Case study

Healing and antimicrobial benefits of bioelectric dressings in a chronic venous leg ulcer: a case report

ABSTRACT

Aims To report the outcome of using Bioelectric Dressings (BED) in reducing bioburden and enhancing the healing of a chronic Venous Leg Ulcer (VLU).

Methods A case report of a patient with a recalcitrant VLU over the right anterior ankle, recurring three times since August 2023, presented to the outpatient wound clinic. The most recent recurrence of the VLU, measuring 7.1cm x 5.5cm (39.05cm^2) post-surgery, was treated with nanocrystalline silver dressing and two-layer compression bandaging (40 mmHg) for 32 days, reducing the size to 22.55cm^2 (57.8%). The treatment was then switched to BED with compression bandaging, achieving further reduction to 16.5cm^2 (42.2%) in 21 days, successfully healing the wound.

Results The VLU has taken in total of 53 days to heal. The wound healing rate was 1.8% per day, while treated with nanocrystalline silver dressing as the primary dressing in the first 32 days. Then the primary dressing was switched to BED, the wound healing rate was 2% per day, in the subsequent 21 days of treatment. The VLU site was fully healed, leaving residual hyperpigmentation and hyperkeratosis at the anterior ankle.

Conclusion BED has shown some promise in accelerating epithelialisation and transitioning wounds from the inflammatory to the proliferative phase.

Keywords bioelectric dressing, chronic wound healing, nursing, venous leg ulcer, wound bioburden

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INTRODUCTION

Venous leg ulcers (VLUs) are among the most common chronic wounds affecting the lower limbs, arising as a complication of chronic venous insufficiency (CVI).[1] The gold standard for VLU treatment involves compression therapy combined with appropriate skin and wound management.[2] However, VLUs are prone to recurrence, recalcitrant healing and infection due to factors such as inadequate or noncompliance with compression therapy, suboptimal wound care, and poor biofilm management.[3]

Wee Ting Goh
Bachelor of Science (Nursing), Nursing Division,
Singapore General Hospital

Nanthakumahrie Gunasegaran*
Masters of Science (Clinical Leadership), Nursing Division,
Singapore General Hospital
Email nanthakumahrie.gunasegaran@sgh.com.sg

Fazila Aloweni
Masters of Science (Health Research Methodology), Nursing Division,
Singapore General Hospital

** Corresponding author*

In Singapore, the prevalence of VLUs was 15 per 100,000 people in 2017, increasing to 38 per 100,000 among those aged 50 and older.[1] A recent study revealed that the cost of compression therapy for VLUs ranged from SGD 80 to SGD 41,713.07, depending on the complexity and duration of treatment.[4]

International best practice guidelines have recommended the use of antimicrobial wound products, such as topical silver-impregnated dressings, to manage infections and promote healing.[2,5,6] Nanocrystalline silver dressings (NCSD) have demonstrated high efficacy in treating local wound infections caused by highly resistant bacteria or antibiotic-resistant organisms.[7]

In recent years, global concerns about antimicrobial resistance have grown, alongside increased awareness of how to address this critical issue. While much of the discussion has centered on the proper use of antibiotics, it is essential to ensure the appropriate use of all antimicrobials to minimise the risk of silver resistance.[7] A step-up or step-down approach is recommended for antimicrobial wound product usage.[5,6] Clinicians are advised to regularly assess and reassess wounds to ensure antimicrobial treatments remain clinically beneficial and are used for an appropriate duration, typically two to four

weeks.[5,6,8] While NCSD is recommended as an early intervention for managing local infections and potentially reducing the duration of antibiotic therapy for patients,[7,8] concerns remain about the cytotoxic effects, which may inhibit fibroblast activity—an essential process for wound healing.[9,10]

This single case study aims to evaluate the efficacy of bio-electric dressings (BED) in healing an infected, recalcitrant VLU. This case study was guided by the CARE guidelines framework.[11] The intervention served as a step-down approach following surgical debridement and four weeks of treatment with NCSD, during which the healing process fluctuated between periods of progress and stagnation.

BACKGROUND

The patient, a 77-year-old female living alone, uses a walking stick and has kyphosis. She has had a left lower limb VLU since 2017 and previously underwent a VenaSeal procedure for long saphenous vein (LSV) insufficiency. She experienced recurrent ulcer episodes, intermittently managed with 2-layer and 4-layer bandages. Her medical history includes hypertension, hyperlipidemia, hyperthyroidism, leiomyosarcoma, lichen amyloidosis and stasis dermatitis. On 10 October 2022, a CVI scan revealed great saphenous vein (GSV) tributary reflux with popliteal vein reflux. The patient's wound care included povidone iodine-impregnated dressing and 2-layer compression bandaging, leading to complete healing of the VLU. Following this, Class II compression stockings were prescribed for maintenance. On 23 November 2023, a repeat CVI scan revealed GSV reflux. However, the wound recurred on 18 March 2024, prompting treatment with hydrogel dressing and the reintroduction of two-layer compression bandaging. On 15 April 2024, the wound care regimen was updated to hydrofiber silver dressing combined with two-layer compression bandaging. By 10 June 2024, the VLU was fully healed.

PRESENTATION

On 28 August 2024, the patient's VLU recurred, leading to admission for surgical wound debridement. The left anterior ankle wound presented with sloughy, greyish-tinged tissue. Debridement was performed until healthy bleeding tissue was achieved, and wound tissue was sent for aerobic culture. The anterior ankle wound measured 7.1cm x 5.5cm, revealing a pinkish-red fibrotic wound bed with a thin layer of fibrin slough (Figure 1). While waiting for the wound culture results, the wound was managed with Cadexomer-iodine ointment dressing only.

On 30 August 2024, tissue culture results identified three bacterial pathogens: *Pseudomonas aeruginosa*, Group B *Streptococcus*, and *Escherichia coli*. The patient was discharged on 31 August 2024, with instructions to continue Cadexomer iodine ointment dressing and a two-week antibiotic course of oral Ciprofloxacin and Clindamycin. On 2 September 2024, vascular surgeons and a vascular specialty nurse reviewed the patient. The wound care regimen was updated to NCSD with a superabsorbent pad, and 2-layer (40mmHg) compression bandaging was reinitiated. The patient was scheduled for weekly dressing and compression bandage changes with the vascular speciality nurse.

DISCUSSION/INTERVENTIONS

The patient underwent weekly dressing changes at the outpatient wound clinic, maintaining the same treatment modality for four weeks. Wound care was consistently managed by the same vascular specialty nurse during each visit.

Chronic VLUs often experience delayed healing due to elevated inflammatory mediators, rather than a lack of growth factors.[12] Addressing the bioburden is essential to prevent further wound deterioration and increase the efficacy of wound care modalities.[5] While wound bed preparation, including wound cleansing and debridement, is critical for promoting healing by enabling the development of a functional extracellular matrix[12,13], it can also disrupt and prevent biofilm reformation. The vascular wound nurse incorporated two wound management strategies for managing this complex venous leg ulcer: the TIME framework and wound hygiene.

To support this practice, conservative sharp wound debridement was performed using a scalpel, along with thorough cleansing of the wound bed and peri-wound skin at each dressing change. Then 2-layer compression bandage was applied and pressure was maintained via the UrgoK2® layer system, which comprises inelastic and elastic bandages: the first layer is a soft-padded short stretch, and the second layer is a cohesive long stretch, delivering a compression pressure of 40mmHg.

Figure 1. Anterior ankle VLU post-surgical debridement

After 32 days of treatment, the anterior ankle wound measured 5.5cm x 3cm (Figure 2). During the outpatient clinic visit on 30 September 2024, the patient expressed distress over the slow wound recovery, despite adherence to compression bandaging (maintaining dry bandages and elevating the legs during rest). A new treatment approach was proposed and agreed upon by the patient. The dressing was switched to BED covered with a superabsorbent dressing, and secured with 2-layer compression bandaging.

Within seven days, the VLU wound presented with a few islands of epithelial tissue over the wound bed. The wound measured 4.9cm x 3.1cm (Figure 3a,b,c). The patient was on the BED dressing in total for 21 days. Patient tolerated the dressing changes well. During the use of BED, patient was comfortable and did not experience any adverse events. During each dressing change, the patient said pain was tolerable during the procedure. The anterior ankle VLU epithelialised and measured 6cm x 5cm. A large area of new epithelial skin was present over the wound bed, suggestive of total wound closure being achieved. Patient was discontinued from the BED dressing. The healed wound was moisturised with emollient and the patient was placed on Class II compression stockings. Patient was reviewed again after a week at the wound clinic. The VLU has fully healed, leaving a scar with minimal residual hyperpigmentation and hyperkeratosis at the anterior ankle (Figure 4).

Figure 2. Anterior ankle VLU after 32 days of NCSD prior to the use of BED

Wound healing is a complex process that requires comprehensive management for effective care. A holistic approach to wound care should focus on reducing bioburden, creating an optimal healing environment, and supporting the host's natural healing response.[5]

In chronic wound management, appropriate use of silver antimicrobial dressings can effectively treat wound infections, prevent biofilm formation, and potentially reduce the duration of antibiotic use.[8] NCSD, with their proven antimicrobial efficacy, have demonstrated the ability to reduce antibiotic usage, shorten hospital stays, lower treatment costs, and decrease the prevalence of antibiotic-resistant organisms (Table 1).[8] However, emphasis should be placed on the recommended 2–4 weeks treatment window, with regular reassessment and evaluation to minimise impact on antimicrobial or silver resistance.[5, 6, 8] Although there is no strong evidence that silver resistance directly leads to treatment ineffectiveness, the concentration of silver in

Figure 3a. Anterior ankle VLU after seven days use of BED; 3b. Anterior ankle VLU after 14 days; 3c. Anterior ankle VLU after 21 days

the dressing needs to be considered. When biofilms form they can exhibit higher tolerance to antibiotics and require 10 to 100 times higher concentrations of silver to eradicate planktonic bacteria effectively.[7] This means that silver dressings with concentrations less than 60ppm may not be effective for biofilm management.[14] Another consideration is that most silver dressings containing concentrations of above 70ppm, which is cytotoxic to keratinocytes and fibroblasts that contribute to wound healing.[15]

In recent years, a novel wound modality, BED, has garnered attention as the only dressing that utilises electrical principles for biofilm management (Table 1).[16,17] BED is a single-layer polyester dressing with a matrix of silver and zinc dots printed on one side. BED generates low-voltage electricity through silver (Ag+) and zinc (Zn+) ions when in contact with moisture or exudate. The Ag+ dots measure 2mm in diameter, while the Zn+ dots are 1mm.[16] When activated by wound exudates or exogenous fluids like normal saline, it delivers a voltage of 0.5–0.9 volts.[18] The micro electrical charges released into the wound bed enhance the electric field to accelerate the wound healing. BED has proven effective in eliminating several multidrug-resistant microorganisms, including *Methicillin-resistant Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* MDR strains, as well as common Gram-negative and Gram-positive bacteria.[18] Biofilm infections often complicate non-healing skin ulcers, with *Pseudomonas aeruginosa* playing a key role in delaying the healing of leg ulcers. BED has shown effectiveness in eliminating and disrupting *Pseudomonas aeruginosa* biofilm.[14]

Figure 4. Anterior ankle VLU healed

BED is non-cytotoxic and utilises weak electrical activity to disrupt biofilm formation and activity, without high silver concentration. BED impedes biofilm formation and aggregation by limiting quorum sensing activities, and it can also suppress planktonic growth.[14,16,19] Additionally, BED features a unique mechanism that accelerates keratinocyte migration, thereby facilitating wound closure.[14] Chronic wound healing is often delayed due to prolonged or persistent inflammation, which is linked to biofilm formation. Nevertheless, BED can limit biofilm formation, reduce inflammation in keratinocytes, and promote migration, ultimately leading to epithelialisation and wound closure.[19] A randomised controlled trial conducted by Chan et al in 2023 has proven and demonstrated that BED significantly accelerates wound healing by reducing and preventing biofilm formation.[17] Similarly, in a case report, BED dressing was used

Table 1. Wound products and intended action

Generic name	Wound product name	Action/rationale for use
Nanocrystalline silver dressing	Acticoat Flex 3	Provides long-lasting antimicrobial action for up to seven days in chronic wounds. The nanocrystalline silver structure ensures a controlled and sustained release of silver into wound fluid. Additionally, the dressing supports and maintains a moist wound environment when combined with a suitable secondary dressing.[23-25] Effectively delivers silver at a consistent concentration to maintain bactericidal activity.[26]
Bioelectric dressing	Procellera™	This broad-spectrum antimicrobial dressing is designed as a single layer to support and maintain a moist wound environment. It features a matrix of alternating silver (Ag) and zinc (Zn) dots embedded in a polyester substrate using a biocompatible binder. Activation occurs in the presence of a conductive fluid, such as wound exudate or external fluids like saline. Once activated, the dressing generates a measurable direct current voltage (0.5–0.9 volts) between the Ag and Zn dots. This micro-electrical field may enhance the natural electric field of injury that arises during the wound healing process.[27] Demonstrates effectiveness against both antibiotic-sensitive strains and multiple antibiotic-resistant strains of wound pathogens.[18]
Superabsorbent pad	ConvaMax™ Superabsorber	Prevents strike-through and aids in moisture vapour transmission. Suitable for high exudating wounds. Safe to use beneath compression bandages.[28]

beneath compression bandaging for VLU, achieving complete healing from an initial size of 10cm² before treatment.[20] Unlike some silver dressings, BED does not stain wounds and is low-adherent, allowing for non-traumatic removal. However, based on our experience with the use of BED on highly exudative VLUs, it appeared unsuitable likely due to its lower or limited vertical wicking capability or low moisture vapor transmission rate (MVTR), which causes peri-wound maceration, even when superabsorbent or foam dressings were used as secondary dressing. There are currently no studies available that provide evidence or insights into BED's MVTR or wicking capability. Exploring the wicking capability of BED in future research could yield significant benefits.

When managing infected or chronic wounds, it is crucial to focus on cleansing, wound bed preparation, wound edge care, and peri-wound skin hygiene before applying dressings.[5,6] Peri-wound skin issues, such as dry skin scales, hyperkeratotic plaques, or calluses with debris, can create an environment conducive to biofilm formation.[21] In particular, the wound edge often harbors active biofilm. Neglecting proper care of the wound edge and peri-wound area can result in delayed healing, increased wound size, a higher risk of infection, elevated treatment costs, pain or discomfort, and a diminished quality of life. Therefore, effective wound management should encompass thorough cleansing, skin protection, exudate control, and the maintenance of a moist wound healing environment.[21,22]

Similarly, an effective management of VLUs requires meticulous care of the wound edge and peri-wound skin, as these areas are crucial for wound size reduction, overall healing progress, and minimising biofilm formation. Thorough cleaning and refashioning of the wound edge to achieve pinpoint bleeding is particularly beneficial.[6] Following this, implementing a structured skincare regimen, along with measures to protect and prevent damage to the peri-wound area and wound edge caused by wound exudate, is especially important when using compression therapy.[2,21]

The efficacy of NCSD in treating this patient's infected VLU is significant. Following the recommended step-up/step-down antimicrobial wound approach, NCSD was discontinued in week five and replaced with BED, which subsequently healed the ulcer. While the selection of the primary dressing is crucial in treating infected and recalcitrant VLUs, the choice of secondary dressing, wound debridement, management of wound edges, and peri-wound skin care are equally important in promoting healing.

Additionally, proper compression therapy, patient adherence to treatment, and modification of other modifiable risk factors, such as blood sugar optimisation, diet, and adequate rest, are essential. Treatment and follow-up for CVI patients should continue even after the VLU has healed. Patient and caregiver education, regular surveillance, and ongoing compression therapy are vital to prevent recurrence.

WHAT THIS PAPER ADDS

BED holds significant promise in the management of recalcitrant VLUs. By leveraging bioelectric signals, these dressings create a conducive environment for wound healing, promoting cellular activity, reducing inflammation, and addressing microbial challenges that often impede recovery. As an adjunct to standard care, BED offers a novel approach to treating stubborn VLUs, potentially enhancing healing rates and improving patient outcomes, particularly in wounds resistant to conventional therapies.

CONCLUSION

Based on this case study, BED is effective in accelerating epithelialisation and transitioning wounds from the inflammatory to the proliferative phase. Patients need reliable access to consistent outpatient services for ongoing care and evaluation. Comprehensive investigations and additional interventions are essential for chronic wound care. Education plays a key role, as patients must understand proper wound hygiene, the purpose of specific interventions, and the rationale behind the chosen wound care products. Furthermore, the psychological impact of living with a chronic wound should not be overlooked. Regular assessments should include evaluating mental well-being, with appropriate referrals made to support services as needed.

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AUTHOR CONTRIBUTION

Goh Wee Ting and Nanthakumahrie Gunasegaran were involved in conceiving and designing this study, acquiring subjects, collecting data, managing data, and reviewing the manuscript.

Goh Wee Ting and Nanthakumahrie Gunasegaran prepared the manuscript writing.

Fazila Aloweni supervised and reviewed the manuscript.

All authors reviewed and extensively edited the manuscript and approved the final version of this manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ETHICS STATEMENT

Ethics approval was waived; however, informed written patient consent was obtained for photography.

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REFERENCES

1. Goh OQ, Ganesan G, Graves N, et al. Incidence of chronic wounds in Singapore, a multiethnic Asian country, between 2000 and 2017: a retrospective cohort study using a nationwide claims database. BMJ Open. 2020;10:e039411. doi: 10.1136/bmjopen-2020-039411
2. Wounds UK. Best Practice Statement: Holistic management of venous leg ulceration. 2016. London: Wounds UK. Available from www.wounds-uk.com
3. Wounds UK. Best Practice Statement: Addressing complexities in the management of venous leg ulcers. 2019. London: Wounds UK. Available from www.wounds-uk.com
4. Aloweni F, Uthaman T, Agus N, et al. The cost of venous leg ulcers in a Singapore tertiary hospital: an explorative study. Wound Pract Res. 2022;30:75–81. doi: 10.33235/wpr.30.2.75-81
5. Swanson T, Ousey K, Haesler E, et al. IWII Wound Infection in Clinical Practice consensus document: 2022 update. J Wound Care. 2022;31:S10-s21. doi: 10.12968/jowc.2022.31.Sup12.S10.
6. Murphy C, Atkin L, Swanson T, et al. Defying hard-to-heal wounds with an early antibiofilm intervention strategy: wound hygiene. J Wound Care. 2020;29(Sup3b):S1-S26. doi: 10.12968/jowc.2020.29.Sup3b.S1
7. Woodmansey EJ & Roberts CD. Appropriate use of dressings containing nanocrystalline silver to support antimicrobial stewardship in wounds. Int Wound J. 2018; 15(6):1025–1032. doi: 10.1111/iwj.12969
8. Hurd T, Woodmansey EJ & Watkins HMA. A retrospective review of the use of a nanocrystalline silver dressing in the management of open chronic wounds in the community. Int Wound J. 2021;18:753–762. doi:10.1111/iwj.13576
9. Yousefian F, Hesari R, Jensen T, et al. Antimicrobial wound dressings: a concise review for clinicians. Antibiotics. 2023;12(9):1434. doi:10.3390/antibiotics12091434
10. Shrestha S, Wang B & Dutta PK. Commercial silver-based dressings: In vitro and clinical studies in treatment of chronic and burn wounds. Antibiotics. 2024;13(9):910. doi:10.3390/antibiotics13090910
11. Gagnier JJ, Kienle G, Altman DG, et al. The CARE guidelines: consensus-based clinical case reporting guideline development. Headache. 2013;53(10):1541–1547. doi:10.1111/head.12246
12. Malone M, Bjarnsholt T, McBain AJ, et al. The prevalence of biofilms in chronic wounds: a systematic review and meta-analysis of published data. J Wound Care. 2017;26:20–25. doi: 10.12968/jowc.2017.26.1.20
13. Trengove NJ, Bielefeldt-Ohmann H & Stacey MC. Mitogenic activity and cytokine levels in non-healing and healing chronic leg ulcers. Wound Repair Regen. 2000;8(1):13-25. doi: 10.1046/j.1524-475x.2000.00013.x
14. Banerjee J, Ghatak PD, Roy S, et al. Silver-zinc redox-coupled electroceutical wound dressing disrupts bacterial biofilm. PloS One. 2015;10(3):e0119531. doi: 10.1371/journal.pone.0119531
15. Ofstead CL, Buro BL, Hopkins KM, et al. The impact of continuous electrical microcurrent on acute and hard-to-heal wounds: a systematic review. J Wound Care. 2020;29(Sup 7):S6-S15. doi: 10.12968/jowc.2020.29.Sup7.S6
16. Khona DK, Roy S, Ghatak S, et al. Ketoconazole resistant Candida albicans is sensitive to a wireless electroceutical wound care dressing. Bioelectrochemistry. 2021;142:107921. doi: 10.1016/j.bioelechem.2021.107921
17. Chan RK, Nuutila K, Mathew-Steiner SS, et al. A prospective, randomized, controlled study to evaluate the effectiveness of a fabric-based wireless electroceutical dressing compared to standard-of-care treatment against acute trauma and burn wound biofilm infection. Adv Wound Care. 2023;13(1):1–13. doi: 10.1089/wound.2023.0007
18. Kim H, Makin I, Skiba J, et al. Antibacterial efficacy testing of a bioelectric wound dressing against clinical wound pathogens. Open Microbiol J. 2014;8(1):15-21. doi: 10.2174/1874285801408010015
19. Barki KG, Das A, Dixith S, et al. Electric field based dressing disrupts mixed-species bacterial biofilm infection and restores functional wound healing. Ann Surg. 2019; 269(4): 756–766. doi: 10.1097/SLA.0000000000002504
20. Harikrishna KR Nair, Sylvia SY Chong & Eruthayaraj A. Use of a unique bioelectric dressing in chronic wound healing. Wounds Asia. 2020;3(3):40-44.
21. Harding K, Dowsett C, Fias L, et al. Simplifying venous leg ulcer management: consensus recommendations. Wounds Int. 2015: 1–28.
22. LeBlanc K, Beeckman D, Campbell K et al (2021). Best practice recommendations for prevention and management of periwound skin complications. Wounds International. Available online at: www.woundsinternational.com
23. Bradbury S, Turner A, Ivins N, et al. Managing chronic wounds with Acticoat Moisture Control™. Wounds UK. 2007;3(2):104–110.
24. Fong J & Wood F. Nanocrystalline silver dressings in wound management: a review. Int J Nanomedicine. 2006;1(4):441–449. doi:10.2147/nano.2006.1.4.441
25. Gago M, Garcia F, Gaztelu V, et al. A comparison of three silver-containing dressings in the treatment of infected, chronic wounds. Wounds. 2008;20(10):273–278.
26. Potgieter MD & Meidany P. Evaluation of the penetration of nanocrystalline silver through various wound dressing mediums: an in vitro study. Burns. 2017;44(3):596–602. doi: 10.1016/j.burns.2017.10.011.
27. Harding AC, Gil J, Valdes J, et al. Efficacy of a bio-electric dressing in healing deep, partial-thickness wounds using a porcine model. Ostomy Wound Manage. 2012; 58(9):50–55.
28. Cook L. Effect of super-absorbent dressings on compression sub-bandage pressure. Brit J Community Nurs. 2011;16(Sup3):38–43. doi:10.12968/bjcn.2011.16.sup3.s38