rochelle)* 9(11): 623–31

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