

geko[®]

UK and Rest of World (ROW)
The geko[®] Device
Annotated Bibliography



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UK and Rest of World (ROW) The geko™ Device Annotated Bibliography

Purpose: To provide a summary of the evidence to date for the geko™ device, particularly as it relates to haemodynamics, edema reduction, wound healing and recovery.

Inclusion: Published papers, PhD thesis in public domain and posters presented at Scientific Meetings.

Exclusion: Unpublished Case Studies with subjects <3 which can be viewed on the geko™ website at: https://www.gekodevices.com/clinical-studies/?fwp_cs_category=3-wound-therapy

In some papers, content in *italics* is taken directly from the abstracts or within the body of the paper.

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1. Introduction

The common peroneal (CP) nerve is a mixed nerve; neuromuscular electrical stimulation activates motor neurons (causing muscle contraction) and both cutaneous and muscle afferents (nerve fibers carrying sensory information into the spine). Electrical stimulation (EST) and low frequency neuromuscular electrical stimulation (NMES) of the common peroneal nerve has been the subject of research in humans for several years, with citations starting around 1988. Various reported benefits of a variety of devices other than the geko™ include regional cutaneous vasodilation in subjects with peripheral vascular disease, rehabilitation of foot drop and spasticity following cerebral vascular accidents (stroke), improving gait and overactive bladder symptoms in patients with Multiple Sclerosis, intra-operative nerve conduction testing for safety, rehabilitation of hemiplegic patients regarding the effort and speed of walking, improved ankle dorsiflexion in incomplete spinal cord lesions, and lasting facilitation of cortical motor-evoked potentials suggesting that gait in patients with a weakness in the tibialis anterior muscle may be improved even after stimulation is discontinued. It is easy to see how a device that painlessly and effectively stimulates the CP nerve could have a multitude of purposes.

Research including the geko™ device focussed initially on local and then more systemic hemodynamic responses, then DVT prophylaxis, edema management, systemic responses, wound healing, quality of life and tolerability. Research continues in several streams internationally.

For the purposes of this Annotated Bibliography, selected papers using geko™, geko™ prototype development, firefly™ or OnPulse™ technology are included.

There is a second version of this document created for the Canadian Market which also contains the Health Canada Device Registration document and the product specifications for the devices carried in the Canadian Market. Otherwise, the content is identical.

2. The geko™ Device Product Output Specifications

Please see the Firstkind geko™ website at <https://www.gekocodevices.com/us/wp-content/uploads/2021/05/WEBSKY01-R18.pdf> for Product Specifications for all of the devices powered by OnPulse™ neuromuscular electrostimulation technology.

3. Hemodynamics and the Effect of the geko™ Device

3-1. Pre-geko™ Research in Stimulation of Common Peroneal Nerve

3-1a. Paper: Tucker AT, Maass A, Bain DS, et al. Augmentation of venous, arterial and microvascular blood supply in the leg by isometric neuromuscular stimulation via the peroneal nerve. *Int J Angiol* 2010; 19:e31–e37.

Methods: Thirty healthy volunteers received modified neuromuscular stimulation to the common peroneal nerve with a range of 1 mA to 40mA, 1Hz to 5 Hz, 200 μs with 15 different stimulation programs. Baseline was when the patient was at rest, and testing was done while volunteer was seated in an economy airline seat. The leg was stimulated x 5 minutes, then the readings occurred with the stimulation turned off, and then the limb rested x 5 minutes before the next test was started. In the first session, settings went from 1 to 15. In the second session, the tests were repeated, but started with the maximum stimulation of 15 and moved down to 1. To create a baseline of what percentage of full dorsiflexion the stimulation would achieve, they used PPG over one of the dorsal foot veins and measured relative changes in optical reflectance which resulted from blood emptying from the vein during 10 sequential full dorsiflexions.

Table of Results:

| Test | Location and Results (Increases) |
|---|---|
| Photoplethysmography (PPG) | Blood emptying from Dorsal foot veins: at least 50% of that achieved with full dorsiflexion; up to 70% with 40 mA vs 50% with 1 mA. $P=0.0004$ <i>60% for geko™ parameters</i> |
| Strain gauge phlethmography (SPG) | Change in mid-calf circumference: 55 to 70% of that achieved with full dorsiflexion $P<0.001$ |
| Duplex ultrasound | Femoral vein venous volume flow range ~160% to 380% of baseline $P<0.01$ <i>Superficial femoral vein 100% increase in volumetric flow and peak velocity for geko™ parameters</i> Femoral vein mean peak venous velocity range ~150 to 360% of baseline $P<0.01$ |
| Transcutaneous oxygen tension (TCP02) on dorsum of foot | Tissue oxygen in the leg decreased from baseline during the evaluation, but stimulated values (~92 to 97%) were consistently significantly higher than unstimulated values $P=0.03$ |
| Laser Doppler Fluxmetry | Skin dorsum of foot microcirculatory flux range of ~400 to 2500% $P<0.01$ <i>400% for geko™ parameters</i> |
| Heart rate | No change |
| Pulse oximetry | No change to oxygen saturation |
| Blood Pressure | No change |

Key Learning Points: Note that the geko™ devices provide 27 (T1-T-2) and 54mA (R-2, W-2) and is 1 Hz; those stimulation parameters provided 60 to 70% of venous emptying response versus the 10 sequential dorsiflexions, considered to be equal to the response seen with walking (cannot do SPG/PPG when individual is ambulatory). The technology used in the study is novel and potentially advantageous compared with similar existing muscle electrostimulation (MEST) methods – first, due to an achieved blood flow increase via indolent nerve stimulation instead of painful direct muscle stimulation, and second, due to its small size, resulting in a wide range of application possibilities. Furthermore, by stimulating the nerve proximal to the posterior/anterior bifurcation, there is simultaneous activation of the tibialis, peroneus longus and lateral gastrocnemius muscles. Together, their contraction provides a near-isometric compression* of the venous valve system within the lower leg, possibly evacuating blood more effectively than by contracting the gastrocnemius alone. No changes were observed in heart rate, blood pressure, oxygen saturation or femoral vein vessel diameter, or in the length of the contracting muscle.

3-1b. Paper: Jawad, Huda. The effect of a novel electrical stimulation method for improving lower limb blood flow in healthy volunteers. PhD dissertation. Queen Mary University of London/ St. Bart's. 2012.

<https://qmro.qmul.ac.uk/xmlui/handle/123456789/3120> (266 pages)

Two chapters (5 & 6) in this thesis contain important early studies with geko™ prototypes in healthy volunteers, while a third (Chapter 7) focused on the geko™ T-1 device, and is described in section 3-2f. *The studies were carried out on healthy adult volunteers, with the intention of investigating the efficacy of a custom built neuromuscular electrical stimulation device (THRIVE) in enhancing lower limb blood flow and supporting the development of a prototype to a commercial medical device (geko™ T-1).*

Chapter 5: The Effect of THRIVE Device on Cardiac Performance in Healthy Volunteers: A Pilot Study. pages 65-77.

Methods: In nine healthy volunteers, following 30 minutes of supine rest, baseline echocardiography assessments were performed by two independently accredited echocardiographers. A custom-built electrical stimulation device (THRIVE) (pre-geko™) was fitted bilaterally to the common peroneal nerve device. Stimulation was then applied at a lower pulse width setting (400 µs), followed by a higher pulse width setting (600 µs). In both settings, the frequency used was 3Hz and the device was current modulated to provide a peak current of 20mA. Each stimulation was active for a period of 30 minutes and 10 minutes resting period was used to separate each pulse width setting, to allow vascular re-equilibration. Echocardiography assessments were performed with the device still active, 5 minutes before the end of each stimulation period.

Table of Cardiac Performance Results:

| Test | Baseline Mean and SD | 400 µs Stimulation Mean and SD | 600 µs Stimulation Mean and SD | Summary/ Significance |
|--|----------------------|---|---|---------------------------|
| Femoral Arterial Flow | 174.1 ± 39.2 ml/min | 258.8 ± 65.6 ml/min 55% increase | 273.1 ± 97.1 ml/min 54% increase | p ≤ 0.05 |
| Cardiac Arterial Peak Velocity | 81.19 ± 13.62 cm/sec | 101.6 ± 22.43 cm/sec Increased x 24% | 100.9 ± 26.37 cm/sec Increased x 24% | p ≤ 0.05 |
| Vessel Diameter and Cross-sectional Area | 0.64 ± 0.10 mm | 0.63 ± 0.12 mm | 0.64 ± 0.11 mm | p>0.05 no real change |
| Skin Microcirculation (foot) (Laser Doppler Flowmetry) | 7.71 ± 3.39 | 107.5 ± 68.1 1186% increase | 117.9 ± 67.8 1552% increase | p ≤ 0.05 |
| Left ventricular outflow tract velocity time integral (LVOT VTI) | 21.96 ± 3.23 | 23.27 ± 3.37 6% increase | 22.79 ± 3.06 4% increase | p ≤ 0.05 |
| Ejection Fraction | 59.9 ± 3.72 % | 60.3 ± 7.44 % | 62.6 ± 4.80 % | p=0.09 no real change |
| Left Ventricular Diastolic Volume | 117.7 ± 37.10ml | 120.2 ± 32.30 ml | 121.1 ± 27.86 ml | p=0.61 no real change |
| E' Velocity | 0.80 ± 0.16 m/s | 0.77 ± 0.12 m/s | 0.76 ± 0.08 m/s | P=0.29 no real change |
| Deceleration Time | 187.4 ± 24.82 ms | 194.1 ± 31.4 ms | 187.9 ± 20.28 ms | P= 0.59 no real change |
| E' Lateral | 3.76 ± 5.53 m/s | 3.79 ± 5.58 m/s | 3.89 ± 5.79 m/s | P=0.75 no real change |

Chapter 6. The Systemic Effect of a Novel Electrical Stimulation Method (Thromboembolic Prevention via Electrical Stimulation [THRIVE]).

Methods: Each of the ten healthy volunteers had two visits; the first visit was to conduct a stimulation study where an electrical stimulation device was applied. The second visit was to carry out a control study where the same investigations were repeated without stimulation. A custom-built electrical stimulation device (THRIVE) (pre-geko) was fitted to the common peroneal nerve in the popliteal fossa of one leg, and was compared to an un-stimulated contralateral control leg. To test the venous response, the device was stimulated for 5 minutes every 15 minutes, followed by a ten minute recover phase, with a low frequency (3 Hz), 25 mA and 600 µs. Microcirculatory blood flow was assessed using

Laser Doppler Perfusion & Temperature Monitor devices, Colour flow duplex ultrasound was used for superficial and deep blood flow, and pulse oximeters for percentages of oxygen saturation (SPO2). To test for the effect on anti

Table of Hemodynamic Results:

| Test | Arterial Velocity (cm/sec) Mean (SD) | Significance | Venous Velocity (cm/sec) Mean (SD) | Significance | Arterial Flow (ml/min) Mean (SD) | Significance | Venous Flow (ml/min) Mean (SD) | Significance | Microcirculation Dorsum of both feet |
|------------------------------------|---|---------------------------|--|-------------------------|-------------------------------------|--------------|-----------------------------------|-------------------------|--------------------------------------|
| Baseline | 69.92 ± 21.32 | P>0.05 No significance | 10.7 ± 4.32 | P<0.001 21% increase | 176.6 ± 65.6 | P≤0.05 | 59.4 ± 41 | P<0.001 81% increase | 4.66 flux units |
| 1 hour | 70.47 ± 28.5 | | 24.09 ± 8.30 (158% increase) | | 288.7 ± 127.2 (125% increase) | | 233.76 ± 114.5 (489% increase) | | 73.59 flux units |
| 2 hours | 76.04 ± 16.47 | | 26.82 ± 6.57 (169% increase) | | 237.3 ± 81.7 (62% increase) | | 223.6 ± 76.3 (374% increase) | | Not provided |
| 3 hours | 83.69 ± 13.03 | | 30.07 ± 13.32 (221% increase) | | 259.4 ± 71.9 (99% increase) | | 253 ± 86.8 (471% increase) | | |
| 4 hours | 82.23 ± 15.56 | | 25.67 ± 5.54 (162% increase) | | 253 ± 100.1 (87% increase) | | 223 ± 76.9 (405% increase) | | 75.85 flux units (p<0.001) |
| Tissue Plasminogen Antigen (tPA) | | | Fell by 14% in the activated leg, 10% in the arm and 1% in the passive leg (p ≤ 0.001) | | | | | | |
| Mean Clotting Time | | | No significant difference was reported throughout the study period, p >0.05 between control and stimulation | | | | | | |
| Plasma von Willebrand Factor (vWF) | | | No significant difference was reported throughout the study period, p >0.05 between control and stimulation | | | | | | |
| 6 Keto PGF1α | | | No significant difference was reported throughout the study period, p >0.05 for stimulation; control group did have an increase thought to be related to sitting for the 4 hour period. After resumption of activity, returned to previous levels. | | | | | | |

Key Learning Points: *“The significant increase in cardiac output reported in our study, could be due to the direct activation of the calf muscle pump, which in turn causes the emptying of both venous beds and sinuses. Another reasoning for the increase in cardiac output, could be stress related and could be due to the exposure to a foreign sensation (electrical stimulation), which may have also resulted in an increase in heart rate. After exposure to the lower pulse width, where there was a 6% increase in LVOT VTI, the increase was only 4% following the higher pulse width, which means that the volunteer may have become accustomed to the foreign sensation applied. However, as heart rate was not monitored throughout the study it is difficult to confirm this reasoning. The study also suggests that the contractions of the calf and foot pumps effectively improve lower limb perfusion at the vascular and micro-vascular level, improving venous return and preventing venous stasis. It enhances fibrinolytic activity. They suggest a possible systemic effect of the stimulation device, as evidenced by the increase in arterial volume flow over 3 hours. “The drop in tPA levels might suggest a fibrinolytic effect.”*

3-1c. Paper: Ogrin R, Darzins P, Khalil Z. The use of sensory nerve stimulation and compression bandaging to improve sensory nerve function and healing of chronic venous leg ulcers. *Current Aging Science* 2009;2(1):72–80.

Note: The devices used were not part of the geko™ development. They had an intensity of 4mA and frequency of 5Hz: lower intensity but faster frequency than geko™. However, this paper is included as it was part of the Canadian Consensus paper [3-9b] and includes venous ulcerations, so is included here.

Methods: 14 patients with chronic venous ulcers randomly allocated to active (mean age 74.8±2.3 years) and 15 to Sham nerve stimulation (mean age 76.5±2.6 years), using low frequency transcutaneous sensory nerve stimulation™ on either the common peroneal or the saphenous nerve (depending on proximity to the wound), plus four-layer compression bandages. Patients used the devices twice daily for 5 minutes for 12 weeks or until the wounds completely healed. For the sham group, the stimulators did not deliver electrical stimulation. Participants and researchers were blinded to allocation.

Results: The activation was for a total of 10 minutes per day, compared to the current geko™ protocol for wounds, which is 6 hours per day, 5-6 days per week, or even to the 20-30 minutes of wear time seen in many geko™ investigations, but the duration of use (12 weeks) is unique and may reflect a cumulative benefit. Patients who healed, regardless of the group, were younger with ulcers of shorter duration than those who did not. Ulcers that healed in the activation group were of longer duration than those that healed in sham group; mean ulcer size in the activation group was larger at baseline than that of the sham group and healing rates in the activation group were greater than the sham: the largest and longest wounds healed more quickly with the active stimulation and compression. There was improvement, in the microvascular blood flow and TCpO₂, nearly four times greater improvement in the nerve sensation and two times the flare response, (both parameters reflecting improvement in C-fiber function) in the actively stimulated leg, although none were statistically significant. C-fiber activation stimulates a release of growth factors and neuropeptides necessary for wound healing.

Table of Results:

| Measure | Sham | | | Activation | | Statistical significance |
|--|---------------------------------|-------------|--------------------------|---------------------------------|----------------|--------------------------|
| Wound Healed by 12 weeks | 10/15 (66%) | | | 8/14 (57%) | | none |
| Average weekly Wound Healing Rate | 0.6 ± 0.2 cm ² /week | | | 1.1 ± 0.3 cm ² /week | | P=0.18 (not significant) |
| All patients | Control | Sham Stim | Statistical significance | Control | Activated Stim | |
| Microvascular Blood Flow(cm ²) | -15.4 ± 60.1 | 16.9 ± 42.1 | P=0.47 | 0.4 ± 5.3 | 25.8 ± 23.9 | P=0.29(not significant) |
| TCpO ₂ @ 39°C (mmHg) | -4.49 ± 9.1 | 5.5 ± 3.6 | P=0.31(not significant) | 2.6 ± 4.9 | 5.1 ± 2.0 | P=0.15 (not significant) |
| TCpO ₂ @ 44°C (mmHg) | 18.7 ± 7.3 | 13.9 ± 5.7 | P<0.05 | 0.9 ± 4.8 | 7.5 ± 3.7 | P=0.21 (not significant) |
| Flare Response to hot red pepper (cm ²) (C-fiber activation) | 2.4 ± 5.0 | 1.7 ± 2.0 | P=0.45(not significant) | 5.6 ± 1.9 | 9.1 ± 4.1 | P=0.32 (not significant) |
| Nerve Sensation Threshold 5Hz ECPT (mA) (C-fiber activation) | -0.4 ± 0.4 | -0.4 ± 0.3 | P=0.77(not significant) | -0.2 ± 0.3 | -0.3 ± 0.5 | P=0.86(not significant) |
| Only Patients who healed | Control | Sham Stim | Statistical significance | Control | Activated Stim | |
| Microvascular Blood Flow(cm ²) | -23.6 ± 31.1 | 39.8 ± 60.1 | P=0.33 | -2.3 ± 5.5 | -1.9 ± 33.9 | P=0.99(not significant) |
| TCpO ₂ @ 39°C (mmHg) | -5.33 ± 5.86 | 3.33 ± 4.23 | P=0.32 (not significant) | 4.8 ± 5.9 | 4.8 ± 1.7 | P=1.00 (not significant) |
| TCpO ₂ @ 44°C (mmHg) | -0.1 ± 5.4 | 18.7 ± 7.3 | P=0.05 | 6.6 ± 6.2 | 5.9 ± 6.1 | P=0.94 (not significant) |
| Flare Response to hot red pepper (cm ²) (C-fiber activation) | 2.4 ± 1.8 | 1.7 ± 5.0 | P=0.99(not significant) | 6.0 ± 3.4 | 11.8 ± 8.1 | P=0.24 (not significant) |
| Nerve Sensation Threshold 5Hz ECPT (mA) (C-fiber activation) | -0.7 ± 0.5 | -0.4 ± 0.4 | P=0.44(not significant) | -0.2 ± 0.2 | -0.9 ± 0.6 | P=0.18 (not significant) |

Key Learning Points: In their comments on this paper, the CAWC consensus group stated: “The improvement of C-fibre activation is also an indicator of the reversal of the neuropathy that may have developed as a result of chronic edema.”

3-2. The geko™ Device And Hemodynamics In The Leg In Healthy Subjects

3-2a. Paper: Zhang Q, Styf J, Ekström L, Holm AK. Effects of electrical nerve stimulation on force generation, oxygenation and blood volume in muscles of the immobilized human leg. *Scand J Clin Lab Invest.* 2014 Aug;74(5):369-77.

Methods: The geko™ T-1 device (27mA) was applied to 28 legs of 14 healthy subjects. Investigations included measuring the force during voluntary isometric ankle joint dorsiflexion and the stimulation-induced myoelectric responses produced by the leg muscle contractions. Muscle oxygen saturation, blood volume and deoxygenated haemoglobin in the tibialis anterior and medial gastrocnemius muscles were measured by near-infrared spectroscopy during venous stasis (40 mmHg thigh tourniquet), with or without electrical stimulation. Myoelectric signals (EMG) were recorded by placing bipolar electrodes over the central muscle bellies of the tibialis anterior (TA), extensor hallucis brevis (EHB), peroneus longus (PL), and medial gastrocnemius (MG) muscles of the lower leg. Force generation during isometric ankle joint dorsiflexion was measured while the foot was rigidly maintained in a neutral position, i.e. 15 degrees plantar flexion, during the stimulation test period.

Results: The primary findings were the following: (1) electrical stimulation of the common peroneal nerve produced two types of muscular activity, concentric contraction of the extensor muscles that caused dorsiflexion of the ankle joint and passive stretch of the calf flexor muscles; (2) the force generation during isometric ankle joint dorsiflexion increased significantly in response to the increase in electrical stimulation intensity; and (3) electrical stimulation of the peroneal nerve counteracted the increases in muscle blood volume and deoxygenation during venous stasis. The geko device™ produced muscle activation of the tibialis anterior and peroneus longus. The stimulation also increased activation in the muscles of the extensor hallucis brevis and medial gastrocnemius measured with surface EMG; however with smaller amplitudes. The geko™ device activated the extensor muscles with an additional stretch of the antagonistic flexor muscles. These are then pulled in a distal direction during dorsiflexion, compressing the flexor muscles by the fascial envelopes. The force produced at the maximum stimulation intensity (level 7) was median 2.25 N (0.02 – 14.14), approximately 2% of the force generated during voluntary MVC. The higher the stimulation intensity, the higher the force generated in the muscles ($r^2 = 0.93, p < 0.001$). The stimulation counteracted increments in muscle blood volume (4 – 9% less increase) and deoxygenated haemoglobin (0.2 – 6% less increase) during venous stasis, although not statistically significant in all muscles. There was no effect on the systemic blood pressure of the subjects.

Key Learning Points: The passive motion of the flexor muscle caused by stimulation of the common peroneal nerve acts as a calf muscle pump, which may enhance venous return by increasing intramuscular pressure, which may be effective in reducing venous stasis and edema, influencing muscle oxygenation, supported by the findings in this study. The results may indicate that electrical stimulation of the common peroneal nerve helps to counteract the increases in muscle blood volume and deoxygenated hemoglobin seen during venous stasis.

3-2b. Paper: Yilmaz S, Calbiyik M, Yilmaz BK, Askoy E. Potential role of electrostimulation in augmentation of venous blood flow after total knee replacement: A pilot study. *Phlebology* 2016 May;31(4):251-6.

Methods: Thirty consecutive patients undergoing total knee replacements were randomized to either receive peroneal nerve electrostimulation plus low molecular weight heparin and below-knee compression stockings or low molecular weight heparin and below-knee compression stockings alone. The device (assume geko™ but not stated in paper) was activated for one out of every 4 hours after the surgery. Peak blood velocity in the femoral vein was assessed with Duplex ultrasonography in the supine position, but it does not state at what point the assessment was made. Presence of leg edema and calf diameter were recorded prior to surgery and at time of discharge but are not reported.

Table of Results:

| Test | Control (no device + stockings + heparin) | Estim Group (device + stockings + heparin) | Summary/ Significance |
|---|---|--|-----------------------|
| Peak Velocity Femoral Vein “Post-operative” | 13.84 ± 3.58 cm/s | 17.46 ± 2.86 cm/s | P<0.02 |
| Peak Velocity Increase Femoral Vein “After the surgery” | Not provided | 67.48 ± 17.38 cm/s 67.5% increase | P<0.001 |

Key Learning Points: Electrostimulation of the common peroneal nerve enhanced venous flow in the lower limb and may potentially be of use as a supplementary technique in deep venous prophylaxis following lower limb orthopaedic operations.

3-2c. Hemodynamic Testing: Speckle Spectroscopy

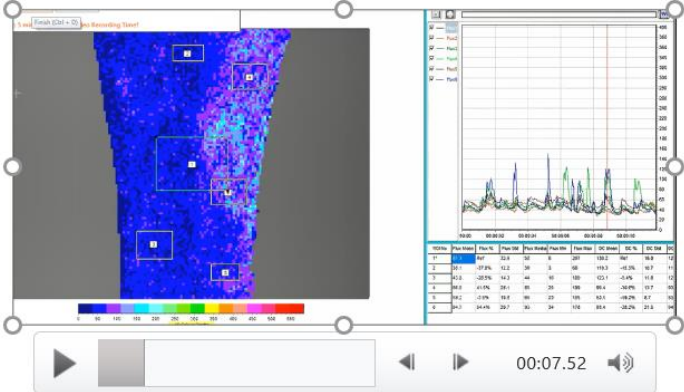
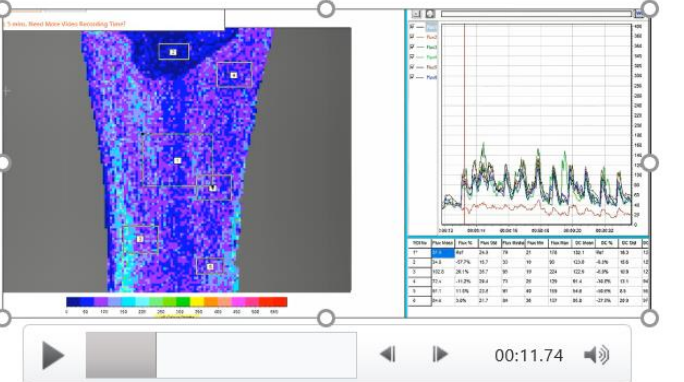
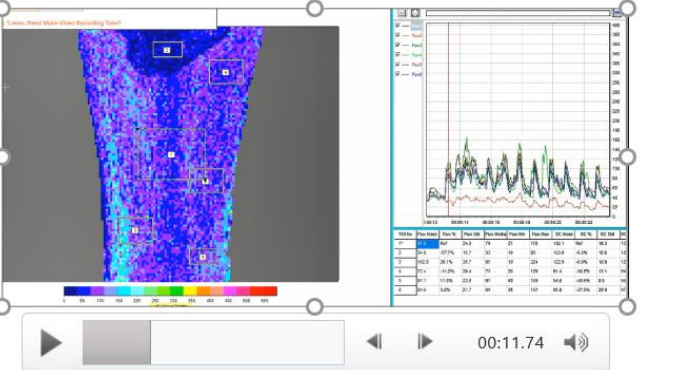
i) Using Speckle contrast optical spectroscopy* to measure microcirculatory tissue perfusion in a healthy leg with:

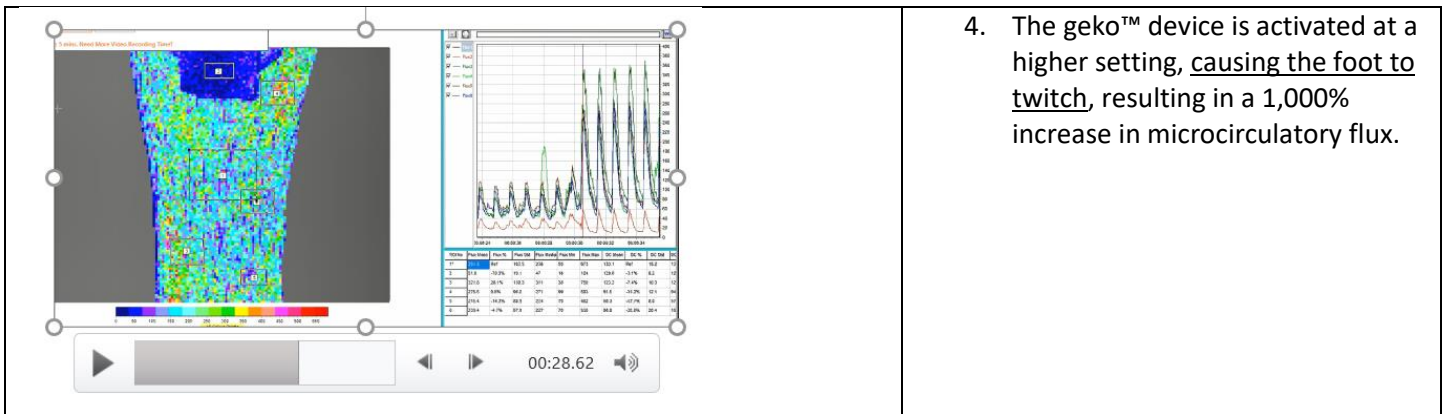
1. geko™ device turned off
2. geko™ device activated with no foot twitch
3. geko™ activated with foot twitch.

Courtesy Firstkind, High Wycombe, UK, part of ongoing research. Please see the images below and on next page.

*Speckle contrast imaging enables rapid mapping of relative blood flow distributions using camera detection of back-scattered laser light (Kazmi et al. 2015).

To view the actual video, please go to: <https://www.gekocodevices.com/geko-videos/speckle-imaging-video-showing-microcirculatory-blood-flow-at-baseline-and-with-the-geko-device-switched-on/>

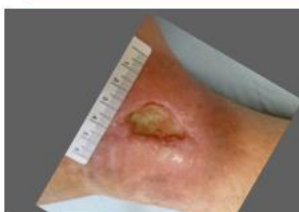
| Image is of the anterior leg just above the ankle and below the knee | Comments |
|---|---|
|  | <p>1. Baseline measurement. The geko™ device is not activated. The light turquoise colour reflects an increase in perfusion due to normal systolic heartbeat.</p> |
|  | <p>2. The geko™ device is activated, <u>before a foot twitch is achieved</u>; resulting in a 100% - 200% increase in microcirculatory flux</p> |
|  | <p>3. The geko™ device is activated, <u>before a foot twitch is achieved</u>; resulting in a 100% - 200% increase in microcirculatory flux</p> |



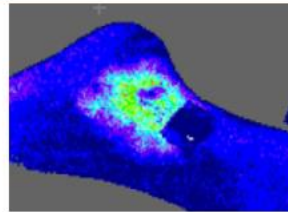
4. The geko™ device is activated at a higher setting, causing the foot to twitch, resulting in a 1,000% increase in microcirculatory flux.

Key Learning Points: While the optimal microcirculatory response is seen with the fully activated foot twitch or movement in this healthy volunteer, there is still a 100-200% increase when the foot twitch is not achieved, which is the reality with many patients with obesity or edema. This was illustrated by Williams in her 2017 PhD thesis, who described nine patients in which the NMES [geko™ T-1 device (27mA)] was unable to elicit a twitch, with a mean BMI of $35.5 \pm 5 \text{ kg/m}^2$, calf circumference $45.9 \pm 6 \text{ cm}$, CEAP $C4.1 \pm 0.6$, and AVVQ 31.3 ± 14 . Although this is a healthy volunteer, these test results suggest that there may be benefit in people with lower limb disease even when a foot twitch is not obtained. Case studies series in Canada (3-6b & c) have shown that patients who did not have an initial foot twitch still benefit by a reduction in edema, pain and wound size. Our recommendation to clinicians is that they do use the device in the absence of a foot twitch and evaluate each patient individually over 1-2 weeks for indications of a positive response.

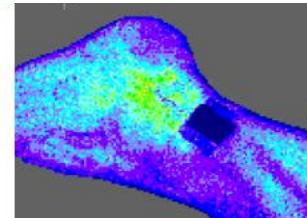
ii) When activated, the geko™ device caused a 225% increase in flux ($p < 0.001$) in the wound bed and a 67% increase in flux ($p < 0.001$) surrounding the peri-wound area. Increases in flux corresponds to an increase in microcirculatory blood flow, which is clearly seen in the comparison below. This results in a rise in red blood cells carrying oxygen and nutrients necessary for energy metabolism and healing. It is noted that in this example with an infected wound, hyperaemia has already occurred in response to the infection. To view the actual video, please go to: <https://gekodevices.com/geko-videos/speckle-imaging-video-showing-microcirculatory-blood-flow-at-baseline-and-with-the-geko-device-switched-on-2/>



Patient with an active, untreated wound infection in a Venous Leg Ulcer



Microcirculatory flux* with normal cardiac systole in same Venous Leg Ulcer



Microcirculatory flux *with the geko™ device activated:
 - 225% increase in flux to the wound bed ($p < 0.001$)
 - 67% increase in flux to peri-wound skin ($p < 0.001$)

Dr. Keith Harding CAWC Conference Nov. 2016

3-2d. NEW Paper: Dutta A, Zhao F, Cheung M, Das A, Tomita M, Chatterjee K. Cerebral and muscle near-infrared spectroscopy during lower-limb muscle activity – volitional and neuromuscular electrical stimulation. 2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC) Oct 31 - Nov 4, 2021. Virtual Conference. Available at: <https://paperhost.org/proceedings/embs/EMBC21/files/1845.pdf> Accessed May 22, 2025. Also posted as a preprint titled: Cerebral and muscle near-infrared spectroscopy during lower-limb muscle activity – volitional and functional electrical stimulation. Available at: https://www.researchgate.net/publication/353382997_Cerebral_and_muscle_near-infrared_spectroscopy_during_lower-limb_muscle_activity_-_volitional_and_functional_electrical_stimulation Accessed May 22_25.

Background: Chronic venous insufficiency (CVI) can lead to blood clotting in the deep veins of the legs, a disease known as deep vein thrombosis (DVT). An estimated 40 percent of people in the United States have venous insufficiency that

may be ameliorated with neuromuscular electrical stimulation (NMES). Near-infrared spectroscopy (NIRS) is a non-invasive optical imaging method for monitoring hemodynamics. NIRS, being an optical technique has no stimulation artefact, can be combined with NMES for theranostics (combining diagnostics and therapeutics to both image and treat a disease) application.

Method:

In order to capture the effects of muscle contraction on hemodynamics, muscle NIRS (mNIRS) was combined with EMG of the calf muscles to detect blood volume changes in the muscle based on total hemoglobin concentration (HbT) at different frequency of tip-toe movements. The subjects were provided a metronome (beats per minute, BPM: 10, 30, 50) to make the tiptoe movements. After a rest of 5 minutes, the baseline measures were taken for 5 minutes while the subject was seated. Then, NMES (geko™ device) was applied at eleven stimulation intensities in random order, with the subjects seated with the knees bent at 90-degrees. In a repeated-measure design, NMES was applied for 2 minutes with a rest of 3 minutes while mNIRS-EMG and fNIRS were recorded for a duration of 55 minutes, combining muscle NIRS (mNIRS) with electromyogram (EMG) of the calf muscles to detect blood volume changes (based on total hemoglobin concentration) in the muscle during volitional tiptoe movements at different frequencies. In the mNIRS+NMES study, cerebral hemodynamics were measured using functional NIRS (fNIRS). The mNIRS was conducted using a frequency domain (FD) method (called FDNIRS) that used a multi-distance method to isolate muscle hemodynamics.

Results: FDNIRS-EMG study in ten healthy humans found a statistically significant ($p < 0.05$) effect of the tiptoe frequencies on the EMG magnitude (and power) that increased with tiptoe frequency. Also, the muscle blood volume (standing/rest) decreased ($p < 0.01$) with increasing tiptoe frequency and there was a significant ($p < 0.01$) effect of the NMES stimulation levels that needs further investigation. In the NMES study, the male and female mNIRS (HbT) responded differently with increasing NMES intensity that was statistically significantly ($p < 0.05$) different (males generally have a larger calf muscle mass than females). Moreover, increasing NMES intensity led to a statistically significant ($p < 0.01$) increase in the cerebral blood volume—measured with fNIRS. Therefore, combined mNIRS and fNIRS with NMES can provide a theranostics application for brain+muscle in CVI. The authors hypothesized that there may be a role for NMES of the common peroneal nerve increasing cerebral blood flow during the acute phase of cerebrovascular accident, thus reducing the final infarct volume and improving the outcome.

Key Learning Points: This paper clearly supports earlier works, for example, 3-1a. Paper: Tucker et al, 3-2t. Griffin et al., that describes the action of the NMES geko™ device enhancing the function of the calf muscle pump, by showing an exact statistically significant result compared to tiptoe movements. It also shows a systemic beneficial effect of the NMES geko™ device increase in cerebral blood volume. It is noted that the study only measured the geko™ effect while the individuals were seated with the knees bent, which brings the common peroneal nerve closer to the skin surface and increases the response. In the real world, the geko™ device is worn continuously for DVT prophylaxis, or 6 hours per day for wound healing therapy, when the individual is up and about, performing activities of daily living.

3-3. Hemodynamic Effect of the geko™ Device Versus Intermittent Pneumatic Compression (IPC)

3-3a. Conference Paper: Williams KJ, Moore HM, Ellis M, and Davies AH. Comparing the venous haemodynamic effect of a neuromuscular stimulation device to intermittent pneumatic compression in healthy subjects. 14th Meeting of the European Venous Forum, Belgrade, Serbia, 27–30 June 2013. Paper 1.5

Methods: Baseline measurements were taken of superficial femoral venous velocity and volume flow, then the subjects received bilateral therapy with the geko™ T-1 device (27mA) and the Intermittent Pneumatic Compression (IPC) device (SCD Express™ Compression System, Covidien, Ireland) in an interventional cross-over trial with 30 minutes of therapy, the measurements were repeated, and finally devices were swapped for another 30 minutes and measurements taken a third time.

Table of Results:

| Test | IPC Venous | Summary/ Significance | geko™ Venous | Summary/ Significance |
|------------------------------------|------------|-----------------------|--------------|-----------------------|
| Peak Velocity | 19% | Not provided | 42% | Not provided |
| Time Averaged Peak Velocity (TAMV) | 12% | Not provided | 27% | Not provided |
| Volume Flow | 7% | Not provided | 46% | Not provided |

3-3b. Paper: Williams KJ, Moore HM, M Ellis and Davies AH. Haemodynamic changes with the use of a neuromuscular stimulation device compared to intermittent pneumatic compression. *Phlebology* First Published Online 10 April 2014. 2015, 30(5): 365–372. We have also included Dr. William’s Doctoral Thesis work which builds on this research and provides additional analysis and results: Williams KJ. Chapter 6.5 Comparison of NMES with intermittent pneumatic compression Thesis submitted to Imperial College London for the degree of Doctor of Philosophy April 2017. Pages 217-231. Available at: <https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf>

Accessed April 12, 2018.

Methods: Ten healthy volunteers (mean age 27.1±3.8 years, body mass index 24.8±3.6 kg/m²) were randomized into two groups, in an interventional crossover trial. Baseline haemodynamic measurements were recorded after an equilibration rest period of 10 min, and the first *geko*[™] T-1 device (27mA) device was applied and activated for a 20 min time period before repeat measurements were taken with the device on, off and 10 min post cessation of device. The subject was allowed to rest for a 20 min wash-out period. The second device was activated and, repeat haemodynamic measurements were taken. The patient was positioned semi-recumbent. The left superficial femoral vein and artery were used for all patients with the knee flexed and the leg externally rotated at the hip 35-40°.

Table of Results:

| Test | IPC Venous | Summary/ Significance | IPC Arterial | Summary/ Significance | <i>geko</i> [™] Venous | Summary/ Significance | <i>geko</i> [™] Arterial | Summary/ Significance |
|------------------------------------|--|-----------------------|--------------|-----------------------|---|-----------------------|-----------------------------------|-----------------------|
| Peak Velocity | 51% | p=0.002 | -8% | No significance | 103% increase Thesis 267 | p=0.002 p<0.05 | 11% increase | p<0.01 |
| Time Averaged Peak Velocity (TAMV) | 5% | p=0.002 | -12% | No significance | 101% increase Thesis 60 | p=0.002 p<0.05 | 84% | p<0.01 |
| Volume Flow | 3% | p=0.002 | -13% | No significance | 101% Thesis 84 | p=0.002 p<0.05 | 75% increase | p<0.01 |
| Microcirculatory Flux | ~ 10% increase Thesis Results: Leg: 5.3% during, 31.5% after Arm: -7.8 & during, 46.5% Post | | | | ~240 % increase in paper but data actually shows 152% (First Kind analysis) Thesis Results: Leg: 251.8 % (p<0.001) during, 39.6% after Arm: -17.2 during, 65.3% Post | | | |

"Post" readings are taken immediately after device is switched off

Key Learning Points: The *geko*[™] device seems to be operating via a modality that affects the flow properties of the vascular bed in the leg. This may be via a local pressure effect, neuronal or endogenous cytokine media, or other unknown local microvascular modification. Further studies into the effect on the arterial system, and effects on subjects with vascular pathology were indicated at the time, and have since been published (see 3-5 Effect of *geko*[™] on patients with mixed venous arterial ulcers and and 3-6. Effect of *geko*[™] on patients with Peripheral Arterial Disease).

3-3c. Paper: Jawad H, Bain DS, Dawson H, Crawford K, Johnston A, Tucker AT. The effectiveness of a novel neuromuscular electrostimulation method versus intermittent pneumatic compression in enhancing lower limb blood flow. *J Vasc Surg: Venous Lymphat Disord* 2014; 2(2):160-5. This material is also covered in: Jawad, Huda. The effect of a novel electrical stimulation method for improving lower limb blood flow in healthy volunteers. PhD dissertation. Queen Mary University of London/ St. Bart’s. 2012. Chapter 7: The effectiveness of the *geko*[™] medical device versus intermittent pneumatic compression: a comparative study Available at:

<https://qmro.qmul.ac.uk/xmlui/handle/123456789/3120>

Methods: 10 healthy volunteers. For each subject, the *geko*[™] T-1 device (27mA) was initially set to a threshold setting (*geko*[™]-TS) (as defined as the minimum setting to elicit a minor muscular contraction in both the calf and the foot) for a period of 30 minutes followed by 10-minutes rest. Following the 10-minute period of rest, a Normal Clinical Use (*geko*[™]-NCU) setting was selected that was characterized by 3 additional levels to the previous threshold setting-the minimum level that can achieve upward and outward twitching of the foot when raised from the ground with short duration of activation. Measurements were taken from the superficial femoral vein and artery, and microcirculation was measured on dorsum of the foot.

Table of Results:

| Test | IPC Venous | IPC Arterial | geko™ Venous “Threshold” | geko™ Venous “Normal Clinical” | Summary/ Significance | geko™ Arterial “Threshold” | geko™ Arterial “Normal Clinical” | Summary/ Significance |
|--|--|------------------------|--|--------------------------------|-----------------------|----------------------------|----------------------------------|-----------------------|
| Mean Blood Flow Volume | -4% | -9 to -16% (2 devices) | 14% | 32% increase | p≤0.001 | -7% | 30% increase | p≤0.001 |
| Mean Blood Flow Velocity | 143% - 166% | -1% to -4% | 73% | 174% increase | | 2% | 24% increase | p≤0.001 |
| Micro-circulation | 44-59% | | 394% (Normal Clinical) and 345% (Threshold) in paper, but data actually showed 270% increase (First Kind analysis) | | | | | p≤0.001 |
| Mean vessel diameter | No significant difference in femoral vessel diameter between the devices | | | | | | | p>0.05 |
| TcPO ₂ and Tissue Oxygen Saturation (SPO ₂) | Remained stable with both devices | | | | | | | p > 0.05 |

Key Learning Points: Although the volume flow increase after the use of the geko T-1 device at the threshold setting is less than that at the normal clinical use setting, it was still much greater than that reported after the use of the IPC devices, for which a decrease in total volume flow was observed. Measurement of arterial peak velocities demonstrated that the geko T-1 device is more effective than IPC devices in producing an increase in the femoral artery. The geko T-1 device is more effective than the IPC devices in increasing venous, arterial blood velocity and flow, and microcirculatory flux. The devices studied were safe and well tolerated by healthy subjects.

3-3d. Paper: Bahadori S, Immins T, Wainwright TW. The effect of calf neuromuscular electrical stimulation and intermittent pneumatic compression on thigh microcirculation. *Microvascular Research* 2017; 111: 37–41.

Methods: Blood microcirculation of ten healthy individuals was recorded using laser speckle contrast imaging (LSCI) technique*. A region of interest (ROI) was marked on each participant thigh. The mean flux within the ROI was calculated at four states: rest, NMES device [geko™ T-1 or T-2 device (27mA)] with visible muscle actuation (VMA), NMES device with no visible muscle actuation (NVMA) and IPC device. * Speckle contrast optical spectroscopy, a non-invasive, diffuse optical method for measuring microvascular blood flow in tissue

Table of Results:

| Test | geko™ with no visible muscle activation | geko™ with visible muscle activation | IPC Device | Significance |
|--|---|--------------------------------------|------------|--------------|
| Mean (SD) of % increased in mean flux from baseline with device. | 150.6 ± 48.8 | 399.8 ± 210.1 | 117.3 ± 17 | P=0.005 |

Key Learning Points: Both NMES and IPC devices increased blood flow in the thigh when stimulation was carried out peripherally at the calf. The NMES device increased mean blood perfusion from baseline by 399.8% at the VMA state and 150.6% at the NVMA state, IPC device increased the mean blood perfusion by 117.3% from baseline. The NMES device at VMA state increased microcirculation by more than a factor of 3 in contrast to the IPC device. Even at the NVMA state, the NMES device increased blood flow by 23% more than the IPC device. Given the association between increased microcirculation and reduced edema, NMES may be a more effective modality than IPC at reducing edema, improve healing and prevent wound complications in populations such as total hip replacements, therefore further research was

recommended to explore this. Please see 5-4. The geko™ device and orthopedic edema for papers published on this subject.

3-4. The Hemodynamic Effect of the geko™ Device with Patients with Chronic Venous Disease

Note 3-4a.i-v. are results of the non-randomized, interventional study: Venous Insufficiency and Neuromuscular Stimulation (VeINS) published between 2014 and 2021.

3-4a.i. Poster: Williams KJ, Babber A., Ravikumar R, Ellis M, Davies AH. Pilot Trial of neuromuscular stimulation in the management of chronic venous disease. Poster VEINS Conference, UK. 2014

3-4a.ii. Poster: Williams KJ, Babber A., Ravikumar R, Davies AH. Pilot Trial of neuromuscular stimulation in the management of chronic venous disease2. Poster VEINS Conference, UK. 2014

3-4a.iii. Abstract: Williams KJ, Davies AH. Pilot trial of neuromuscular stimulation in the management of chronic venous disease. VSGBI Abstracts from The Vascular Societies' Annual Scientific Meeting. *British Journal of Surgery* 2015;102():20.

3-4a.iv. Doctoral Thesis: Williams KJ. Chapter 7.1. NMES in the management of chronic venous disease (VeINS). Neuromuscular Stimulation of the Leg. Thesis submitted to Imperial College London for the degree of Doctor of Philosophy April 2017. Pages 258- 269. Available at:

<https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf>

Accessed April 12, 2018.

Methods: Ten healthy volunteers served as the controls, with 30 individuals with Chronic Venous Disease in 3 groups: 10 with superficial venous insufficiency, 10 with deep venous insufficiency and 10 with deep venous obstruction. The geko™ T-1 device (27mA) was set to the Normal Clinical Use setting-the minimum level that can achieve upward and outward twitching of the foot when raised from the ground (dorsiflexion).

Baseline measurements were taken before activation of both devices, and 20 minutes after activation of the device, with subjects supine and semi-recumbent, and allowed to rest x 10 minutes to acclimatize. Ultrasound testing was done in the right femoral vein 3-5 cm from the saphenofemoral junction, taking 5 ultrasound measurements of venous parameters were taken from the femoral vein, and the mean was calculated. Laser doppler fluximetry was measured in the dorsum of the left hand and foot, and leg circumference measurements were taken at the calf and ankle. Bilateral geko™ devices were worn for 4-6 hours per day, 5 days per week for 6 weeks, at which time the haemodynamic measurements were repeated. Quality of life questionnaires were also taken at week 0, 6 and 8 (see Section 8-7a).

Table of Results 1: Median Measurements taken at Femoral Vein (from Thesis Tables 24)

| % change from baseline (geko™ OFF) after 20 minutes of geko™ stimulation | | | | |
|--|---------|----------------------------------|---------------------------|-------------------------|
| | Healthy | Superficial Venous Insufficiency | Deep Venous Insufficiency | Deep Venous Obstruction |
| Peak Velocity | 34.8** | 62.8** | 9.0 | 14.8 |
| Time Averaged Peak Velocity (TAMV)[blood flow] | -14.2 | 28.1** | 28.2 | -5.1 |
| Volume Flow | -22.5 | 37.5* | 17.4* | 5.9 |

*p<0.05 **p<0.01 wilcoxon signed-rank

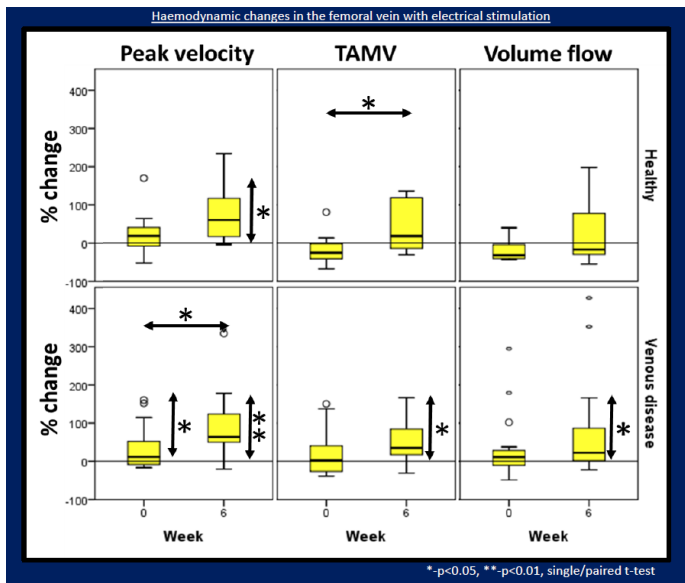


Table of Results 2: Comparison of Hemodynamic changes in the femoral vein from baseline to week 6 (geko™ devices on in both) (from poster)

Used with Permission.

Plain language explanation of graph using the Peak Velocity recordings as the example: Each ‘box + whiskers’ plot refers to the % increase of that variable resulting from the geko™ device switched on:

- the top left box shows the interquartile range (10 healthy subjects) of the increase in peak velocity **at week 0** when geko™ is switched on, with a median value represented by the black horizontal line.
- the range and median increase **at 6 weeks** in the same group are shown in the ‘box +whiskers’ plot immediately to the right of that. The vertical double arrow on this plot refers to a paired t-test performed between these values at 6 weeks and baseline at 6 weeks and indicates significance at a level $p < 0.05$. This means that at 6 weeks, geko significantly increased peak velocity in the healthy group
- the bottom left box shows corresponding data for the (n=30) venous disease patients. A vertical double arrow with a single star at 0 weeks indicates that geko™ significantly ($p < 0.05$) increased peak velocity at 0 weeks. A vertical double arrow with 2 stars indicates that at 6 weeks geko™ very significantly ($p < 0.01$) increased peak velocity. The horizontal double arrow with a single star indicates that a paired t-test shows a significant ($p < 0.05$) increase in peak velocity between 6 weeks and 0 weeks.

Laser Doppler fluximetry changes in the dorsum of the left hand and foot with “device off” (baseline) compared to “device on” (from Thesis) – also covered in 3-5b.

| Percentage Change from Baseline | Healthy Subjects | Superficial Venous Insufficiency | Deep Venous Insufficiency | Deep Venous Obstruction |
|---------------------------------|------------------|----------------------------------|---------------------------|-------------------------|
| Leg Flux | 274.8 ± 279** | 264.9 ± 283* | 69.3 ± 126 | 46.9 ± 50* |
| Arm Flux | 84.0 ± 126** | 71.3 ± 76* | 23.7 ± 57 | 106.5 ± 115* |

(* $p < 0.05$, ** $p < 0.01$, Wilcoxon signed rank) These results did not change over the 6 weeks of use.

Over 6 weeks median unilateral leg volume decreased by an average of 0.2% (26.3ml, $p = 0.61$) for healthy subjects, and 11.6% (225.4ml, $p = 0.03$) for those with symptomatic venous disease, but this was not significant.

Key Learning Points: Regular use of 4-6 hours per day over 6 weeks increased all venous parameters, less so in patients with deep venous disease, although only peak velocity showed statistically significant improvement. The median unilateral leg volume decreased by a statistically significant average of 11.6% (225.4ml, $p = 0.03$) for those with symptomatic venous disease. The significant changes in arm laser Doppler flux in all but the individuals with deep venous insufficiency suggests that there IS a systemic benefit in using the geko™ device, similar to the systemic roles that exercise and enhanced venous return have on the circulatory system. It is not clear why the individuals with Deep Venous Insufficiency did not show significance in this.

3-4a.v. Paper: Williams KJ, Moore HM, Ellis M, Davies AH. Pilot Trial of Neuromuscular Stimulation in Human Subjects with Chronic Venous Disease. Vasc Health Risk Manag. 2021 Dec 1; 17:771-778. Paper available at:

<https://www.gekodevices.com/wp-content/uploads/2021/12/Pilot-Trial-of-Neuromuscular-Stimulation-in-Human-Subjects-with-Chronic-Venous-Disease.pdf>

Abstract:

Introduction: Neuromuscular stimulation (NMES) has been shown to improve peripheral blood flow in healthy people. We investigated the effect of bilateral leg NMES (geko™ T-1 device) on the symptoms of chronic venous disease.

Methods: Forty subjects were recruited from four groups: healthy, superficial insufficiency, deep insufficiency, and deep obstruction. Haemodynamic venous measurements were taken from the right femoral vein with ultrasound, laser Doppler fluximetry from the left hand and foot. Devices were then worn for 4–6 hours per day, for 6 weeks.

Haemodynamic measurements were repeated at week 6. Quality of life questionnaires were taken at week 0, 6 and 8.

Results: The mean age was 48.7, BMI 28.6kg/m², and maximum calf circumference 39.0 cm. Twenty-four subjects were men. NMES increased femoral vein peak velocity, TAMV and volume flow by 55%, 20%, 36% at 20 minutes (all $p < 0.05$), which was enhanced at week 6 (PV and TAMV $p < 0.05$). Mean increases in arm and leg fluximetry were 71% and 194% (both $p < 0.01$). Leg swelling was reduced by mean 252.7 mL (13%, $p < 0.05$) overall; 338.9 mL (16%, $p < 0.05$) in venous disease. For those with venous pathology, scores for disease specific and generic quality of life questionnaires improved. Those with C4-6 disease benefitted the most, with improvements in VDS score of 1, AVVQ of 6, and SF-12 of 10.

Conclusion: NMES improves venous haemodynamic parameters in chronic venous disease, which is enhanced by regular use. NMES reduces leg oedema, improves blood supply to the skin of the foot, and may positively affect quality of life.

Clinical Trials: This trial was registered with www.clinicaltrials.org.uk (NCT02137499). Results available at:

<https://clinicaltrials.gov/ct2/show/NCT02137499>

Key Learning Points: Use of the geko™ device enhances venous and arterial circulation in patients with chronic venous disease, including those with obstructive pathology. Repeated use of the geko™ devices over 6 weeks decreased leg edema and possibly improved quality of life improvements in those patients. Laser Doppler fluximetry increases in the feet of subjects with venous disease suggesting improved blood flow to the skin. This may be very helpful in the management of venous ulcers, especially where compression therapy, the cornerstone of treatment of venous disease, is not possible. *The authors postulate that this may be due to synergistic local and systemic factors (e.g. muscle tone with exercise, neuroendocrine modulation, or functional modulation of capillary networks).* Please see Section 7-2. The geko™ device and Venous Leg Ulcers and Lower Leg Wounds for papers published on this subject.

3-4b. Paper: Ravikumar R, Williams KJ, Babber A, Lane TR, Moore HM, Davies AH. Pilot Randomised Control Trial: Neuromuscular Electrical Stimulation in Treating Venous Disease. *European Journal of Vascular and Endovascular Surgery* 2015; 50(3): 390e404.

Methods: *Twenty-two patients with CEAP C2-C4 venous disease were randomised to a sham or test device (assumed to be geko™ T-1 device [27mA]). Patients were asked to use the device for 30 minutes per day for 6 weeks. Haemodynamic measurements (duplex ultrasound and laser doppler fluximetry), limb volume (perometer), venous refill time (digital photoplethysmography) and quality of life outcome measures were measured at baseline and after 6 weeks.*

Results: *The mean age of participants was 62 years, BMI 28.6, with a 15:7 female preponderance. At week 0, there was a significant improvement in femoral vein haemodynamics (from baseline) whilst using the device in the test compared to sham group (time averaged mean velocity (TAMV) 102.4% versus -9.1%, $p < 0.0001$; volume flow 107.9% versus -3.7%, $p < 0.0001$; peak velocity 377.7% versus -6.7%, $p < 0.0001$). The sham group demonstrated an increase in limb volume, which was prevented with the use of the device in the test group (sham +2.0%, $p < 0.0001$; test +0.8%; $p = 0.0623$). There was no improvement in limb volume in either the sham or test group over the 6 weeks (sham +0.7%, $p = 0.16$; test +2.3%, $p = 0.74$). A non-statistically significant improvement in disease specific quality of life outcome measures (AVVQ) was observed in the test group over the 6 weeks. Due to the small sample size, some improvements were not statistically significant and subgroup analysis was not performed.*

Key Learning Points: Although this study was conducted over 6 weeks, the NMES devices were only used for 30 minutes per day. *Further trials are required to determine optimal frequency and duration of device usage and the effect on different subgroups of patients with venous disease.* Of interest, the geko™ Wound Therapy Device, developed since this paper was published, provides active therapy for 12 hours per day.

3-4c.i. Poster: Das S; Dhoonmoon L; Bain D ; Chhabra S. A novel method of assessment of microcirculatory changes with the use of geko™ device in patients with Venous Leg Ulcers. *European Venous Forum 20th annual meeting, Zurich University, Zurich, Switzerland 27-29 June 2019.* <https://europeanvenousforum.org/index.php/epresentations/>

Background: *Laser Speckle Contrast Imaging (LSCI) is a non-invasive and non-contact technique that is used to measure the changes in microcirculatory flux in the skin or other areas where blood vessels are superficial. This has shown to accurately measure blood flow over moving skin surfaces.*

Aim: To examine the effects of the geko™ device on the microcirculation of the wound bed and peri-wound area in patients with venous leg ulcers.

Method: Patients meeting the inclusion criteria were recruited from the complex wound clinic. Each patient was examined in a recumbent position with the leg outstretched resting on an evacuated bean bag cushion to immobilise the leg for measurements. A reference marker, consisting of an opaque foil strip, was affixed to the skin adjacent to the wound, to allow for correction of movement artefact. The LSCI imager was positioned to record images in the wound bed, peri-wound area and the reference marker. Measurements were made of Baseline (following a 10-minute stabilisation period with the patient at rest in recumbent position) and with the geko™ fitted and active for 10 minutes with the patient at rest in recumbent position.

Results: Sixteen patients with chronic venous leg ulcers consented to participate. In both the wound bed and the peri-wound area, geko™ produces a substantial and significant ($p=0.014$, $p=0.004$) increase in flux. The geko™ device has an even more pronounced and highly significant ($p<0.001$, $p<0.001$) effect on pulsatility in both the wound bed and the peri-wound area. This is of particular pertinence to wound healing, since pulsatile flow is considered to be vital. Pulsatile blood flow results in shear forces at the endothelial surface and results in chemical signalling and transduction. This intermittent pressure and velocity in vessels result in forces at the cellular level initiating biochemical changes, including the production of growth factors, Nitric oxide production, and the reduction of oxidative stress.

Key Learning Points: These results further confirm that the geko™ device improves the microcirculatory environment in the wound and peri-wound area and may be beneficial in wound healing.

3-4c.ii Paper: Das SJ, Dhoonmoon L, Bain D, Chhabra S. Microcirculatory changes in venous leg ulcers using intermittent electrostimulation of common peroneal nerve. *J Wound Care*, 2021; 30(2):151-155.

Objective: Activation of the venous muscle pumps of the leg by intermittent transdermal neuromuscular stimulation of the common peroneal nerve has been previously shown to augment venous and arterial flow in patients with leg ulcers. This study aims to establish if microcirculation in the wound bed and periwound area are augmented by the activation of a neuromuscular electrostimulation device (NMES) (geko™, Firstkind Ltd., UK).

Method: In this self-controlled, observational study, laser speckle contrast imaging was used to map and quantify microcirculatory flow in the wound bed and periwound area of patients with venous leg ulcers (VLU). Values of flow and pulsatility in these locations were compared with the NMES device, both active and inactive.

Results: A total of 16 patients took part in the study. Microvascular flux increased by 27% ($p=0.014$) in the wound bed, and by 34% ($p=0.004$) in the periwound area, when the NMES device was activated. Pulsatility increased by 170% ($p<0.001$) in the wound bed and 173% ($p<0.001$) in the periwound area when the device was activated.

Conclusion: Intermittent electrostimulation of the common peroneal nerve substantially increased both microcirculatory flux and pulsatility in the wound bed and in the periwound area of the VLUs of patients in this study. This provides a plausible mechanistic explanation for its reported efficacy in healing VLUs.

Key Learning Points: Electroactivation of the common peroneal nerve considerably increases both continuous flux and of particular importance to wound healing, to pulsatility. Limitations of the study were that they were not able to compare the effects of NMES and compression therapy on the wound bed, and the test results demonstrated the impact of a 30-minute NMES application, not a cumulative result after hours per day over several weeks which is the current clinical use.

3.4d. Paper: Das SK, Dhoonmoon L, Chhabra S. Neuromuscular stimulation of the common peroneal nerve increases arterial and venous velocity in patients with venous leg ulcers. *Int Wound J* 2021;18(2):187-193. Available at:

<https://onlinelibrary.wiley.com/doi/epdf/10.1111/iwj.13510>

Background: Activation of the venous muscle pumps by neuromuscular stimulation of the common peroneal nerve has been previously shown to increase venous and arterial flow in the legs of healthy subjects.

Aim: The aim of this study is to determine whether a similar effect is observed in patients with chronic venous leg ulcers, in which the primary aim of treatment modalities is to reduce oedema and aid venous return, most commonly with compression therapy.

Method: 1 Hz intermittent electrostimulation of the common peroneal nerve using either the geko™ T-2 (27mA) or R-2 (54mA) devices was applied to 14 patients with venous leg ulcers measuring between 1 and 10 cm in diameter, who were currently treated with Class II below the knee Compression, eliciting a small, painless, regular, muscular twitch of the leg. Blood flow was measured using Duplex ultrasound in the popliteal vein and the popliteal artery, with patients in both the sitting position with the knee bent, and in a recumbent position with the leg straight and horizontal, both before application of the geko™ device and after the geko™ device was activated for 10 minutes.

Results: Peak arterial velocity increased from 57 to 78 cm/s ($P = .001$) in sitting position, and from 79 to 98 cm/s in recumbent position ($P = .001$). Peak venous velocity increased from 10 to 33 cm/s ($P = .001$) sitting, and from 14 to 47 cm/s ($P = .001$) recumbent. Significant increases were observed in both venous and arterial blood flow in the lower limb.

Conclusion: This suggested that activation of the venous muscle pump and improvement of arterial flow assisted oxygen delivery at the wound site, which may explain the increased healing rates with NMES previously reported. Moreover this may be a worthwhile intervention to assist in the healing of venous leg ulcers, and may provide a mechanistic explanation for the increased healing rates previously reported with neuromuscular stimulation of the common peroneal nerve.

Key Learning Points: With activation of the geko™ device for only 10 minutes, the peak venous and arterial velocities in patients with venous leg ulcers saw a statistically significant increase. It would be very interesting to see the effect after the 12 hours of active NMES therapy that the geko™ Wound Therapy Device delivers.

3-5. NEW: The Effect of the geko™ Device on Patients with Mixed Venous Arterial Etiology Leg Ulcers

3.5a. NEW: Paper: Harding KG, Blow M, Ashton F, Bosanquet D. Neuromuscular electrostimulation increases microcirculatory flux in mixed etiology leg ulcers. *Adv Skin Wound Care* 2025 Jan-Feb;38(1):25-30. Available at: https://journals.lww.com/aswcjournal/fulltext/2025/01000/neuromuscular_electrostimulation_increases.5.aspx Accessed April 25, 2025.

Objective:

About 13% of all chronic wounds are a combination of venous and arterial etiology, where high compression therapy is contraindicated yet the venous component of these ulcers is the key factor for allowing healing. *To determine if intermittent neuromuscular electrostimulation (NMES) of the common peroneal nerve increases microvascular flow and pulsatility in and around the wound bed of patients with combined venous and arterial etiology, similar to that previously demonstrated in the wound bed of both arterial and venous leg ulcers.*

METHODS:

Seven consenting participants presenting with mixed etiology leg ulcers participated in this study. Microvascular flow and pulsatility was measured in the wound bed and in the skin surrounding the wound using laser speckle contrast imaging. Measurements were made at baseline and when the venous pumps of the leg were activated by 1 Hz intermittent neuromuscular stimulation of the common peroneal nerve for 30 minutes following a 5-minute equilibration period. The nerve was stimulated transdermally at the head of the fibula.

RESULTS:

When activated by NMES, wound bed flux increased by 38% (95% CI, 11%–73%; $P = .023$), and periwound flux increased by 19% (95% CI, 9%–32%; $P = .009$). Pulsatility increased in the wound bed by 214% (95% CI, 51%–985%; $P = .017$) and in the periwound by 122% (95% CI, 38%–299%; $P = .014$). These are substantial increases.

CONCLUSIONS:

The results indicate that NMES is effective in augmenting microvascular flow in leg ulcers with combined venous and arterial etiology after only 30 minutes of use.

Key Learning Points: Mixed etiology leg ulcer patients receiving reduced levels of compression may achieve better healing by using NMES as an adjunct to compression, given that NMES and compression (including inelastic compression) have a mutually supportive effect. Those patients who are unable to tolerate compression or where ANY type or level of compression is contra-indicated may also benefit. The authors also hypothesize benefits of NMES for patients with peripheral arterial rest pain where revascularization is not possible.

3-6. The Effect of the geko™ Device on Patients with Peripheral Arterial Disease

3-6a. Paper: Barnes R, Shahin Y, Tucker AT, Chetter IC. Haemodynamic efficacy of the geko™ electrical neuromuscular stimulation device in claudicants. Oral presentation at Society of Academic & Research Surgery, 2014 Annual Meeting (January 8/9, 2014), Cambridge University, England.

Methods: A prospective observational series. Sixteen patients with claudication attending a structured exercise program were studied. Following a 30-minute rest period, baseline measurements of arterial, venous and microcirculatory flow (Laser Doppler) were taken bilaterally. The geko™ T-1(27mA) device was applied for 40 minutes, unilaterally, and flow measurements repeated. The difference in flow from baseline was calculated for each measurement. The mean resting ABPI of the active limbs was 0.68 ± 0.23 .

Results 16 patients, 11 male, 5 female, with a mean age of 67 years (SD 7.7) were recruited. The mean resting ABPI of the active limbs was 0.68(SD 0.23). The mean change in arterial volume flow in the active limb was 0.65 L/min compared

to control limb 0.003L/min (p=0.026). Venous volume flow increased by 0.041L/min in the active limb versus control 0.0005L/min (p=0.023). Microcirculatory flow, measured by laser Doppler increased by a mean of 21.16 flux units in the active compared to a decrease of 6.21 in the control group (p<0.01).

Table of Results:

| Test | Control (no geko™) Amount of change | Activated geko™ Amount of Increase | Summary/ Significance |
|-----------------------|--|---------------------------------------|-----------------------|
| Arterial Volume Flow | 0.003 L/min | 0.65 L/min 29% increase | p=0.026 |
| Venous Volume Flow | 0.0005L/min | 0.041L/min 23% increase | p=0.023 |
| Microcirculatory Flow | Decrease of 6.21 flux units | 21.16 flux units | P<0.01 |

Key Learning Points: Transcutaneous electrical neuromuscular stimulation with the geko™ device augments arterial, venous and microcirculatory flow in patients with claudication and may prove a useful treatment adjunct in this cohort of patients. The limb that did not have the geko™ activated was not affected.

3-6b. Paper: 0161 Short Paper Prize Section: Barnes R, Shahin Y, Tucker A, Chetter I. Haemodynamic augmentation in patients with peripheral arterial disease with the geko™ transcutaneous neuromuscular electrical stimulation device. *Abstracts / International Journal of Surgery* 2015; 18:239.

Methods: After 30 minutes to acclimatize, bilateral baseline arterial, venous and microcirculatory flow was measured by laser doppler. The geko™ T-1 (27mA) device was applied for 60 minutes on one leg only and the measurements were repeated, with the leg without geko™ being considered the passive limb.

Results: In 43 patients, 24 with claudication and 19 post-operative femoro-popliteal bypass grafts, the geko™ device was shown to be statistically significant in increasing venous and arterial volume and microcirculatory flow.

Table of Results:

| Haemodynamic Tests | gek™ Baseline | Increase passive leg after 60 minutes activation | Increase gek™ leg after 60 minutes activation | Paired t-test |
|-----------------------|---------------|--|--|---------------|
| Arterial Volume Flow | | -0.004L/min (mean) | 0.68 L/min (mean) | p<0.001 |
| Venous Volume Flow | | 0.002 L/min (mean) | 0.034 L/min (mean) | p<0.001 |
| Microcirculatory Flux | | 0.39 flux units | 22.25 flux units (mean) | p<0.001 |

Key Learning Points:

Transcutaneous electrical neuromuscular stimulation of the common peroneal nerve with the geko™ device augments arterial, venous and microcirculatory flow in peripheral arterial disease patients and may prove a useful treatment adjunct in these patients. This paper documents hemodynamic testing showing improvement due to activation of the geko™ device in ABPIs as low as 0.45 in a group of 16 claudicants (the mean resting ABPI of the active limbs was 0.68 (SD 0.23)).

3-6c. Paper: Barnes R, Madden LA, Chetter IC. Fibrinolytic effects of peroneal nerve stimulation in patients with lower limb vascular disease. *Blood Coagulation and Fibrinolysis*. 2016; 27:275-280.

Methods: 75 participants:

- 30 with claudication;
- 25 post-op infra-inguinal bypass grafts, and
- 22 with varicose veins

Tested with the geko™ T-1 (27mA) device on 1 leg (active) vs none on other leg (passive), and inactive geko™ on one leg (control) x 45 minutes. Arterial flow measurements of the superficial femoral artery, and venous blood samples were taken bilaterally at baseline and following 45 minutes of stimulation. Tissue Plasminogen activator (t-PA) and plasminogen activator inhibitor 1 (PAI-1) were measured at baseline and after the 45 minutes in the passive, active and control limbs.

Table of Results:

| Test | Passive (no geko™) | Active (activated geko™) | Control (inactive geko™) | Summary |
|---------------------------|----------------------|--------------------------|--------------------------|---|
| Mean change in t-PA | -302.4 pg/ml (-5.5%) | -302.4 pg/ml (-7.7%) | -287.2 pg/ml (-6.85%) | No significant effect on t-PA levels |
| Mean change in PAI-1 | -11.4 ng/ml (-3.6%) | -34 ng/ml (-16.2%) | -2.73ng/ml (-2.6%) | Statistically significant LOCAL fibrinolytic effect (not found in passive limb) $P<0.001$ |
| Increase in Arterial Flow | 1.1% | 31.5% | 2.5% | Statistically significant difference between active and control $P<0.001$ |

Key Learning Points: *“Increasing fibrinolytic activity by reducing levels of plasminogen activator inhibitor 1 could have many beneficial long-term effects through the prevention of thrombosis. Increased PAI-1 levels have been shown to be implicated in the ageing-associated thrombosis and cardiovascular ageing. As such, the ability to reduce circulating levels may slow disease progression in the elderly.”*

Reducing plasma levels of PAI-1 have also been shown in experiments to slow progression of chronic kidney disease and may even result in a degree of disease resolution, which has led to attempts to develop drugs and therapies, which could target its activity. It has also been shown that high levels of PAI-1 may be responsible for the development of microvascular complications associated with Type II diabetes mellitus. It can therefore be seen that peroneal nerve stimulation would be a useful treatment adjunct or prophylaxis within the vascular disease population, many of whom have multiple risk factors for thrombotic disease.

3-6d. Paper: Yilmaz S, Mermi EU, Zobaci E, Aksoy E, Yastı C. Augmentation of arterial blood velocity with electrostimulation in patients with critical limb ischemia unsuitable for revascularization. *Vascular*. 2017;25(2):137-141. Article first published online: May 6, 2016.

Aim: This pilot study aimed to reveal whether combination of electrostimulation with Iloprost, a synthetic analogue of prostacyclin PGI₂ that dilates systemic and pulmonary arterial vascular beds used to treat pulmonary arterial hypertension (PAH), achieves better results compared to Iloprost alone in patients with critical limb ischemia.

Material and methods: Patients were considered eligible if they had Fontaine class III–IV symptoms with critical peripheral arterial stenosis or occlusion in arterial duplex ultrasound or computed tomography angiography and if they were not suitable candidates for surgical or endovascular revascularization due to poor distal vascular bed, failed previous grafts or stents, and high risk of operative failure. Arterial Doppler Ultrasound and pulse oximetry of the first toe or any toe without ischemic lesions were measured the day before the treatment started and the day before hospital discharge. In both groups, peak blood velocities in the anterior and posterior tibialis arteries were measured using a 7.5-MHz linear array probe with the patient laid in supine position, below the knee level and at about 5 cm proximal to the ankle. Patients were randomized into Group 1 (n = 11, mean age: 65.3 ± 4.2 years, received iloprost infusion protocol alone) or Group 2 (n = 11, mean age: 62.9 ± 6.7, received iloprost infusion plus standardized protocol of peroneal nerve electrostimulation). Electrostimulation was delivered with by the geko T-1 device with 1 Hz frequency, 27 mA current, and 200 ms pulse width, for one hour in every four, monitored by nurses. The device was set to a level to obtain a foot twitch, but operated only while the patients were resting in bed lying in supine position. If necessary, the level was reduced for patient tolerance. Peak blood flow velocities in the anterior and posterior tibialis arteries were measured with duplex ultrasound.

Results: There was a slight insignificant increase in blood velocity in anterior tibialis artery in Group 1 (from 17.6 ± 13.0 to 18.6 ± 13.1, $p=0.57$), whereas the increase in Group 2 was statistically significant (from 23.8 ± 18.3 to 32.2 ± 19.7, $p=0.01$). No significant difference was seen in the increase in blood velocity in the posterior tibialis artery. The final pulse oximetry oxygen saturation levels were not significantly different when compared between the groups, although both had statistically different increases individually ($p=0.01$). In both groups, mean walking distance significantly improved at the end of the treatment (increased from 86.3 ± 79.9 to 182.7 ± 157.6 m in Group 1, $p=0.009$ and from 89.0 ± 45.9 to 300.0 ± 80.6 m in Group 2, $p=0.001$). The difference in walking for Group 2 compared to Group 1 at the end of the treatment was statistically significant ($p=0.03$).

Conclusion: Electrostimulation of the peroneal nerve caused a substantial increase in anterior tibialis artery blood velocity when used.

Key Learning Points: Use of the geko™ device as an adjunct to medical therapy in patients with critical limb ischemia may be associated with better clinical outcomes, including longer walking distance. Walking exercise is indicated as an important part of therapy for people considered to be fit for exercise intervention suffering with intermittent claudication (Cochrane 2017 https://www.cochrane.org/CD000990/PVD_exercise-reducing-intermittent-claudication-symptoms)

3-6e. Poster: Barnes R, Barakat H, Tucker A, Chetter A. ASiT 2014 Conference Poster Abstracts: Prospective observational series to evaluate the efficacy of the geko™ neuromuscular electrical stimulation device to produce muscle contraction in vascular patients. *International Journal of Surgery* 2014; 12 (S3): s110.

Introduction: *Transcutaneous neuromuscular stimulation (TNS) can improve micro- and macro-circulatory flow in healthy volunteers. This suggests it may be beneficial in DVT prevention and flow augmentation in vascular patients. The geko™ is a neuromuscular stimulation device, which stimulates the common peroneal nerve. This study aimed to establish whether the device effectively stimulates visible muscle twitch and as such may augment flow in vascular patients.*

Methods: *A prospective observational series. Background information, clinical examination and neuropathy scores were performed. Following geko™ T-1 (27mA) device application, the presence of a response was recorded. Univariable and multivariable analyses were performed to compare responders with non-responders.*

Results: *100 patients AAA (13%), claudication (57%), critical limb ischaemia (4%), post-op femoro-popliteal bypass graft (7%), post-angioplasty (1%), diabetic ulcers (8%), varicose veins (5%) and healthy volunteers (5%) were included. 66 males and 34 females, mean age 69 years (SD 11). Calf circumference ≥ 35 cm (Odds ratio (OR) 5.774, 95%confidence interval (CI) 1.124-29.653; $P=0.036$) and Neuropathy score >5 (OR:17.831, 95%CI 2.713-117.193; $P=0.003$) were significant for non-response on multivariable analysis.*

Conclusions: *Failure to respond to TNS devices may be predicted by greater calf circumference and neuropathy score of >5 . Identifying such patients can save time and prove cost-effective.*

Key Learning Points: This 2014 paper identified that patients with larger calf circumference or those with a neuropathy score of > 5 may not have a visible muscle twitch or foot movement with activation of the geko™ device. Subsequent hemodynamic testing and case series with patients of varying limb size has shown that when there is little or no visible activation, the microcirculation is still increased (see 3-2c) and wound healing is occurring (3-6b-d). It may be that length of time to healing may be decreased as a result of the geko™ device therapy with those patients. Further evaluation and research is needed.

3-6f. Doctoral Thesis: Williams K. Section 7.2 Adjuvant NMES in the management of peripheral arterial disease (PAD). Neuromuscular Stimulation of the Leg. Thesis submitted to Imperial College London for the degree of Doctor of Philosophy April 2017. Pages 270-288. Available at: <https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf> Accessed April 12, 2018.

Aim: This pilot study's purpose was to evaluate the effect of NMES on patients with peripheral arterial disease.

Methods: In this controlled interventional trial, patients were recruited from a vascular outpatient clinic and randomized to either *the control group, treated according to local and national guidelines (e.g. lifestyle advice, exercise class referral, smoking cessation advice, and pharmacological intervention as appropriate), or the device group, who in addition to best medical treatment, were allocated to use neuromuscular stimulation at the common peroneal nerve with the geko™ T-1 (27mA) device, 4-6 hours daily, 5 times a week.* All patients completed both generic and disease-specific quality of life questionnaires (EQ-5D, SF-12, CES-D, ICQ), and an exercise treadmill test. Arterial ultrasounds performed within 6 months were analyzed for degree of disease. Ultrasound Blood flow measurements were taken from the groin of the most symptomatic leg. At 6 weeks, all measurements were repeated and compared to baseline values.

Results: *35 subjects were recruited and randomised, with 19 in the control group, and 16 in the device group. Diary recorded device hours showed good protocol adherence, with subjects using the device for mean (SD) 5.15 (+/-1.6) hours. Both groups increased their walking distances by statistically significant amounts, but there was no statistically significant difference. With activation of the NMES devices, the percentage increases in arterial TAMV (104%) and volume flow (118%) and venous peak velocity (43%) were all significant.*

Key Learning Points: This study showed that use of the geko™ device significantly improved both arterial (TAMV and Volume flow) and venous (peak velocity) in this patient population with peripheral arterial disease.

3-6g. Paper: Bosanquet DC, Ivins N, Jones N, Harding KG. Microcirculatory Flux and Pulsatility in Arterial Leg Ulcers is Increased by Intermittent Neuromuscular Electrostimulation of the Common Peroneal Nerve. *Ann Vasc Surg.* 2021; 71:308-314. Open Access available at: <https://www.sciencedirect.com/science/article/pii/S0890509620306221>

Background: Neuromuscular electrical stimulator (NMES) devices increase blood flow to the lower limb by a process of intermittent muscular contraction initiated by a transdermal stimulus to the common peroneal nerve. However, its effects on localized microvascular blood supply to lower limb wounds are unknown. This study is a single-center open label study measuring the effect of neuromuscular stimulation of the common peroneal nerve on the microvascular blood flow within the wound bed and periwound area of arterial leg ulcers.

Methods: Eight patients with ischemic lower limb wounds (mean ABPI 0.5 ± 0.05) had an NMES (geko™) applied to the common peroneal nerve, eliciting a muscular response. Analysis of blood flow to the wound bed and edge was performed using Laser Speckle Contrast Imaging. Mean flow (flux) and pulse amplitude (pulsatility) were measured at baseline after 30 minutes of stabilisation in the lab, and after 30 minutes of NMES activation and stabilisation.

Results: Stimulation of the common peroneal nerve with the NMES resulted in a significantly increased flux and pulsatility in both the wound bed and the wound edge in all 8 patients. NMES increased wound bed flux by 64% ($p=0.0005$) and pulsatility by a mean of 452% ($p=0.004$). With use of the NMES device, peri-wound area flux increased by a mean of 37% ($p=0.02$) and pulsatility by a mean of 188% ($p=0.002$). The increase in pulsatile flow, considered vital for wound healing, is of pertinence and is discussed within the paper. The results for all patients was similar.

Conclusions: The geko™ device applied to the common peroneal nerve substantially and immediately increases microcirculatory blood flow to the wound bed and edge in patients with ischemic lower limb wounds. These data may provide mechanistic insight into the clinical efficacy of NMES in healing wounds. www.clinicaltrials.gov [NCT03186560](https://clinicaltrials.gov/ct2/show/study/NCT03186560).

Key Learning Points: Even with ischemic lower leg wounds, wound bed and peri-wound area flux and pulsatility were significantly improved, suggesting that this patient population, which is chronically difficult to heal, may benefit from use of the geko™ wound therapy device in addition to local wound care.

3-7. The geko™ Device and Effect on Deep Veins

3-7a. Poster: Griffin M, Bond D, Nicolaides A. Measurement of blood flow in the deep veins of the lower limb using the geko™ neuromuscular electrostimulation device. Available at: https://gekodevices.com/wp-content/uploads/2018/04/13339_geko_poster_a0.pdf

Paper: Griffin M, Bond D, Nicolaides A. Measurement of blood flow in the deep veins of the lower limb using the geko™ neuromuscular electro-stimulation device. *International Angiology* 2016; 35(4):406-10.

Methods: The aim was to determine the effect of the geko™ T-1 (27mA) device on the velocities and volume flows in the peroneal, posterior tibial (PTV) and gastrocnemial veins in 18 healthy volunteers, and to assess the safety of the device. One leg randomly chosen; placed in sitting position with legs suspended over the couch and resting on a stool x 5 minutes to achieve baseline equilibrium. The intensity of the stimulus was dictated by each participant's ability to comfortably tolerate the effect, using one leg per individual determined in a random selection. Blood velocity and volume flows were measured in the peroneal, posterior tibial and gastrocnemius calf veins in a longitudinal section using the IU22 ultrasonic scanner and a broad bandwidth L9-5 linear array transducer. Measurements were taken mid-calf for the posterior tibial and peroneal veins, gastrocnemius veins just distal to the confluence with the popliteal vein. Peak velocity (PV) (cm/sec) diameter of the vein at the point of sampling and the duration of the Doppler spectral waveform produced by the calf muscle contraction were measured. All measurements were repeated 3 times and the mean value was used.

Table of Results:

| Test | Peroneal Vein with Activated geko™ % Increase over baseline | Post-Tibial Vein with Activated geko™ % Increase over baseline | Gastrocnemius Vein Activated geko™ % Increase over baseline | Summary/ Significance |
|----------------------------------|--|---|--|--------------------------|
| Peak Velocity (cm/sec) | 216% | 112% | 137% | P<0.001 |
| Ejected volume per stimulus (ml) | 113% | 38% | 50% | P<0.001 to <0.003 |

| Test | Peroneal Vein with Activated geko™ % Increase over baseline | Post-Tibial Vein with Activated geko™ % Increase over baseline | Gastrocnemius Vein Activated geko™ % Increase over baseline | Summary/ Significance |
|---------------------------------------|--|---|--|--------------------------|
| Volume Flow during Muscle Contraction | 36% | 25% | 17% | P<0.015 to <0.036 |

Key Learning Points: Venous flow in all calf veins significantly increased during neuromuscular stimulation from the geko™ device as shown above, but this was in healthy volunteers with a short period of stimulation. The activation of the foot and calf muscle pump effect was not confined to the peroneal compartment but extended to all the axial veins. The increases over baseline are key factors in preventing venous stasis, but the results cannot be extrapolated to patients with existing venous stasis disease or in other life situations. Since this work was completed, we now have a growing body of evidence showing the beneficial effects of the geko™ Device with patients with chronic venous sufficiency and venous leg ulcers. Please see Section 7-2. The geko™ device and Venous Leg Ulcers and Lower Leg Wounds.

3-7b. Paper: Avazzadeh S, O’Farrell A, Flaherty K, O’Connell S, ÓLaighin G, Quinlan LR. Comparison of the Hemodynamic Performance of Two Neuromuscular Electrical Stimulation Devices Applied to the Lower Limb. J Pers Med. 2020;10(2):36. Available at: <https://pubmed.ncbi.nlm.nih.gov/32392699/>

2020;10(2):36. Available at: <https://pubmed.ncbi.nlm.nih.gov/32392699/>

Background: Currently, 1% of the population of the Western world suffers from venous leg ulcers as a result of chronic venous insufficiency. Current treatment involves the use of moist wound healing, compression bandages, and intermittent pneumatic compression. Neuromuscular electrical stimulation is a novel potential new therapeutic method for the promotion of increased lower limb hemodynamics.

Aim: The aim of this study was to measure the hemodynamic changes in the lower limb with the use of two neuromuscular electrical stimulation devices.

Methods: Twelve healthy volunteers received two neuromuscular stimulation device interventions. The geko™ and National University of Ireland (NUI) Galway neuromuscular electrical stimulation devices were randomized between dominant and non-dominant legs. Hemodynamic measurements of peak venous velocity (cm/s), the time average mean velocity (TAMEAN) (cm/s), and ejected volume (mL) of blood were recorded.

Results: Peak venous velocity was significantly increased by the geko™ and the NUI Galway device compared to baseline blood flow ($p < 0.0001$), while only the voluntary contraction produced significant increases in TAMEAN and ejected volume (both $p < 0.05$). Neuromuscular electrical stimulation can produce adequate increases in lower limb hemodynamics sufficient to prevent venous stasis.

Key Learning Points: Greater use of neuromuscular stimulation devices could be considered in the treatment of conditions related to chronic venous insufficiency but requires further research to determine their benefit in actively treating VLUs. We now have a growing body of evidence showing the beneficial effects of the geko™ Device with patients with chronic venous sufficiency and venous leg ulcers. Please see Section 7-2. The geko™ device and Venous Leg Ulcers and Lower Leg Wounds.

3-8. The geko™ Device and Effect on Venous Blood Flow and Microcirculation with Casting

3-8a. Paper: Warwick DJ, Shaikh A, Gadola S, Stokes M, Worsley P, Bain D, Tucker AT, Gadola SD. Use of the geko™ device in below knee cast patients. Neuromuscular electrostimulation via the common peroneal nerve promotes lower limb blood flow in a below-knee cast. Bone Joint Res 2013; 2:179–85.

Methods: Ten healthy volunteers were tested with geko™ T-1 (27mA) device in 4 postures: standing (weight bearing and non-weight bearing, supine lying with lower limb horizontal and then elevated. Duplex ultrasonography of the superficial femoral vein measured venous flow and cross-sectional area before (after laying 30 minutes to achieve equilibrium) and 5 minutes after device was activated in each position. A plaster below knee cast was applied and the tests were repeated in each position, with and without the device activated.

Table of Results: Increase in Venous Blood Flow at the Superficial Femoral Vein

| Position | Non-activated geko™ Mean ± SD | geko™ activated No cast Mean ± SD | Summary/ Significance | Plaster Cast Non-activated geko™ Mean ± SD | Plaster cast geko™ activated Mean ± SD | Summary/ Significance |
|--|-------------------------------|-----------------------------------|-----------------------|--|--|-----------------------|
| Supine leg horizontal | 15.3 ± 1.6 | 21.6 ± 2.2 41% increase | p=0.04 | 15.5 ± 1.0 | 25.3 ± 3.1 63% increase | P=0.03 |
| Supine leg elevated (venous flow is already high in this position) | 21.8 ± 3.4 | 23.4 ± 2.9 7.34% increase | P=0.75 | 19.5 ± 2.1 | 24.6 ± 2.8 26% increase | P=0.13 |
| Standing weight bearing | 13.8 ± 1.9 | 21.8 ± 3.4 57.9% increase | P=0.1 | 10.0 ± 1.6 | 22.3 ± 3.6 123% increase | P=0.02 |
| Standing non-weight bearing | 11.8 ± 1.0 | 26.8 ± 3.1 127% increase | P<0.001 | 10.7 ± 1.0 | 29.3 ± 2.8 173% increase | P<0.001 |

No statistical change in Cross-Sectional area of the femoral vein with geko™ activation with or without casting.

Key Learning Points: *The device presents a number of advantages over previous ES devices. Indirect muscle stimulation via the nerve allows muscle contraction to be affected using a much lower level of stimulus than direct muscle stimulation. This means that a given level of contraction is considerably more tolerable to the patient. The branching of the common peroneal nerve distal to the knee results in contraction of a whole complex of lower leg muscles, including those muscles responsible for foot dorsiflexion, and stabilisers. Dorsiflexion has been shown to provide more effective blood pumping than plantar flexion. This gives a more effective evacuation (by distension) of the valved vessels of the calf than by contraction of the gastrocnemius muscle.*

3-8b. Paper: Warwick D, Shaikh A, Worsley P, Gadola S, Bain D, Tucker A, Gadola SD, Stokes M. Microcirculation in the foot is augmented by neuromuscular stimulation via the common peroneal nerve in different lower limb postures: a potential treatment for leg ulcers. *Int Angiol* 2015;34(2):158-65.

Methods: Ten healthy volunteers were tested with geko™ T-1 (27mA) device in 4 postures: standing (weight bearing and non-weight bearing, supine lying with lower limb horizontal and then elevated). Flux was measured with laser Doppler fluxmetry on the dorsum of the foot before and 5 minutes after device was activated in each position. A plaster below knee cast was applied and the tests were repeated in each position, with and without the device activated. Measures of flux were compared to baseline levels with no cast and an inactive geko™ device.

Table of Results:

| Position | geko™ activated No cast | Plaster Cast non-activated geko™ | Plaster cast geko™ activated | Summary/ Significance |
|-----------------------------|-------------------------|----------------------------------|------------------------------|--|
| Supine leg horizontal | 91.2 ± 44.1 | 24.8 ± 32.5 | 154.1 ± 35.4 | Activated geko increased flux in all positions with and without cast p=0.001. Without cast, weight bearing had least increase; with cast increases were similar in all positions |
| Supine leg elevated | 120.7 ± 57.5 | 3.9 ± 23.7 | 278.9 ± 87.8 | |
| Standing weight bearing | 30.5 ± 36.4 | -0.7 ± 19.5 | 208.5 ± 86.1 | |
| Standing non-weight bearing | 99.6 ± 47.4 | 42.5 ± 42.9 | 210.7 ± 38.7 | |
| Microcirculatory Flux | 41% increase | | 73% increase | |

Key Learning Points: Marked increase in flux due to plaster cast could be due to artifact with instrument or increased skin temperature. The third possibility (which is supported by short stretch compression literature) is that the rigid shell of the cast with fixed volume and cross-sectional areas (CSA) provides resistance and increases the strength of the calf

muscle pump mechanism in response to the geko™ stimulation. Muscle contractions cause an increase in CSA of the muscle, and if the overall CSA of the leg is constrained, the CSA area of the vein or other fluid reservoirs (e.g. edema) must evacuate to accommodate this.

3-9. The geko™ Device Reduces Venous Blood Sludging

3-9a. Poster: Lattimer C, Azzam M, Kalodiki E. Common peroneal nerve stimulation reduces blood sludging in the popliteal vein standing and lying. 2016. See videos for dynamic view: <https://www.gekodevices.com/geko-videos/sludge-blood-without-the-geko-device-switched-on-2/> and <https://gekodevices.com/geko-videos/sludge-blood-with-the-geko-device-switched-on/>

Paper: Lattimer CR, Azzam M, Papaconstantinou JA, Villasin M, Ash S, Kalodiki E. Neuromuscular electrical stimulation reduces sludge in the popliteal vein. *J Vasc Surg Venous Lymphat Disord* 2018;6(2):154-162.

Methods: The aim was to determine whether the Common Peroneal Nerve Stimulation (CPNS) geko™ T-2 (27mA) device reduces stasis using the ultrasound derived venous sludge index (VSI). Twenty-five **healthy volunteers** had their right popliteal vein video recorded (B-mode ultrasound at 22 frames per second) in longitudinal and transverse views, standing and lying. First with the CPNS off and then with the CPNS on. A single frame out of the possible 154 frames (7 seconds) was selected at random, for the image analysis. The VSI, a grey scale index (0-255), was used to quantify the 'brightness' of the erythrocyte aggregates within the circular sampling area.

Results: Poster: Before the device was activated, they found a much higher VSI when the volunteers were standing, versus laying, with both views. When off, the Venous Sludge Index (VSI) was 53.5, when activated, the geko™ stimulation reduced the VSI to 7.6 in both positions and both views, which was highly significant ($p=0.0005$).

Paper: *Activation of the CPNS significantly reduced all the VSI values ($P < .0005$) shown (longitudinal view, 2 [1.1-3.2] and 1.5 [0.5-3.1]; transverse view, 1.1 [0.6-2.7] and 0.8 [0.5-2.1]).*

Key Learning Points: The CPNS device significantly reduces the Venous Sludge Index irrespective of whether the subject is standing or lying down. *The principal mode of action of the device in the claim that it may reduce venous thromboembolism risk may be through a reduction of venous sludge.* The relationship between erythrocyte aggregation, stasis and VTE risk requires more investigation.

3-10. The geko™ Device and Effect on Ambulatory Venous Pressure (AVP), Calf Venous Transit Time (VTT) And Leg Volumes

3-10a. Poster: Khanbhai M, Hansrani V, Sultan J, Burke J, McCollum CN. The effect of neuromuscular electrostimulation on lower limb venous physiology. Academic Surgery Unit, Institute of Cardiovascular Sciences, Manchester Academic Health Science Centre. Society of Academic & Research Surgery, VASCULAR 1 Wednesday 7 January, 2015 09.45-11.20

Methods: The geko™ device was applied over the upper lateral calf just below the knee in 19 **healthy volunteers**. Three power settings with pulse widths of 100, 200 and 400µs were compared with no device. Calf venous transit time (VTT) in seconds was measured using duplex to detect the time between injecting contrast into a dorsal foot vein and the arrival in the popliteal vein, standing, sitting and lying. Ambulatory venous pressure (AVP) and leg volumes were also recorded.

Results: The results with geko™ were statistically significant with the device at all three settings, and in all three positions. The geko™ device reduced the VTT (increased rate of blood flow) most in the laying position, where there would be no obstruction due to the knee being bent, and with the output of 400 µs. The ambulatory venous pressure and the leg volume also reduced, caused by the augmentation of the calf muscle pump function reducing venous refilling and venous volume, both implicated in venous stasis.

Table of Results:

| Mean Venous Transit Time (VTT) from dorsal foot to Popliteal Vein | Baseline No Device | geko™ @100 µs | geko™ @200 µs | geko™ @400 µs | Statistical Significance |
|---|--------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------|
| VTT Patient Standing | 37 ± 3.0 | 31.3 ± 3.8 (15% reduction) | 25.2 ± 4.0 (31% reduction) | 19.8 ± 3.6 (46% reduction) | P< 0.001 |
| VTT Patient Sitting | 35.0 ± 2.8 | 27.6 ± 3.5 (21% reduction) | 22.2 ± 4.1 (36% reduction) | 16.3 ± 3.6 (53% reduction) | P< 0.001 |
| VTT Patient Lying (Supine) | 31.4 ± 2.4 | 21.3 ± 3.3 (32% reduction) | 15.7 ± 3.1 (50% reduction) | 11.3 ± 2.6 (64% reduction) | P< 0.001 |

| Mean Venous Transit Time (VTT) from dorsal foot to Popliteal Vein | Baseline No Device | geko™ @100 μs | geko™ @200 μs | geko™ @400 μs | Statistical Significance |
|---|--------------------|----------------------------------|----------------------------------|---------------------------------|--------------------------|
| Mean fall in Ambulatory Venous Pressure (AVP) | 17.7 ± 2.1 | 15.2 ± 2.7 (14% fall) | 9.3 ± 5.4 (47% fall) | 5.7 ± 1.9 (67% fall) | P< 0.001 |
| Mean Leg Volumes | 3414 ± 148.6 | 3312 ± 146.1 (2.9% reduction) | 3122 ± 143.7 (8.5% reduction) | 2820 ± 302.8 (17% reduction) | P< 0.001 |

Reviewer’s comments: The T-1 was used in many of the early evaluations and has the capability to provide the following pulse widths or settings: 50, 70, 100, 140, 200, 280, 400 and 560μs. The poster does not specify how much contraction was seen with each pulse width setting, or which device was being used. Without knowing how much of a response the individuals had with each setting, it is difficult to reproduce the benefit found at 400 μs. The common peroneal nerve moves away from the fibular head by up to 18 mm when the leg is fully extended, so there tends to be less of a “twitch” seen, therefore thought to be less than therapeutic. Some patients will have a therapeutic twitch with a setting of 1 (50 μs), while others have no twitch at 8 (560 μs).

Key Learning Points:

The present study provides a detailed study of venous physiology utilizing venous transit time, volumetry and ambulatory venous pressure. Neuromuscular electrostimulation independently enhances venous flow by augmenting calf muscle pump function resulting in reduced venous refilling and venous volume.

3-11. The geko™ Device and Effect on Achilles Tendon And Foot Blood Flow

3-11a. Paper: Pelech N. Acupuncture at Urinary Bladder 40 (UB-40) and neuromuscular stimulation (geko™ device) effecting short-term lower limb blood flow in healthy subjects: a comparative study. Barts and the London School of Medicine and Dentistry. Paper submitted in part fulfilment of the intercalated BSc in Sports & Exercise Medicine. 2012. Firstkind Archives.

To our knowledge, this study is the first to investigate the effect of the geko™ on Achilles tendon and foot blood flow.

Background: *Improving training and injury recovery is important in reducing disruption to athletic performance. Neuromuscular stimulation and acupuncture are both used by athletes for this purpose with benefits possibly attributed to increased blood flow. The geko™ T-1 (27mA) device, a neuromuscular stimulator, and UB-40 acupuncture are applied at the popliteal fossa and may increase lower limb blood flow.*

Objectives: *Ascertain and compare short-term lower limb blood flow changes during either ipsilateral neuromuscular stimulation with the geko™ or UB-40 acupuncture, in healthy subjects. Ipsilateral and contralateral legs are also to be compared. In addition, thermography, discomfort questionnaires and safety measures will be assessed.*

Methodology: *Twelve healthy volunteers rested x 30 minutes, then were randomized to one or the other intervention on one or the other leg x 30 minutes, then were tested, rested x 30 minutes and had the other treatment applied to the alternate leg x 30 minutes and were tested again.*

Results: *There were significant differences between the interventions (p≤0.01). The geko™ increased microcirculatory velocity by 306% in the ipsilateral Achilles peritendinous space whereas UB-40 acupuncture decreased microcirculatory volume by 36% in the ipsilateral toe pulp (p≤0.05). During geko™ the ipsilateral knee temperature increased (p≤0.05), contralateral knee and ipsilateral Achilles remained constant (p≥0.05) and both calves and contralateral ankle decreased (p≤0.05). Throughout acupuncture temperature remained constant bilaterally at all sites (p≥0.05). Discomfort data revealed no difference between the interventions (p≥0.05), rated minimal sensation/mild discomfort. No changes were detected in safety measures (p≥0.05).*

Conclusion: *The geko™ considerably increased peritendinous microcirculatory velocity, which could benefit injury healing and training recovery, without significantly increasing calf muscle metabolic activity. Acupuncture at UB-40 decreased microcirculatory volume and maintained a stable temperature bilaterally. Strong evidence for the clinical use of UB-40 is still lacking. Future studies should employ larger samples sizes and use patients with pathologies.*

Key Learning Points: *Wounds to the achilles tendon are traditionally extremely difficult to heal due to the mobility of the tendon and poor vascular response and pain is usually very high. With this supporting evidence; it seems appropriate to utilize the geko™ device to promote healing of wounds involving the achilles tendon area.*

3-12. Hemodynamic effect of the geko™ Device With Concomitant Use Of Graduated Compression Stockings

3-12a. Paper: Williams K. Section 6.4 Concomitant use of common peroneal nerve stimulation and graduated compression stockings. Neuromuscular Stimulation of the Leg. PhD Thesis, Imperial College London for the degree of Doctor of Philosophy. April 2017. Pages 208-216. Available at: <https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf> Other leg volume results from this thesis are reported in 3-2i.

Purpose: Neuromuscular stimulation has part of its haemodynamic effect through activation of the muscle pumps of the leg. Bench testing was performed to see if the application of compression hosiery might enhance the effect of NMES on blood flow in the lower limb.

Methods: 5 healthy subjects were seated on a chair, with feet resting on the floor. Laser doppler fluximetry probes were attached to the dorsum of the left and right feet. A below-knee grade 2 graduated compression stocking (Medi, UK) (22mmHg compression) was placed on the left leg, non-compressive hosiery for warmth placed on the right. (Geko™ devices) were placed bilaterally over the common peroneal nerve according to manufacturer's instructions. Stimulation levels used were titrated to give a definite dorsiflexion movement of the foot, whilst still ensuring comfort. Hemodynamic ultrasound measurements were taken from common femoral artery and femoral vein, and marked on the skin for repeat measurement. Baseline values were recorded after 15 minutes relaxation. Stimulation values were recorded 10 minutes after initiation of stimulation, with devices on. After 10 minutes stimulation with the NMES devices, the compression and non-compression hosiery were swapped, with devices left on. Stimulation values were compared to baseline.

Results: The geko™ device significantly increased arterial PV, TAMV and volume flow. The addition of grade 2 graduated compression stockings increased mean values for TAMV, and doubled volume flow compared to no compression, but did not reach statistical significance. Use of the NMES device caused mean increases in venous parameters, but did not reach statistical significance. The addition of compression hosiery reduced recorded peak velocity values compared to baseline, and percentage changes with compression were significantly more negative than without compression. Laser doppler fluximetry measurements taken from the dorsum of the foot were increased with compression (59% versus 297%). This could represent changes in the effective capacity of the arterioles, capillaries and venules; either through reflexive or neuroendocrine vasodilatation, pressure dilatation, or recruitment of more numbers of open vessels.

Limitations: A small study of five subjects is prone to type 2 statistical error (failure to reject the null hypothesis).

Conclusions: There may be changes to the microvascular system in the presence of compression. Venous ulcers are often managed with dressings and four-layer compression. There is the possibility that the use of NMES in conjunction with four-layer bandaging may enhance the blood supply to the skin of the foot, and by inference improve ulcer healing rates.

Possible application to practice regarding use with compression bandaging: Graduated compression stockings are recommended for prevention of Venous Ulcers and to manage chronic venous insufficiency. The theory is that graduated compression stockings are elastic in nature and will stretch with calf-muscle pump contraction. In contrast, multilayer and short stretch bandaging systems are resistant, and are described by the degree of stiffness. Multilayer systems containing one layer of elastic bandaging are more effective in treating venous leg ulcers¹. A high stiffness compression system causes fluctuations in the lower leg during walking compared to a low stiffness or elastic system², producing the greatest improvements in venous blood flow, e.g. in ejection volume and ejection fraction, from the lower leg³. A similar study would be helpful in demonstrating what happens with patients with venous disease using the geko™ devices in combination with a multilayer bandaging system containing both elastic and inelastic components¹. At this time we consider the geko™ device to be an adjunctive therapy combined with a compression system, now supported by a Within-Patient Controlled Trial (2023) (Section 7-2m.), or when the patient cannot tolerate optimal or any compression, supported by the Canadian Consensus Statement for the Management of Venous Leg Ulcers (2023) (Section 7-2s.).

1. O'Meara S, Cullum N, Nelson EA, Dumville JC. Compression for venous leg ulcers. Cochrane Database of Systematic Reviews 2012, Issue 11.

2. Partsch H, Clark M, Mosti G, et al. Classification of compression bandages: practical aspects. *Dermatol Surg* 2008; 34(5): 600–9.65.

3. Mosti G, Mattaliano V, Partsch H. Inelastic compression increases venous ejection fraction more than elastic bandages in patients with superficial venous reflux. *Phlebology* 2008; 23(6): 287–94.)

3-13. Position of Knee Angle Using the geko™ Device Affecting Muscle Activation

3-13a. Paper: Gavin JP, Cooper M and Wainwright TW. The effects of knee joint angle on neuromuscular activity during electrostimulation in healthy older adults. *Journal of Rehabilitation and Assistive Technologies Engineering*. 2018; 5: 1–10. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6453066/pdf/10.1177_2055668318779506.pdf

Introduction: Electrostimulation devices stimulate the common peroneal nerve, producing a calf muscle-pump action

to promote venous circulation. Whether knee joint angle influences calf neuromuscular activity remains unclear. Our aim was to determine the effects of knee joint angle on lower limb neuromuscular activity during electrostimulation.

Methods: Fifteen healthy, older adults underwent 60 min of electrostimulation (geko™ T2, Firstkind Limited, Bucks, UK), with the knee joint at three different angles (0°, 45° or 90° flexion; random order; 20 min each). Outcome variables included electromyography of the peroneus longus, tibialis anterior and gastrocnemius medialis and lateralis and discomfort.

Results: Knee angle did not influence tibialis anterior and peroneus longus neuromuscular activity during electrostimulation, but neuromuscular activity was greater in the gastrocnemius medialis ($p=0.002$) and lateralis ($p=0.002$) at 90°, than 0° knee angle. Electrostimulation intensity was positively related to neuromuscular activity for each muscle, with a knee angle effect for the gastrocnemius medialis ($p=0.05$).

Conclusion: Results suggest that during electrostimulation, knee joint angle influenced gastrocnemii neuromuscular activity; increased gastrocnemius medialis activity across all intensities (at 90°), when compared to 0° and 45° flexion; and did not influence peroneus longus and tibialis anterior activity. Greater electrostimulation-evoked gastrocnemii activity has implications for producing a more forceful calf muscle-pump action, potentially further improving venous flow.

Key Learning Points: the common peroneal nerve becomes displaced from the fibular head by approximately 17mm when standing or sitting with 0° knee flexion, when compared to sitting with 90° knee flexion. In addition, varying the knee and ankle joint angles influences the gastrocnemii muscle length and force-producing capacity, as well as the passive knee flexion moment. As the human gastrocnemii operates on the ascending limb of the force-length relationship, passive tension begins to develop at short muscle lengths (i.e. in 90° knee flexion), before approaching near-maximum at longer muscle lengths (i.e. 0° knee extension). As a consequence, at longer muscle lengths, the contribution of the active, contractile component becomes near-maximum with greater passive force exerted. Therefore, electrostimulation may be less effective at activating the calf muscle pump with the knee extended with the gastrocnemii muscle tendon unit at a longer muscle length.

3-14. NEW: Use of the geko™ Device Increases Microvascular Flux in the Wound Bed of Diabetic Foot Ulcers

3-14a. NEW: Paper: Bosanquet DC, Blow M, Ashton F, Harding KG. Neuromuscular electrostimulation of the common peroneal nerve increases microvascular flux in the wound bed of diabetic foot ulcers. *Int J Low Extrem Wounds*. 2025 Apr 27:15347346251331254. doi: 10.1177/15347346251331254. Online ahead of print. Available at: https://journals.sagepub.com/doi/full/10.1177/15347346251331254?rfr_dat=cr_pub++0pubmed&url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org Accessed May 18, 2025.

Objective:

To measure the effect of neuromuscular stimulation of the common peroneal nerve on the microvascular blood flow within the wound bed of diabetic foot ulcers.

Methods: 13 patients with diabetic foot ulcers (11 neuropathic, 2 neuroischemic) were recruited. Microvascular flux and pulsatility were measured in real time in the wound bed, and at the wound edge, using Laser Speckle Contrast Imaging (Moor FLPI-2; Moor Instruments Ltd, Axminster, United Kingdom). Changes from baseline were measured when the leg muscle pump was activated by 1 Hz neuromuscular stimulation of the common peroneal nerve, using a wearable device (geko™, Firstkind Ltd Daresbury, United Kingdom).

Results: In the 11 neuropathic ulcers, significant increases were seen in all microvascular parameters. Wound bed flux increased by 36% (95%CI 11%-68%, $P = .002$), and peri-wound flux increased by 92% (95%CI 46%-160%, $P = .001$). Pulsatility in the wound bed increased by 183% (95%CI 61%-517%, $P = .005$), while pulsatility in the peri-wound increases by 359% (95%CI 264%-455%, $P = .001$). Additionally, an increase in flux and pulsatility was observed in the neuroischemic ulcers.

Conclusions: Neuromuscular stimulation of the common peroneal nerve presents a mode of activating the leg muscle pump without additional pressure insult to the foot and has potential to support the microcirculation during wound-healing, effectively emulating exercise without any of the attendant risks of exercise to the neuropathic or neuroischemic foot.

Key Learning Points: Patients with diabetic foot ulcers on the plantar surface of the foot requiring offloading devices such as total contact casting have restricted mobility and impaired action of the leg muscle pumps, precluding the improved perfusion to the foot from exercise. Exercise can cause increased mechanical damage due to pressure, friction or shear forces in the foot that has loss of protective sensation from neuropathy. Use of the geko™ NMES device

provides a safe alternative to the benefits of exercise particularly a statistical improvement in the wound and peri-wound flux and pulsativity without the risk of actual exercise for this patient population.

4. The geko™ Device and DVT/VTE Prophylaxis

4-1. The geko™ Device and General DVT/VTE Prophylaxis

4-1a. Paper: The geko device for reducing the risk of venous thromboembolism. Medical technologies guidance.

Published: 25 June 2014 nice.org.uk/guidance/mtg19 <https://www.nice.org.uk/Guidance/mtg19>

Recommendation: *The case for adopting the geko™ device is supported for use in people who have a high risk of venous thromboembolism and for whom other mechanical and pharmacological methods of prophylaxis are impractical or contraindicated. Although clinical evidence is limited, the case is supported because of the plausibility that the geko™ device may reduce the high risk of venous thromboembolism in patients who cannot use other forms of prophylaxis, and the low risk of the device causing harm.*

Explanation of NICE Process: Summers JA, Clinch J, Radhakrishnan M, Healy A, McMillan V, Morris E, Rua T, Ofuya M, Wang Y, Dimmock PW, Lewis C, Peacock JL, Keevil SF. The geko™ Electro-Stimulation Device for Venous Thromboembolism Prophylaxis: A NICE Medical Technology Guidance. Appl Health Econ Health Policy. 2015; 13(2): 135–147. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4376951/>

4-1b. Paper: Implementing the NICE guidance on the geko™ device for reducing the risk of venous thromboembolism (MTG19) <https://www.nice.org.uk/guidance/mtg19/resources/costing-statement-pdf-10461277> *The technology is recommended for patients at high risk of venous thromboembolism for whom pharmacological and mechanical prophylaxis treatment options are contraindicated. This is currently an unmet need. Venous thromboembolism – reducing the risk (NICE clinical guideline 92) recommends that patients assessed as having risk factors for bleeding should not be offered pharmacological prophylaxis, unless the risk of VTE outweighs the risk of bleeding. For a small investment in the device, savings may result from reduced rates of venous thromboembolism. Savings are anticipated for providers in secondary care as a result of lower treatment costs, and decreased bed days.*

4-1c. Paper: Hajibandeh S, Hajibandeh S, Antoniou GA, Scurr JRH, Torella F. Neuromuscular electrical stimulation for the prevention of venous thromboembolism. Cochrane Database of Systematic Reviews 2017, Issue 11. Art. No.: CD011764. DOI:10.1002/14651858.CD011764.pub2. Available at:

<https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD011764.pub2/epdf/full>

This Cochrane Review looked at ALL studies involving NMES to prevent VTE/DVT, not only geko™ device publications.

Study characteristics and key results:

Eight studies (current until 22 March 2017) enrolling a total of 904 participants that compared NMES with no treatment or with other methods for preventing blood clots, such as low-dose heparin and compression stockings. They found no clear difference in the risk of unwanted blood clots in the legs between NMES and alternative methods of blood clot prevention. They also found that NMES is associated with lower risk of formation of unwanted blood clots in the legs when compared with no treatment, but higher risk of unwanted blood clot formation when compared with heparin. Additional studies are required to obtain stronger evidence.

Quality of the evidence:

Overall, the quality of available evidence is low and has been downgraded owing to high or unclear risk of bias, differences between studies, and imprecise effect estimates due to small numbers of studies and events.

Authors' conclusions:

Low-quality evidence shows no clear difference in the risk of DVT between NMES and alternative methods of prophylaxis but suggest that NMES may be associated with lower risk of DVT compared with no prophylaxis (moderate-quality evidence) and higher risk of DVT compared with low-dose heparin (low-quality evidence). The best available evidence about the effectiveness of NMES in the prevention of VTE is not adequately robust to allow definitive conclusions. Adequately powered high-quality randomised controlled trials are required to provide adequately robust evidence.

4-1d. Paper: Lattimer CR, Zymvragoudakis V, Geroulakos G, Kalodiki E. Venous Thromboprophylaxis With Neuromuscular Stimulation: Is It Calf Muscle Pumping or Just Twitches and Jerks? Clin Appl Thromb Hemost. 2018 Apr;24(3):446-451.

Available at: <https://journals.sagepub.com/doi/pdf/10.1177/1076029617726601>

Purpose: *The aim was to quantify the claim in the NICE medical Guidance 19 document that the geko™ device “drives the venous muscle pump and imitates walking.” The NICE Guidance statement in full is: “The muscular action drives the*

venous muscle pump of the lower leg, facilitating the emptying of veins and increasing the return of blood to the heart. This is designed to imitate the process normally achieved by walking, without the person having to move” (page 4, 2.2).

Method: *Twelve healthy volunteers performed 10 tip-toe maneuvers and 10 ankle dorsiflexions to imitate walking movements. The reductions in calf volume were recorded using air plethysmography (APG). The common peroneal nerve was stimulated for over 10 seconds at each of the 7 increasing electrical impulse settings (with the geko™ T-1 or T-2 device), and the volume reductions were measured for comparison. The results are expressed as median (interquartile range) absolute (mL), and percentage reduction in calf volume.*

Results: *Tip-toe and dorsiflexion pumping maneuvers were not significantly different: 59 (33.6-96.1), 81.9% vs 51.4 (34-68.5), 59.7%, respectively (P = .53). However, they both outperformed the CPNS: 10.8 (7.3-18), 13.2% (P = .002 and P = .002 respectively). Qualitatively, the CPNS registered on the tracings as a small spike (muscle twitch) at low settings, with larger amplitudes (ankle jerk) at higher settings. The CPNS activity spikes were discrete, lasting a median (range) of 0.24 (0.16- .3) seconds. The claim that the CPNS empties veins by pumping is supported by statistical tests which demonstrated the same significance (p=0.002) as the tip-toe and dorsiflexion maneuvers versus stationary standing. However, the amount was small with the CPNS (geko™).*

Firstkind Comments regarding methodology: Although the authors state that the placement of the geko™ device was positioned as recommended by the manufacturer across the common peroneal nerve, the photograph on page 447 shows the line of arrows that should be on the fibular head as being far posterior to it. This means that the device could not elicit the intended response. The recommended recovery period between each of the 11 serial controlled variable conditions (i.e. baseline, standing, tip-toes, dorsiflexions, and 7 successive settings of geko™) were omitted. The manufacturer of the Air Plethysmography system [<http://acimedical.com/wp-content/uploads/2017/08/APG-advanced-course-v2.pdf>] (page 5, para 3) states that to prevent exercise-induced hyperemia and engorgement of the muscles (seen in serial tests,) ensure a return to resting levels (below 2 ml/sec) prior to doing additional VFI tests, which could take 15 minutes or more. This means that in the later geko™ tests, the baseline working venous volume would be much higher than the original fill level at the beginning of the testing, so any comparison is biased in favour of the earlier tests. The authors also prematurely establish working venous volume as a reference, whereas it continues to creep up substantially throughout the study (most likely because of the exercise hyperaemia resulting from multiple activations. Again, this favours earlier tests over later tests with geko™.

4-1e. Paper: Ravikumar R, Williams KJ, Babber A, Moore HM, Lane TRA, Shalhoub J, Davies AH. Neuromuscular electrical stimulation for the prevention of venous thromboembolism. *PHLEBOLOGY* 2018; 33: 367-378.

Objective: *Venous thromboembolism, encompassing deep vein thrombosis and pulmonary embolism, is a significant cause of morbidity and mortality, affecting one in 1000 adults per year. Neuromuscular electrical stimulation is the transcutaneous application of electrical impulses to elicit muscle contraction, preventing venous stasis. This review aims to investigate the evidence underlying the use of neuromuscular electrical stimulation in thromboprophylaxis.*

Methods: *The Medline and Embase databases were systematically searched, adhering to PRISMA guidelines, for articles relating to electrical stimulation and thromboprophylaxis. Articles were screened according to a priori inclusion and exclusion criteria.*

Results: *The search strategy identified 10 randomised controlled trials, which were used in three separate metaanalyses: five trials compared neuromuscular electrical stimulation to control, favouring neuromuscular electrical stimulation (odds ratio of deep vein thrombosis 0.29, 95% confidence interval 0.13–0.65; P =.003); three trials compared neuromuscular electrical stimulation to heparin, favouring heparin (odds ratio of deep vein thrombosis 2.00, 95% confidence interval 1.13–3.52; P =.02); three trials compared neuromuscular electrical stimulation as an adjunct to heparin versus heparin only, demonstrating no significant difference (odds ratio of deep vein thrombosis 0.33, 95% confidence interval 0.10–1.14; P =.08).*

Conclusion: *Neuromuscular electrical stimulation significantly reduces the risk of deep vein thrombosis compared to no prophylaxis. It is inferior to heparin in preventing deep vein thrombosis and there is no evidence for its use as an adjunct to heparin.*

Key Learning Points: The authors conclude by stating: *“Despite the limitations of the studies included, this paper provides evidence supporting the NICE guidance on the use of NMES in VTE prophylaxis for patients in whom other methods of thromboprophylaxis are contraindicated. It is inferior to heparin as a method of thromboprophylaxis. Evidence is limited for its use as an adjunct to thromboprophylaxis due to the small studies conducted using modern day devices. Large well-designed RCTs would be required to assess the role of NMES in VTE prophylaxis.”* Since this time,

several papers have been published looking specifically at the geko™ device and VTE prophylaxis in orthopedics (Section 4-2.), Acute Stroke (Section 4-3.), Obstetrics (Section 4-4.) and with Covid-19 (Section 4-5.).

4-2. The geko™ Device and DVT/VTE Prophylaxis in Orthopedics

4-2a. Paper: Jingwei L, Zhe Z, Xuesong L, Hui J, Ning L, Wenbo W. Clinical Observation of Neuromuscular Electrical Stimulation in Prevention of Deep Venous Thrombosis after Total Hip Replacement. *Chin J Bone Joint Injury.* 2017; 32(6): 615-616.

Purpose: *To observe the clinical efficacy of GEKO Neuromuscular Electrical Stimulation (NMES) in the prevention of deep venous thrombosis (DVT) after Total Hip Arthroplasty (THA).*

Methods: *Standardized THA was the operative treatment of 72 cases of femoral head necrosis from 01-2016 to 08-2016, which were assigned to the observation group (basic prevention method plus NMES) and the control group (basic prevention method). NMES (the authors did not describe which device was utilized) was employed immediately for 24 hours/time x 3 days post-operatively. Low-intensity stimulation was advocated in early stages, then the stimulation could be gradually enhanced. DVT preventative exercises as well as instruction in rehabilitation exercises including early stage muscle relaxation and contraction, active joint movement and massage were provided to both groups. Post-operative negative pressure drainage was observed for 24 hours, with VAS scoring at day 3 post-operatively, and plasma D-dimer content measurement at day 3 pre-operatively and post-operatively. Plasma D-dimer is a fibrin degradation product (or FDP), a small protein fragment present in the blood after a blood clot is degraded by fibrinolysis. Colour Doppler ultrasound DVT screening and examination were performed prior to and after the operation.*

Results: *There was no statistically significant difference ($P>0.05$) between the two groups in post-operative negative pressure drainage. The observation (NMES) group was superior to the control group in terms of post-operative VAS score ($P=0.001$), DVT incidence rate ($P=0.047$) and 3 days post-surgery Plasma D-dimer content ($P<0.05$). The differences were statistically significant ($P<0.05$), and no apparent adverse reactions were found in the observation group.*

Conclusions: *Application of NMES in early recovery of patients after THA could increase the lower limb venous blood flow rate and alleviate pain, serving as an effective physical therapy in the prevention of DVT.*

Key Learning Points: *Most patients reported that they were able to sleep with the device activated, and there was a statistically significant reduction in pain. The authors did not comment on a reduction in the need for narcotic analgesia and subsequent side-effects, or any differences in post-operative mobility. These would be important secondary outcomes in additional studies.*

4-2b. Paper: Wainwright TW, Burgess LC, Middleton RG. A single-centre feasibility randomised controlled trial comparing the incidence of asymptomatic and symptomatic deep vein thrombosis between a neuromuscular electrostimulation device and thromboembolism deterrent stockings in post-operative patients recovering from elective total hip replacement surgery. *Surgical Technology International.* 2020; May 28;36: 289-298. Available at: <https://www.gekodevices.com/wp-content/uploads/2020/04/Paper-Wainwright-A-Single-centre-feasibility-randomised-controlled-trial-comparin-incidence-of-Asymptomatic-and-Symptomatic-DVT-between-NMES-device-and-Deterrent-002.pdf>

Background: *Total hip replacement is recognised as a major risk factor for deep vein thrombosis (DVT). The aim of this study was to investigate the feasibility of using a novel neuromuscular electrical stimulation device (NMES) for DVT prevention in patients recovering from elective hip replacement surgery.*

Methods: *Twenty-eight patients undergoing total hip replacement were randomised to receive postoperative treatment with either the NMES device (geko™ T-2 or R-2 devices activated to achieve a discernable dorsiflexion of the foot) or compression stockings (Thromboembolism Deterrent Stockings [TEDs] providing 18 mm Hg \pm 20%) continually from post-surgery until discharge (day 4). All patients received chemoprophylaxis as per NICE guidelines in addition to the allocated intervention. The primary outcome measure was the presence of symptomatic or asymptomatic DVT at 48 hours post-surgery and on the day of discharge from hip replacement surgery, as assessed by Duplex ultrasound. Secondary outcomes included hemodynamic responses to the devices, lower limb oedema, sit-to-stand and timed-up-and-go (TUG) scores, and hip range of motion.*

Results: *In the compression stockings group, two cases of asymptomatic DVT were identified by Duplex ultrasound at 48 hours post-surgery. No cases were found in the NMES group. Patients in the NMES group demonstrated a general trend of a decrease in leg volume from post-surgery to discharge, whereas leg volume largely remained static for the compression stockings group. In addition, positive hemodynamic effects were found in favour of the NMES group in the*

non-operated leg. The percentage change in TUG scores also favoured the NMES group (NMES: $150 \pm 152\%$, compression stockings: $363 \pm 257\%$ [$p=0.03$]), whereas no differences in sit-to-stand scores or hip range of motion were observed.

Conclusions: This study supports the feasibility of NMES as an alternative mechanical prophylaxis worn in the postoperative phase until discharge and provides important findings for clinicians considering novel mechanical prophylaxis options.

Key Learning Points: In this small study in the geko™ group, there were no silent VTE episodes, the timed-up-to go (TUG) score was significantly better and there was a decrease in leg volume from post-surgery to discharge, suggesting that the geko™ device had additional benefits beyond VTE prophylaxis.

4-3. The geko™ device and DVT/VTE Prophylaxis in Acute Stroke **NEW: 4-3b.**

4-3a.i. Poster: Williams J, Roffe C, Natarajan I, Moss C, Lambert C, Richards L. The use of the geko™ device and the activation of the foot and calf pumps for prevention of venous thromboembolism in patients with acute stroke. Oct 10, 2018. 11th World Stroke Congress, Montreal, QC, Canada. Poster available at: <http://www.gekodevices.com/wp-content/uploads/2018/03/Poster-VTE-Prevention-Stroke1.pdf>

Background and Aims: Venous thromboembolism (VTE) is a common and potentially fatal complication of acute stroke. The UK National Clinical Guidelines for Stroke¹ recommend intermittent pneumatic compression (IPC) as the primary method of VTE prevention after acute stroke, as the risk of symptomatic intracerebral haemorrhage outweighs the benefit from VTE prevention with routine anticoagulation with low dose heparin (including low molecular weight heparin) after stroke. Venous Thrombo Embolism (VTE) prophylaxis using Intermittent Pneumatic Compression devices (IPC) is not possible in all stroke patients. The post-stroke pathway in the Acute Stroke Unit, Stoke on Trent, United Kingdom was changed to include the geko™ device (model of device not stipulated) as an alternative to IPC for patients with acute stroke who had contradictions/not tolerate IPC. This audit was completed to assess the acceptability of this new practice for patients and staff and its impact on VTE.

Method: The audit included 455 patients admitted to the Acute Stroke Unit at Royal Stoke University Hospital (RSUH). All stroke patients who are immobile are given VTE prophylaxis, unless they are palliative, refusing the intervention, or fully anticoagulated. Every patient is reviewed daily on a nurse-led VTE ward round to monitor compliance with VTE prophylaxis.

Results: In total 6/455 (1.3%) patients developed symptomatic VTE (3 DVTs and 3 PEs) within 90 days. Of these, 4 patients (1.6%) were prescribed IPC, 1 patient (1.3%) was prescribed the geko™ device as a secondary intervention and 1 patient (1.5%) patient was prescribed anticoagulation. There was no DVT or PE in patients treated with the geko™ device as the primary VTE prophylaxis.

Conclusion: This audit shows a low incidence (1.3%) of symptomatic VTE in a high-risk population of all immobile stroke patients during the audit period. The number of patients who were contraindicated to IPC or did not tolerate IPC and were treated with the geko™ device in this project was 35.6%. Whilst limited, our data suggests that the geko™ device may be as effective as IPC in our patient cohort.

Key Learning Points: Patients suffering from stroke where anticoagulant therapy is contraindicated due to risk of cerebral hemorrhage, or whom cannot have or tolerate IPC may benefit from the geko™ as part of the standard of care. A recent paper by Kim et al. (2018)* found that 74-76% of patients for whom IPC was ordered for DVT prophylaxis did not receive it correctly. Use of the geko™ device may be more acceptable, and easier to administer. Further research is warranted.

*Kim PS. et al. The staff and patient perspectives on compliance with mechanical prophylaxis for venous thromboembolism J Vasc Surg: Venous and Lym Dis 2018; 1-8.

4-3a.ii. Updated Poster: Natarajan I, Williams J, Richards L, Moss C, Lambert C, Roffe C. The use of the geko™ device (a neuromuscular electrostimulation device) and the resulting activation of the foot and calf muscle pumps for the prevention of venous thromboembolism in patients with acute stroke. 2018. Additional information on this work is now available in two journals: "Comment: Changing clinical practice in VTE prevention" Building Better Healthcare, April 2020. Available at: <https://www.gekodevices.com/news-events/changing-clinical-practice-the-burden-of-post-stroke-vte-prevention/> and "Changing clinical practice: the burden of post-stroke VTE prevention" Clinical Services Journal August 2020. Available at: <https://www.gekodevices.com/news-events/clinical-service-journal-article-changing-clinical-practice-in-vte-prevention/>

Background: In patients with ischemic strokes the primary method of VTE prophylaxis in immobile stroke patients is IPC (IPC alone), unless contraindicated. Prophylactic low-dose anticoagulation is not given routinely. If patients are fully anticoagulated for other reasons no VTE prophylaxis other than the generic measures above is provided. Surface neuromuscular stimulation of the peroneal nerve using the geko™ is used as primary VTE prophylaxis (geko™ alone) for patients with contraindications to IPC (Table 1). The geko™ is also used when IPC pumps or sleeves are not available. Patients are switched from IPC to geko™ if they do not tolerate IPC or if they are restless, agitated or at risk of falls, have peripheral vascular disease or leg ulcers.

Results: 1000 patients were audited; of these, 813 (81.3%) of patients were prescribed VTE prophylaxis. Of these 544 (54.4%) were initially given IPC devices (**IPC alone**), 122 (12.2.0%) were initially given geko™ (**geko™ alone**), and 125 (12.5%) were initially given anticoagulants (**drug prophylaxis**). 81 (8.1%) patients who were initially prescribed IPC became intolerant to this intervention and were then changed to the geko™ device as a secondary intervention (**IPC primary + geko™ secondary**) and 22 patients refused IPC or the geko™ device. Of the 688 patients prescribed mechanical VTE prophylaxis, 203/688 (29.5%) were treated with the geko™ device either as primary or secondary mechanical prophylaxis. The median length of patient use for the geko™ device was 9 days.

VTE incidence: In total 15/1000 (1.5%) patients developed symptomatic VTE (9 DVTs and 6 PE's) within 90 days. Of these, 11 patients (2.4%) developed VTE were prescribed IPC alone, 1 patient (1.2%) was prescribed IPC and the geko™ device as a secondary intervention and 1 patient (0.8%) was prescribed anticoagulation. There was 1 VTE event in a patient who reused prophylaxis (4.8%) and 1 event in a patient who was deemed mobile and was not prescribed prophylaxis (0.5%). There was no DVT or PE in patients treated with the geko™ device as the primary VTE prophylaxis.

Conclusions: The findings of this audit suggest that geko™ is safe and well tolerated in patients with acute stroke. A randomized controlled trial (RCT) is needed to provide evidence for effectiveness in comparison with established methods of VTE prophylaxis.

Key Learning Points: In the absence of data from a RCT the results of this audit support the use of geko™ as a meaningful addition to prophylactic options for stroke patients at high risk of VTE who have contraindications to IPC.

4-3b. Poster: Nihara D, Sethuraman S, Sekaran L, Phiri D, Asokanathan A, Alwis L. The use of the geko™ device for the prevention of venous thromboembolism in patients with acute stroke at The Luton & Dunstable University Hospital (L&D). Poster available at: <https://www.gekodevices.com/wp-content/uploads/2020/12/Poster-%E2%80%93VTE-prevention-LD.pdf>

Introduction: Venous thromboembolism (VTE) remains a common complication in acute stroke which is further exacerbated if a patient is immobile for a prolonged period. In such circumstances NICE and the UK National Clinical Guidelines for Stroke both recommend intermittent pneumatic compression (IPC) as the primary method of VTE mechanical prophylaxis, alongside standard treatments, after acute stroke (NICE NG89 2018).

The Luton and Dunstable Hospital (L&D) identified that IPC is not suitable for all immobile acute stroke patients because of immediate contraindication due to vascular disease, fragile skin, skin reactions from the cuff materials and patient intolerance. In addition, it was noted that IPC leads and hoses can present a trip hazard.

NICE guidance MTG19 recommends the geko™ device for VTE prophylaxis in all hospital patients where standard prophylaxis treatments are impractical or contraindicated. The geko™ device (Firstkind Ltd) is an NMES (neuromuscular electrostimulation) device which prevents stasis in the deep veins of the calf by activation of foot and calf muscle pumps via stimulation of the peroneal nerve.

Real world data at the Royal Stoke Hospital, University Hospital of the North Midlands NHS Trust UK has previously quantified when IPC could not be prescribed for immobile stroke patients and found the need for the geko™ device as an alternative anti-stasis device to be ~30%. These patients would otherwise have had no other form of mechanical prophylaxis intervention available to them with the reliance on standard treatment of aspirin and hydration to reduce VTE risk; perhaps with an associated VTE exposure of 8.7% (CLOTS 35). Instead the geko™ was prescribed alongside standard measures (either as the only or secondary VTE intervention), and a 90 VTE outcome review reported a 0.3% incidence in 316 patients who were prescribed the geko™ device.

Aims: The aim of this audit was to evaluate the number of patients where IPC could not be prescribed as part of standard of care and assess whether geko™ could play a role as an alternative mechanical prophylactic intervention.

Methodology: The audit covered a time interval assessing 320 acute stroke patients in total. A sub-analysis of this cohort showed that 185 patients (Group A) had IPC and chemical prophylaxis as available interventions; whilst of 135 patients (Group B) had IPC, anticoagulation but also the geko™ device as an alternative intervention when either IPC or

anticoagulation was contraindicated or not tolerated (all interventions in addition to standard of care). This sub-analysis would allow a review to highlight any indicative changes in intervention patterns when the geko™ device was on service. **Results:** The demographic analysis of the n=320 patients showed that 186 were males (58.1%) and 134 were female (41.9%). In respect to stroke aetiology 266 patients (83.1%) suffered an ischemic stroke and 54 patients (16.9%) had a haemorrhagic stroke. In terms of VTE prevention 215 of 320 patients from the audit were deemed immobile and required some form of prophylactic intervention. It should be noted that anticoagulation was either used adjunctively with either IPC or geko™ or alone when deemed appropriate. Furthermore, patients had successive interventions i.e. IPC or geko™ followed by anticoagulation. In summary, patients often had more than one successive intervention until they were either mobile or discharged. In Group A – this subgroup had 117 patients in need of VTE prophylaxis who required a total of 146 prescribed interventions. In Group B – this subgroup had 98 patients in need of VTE prophylaxis who required a total of 132 prescribed interventions. Patients were who were independently mobile, or due for discharge or had entered end of life pathway management were not prescribed any VTE prophylaxis. In Group A, IPC accounted for 58.9% of mechanical interventions required. In Group B, when the geko™ device was also available, as a mechanical intervention, total mechanical use increased to 71.9%. In Group B, the geko™ device served 17% of all mechanical prophylaxis interventions. In Group B, when the geko™ device was on service, anticoagulation use decreased from 41% to 28%. A meaningful reduction of 13%.

Our observational review also considered VTE incidence at 90 days for all patients (n=320). We noted 1 DVT and 2 bilateral PE's in patients who were prescribed IPC and anticoagulation for VTE prophylaxis. The geko™ device was highly tolerated by patients and deemed to be safe to use.

Key Learning Points: The geko™ device provides a meaningful alternative anti-stasis device when IPC or anticoagulation cannot be prescribed or tolerated. The geko™ device was easily incorporated into the VTE prophylaxis protocol and is now fully embedded into our enhanced VTE stroke pathway.

4-3c. Poster: Hitchcock K, Austin L. Introduction of the geko™ device at North Bristol Trust UK. Presented at the UK Stroke Forum, Liverpool 2022. Poster available at: <https://www.gekocodevices.com/wp-content/uploads/2023/03/Poster-Introduction-of-the-geko%E2%84%A2-device-at-North-Bristol-Trust-UK.pdf>

Background: A recent study at the Royal Stoke Hospital quantified that 33% of stroke patients were unable to be prescribed Intermittent Pneumatic Compression (IPC) during their acute stay due to conditions such as congestive heart failure and lower limb oedema or those who are unable to tolerate IPC.

Methods: A review of acute stroke patients admitted to the North Bristol Trust revealed 20 patients where IPC devices were contraindicated or not tolerated and the geko™ neuromuscular electrical stimulation (NMES) device was prescribed for DVT/VTE prophylaxis.

Results:

- Patients found geko™ more comfortable than IPC.
- Patients preferred geko™ overnight (92% concordance level reported) as IPC's impacted on quality of sleep.
- Reduced risk of patient falls with the geko™ device.
- Can be expensive as £22 a pair and must be changed every 24 hours although the NICE economic review states the device is cost saving vs. the cost consequence of no VTE prophylaxis.
- Care plans proved to be an effective means of correct device fitting.
- Staff gave positive feedback and felt the devices were easy to apply.
- Patients can wear the devices more easily than IPC's when sitting.

Key Learning Points: The geko™ device has now been added to the Stroke VTE prevention protocol at the North Bristol NHS trust, for those patients determined to be at risk of VTE and unable to use IPC.

4-3d. NEW: Paper: McWilliams D, Zamani R, Limaye S. Assessing the quality of use of venous thromboembolism (VTE) prophylactic devices for stroke patients at Leeds General Infirmary: an audit and re-audit. Cureus. 2024 Dec 13;16(12):e75636.doi: 10.7759/cureus.75636. eCollection 2024 Dec. Available at: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11646159/> Accessed May 18, 2025.

Background: Venous thromboembolism (VTE) is a significant cause of morbidity and mortality in patients suffering from stroke. Intermittent pneumatic compression devices (IPCs) and geko™ devices are used to reduce the risk of VTE in patients who have suffered an acute stroke. Correct use of the devices is essential for achieving the reduced risk of VTE.

Objectives: To assess the quality of use of VTE prophylactic devices by observing if they are both applied and working correctly. To identify and address factors that contribute to suboptimal use of VTE prophylactic devices.

Methods: Patients in beds 1-20 in the Acute Stroke Unit at Leeds General Infirmary were assessed on three separate days in June 2024. Data collected included: 'VTE prophylaxis prescribed', 'VTE prophylaxis in place and working correctly?', 'If not, how so?', 'Notes'. Following an intervention, an identical audit was performed three months later. A total of 41 and 42 patients were included in the audit and re-audit, respectively.

Results: The audit included 35 patients who were prescribed IPCs (Kendall SCD™ 700 Smart Compression System) and demonstrated a very poor quality of use, with only 22.9% (n=35) observed to be in place and working correctly. The audit included six patients who were prescribed geko™ devices (Firstkind Ltd.) and found that 50% (n=6) were observed to be in place and working correctly. After a presentation of the results at local clinical governance and implementation of interventions, the re-audit demonstrated a substantial increase in the quality of use of both devices. The re-audit included 36 patients who were prescribed IPCs and six who were prescribed geko™ devices. The percentage of IPC and geko™ devices in place and working correctly increased to 75.0% (n=36, p<0.01) and 88.3% (n=6, p>0.01), respectively.

Conclusions: The intervention focused on increasing staff awareness of the importance of proper use of VTE prophylaxis and awareness of how to use the devices. It is reasonable to conclude that the improvement seen is a result of a change in these factors. To maintain and further improve quality, awareness of the importance of the devices and how to use them must also be maintained and improved. This should be done by additional systematic measures, such as regular training, and should be regularly reassessed.

Key Learning Points: Regular assessment that VTE prevention devices are in place and being used properly appears to be a much-needed continuous quality improvement measure. Of interest one strategy mentioned to increase staff awareness was a poster created to improve staff understanding of the rationale for, and practicalities of, using VTE prophylactic devices, both IPC and geko™. It was displayed in several areas of the Acute Stroke Unit, and staff were directed to review it at handovers. The actual poster contained a QR code and the Youtube link for the Kendall IPC instructional video, but there was not a corresponding one for the geko™ device.

4-4. The geko™ Device and DVT/VTE Prophylaxis in Obstetrics

4-4a.i. Poster: Verghese TS, Lafferty K, Fawzy M. Is there a role for geko™ Electro-Stimulation Device for reducing the risk of Venous Thromboembolism (VTE) in obstetrics? Observational study, Barnsley Hospital, presented at BMFS Conference, Brighton, April 2018.

Background: The NICE medical technologies guidance recommended adopting the geko™ device for use in obstetric patients with high risk of VTE and for whom other mechanical and pharmacological methods were impractical or unsafe.

Purpose: To determine the most appropriate prophylaxis, several patient-related factors must be considered: the reason for hospitalisation, medical history, expected treatment from the intervention, possible harm of prophylaxis and patient preference.

Methods: The study was conducted at Barnsley Hospital. High risk women in whom pharmacological thrombo-prophylaxis was considered unsafe or impractical were offered geko™ until pharmacological thrombo-prophylaxis could be introduced.

Results: 23 women were recruited over a period of 6 months (Dec 2016 - May 2017).

65% (15/23) postnatal women needed the device as their only method of thrombo-prophylaxis. Of these women, 87% (13/15) had postpartum haemorrhage and 13% (2/15) had low platelets for which Dalteparin was contra-indicated. Quarter (6/23) of the women with severe pre-eclampsia benefitted from the device antenatally during their admission as they were at risk of needing urgent delivery. Eight percent (2/23) women who had antenatal Dalteparin used geko™ during labour. Only two women did not tolerate the device and subsequently discontinued.

Key Learning Points: The device is potentially useful as a method of thrombo-prophylaxis in high- risk patients where other pharmacological methods are contraindicated or impractical. In addition, compared to pneumatic sleeves, geko™ allowed patient mobilisation thereby reducing their risk.

4-4a-ii. Updated Poster: Andrzejowska M, Godwin B, Fawzy M. Further update on the role of geko™ in reducing the risk of venous thromboembolism (VTE) in Obstetrics. Presented in 2018 at the British Maternal Fetal Medicine Society event in 2018. The poster was also listed for the best poster prize. Poster available at: <https://www.gekodevices.com/wp-content/uploads/2020/08/Obstetrics-Poster- DIGITAL-2.pdf>

Objective: To further explore the role of mechanical electro-stimulation device (geko™ Firstkind Ltd) for VTE prophylaxis in obstetrics with a larger number of patients.

Method: The prospective observational study was conducted at Barnsley Hospital. High risk women in whom pharmacological thrombo-prophylaxis was considered unsafe or impractical were offered the geko™ device until pharmacological thrombo-prophylaxis could be introduced.

Results: 90 women were recruited over a period of 17 months all of whom required the geko™ device at some stage of their labour, representing a 2% need overall. We found 54% (49/90) postnatal women needed the geko™ device as their only method of thrombo-prophylaxis. Of these women, 94% (46/49) had postpartum haemorrhage (PPH) and 6% (3/49) had low platelets for which Dalteparin® was contraindicated. Sixteen percent (15/90) of the women with severe preeclampsia benefitted from the geko™ device antenatally during their admission as they were at risk of needing urgent delivery. Fourteen percent (13/90) of the women had severe oedema or high BMI resulting in TED stockings being impractical to use. Eight percent (7/90) of the women were deemed high risk therefore geko™ was used to aid their mobility. Two percent (2/90) women who had antenatal Dalteparin® used the geko™ device during labour. Only five women did not tolerate the device and subsequently discontinued.

Conclusions:

- The geko™ device studied was safe and well tolerated.
- The geko™ device is potentially useful as a method of thrombo-prophylaxis in high-risk obstetric patients where other pharmacological methods are contraindicated or impractical.
- In addition, compared to pneumatic sleeves, the geko™ device allows early patient mobilisation thereby reducing their VTE risk.
- Further studies with larger sample size will assist in development of clear protocol on the indications for use of the geko™ device in obstetrics.

4-5. The geko™ Device and VTE Prophylaxis with COVID-19

4-5a. Poster: Welsh Case Study/ geko™ device – product evaluation and Welsh supply chain logistics – an innovation case study. 2024. Available at: <https://www.gekodevices.com/wp-content/uploads/2021/04/An-Innovation-Case-Study-%E2%80%93-Covid-19-English.pdf>

Background: COVID-19 is a highly thrombotic syndrome that leads to both micro and macro-thrombosis and resultant multi-site embolism. Strict thromboprophylaxis has been widely indicated, but traditional anticoagulant therapy has, in some patients resulted in severe bleeding. This has led to an opportunity to explore other options to support the management of VTE in this patient population.

Aim: To undertake a clinical product evaluation of the geko™ device in patients with symptoms of COVID-19, and, to enhance the device manufacturer’s capabilities, resilience and sustainability within Wales.

Methods: The project is being delivered by way of two parallel strands and focuses upon the geko™ device and its use with COVID-19 patients.

Strand 1. A clinical product evaluation of the geko™ device in COVID-19 patients is being undertaken within Aneurin Bevan University Health Board (AB UHB). This device is being added to standard care and may reduce the risk of clot formation in this patient group without the risk of severe bleeds.

Strand 2. Involves seeding the work around optimising geko™ device manufacturing capability in Wales. This work will explore new processes and strategies to enhance the Welsh manufacturer’s capabilities through a sustainable Welsh supply chain and opportunities to enhance the manufacturing line.

Expected Outcomes: Include the following:

- Clinical data from the product evaluation
- Introduction of the geko™ device into ITU and acute respiratory unit for increased blood circulation, the prevention of venous thrombosis and, the prevention and treatment of oedema
- Consideration of changes to the clinical pathway for the management of COVID patients in the AB UHB
- Improved supplier assessment and procurement process with a focus on a developing a resilient and sustainable Welsh supplier base
- Iterations to the automated manufacturing process for the geko™ device
- Case studies and peer-reviewed publications with possible definitively powered randomised controlled clinical trial

- *Seeding of future work exploring use of the geko™ device in specific patient cohorts across Wales*

KEY LEARNING POINTS:

COVID-19 poses huge challenges to the clinical interventions required in supporting patients and in the delivery of the devices to aid clinicians. This requires a multidisciplinary approach, exemplified in this project with the involvement of Healthcare, Industry, Academia Health Board, schools of Medicine, Business and Engineering.

4-6. NEW The geko™ device and effects on somatosensory-evoked potential (SSEP) acquisition

4-6.a. Paper: Bohl MA, Newell CA, Shvarts V, Haque A. Neuromuscular electrical stimulation for venous thromboembolism prophylaxis and its effects on somatosensory-evoked potentials: a pretrial study of a new, U.S. Food And Drug Administration–approved device. *World Neurosurgery* Volume 144, December 2020, Pages e605-e611. Not open access.

Background: *Neuromuscular electrical stimulation (NMES) has emerged as a viable alternative for venous thromboembolism prophylaxis. The utility of NMES in preventing VTE in neurosurgical patients has yet to be adequately assessed in a clinical setting. The FDA recently approved the geko™ NMES device for use with high-frequency surgical equipment, thus permitting these devices to potentially be used intraoperatively for VTE prophylaxis. Electrical stimulation of the peroneal nerve using NMES may potentially interfere with the electrical activity of the brain that results from the stimulation of touch (somatosensory-evoked potential [SSEP] acquisition). This feasibility study evaluates a NMES, the geko™ device and its effect on SSEP acquisition as an initial step in a randomized clinical trial to assess NMES for intraoperative venous thromboembolism prophylaxis.*

Methods: *Healthy volunteers underwent SSEP testing during NMES in an outpatient setting. Concurrently, SSEP recordings of the posterior tibial nerve with stimulation at each ankle were obtained in 3 conditions:*

- sham: NMES in place but inactive
- ipsi: NMES active on leg ipsilateral to SSEP acquisition
- contra: NMES active on the leg contralateral to SSEP acquisition.

Nonparametric statistical methods, including repeated measures, were used for data analysis.

Results: *Stimulation intensities on the left, right, and bilaterally did not differ ($P \geq 0.20$). Strong positive correlations were noted between the ipsilateral geko™ stimulus pulse width and ipsilateral SSEP stimulation intensities (left: $r_s = 0.866$, $P = 0.001$; right: $r_s = 0.877$, $P = 0.001$). Women required significantly greater pulse width settings than men ($P = 0.01$). Finally, visual inspection of waveforms, as used during dynamic IONM, did not show any significant variations of P37 cortical waveforms during NMES.*

Conclusions: *As a preliminary step to testing NMES intraoperatively for venous thromboembolism prophylaxis, interference with SSEP acquisition was investigated in the outpatient laboratory setting. Within a small sample of healthy volunteers, no significant changes were seen in P37 cortical latencies to suggest interference between the NMES device and SSEP waveforms.*

Key Learning Points: This study provides the first analysis of NMES use during continuous SSEP monitoring. The authors state that these results demonstrate that the NMES geko™ devices are safe to use with SSEP monitoring. The planned Randomized Control Trial results are not yet searchable.

5. The geko™ Device and Edema Reduction

Please also see paper 3-1b. for the hypothetical correlation of geko™ effect on microcirculation and edema.

5-1 a-b. The geko™ Device and Post-operative kidney and pancreas transplant edema

5-1a. Poster: Alharbi B. Master's Thesis: The Effect of the Geko™ Device on Post Kidney and Pancreatic Transplantation Leg Edema. 2016. Western University, London, Ontario, Canada. (A poster presented earlier this same year contained data on only 93 patients and the results are slightly different). Thesis available at:

<https://ir.lib.uwo.ca/cgi/viewcontent.cgi?article=5927&context=etd>

Background: Kidney and pancreas transplant recipients undergo significant fluid shifts in the post-operative period leading to significant lower limb edema. Intermittent compression (IPC) devices are used to reverse the edema, however many factors may limit the use of IPC units.

Methods: prospective, randomized, controlled study where 101 patients were randomly assigned to wear IPC (Group 1, n= 55) or the geko™ device (Group 2, n=46) post-operatively until day 6 after surgery. Ultrasound Doppler of the allograft and of the lower limbs was carried out on post-operative days 1 and 5 to assess venous flow velocity in the

femoral vein in addition to monitoring total urine output, serum creatinine levels, patient weight and lower leg and thigh circumferences daily, and patient satisfaction on days 3 and 6 post-op.

Table of Results:

The use of the geko™ device in the immediate postoperative setting following a kidney or kidney and pancreas transplant results in a significant reduction in lower leg and upper thigh circumference, increased urine output and a concomitant increase in femoral vein velocity suggestive of improved circulatory blood flow. It was noted that geko™ device improved led to increased venous blood velocity which signifies an improvement in blood circulation and consequently a rise blood flowing through various organs; including the renal, thus leading to the increase in urine output. In addition, we demonstrate that patients had much higher satisfaction scores wearing the geko™ device compared to the IPC+TED, especially in terms of improved comfort, perception of decreased edema, improved post-operative sleep hygiene, and enhanced early mobility.

| Measurement | Group 1 IPC | Group 2 geko™ | Statistical Significance |
|---|----------------|-------------------|--------------------------|
| Increase in calf circumference from baseline | 2.3 ± 2.1 cm | 0.25 ± 1.2 cm | p<0.0001 |
| Increase in thigh circumference from baseline | 2.5 ± 2 cm | 0.5 ± 0.8 cm | p<0.001 |
| Increase in mean flow velocity | 21 ± 7 cm/sec | 28 ± 8 cm/sec | p<0.04 |
| Total Urine output in 6 days | 8,800 cc's | 17,900 cc's | P= <0.05 |
| Serum Creatinine | 270±29 umol/l | 240 ± 36.1 umol/l | No significance |
| Patient Satisfaction | Less satisfied | More satisfied | - |

Key Learning Points: *The MPA device improved blood flow to the renal allograft with higher peak systolic velocity in the renal arcuate artery (p=0.001) and higher femoral vein velocity (p=0.001). This corresponded to significantly higher urine output in the MPA group (p=0.003). Patients were more satisfied with the use of geko™ Plus device than TED+IPC and had an improved rate of edema reduction with the geko™ device. There were no complications because of the study in either group.*

5-1b. Shahid A, Alharbi B, Navaratnamb R, Sharma H, Luke PP, Sener A. Use of a muscle pump activator leads to improved lower limb edema, lower limb blood flow, and urine output compared with standard ted stockings and compression devices following kidney transplant: a randomized controlled trial. *Transplantation Proceedings*. 2019; 51(6): 1838-44. Available online 27 June 2019 <https://doi.org/10.1016/j.transproceed.2019.04.032>

Objective: *The aim of this study was to evaluate the effects of using thromboembolic deterrent (TED) stockings and intermittent pneumatic compression (IPC) vs a muscle pump activator (MPA) device on limb edema and patient satisfaction after transplant.*

Methods: *In this single-center randomized controlled trial, 118 patients were randomly assigned to wear TED + IPC (n = 64) or the MPA device (n = 54) from postoperative days 1 to 6. We measured patients' weight and lower leg and thigh circumferences daily. Ultrasonography of the allograft and lower limbs was carried out on postoperative days 1 and 5 to assess resistive index in the transplanted kidney and flow in the femoral vein. We monitored urine output and serum creatinine level.*

Results: *We observed a significant increase in calf and thigh circumference from baseline in the TED + IPC group but not in the MPA group (2.3 [SD, 1] cm vs 0.25 [SD, 0.8] cm, respectively, P < 0.002). Ultrasonography showed higher femoral vein velocities in the MPA group than the TED + IPC group (0.5 [SD, 0.2] cm, P < 0.001). The mean total urine output in 6 days was higher in the MPA group than the TED + IPC group (P = 0.05), which corresponded to large change in TED + IPC weight of 6.2 kg vs 2.1 kg in the MPA group (P = 0.04). Patients were more satisfied with the use of the MPA device than TED + IPC. Only 14% of patients receiving TED + IPC stated that they were comfortable with it, compared to 64% with the geko™ MPA device (p < 0.001). Fifty-seven percent of TED + IPC patients stated that they would use it in another surgery, versus 83% with geko™ (p=0.002). In regard to their ability to fall asleep with the devices on, 31% of the TED + IPC group reported device-related difficulties, compared to 16% of the MPA group. Mobility was positively impacted in the MPA group, where 73% reported an improvement in mobility compared to 43% in the TED + IPC group (p=0.002). No major complications were encountered in either group.*

Conclusions: *This is the first study to show that the use of an MPA device in the immediate post-operative period following kidney transplant leads to decreased post-operative lower limb edema and weight gain, increased total urine output and improved patient satisfaction compared to the standard of care (TED + IPC).*

Key Learning Points: The increased urine output in the first 6 days following transplant in ALL donor types. If it could be proven that use of the MPA device in the peri-transplant period could improve graft function rates and reduce the need for post-transplant dialysis treatments in DCD (Donation after Cardiac Death) kidney recipients, it would provide a previously unexplored therapeutic option for these patients.

5-2. The geko™ Device and Chronic Edema

5-2a. Paper: Ingves MV, Power AH. Two Cases of Transcutaneous Electrical Nerve Stimulation of the Common Peroneal Nerve Successfully Treating Refractory, Multifactorial Leg Edema. *Journal of Investigative Medicine High Impact Case Reports*. October-December 2014: 1–4. Available at: <http://journals.sagepub.com/doi/abs/10.1177/2324709614559839>

Methods: the geko™ devices were offered to two patients with leg edema that was not responding to other treatments. Case 1: CAD, 2 previous MIs, congestive heart failure, bilateral disabling lower-extremity edema and a right ankle ulcer for >1 year; cellulitis present on the right foot, extending to above the ankle; multiple varicosities and skin changes consistent with CVI and chronic lymphedema in both feet. Her arterial circulation demonstrated weakly palpable lower-extremity pulses and ABPIs mildly reduced. Duplex ultrasound showed deep venous reflux but no superficial venous insufficiency. Compression wrappings, exercise, and leg elevation did not effectively improve her pain or ulceration over the past year.

Case 2: complex left leg swelling and pain; Charcot left foot deformity, foot ulcers, and peripheral neuropathy secondary to diabetes Mellitus, previous right below-knee amputation secondary to complications of DFU; lower-extremity edema r/t significant cardiac history, renal failure, CVI and liver cirrhosis; 1-month history of left lower leg edema below the knee and no longer able to fit into his left leg brace and orthotic boot: developed significant pain that limited his ability to ambulate and elevate his leg for prolonged periods. The swelling in his left lower leg was maximal in the ankle and foot.

Results: 2 cases of multifactorial and refractory leg edema successfully reduced by 7 and 21% with the geko™ device over a period of 4 to 16 weeks.

Key Learning Points: In addition to helping resolve the multifactorial and refractory leg edema, the geko™ device also appears to have improved pain and chronic wound healing; both patients were able to resume leg elevation and exercise regimes, and in case 2, return to use of brace and orthotic boot for left leg/foot.

5-3. The geko™ Device and Occupational Leg Edema

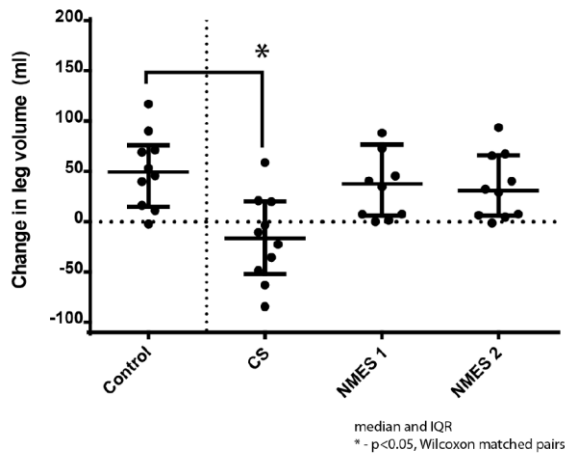
5-3a. Poster: Wou J, Williams KJ, Davies AH, 2015, A comparative study of the effect of graduated compression stockings and neuromuscular stimulation devices in the management of occupational leg edema. Annual Meeting of the Society-of-Academic-and-Research-Surgery (SARS), Publisher: WILEY-BLACKWELL, Pages: 28-28, ISSN: 0007-1323 <http://www.surgicalresearch.org.uk/wp-content/uploads/2014/12/PosterOfDistinction.pdf>

Paper: Wou J, Williams KJ, Davies AH. Compression Stockings versus Neuromuscular Electrical Stimulation Devices in the Management of Occupational Leg Swelling. *International Journal of Angiology*_2016; 25(02):104-109.

Thesis: Williams K. Section 6.6 NMES compared to graduated compression stockings for the management of edema. Neuromuscular Stimulation of the Leg. PhD Thesis, Imperial College London for the degree of Doctor of Philosophy. April 2017. Page 232 Available at: <https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf>

Method: 10 subjects (10 legs) were recruited from a clinical workspace, with no history of vascular disease. The right leg volume and great saphenous vein (GSV) diameter at the knee was measured in the morning, six hours later scans were repeated. On subsequent separate days, Grade 2 graduated compression stockings (GCS; medi, UK) for 6 hours, peroneal nerve neuromuscular stimulation (NMES 1) device geko™ T-1 (Firstkind, UK) for 4 hours, and footplate NMES 2 device Revitive™ (Actegy, UK) for 30 minutes were used bilaterally according to manufacturer's instructions. With the stockings and geko™ the person could be fully mobile, with the footplate they had to be stationary for the 30-minute duration.

Results: On the first day, leg volumes increased over 6 hours by median 41ml (IQR 7.7-74.0, $p < 0.05$) with no intervention. Percentage increase in leg volume was found to be significantly reduced by GCS compared to control (-0.52ml, $p < 0.01$). Although NMES devices did reduce leg volumes compared to control, they were not as effective as GCS and did not reach statistical significance. Percentage changes in GSV diameter poorly correlated with percentage changes in volume.



Graph used with Permission of Katie Williams.

Key Learning Points: Occupational edema can occur in as little as 6 hours in an office environment. In this small pilot study, all devices were well tolerated and reduced leg swelling, but GCS were the only device to statistically reduce leg swelling. Lyons et al. (2002) found that the effect of NMES is augmented by a factor of 2 when used in conjunction with GCS. Further studies evaluating NMES devices with and without compression are needed to better understand the role with compression versus without compression.

5-4. The geko™ Device and Orthopedic Edema

5-4a. Poster: Wainwright TW, Immins T, Middleton RG. An RCT comparing the effect of the geko™ device and TED stockings on post-operative edema in Total Hip Replacement patients. Physiotherapy UK, October 2014, Birmingham.

Paper: Wainwright TW, Burgess LC, Middleton RG. A feasibility randomised controlled trial to evaluate the effectiveness of a novel neuromuscular electrostimulation device in preventing the formation of edema following total hip replacement surgery. *Heliyon* 2018;4(7); e00697. Available at: <https://www.heliyon.com/article/e00697> Open Access article. Accessed October 30, 2018.

Aim: The aim of this feasibility study was to investigate the potential role of a novel neuromuscular electrical stimulation (NMES) device in preventing the formation of edema following total hip replacement (THR).

Methods: Successive primary THR patients were recruited into a randomised controlled trial to wear either the NMES (geko™ device [model not stipulated] or Thrombo Embolitic Deterrent stockings (TEDS) continually from post-surgery until discharge. They were used continually on bilateral legs post-surgery until discharge. The main outcome measure was presence of lower limb edema, assessed by taking measurements of the circumference of the ankle, knee and thigh on the operated leg and non-operated leg, pre-operatively, post-operatively, at two days postoperatively and every day until discharge. Secondary objectives were to compare adverse events, the presence of asymptomatic and symptomatic deep vein thrombosis (DVT) and device tolerability between groups. Analysis was done by considering the leg to be a stack of two truncated conical segments (ankle to knee is one conical segment, and knee to thigh second conical segment), and assuming knee location is half-way between ankle and thigh, the volume of each conical segment was calculated.

Results: Data from 40 participants were analysed (NMES (n= 20), compression stockings (n=20)). The NMES group had significantly less edema in the operative and non-operative limbs, and the device was found to be tolerable and safe. Although the ankle measurements increased post-operatively in the operative leg in both groups, the increase was smaller in the NMES group, but this was not statistically significant ($p = 0.27$). In the knee of the operated limb, there was a decrease in size for the NMES group, which alone was not significant. However, when compared to the increase in size for the compression stockings group, it was significant ($p = 0.02$). Similarly, in the thigh of the affected limb, the NMES group also had a non-significant decrease in size over pre-op, which became significant when compared to the increase in size experienced by the stockings group ($p = 0.02$). In calculations of volume, the TED group had ~ 3 times the volume increase post-operatively compared to geko™ ($p=0.03$). Of interest, in the unoperated limb, the change in limb volume for the TEDS group from pre-op to discharge was also ~ 3 times the volume of the geko™ group.

Conclusion: The results of this study suggest that the NMES is a safe and well tolerated alternative to compression stockings, which should be considered by clinicians seeking the additional benefit of reducing post-operative edema. In addition, the NMES device should be considered as part of a DVT prophylaxis.

Key Learning Points: The geko™ device has been shown to be significantly effective in managing post-operative edema in the knee and the thigh in the operative limb following Total Hip Arthroscopies compared to use of TED stockings, also benefiting the non-operative limb by reducing limb volume. There may also be a benefit with the geko™ device in reducing the risk of pressure injuries in this population, where edema causing a reduction in tissue perfusion plus reduced mobility pose a real threat to tissue integrity.

5-4b. Paper: Kocalkowski C, Pickford N, Bhosale A, Pillai A. The geko™ device: a novel treatment for the reduction of post-operative swelling following forefoot surgery. *Research*. 2014; 1:1272. Available at:

<https://www.gekodevices.com/clinical-study/paper-16/>

Methods: 40-year old female diagnosed with Hallux Valgus and had a right scarf and Akin osteotomy. Device was used for 10 days with daily patient review.

Results: The device was well tolerated and at 4 days post-operatively, swelling reduced significantly and Visual Analogue Scale (VAS) pain scores showed a clinically significant improvement from 8/10 to 1/10, (VAS 1-10: 0-no pain, 10-most pain). First day post-operatively the patient reported 8/10 pain, reducing to 5/10 on the second day post-operatively and 3/10 on the third day post-operatively. Both patient and surgeon reported they thought the device was extremely beneficial.

Key Learning Points: There was no discomfort or adverse effects, no difficulty sleeping with the device switched on and no disturbance with mobility. Treatment with the geko device demonstrated a marked reduction in swelling, following three days of consecutive treatment. There was a decrease in the patient's pain score using the Visual Analogue Scale.

5-4c. Poster: Baker P, Mahmood I, Chandler H, Anwar S, Eardley W, Rangan A. A pilot clinical study comparing the geko™ neuromuscular electrostimulation device, with current standard of care to evaluate edema reduction and readiness for theatre in patients requiring open reduction internal fixation following ankle fracture. *Trauma / Foot & Ankle Trauma / Surgical Treatment South Tees NHS Trust, Middlesbrough, United Kingdom*. Submitted to European Federation of National Associations of Orthopaedics and Traumatology (EFORT) 2018. http://gekodevices.com/wp-content/uploads/2018/04/pre-op_edema_abstract.pdf

Paper: Mahmood I, Chandler H, Kottam L, Eardley WS, Rangan A, Baker P. Neuromuscular electrostimulation device reduces preoperative edema and accelerates readiness for theater in patients requiring open reduction internal fixation for acute ankle fracture. *Techniques in Foot & Ankle Surgery*. 2020;19(4):215-219.

Background: Ankle swelling can delay surgical fixation (up to 7 days) due to risk associated with operating on swollen tissue, including wound dehiscence (complications) and subsequent infection. "Interventions that would reduce swelling and accelerate surgical fixation could provide significant benefits to patients and healthcare providers." Due to their unstable nature, ankle fracture patients may require open reduction internal fixation (ORIF). Typically requires up to 7 days of **inpatient** bed rest and elevation with a:

- Backslab plaster cast
- Backslab plaster cast + external fixation
- Backslab plaster cast + intermittent pneumatic compression.

"Sitting in a hospital bed for a week can be very frustrating and can also cause people to lose muscle mass."

Intervention: A prospective & retrospective, case control pilot study investigated the use of geko™ neuromuscular electrostimulation (NMES) device to reduce pre-operative edema in uni-, bi- and tri-malleolar fractures.

Method: Recruited ankle fracture patients requiring surgical fixation, fitting the geko™ (T-2) device above their backslab plaster casts. If the T-2 (27mA) device did not generate a satisfactory contraction, a R-2 (54mA) device could be used, but this was not needed as there were no nonresponders with the T-2 device. Results were compared to the current standard of care, as well as patient compliance and readiness to theatre, using a historical cohort for comparison, using age 5 required matches (\pm 5yrs, sex, ethnicity, fracture type [uni vs, bi/tri], dislocation at presentation).

Results: 20 patients. 2 pre-operative bed days saved on average per patient.

- 60% of patients ready for theatre in 2 days, compared to 27% in control arm, a 122% improvement.
- Current treatment = 3.66 days readiness to theatre (average).
- The geko™ device + plaster cast = 1.66 days readiness to theatre (average) (P=0.001)
- The geko™ device was well tolerated and easy to use; patients were more mobile and able to get out of bed compared to the ICP patients.

Conclusions: *Independent health economic modeling of this scenario suggests that the savings associated with*

this accelerated readiness for theater is £569 per patient. The NMES device is safe and well tolerated by patients with ankle fractures. It is easy to apply, can be worn continuously and does not restrict patients to their bed space. This study suggests that it is effective in reducing ankle edema and accelerating readiness for theater and may therefore allow earlier surgery and reduced length of stay in this patient group.

Key Learning Points: The NMES device can be safely used in ankle fracture patients in which soft tissue swelling does not allow immediate surgery or if this is not possible because of other factors such as theater availability.

5-4d. Paper: Zhao Y, Zhang B, Wang Y, Liu J. Effectiveness of Neuromuscular Electrical Stimulation for Enhanced Recovery After Total Hip Replacement Surgery: A Randomized Controlled Trial. *Geriatr Orthop Surg Rehabil.* 2022 Sep 23;13:21514593221129528. doi: 10.1177/21514593221129528. PMID: 36177369; PMCID: PMC9513569. Paper available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9513569/pdf/10.1177_21514593221129528.pdf Accessed April 14, 2023.

Background: The aim of this study was to investigate the feasibility of using a novel neuromuscular electrical stimulation (NMES) device for enhanced recovery after total hip replacement surgery.

Methods: Sixty patients undergoing total hip replacement for osteoarthritis of the hip were randomized and divided into 2 groups: 1 group received postoperative treatment with the NMES device, and the other group did not receive NMES. The primary outcome measures were postoperative pain, lower limb swelling, and length of stay (LOS) post surgery. Secondary outcomes included wound drainage at 24 hours and acceptability by the intervention of the device.

Results: Data from 60 participants were analyzed (NMES (n = 30), control group (n = 30)). Patients in the NMES group demonstrated a significant difference between the 2 groups of pain on Day 1 and Day 3 after the operation during mobilization (P < .05, respectively), although it equalized by Day 5. Post-operative calf swelling was less with the NMES group Days 3-5 (P < .05) but there was no effect on thigh swelling, and average length of stay from postoperative to discharge was shorter (6.9 ± 1.8 for the NMES group and 8.6 ± 2.0 for the control group (P = .002). However, wound drainage largely remained static for both groups. The overall comfort rate of the device was 93.3%.

Conclusions: The results of this study suggest that the geko™ NMES device is partly useful for enhanced recovery after total hip replacement surgery. In addition, the device should be considered tolerable and safe. A larger study is required with this device in the future to determine its effectiveness on compelling data.

Key Learning Points: In this study, NMES enhanced analgesia and diminution of post-operative swelling of the lower legs. Patients can get up, walk with walking aids indoors, get dressed, and do personal hygiene completely independently as early as possible, relieving burden on nursing staff. The results on LOS show that using NMES encourages mobilization and thus improves muscular strength and the achievement of discharge criteria early.

5-4e. Paper: Zhao X, Zhang J, Li Y, Nie Z, Wang W and Dong Y. Impact of geko neuromuscular stimulator on preoperative preparation in ankle fractures. *J Coll Physicians Surg Pak* 2024; 34(05):568-572. Available at: <https://jcpssp.pk/article-detail/pim-pact-of-geko-neuromuscular-stimulator-on-preoperative-preparation-in-ankle-fracturesorp> Accessed June 28, 2024.

Objective: To explore the impact of the geko™ neuromuscular stimulator on preoperative preparation in patients with ankle fractures.

Background: Some patients with closed ankle fractures miss the optimal surgical timeframe (6-8 hours post-injury) due to post-injury swelling, increasing anxiety for patients and lengthening the hospitalization.

Methodology: This quasi-experiment study included patients with ankle fractures treated with the geko™ neuromuscular stimulator device before surgical fixation. The geko™ device was applied to the affected lower leg below the knee to stimulate the common peroneal nerve for two-3 hour sessions per day with an interval of 8-10 hours between sessions. The article does not provide an explanation for choosing this particular geko™ treatment regime (frequency x duration). The devices were set to a level tolerated by the patients yet producing muscle contraction of the lower leg without discomfort to the patient. The primary outcome was limb swelling at 24, 48, and 72 hours after admission, and the secondary outcomes were pain according to visual analogue scale (VAS) at 12, 24, and 48 hours after admission, preoperative waiting time, and comfort level 4 and 72 hours after admission.

Results: A total of 60 patients were included in the study; 30 in the conventional treatment group (mean age 41.16 ± 2.01 years) and 30 in the geko™ group (mean age 40.22 ± 2.68 years). The swelling of the affected limb was significantly different between the geko™ and conventional treatment groups (p = 0.004), with swelling values at 48 (p < 0.001) and 72 (p < 0.001) hours significantly lower than those at 24 hours. The pain in patients was significantly lower for the

patients treated with geko™ and those receiving conventional treatment ($p = 0.007$). Comfort was significantly higher at 4 h (69.54 ± 2.18 vs. 67.22 ± 3.14 , $p = 0.002$) and 72 h [88.50 ($84.00 - 94.00$) vs. 82.14 ± 3.08 , $p < 0.001$] after admission for the patients treated with geko™. The preoperative waiting time (3.52 ± 1.8 vs. 5.15 ± 2.1 hours, $p = 0.002$) was significantly shorter in the geko™ group.

Key Learning Points: In this patient population having closed ankle fractures, use of the geko™ device to stimulate the common peroneal nerve, thereby causing muscle contraction of the lower leg, resulted in decreased traumatic swelling of the affected limb, decreased pain, increased comfort and shorter pre-operative waiting times.

6. The geko™ Device and Systemic Responses

6-1. The geko™ Device and Chronic Venous disease

6-1a. Poster: Williams KJ, Babber A, Ravikumar R, Davies AH. Pilot Trial of Neuromuscular Stimulation in The Management of Chronic Venous Disease. VEINS Conference. 2015.

Paper: Williams KJ, Davies AH. Pilot trial of neuromuscular stimulation in the management of chronic venous disease. VSGBI Abstracts from The Vascular Societies' Annual Scientific Meeting. British Journal of Surgery. 2015;102():20. Other results for this paper are found in section 3-2, section 8 for QoL results and section 9 for tolerance to the device.

Methods: 30 subjects with venous disease and 10 healthy controls were recruited. Bilateral geko™ devices (T1, FirstKindLtd, UK) were applied to the common peroneal nerve, at a pulse width to achieve dorsiflexion of the foot (1Hz, 27mA). Laser doppler fluximetry (non-invasive measurement of microcirculation) was measured from the left hand and foot.

Table of Results: Change in Laser Doppler Fluximetry Reading with bilateral geko™ devices

| Percentage Change | Healthy | Superficial CVI | Deep Insufficiency | Deep Obstruction |
|-------------------|---------|-----------------|--------------------|------------------|
| Left Leg Flux | 275** | 265* | 69 | 47* |
| Left Hand Flux | 84** | 71* | 24 | 107* |

* $P < 0.05$, ** $p < 0.01$ single t-test

Key Learning Points: NMES with the geko™ device to both legs improves blood supply to the skin of the foot, and has a systemic effect as evidenced by a statistically significant change to the fluximetry readings to the left hand in patients with superficial CVI and CVI with deep obstruction. There is no explanation as to why those with deep insufficiency did not also show a statistically significant improvement.

6-2. Effect of geko™ and Coronary Blood Flow / Ejection Fraction

Please also see section 3-1b. for THRIVE study results for geko™ prototype results for Cardiac results: Arterial Peak flow, Left ventricular outflow tract velocity [LVOT-VTI], Ejection fraction, Left ventricular diastolic volume, E' velocity, Deceleration time and E' Lateral).

6-2a.i. Poster Abstract: Lavi S, Alemayehu M, McLellan A, D'Alfonso S. Peripheral Muscle Stimulation Increases Coronary Blood Flow. JACC 2015; 65(10S); A1841. Poster abstract available at:

http://www.onlinejacc.org/content/65/10_Supplement/A1841/F1 Poster available at:

https://www.gekodevices.com/us/wp-content/uploads/2020/06/0166_lavi_et_al_peripheral_muscle_stimulation_increases_coronary_blood_flow_mpdpo0166.pdf Poster results reported in paper below.

6-2a.ii. Paper: Camuglia AC, Alemayehu M, McLellan A, Wall S, Abu-Romeeh N, Lavi S. The impact of peripheral nerve stimulation on coronary blood flow and endothelial function. Cardiovascular Drugs Ther. 2015;29: 527-533. Paper available at: <https://www.gekodevices.com/wp-content/uploads/2020/06/0253-Lavi-et-al-The-impact-of-Peripheral-Nerve-Stimulation-on-Coronary-Blood-Flow-and-Endothelial-Function-.pdf>

Methods: Peripheral blood flow studies were measured at baseline and after one hour of exposure to geko™ T-1 device (27mA) with 2D and Doppler derived ultrasound estimation of popliteal artery flow (artery area and velocity). At the same visit, endothelial function was assessed at baseline and after one hour of geko™ activation, by measuring the peripheral vasodilator response using fingertip pulse amplitude tonometry (PAT).

Coronary flow velocities were measured using a 0.014" Doppler tipped flow wire into the coronary vessel (undiseased vessel and stenosed vessel), recording average peak velocity (APV) at baseline, with geko™ T-1 on low pulse width setting (a visible muscle twitch) x 2 minutes and with geko™ on maximum setting for another 2 minutes (total of 4 minutes with geko™ activated). Sample Size was 10.

Table of Results (from Paper):

| Test | | Results with geko™ (Increase) | | | Summary/ Significance |
|---|-----------------------------|------------------------------------|--|-----------------------------|--|
| | | Baseline | Minimal Twitch X 2 minutes | Maximum Setting X 2 minutes | |
| Coronary Blood Flow-stenosed vessel | Average Peak Velocity (APV) | 21.9 ± 12 cm/s | 23.9 ± 12.9 cm/s (unclear which setting) | | No significant difference p=0.23 |
| | Coronary Flow Reserve (CFR) | 2.2 ± 0.9 cm/s | 1.9 ± 0.3 cm/s (unclear which setting) | | No significant difference p=0.4 |
| Coronary Blood Flow-Control (undiseased vessel) | Average Peak Velocity (APV) | 20.3 ± 7.7 cm/s | 21.0 ± 8.3 cm/s | 23.5 ± 10 cm/s | Statistically Significant increase (15.8%) P=0.03, perhaps r/t increased venous return |
| | Coronary Flow Reserve (CFR) | 2.2 ± 0.6 cm/s | 2.4 ± 0.6 cm/s (unclear which setting) | | No significant increase P=0.4, think that longer duration |
| geko™ x 1 hour at Separate Appointment | | | | | |
| Systemic Endothelial Function | Rh-PAT* index | 2.28 ± 0.39 | | 2.67 ± 0.6 | Statistically significant increase with geko™ activation P=0.045 “Represents a potentially disease-modifying mechanism” |
| Peripheral Blood Flow | | Increased in all patients except 1 | | | No significant increase P=0.13; thought to be a Type 2 error r/t small sample size |

*Rh-PAT=Reactive hyperemia-peripheral arterial tonometry

Key Learning Points: Compared to baseline, there was a significant increase in coronary blood flow as measured by average peak velocity (APV) in the control vessel with nerve stimulation and non-significant increase in the stenotic vessel. Coronary flow reserve did not change significantly.

Endothelial dysfunction continues to emerge as a key causative mechanism in coronary vascular disease. Patients with documented endothelial dysfunction have been demonstrated to have a higher preponderance of adverse cardiovascular events. The effect of geko™ to improve the RH-PAT index, a previously validated method of endothelial function assessment, represents a potential disease modifying mechanism given the association between endothelial dysfunction and adverse clinical outcomes. The effect on endothelial function was beyond an effect on blood pressure that was similar at baseline and following one hour of nerve stimulation. A few minutes of peripheral muscle stimulation may improve coronary blood flow. The effect of longer duration of stimulation on coronary flow and angina should be further studied.

6-2c. Paper: Bain DS, Jawad H, Adams K, Mathur A, Johnston A, Tucker AT. Isometric stimulation of lower leg via transdermal electro-stimulation of the common peroneal nerve improves Heart Ejection Fraction in Healthy Volunteers. Unpublished paper courtesy of Firstkind Ltd. William Harvey Research Institute, Barts and The London School of Medicine and Dentistry, Queen Mary University, London, UK. 2011.

Aims: To determine the effects on cardiac function of a device delivering painless neuromuscular stimulation of the lower leg.

Methods: Nine Healthy volunteers were given bilateral 3Hz transdermal electrostimulation with a custom-built stimulator (pre-geko™) with two different pulse widths (400µs & Box 2: 600µs) via the common peroneal nerve in the lower leg, causing isometric contractions of muscle structures in the lower leg surrounding the soleus valve pump.

Results: Echocardiogram measurements of ejection fraction (EF) using Simpson’s method showed an augmentation of 4.5%, and Left Ventricular Outflow Tract Time Integral (LVOT vti) increased by 6% relative to baseline (p=0.02). In addition, skin blood flow as measured by Laser Doppler Flowmetry (LDF) showed a 14-fold increase (p < 0.0001) relative to baseline.

Conclusion: *The increase in ejection fraction in healthy volunteers using transdermal electro-stimulation was of a similar level to those achieved by pharmacological interventions used in the treatment of patients with heart failure. Thus, if the increase in cardiac performance seen in the healthy volunteers can be translated to patients with heart failure, isometric neuromuscular stimulation of the lower leg may well have a beneficial role to play in treating heart failure.*

Key Learning Points: There may be physiological cardiac benefits when using the geko™ device. The possible role in treating heart failure requires further exploration.

6-3. Effect of the geko™ Device in Reducing Hospitalization And Improving Graft Function Post-Renal Transplantation

6-3ai. Oral Poster: Yan Xie W, Levine M, Aquil S, Pacoli K, Al-Ogaili R, Luke P, Sener A. Daily use of a muscle pump activator device reduces hospitalization and improves graft function post-transplantation: A randomized controlled trial. *Can Urol Assoc J.* 2019;13(4Suppl3):S31-41. Available at: <http://dx.doi.org/10.5489/cuaj.5974> Published online April 8, 2019. Results described below.

6-3aii. Poster: Xie W, Aquil S, Pacoli K, Al-Ogaili R, Luke P, Sener A. Daily use of a muscle pump activator device reduces hospitalization and improves graft function post-transplantation: a randomized controlled trial. *Am J Transplant.* 2019; 19 (suppl 3). Available at: <https://atcmeetingabstracts.com/abstract/daily-use-of-a-muscle-pump-activator-device-reduces-hospitalization-and-improves-graft-function-post-transplantation-a-randomized-controlled-trial/> Accessed March 27, 2020.

Methods: *In this single center, prospective, randomized-controlled trial, 221 kidney or SPK transplant recipients (Donation after Neurological Death=109, Living Donor=52, Donation after Cardiac Death=60) were randomized as above to either wearing TED/IPC or MPAs for 7 days post-operatively. Post-operative care and discharge planning was performed by an independent nephrology team. Groups were compared with respect to days in hospital, post-operative lower limb edema, weight, mobility, urine output, serum creatinine, delayed graft function (DGF), need for dialysis, renal blood flow and incisional wound healing.*

Results: *Patients assigned to wear the MPA device were found to have a significantly shorter hospital stay compared to the TED/IPC group (8.15 vs 9.36 days, p=0.038).*

Changes in mid-calf leg circumference and patient weight were significantly lower in the MPA group (p=0.001 and p=0.003, respectively). The TED/IPC group were overall less mobile with less total steps recorded on a pedometer (p=0.009). The MPA device improved blood flow to the renal allograft with higher peak systolic velocity in the arcuate artery (p=0.001) and higher femoral vein velocity (p=0.001). There was significantly higher urine output in the MPA group (p=0.003) but objective measures of renal function, including frequency of DGF, number of dialysis runs, and serum creatinine, were not different between the two groups.

Conclusions: *Postoperative use of the MPA device decreases duration of hospitalization after kidney transplantation. This may be attributable to improved renal blood flow to the transplant allograft and thus increased urine output and decreased fluid retention. Better post-operative mobility likely reduced the risk of developing DVTs and other complications.*

Key Learning Points: Patients assigned to wear the MPA device were found to have a significantly shorter hospital stay, and to have improved blood flow to the renal allograft with higher peak systolic velocity in the arcuate artery (p=0.001) and higher femoral vein velocity (p=0.001). There was significantly higher urine output in the MPA group (p=0.003).

6-4. The geko™ Device and Diabetic Peripheral Neuropathy

6-4a. Paper: Williams K. Section 7.4 NMES in the management of diabetic peripheral neuropathy (NERVES). Neuromuscular Stimulation of the Leg. PhD Thesis, Imperial College London for the degree of Doctor of Philosophy. April 2017. <https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf>

Methods: Subjects using the geko™ T-1 (27mA) device were asked to wear the devices for 4 or more hours per day, 5 times a week, and asked to keep a diary of usage. The device was applied bilaterally with the stimulation level set to the minimum level that can achieve outward and upward twitching of the foot when raised from the ground. Subjects allocated to “no device” continued with management regimes as prescribed by their physician. Nerve conduction velocity was measured at baseline and at 10 weeks as well as Haemodynamic ultrasound measurements taken in the femoral vessels (baseline and device on), quality of life questionnaires (PAID, MNSI, NTSS-6, EQ-5D, SF-36), tolerability scores (VAS, VRS), and device usage diary.

Results: 9 individuals to geko™ device; 5 to control (no geko™). 5 subjects (56%) allocated to device were unable to elicit a twitch to stimulation.

QoL: Only those in the device group showed a statistically significant decrease in diabetes symptom severity ($p < 0.05$) in 1 disease-specific QoL tool, the “Problem Areas in Diabetes” (PAID) tool. There was no significant change in either the Neuropathy Total Symptom Score-6 (NTSS-6) or the Michigan Neuropathy Screening Instrument (MNSI), or any of the generic quality of life questionnaires after the 10 weeks. Improvement in both groups functional (particularly psychological) scores suggest a confounding Hawthorne effect. Overall, no change in generic quality of life was seen in either group.

Hemodynamics: Velocity and volume flow increased with geko™ devices on both legs. Percentage increase from baseline in arterial parameters were comparable to healthy subjects, but venous parameters were much reduced in those with diabetic neuropathy (See Table of results below). *This may represent a vastly different baseline (e.g. resting venous tone), or a physiologically different response to stimulation (e.g. differences in arteriovenous sphincter reactivity, or restricted venous inflow through calcified microcirculatory channels).*

Table of results: Absolute and % Changes from Baseline in Subjects with Diabetic Neuropathy with geko™ T-1 device (adapted from Thesis Table 46 page 315)

| Parameter Measured in Femoral Vein and Artery | Mean | SD | % change from Baseline (n=5) |
|---|-------|------|------------------------------|
| Arterial Peak Velocity [PV] (cm/s) | 11.53 | 9.2 | 14.15% |
| Arterial Time Averaged Maximum Velocity [TAMV] (cm/s) | 2.82 | 1.9 | 222.17% |
| Arterial Volume Flow [VF] (ml/min) | 92.14 | 74 | 209.60% |
| Venous Peak Velocity [PV] (cm/s) | 4.09 | 9.8 | 31.19% |
| Venous Time Averaged Maximum Velocity [TAMV] (cm/s) | 0.63 | 2.8 | 15.41% |
| Arterial Volume Flow [VF] (ml/min) | 36.89 | 67.4 | 32.82% |

There was a lack of microcirculatory changes with the device (n=6), with Laser doppler fluximetry values in the foot showing a 16% increase, and the hand a 19% increase, neither statistically significant.

Final Nerve conduction study data missing for 6 of the 14 subjects: Large mixed nerves and sensory nerves tested: no statistically significant difference in conduction velocities across the protocol in either group

Key Learning Points:

This small study could not demonstrate any physical evidence of improvement of nerve conduction velocity with use of the geko™ device, yet we continue to hear from our patients that their neuropathic symptoms are diminished when using the geko™ device, and their ability to feel normal touch returns. Further research using validated tools and nerve conduction studies is needed if we are to understand the effect of geko™ on Neuropathic Pain.

7. The geko™ Device and Wound Healing

7-1. The geko™ Device and recalcitrant wounds with PVD

7-1a. Paper: Williams KJ, Davies AH. The use of a novel neuromuscular electrical stimulation device in peripheral vascular disease. *Int J Case Rep Images* 2014;5(11):744–747. Paper available at:

<https://www.ijcasereportsandimages.com/archive/2014/011-2014-ijcri/CS-10048-11-2014-williams/ijcri-1004811201448-williams.pdf#sthash.IVO6xFjf.dpuf>

Methods: Three cases include the management of recalcitrant ulcers, non-reconstructable critical limb ischemia, and an infected arterial bypass graft. Case 1: unilateral device to affected leg 24 hours per day x 14 days; had to stop due to rash under device. Case 2: unilateral device to remaining limb, wore it for 6–10 hours per day for six weeks. Case 3: devices were applied bilaterally and activated continuously for two weeks.

Results: Although no patients wore devices complete to healing, improvement in various dimensions were reported; improved wound appearance, decreased wound depth and a reduction in surface area of 71% in Case 1, with complete healing after 4 more weeks; Case 2 had a slight reduction in leg volume (3.4%), had improvement in 2/3 Quality of Life surveys, had increased motivation to leave the house in his wheelchair; Case 3 had reduction in edema while device was used, healing of wounds at 6 weeks.

Key Learning Points: *Neuromuscular electrical stimulation (NMES) can potentially enhance peripheral circulation in vascular patients. Difficult or recalcitrant vascular cases may benefit from it as an adjunct to best medical care. NMES has few side effects and may be especially useful where polypharmacy is an issue. The incidence of a skin reaction may necessitate device discontinuation.*

7-2. The geko™ Device and Venous Leg Ulcers and Lower Leg Wounds **Update 7-2s. New-7-2.t-v.**

7-2a. Poster Wounds Canada Conference: Stimulating Non-healing Venous Leg Ulcers: Evaluation of Innovative New Muscle Pump Activator. May 2017. (same authors and results as paper).

Paper: Harris, C, Loney, A, Brooke, J, Charlebois, A, Coppola, L, Mehta, S, Flett, N. Refractory venous leg ulcers: observational evaluation of innovative new technology. International Wound Journal. 2017. 14;6: 1100-1107. Available at: <http://onlinelibrary.wiley.com/doi/10.1111/iwj.12766/epdf>

Background: Introducing more advanced therapies in combination with compression may reduce total treatment costs and shorten the length of time to closure for chronic, non-healing Venous Leg Ulcers (VLUs).

Aim: To determine the wound-healing response to the geko™ device as an adjunct to standard of care for patients with non-healing VLUs and if the technology should be made available for routine care in the community setting.

Methods: Clinically challenging and complex VLU patients whose wounds had failed to heal within 24 weeks of standard therapy consented to evaluate the geko™ device as an adjunct to standard of care, in 2 Community Access Centres in Ontario, Canada. The geko™ T-2 (27 mA) devices were applied to both legs for 6 hours per day 5 days per week, during a period where the patient could be sitting some of the time in order to get the largest therapeutic response to the stimulation. During the course of the evaluation, the devices were replaced by the new generation, higher powered R-2 (54mA) devices.

Results: Eleven patients consented to the evaluation with a combined 107-year history of recalcitrant, leg ulcers. Although the pre-geko™ healing rate was unknown, all were considered non-healing. The average weekly % change in surface area (SA) for the 28 measured wounds was a 4.5% reduction (range of -3% to 40%). Two circumferential leg wounds in one patient were never measured. Six patients (54%) with 16 wounds were adherent to geko™ and best practice wound care had a 7% reduction in SA per week. In retrospect, one patient who was adherent to care was likely not healable, having been offered amputation prior to the evaluation. By removing her data, the average weekly percentage change for adherent, healable patients was 7.6% (reduction). By comparison, the average weekly percentage change for wounds in the 5 (46%) non-adherent patients with 12 measurable wounds was 1.82% (reduction). Four of the five were withdrawn from the evaluation, and returned to previous standard of care

Key Learning Points: Provisos for success appear to include an arterial status adequate for healing, effective and prompt management of wound infections and that the patient is adherent with the treatment schedule. Importantly, patients or family members quickly mastered use of the device.

7-2b.i. Poster Evaluation of an Exciting Neuromuscular Electrical Stimulation Device for Non-Healing Venous Leg Ulcers. May 2017 Wounds Canada Conference. Results presented in paper below.

7-2b.ii. Paper: Harris, C, Duong, R, van der Heyden, G, Byrnes, B, Cattryse, R, Orr, A, Keast. Evaluation of a muscle pump-activating device for non-healing venous leg ulcers. International Wound Journal. 2017. 14;6: 1189-1198. Available at: <http://onlinelibrary.wiley.com/doi/10.1111/iwj.12784/epdf>

Background: Healing of Venous leg ulcers (VLUS) can take from 6 months to many years, with recurrence rates up to 69%, all with incremental increases in cost.

Aim: The aim was to evaluate and determine if the geko™ is effective in this population and if it should be added to the medical supply formulary.

Methods: Patients with non-healing VLUS were recruited from two participating Community Care Access Centres in the province of Ontario, Canada. They were followed for up to 20 weeks, until the wounds healed, they chose to discontinue the device, or the evaluation finished. Three patients continued with the device past the 20 weeks. The geko™ devices were to be applied to both legs for 6 hours per day 5 days per week, during a period where the patient could be sitting some of the time in order to get the largest therapeutic response to the stimulation.

Results: Twelve patients with eighteen VLUs recalcitrant to treatment consented to evaluate the geko™ R-2 (54mA) device. Forty-four percent of the wounds healed, 39% decreased in surface area. One patient who was non-adherent with geko™ and best practices had wound deterioration in their three wounds. The average weekly wound healing rate at baseline, prior to the geko™ evaluation was 0.06% (±SD 0.10); with the device, it increased to 9.35% (±SD 0.10) P <0.01. Three patients who were not in optimal compression at baseline could start or increase the existing levels of compression therapy due to decreased pain, further enabling healing (compression therapy being the key intervention in treating VLUS).

Key Learning Points: This evaluation provided an opportunity to evaluate the effectiveness of the geko™ device on the hard-to-heal venous leg ulcer population. The weekly healing rate with geko™ was 9.35% (±SD 0.10) compared to 0.06% (±SD 0.10) before using geko, this result is highly significant with a P-value of <0.01.

7-2c.i. Poster: Harris C, Ramage D, Bolorochi A, Vaughn L, Kuilder G, Sandcroft W. Using a Neuromuscular Electrostimulation Device for Non-healing Lower Leg Wounds in Long Term Care Residents. May 2017. Wounds Canada Conference. Results presented in paper below.

7-2c.ii. Paper: Harris C, Ramage D, Bolorochi A, Vaughan L, Kuilder G, Rakas S. Using a muscle pump activator device to stimulate healing for non-healing lower leg wounds in long term care residents. *IWJ* 2019;16(1):266-274.

Open access available at: <https://onlinelibrary.wiley.com/doi/epdf/10.1111/iwj.13027>

Aim: The objective of this Long-Term Care (LTC) Innovation pilot was to test the value of a promising new neuromuscular stimulation device in elevating the experience and satisfaction of the residents; engaging and empowering the nursing staff; and improving healing and/ or reducing costs.

Methods: Nurses in four LTC homes identified residents with non-healing lower leg wounds. Consent was obtained, and on-site training was delivered in use of the geko™ R-2 (54mA) devices.

Results:

In the sector, eleven residents in 4 long term care homes in Ontario and Manitoba were evaluated with the geko™ device in 2016. Three residents had Diabetic Foot Ulcers (DFU), 3 had Venous Leg Ulcers (VLU) with lower leg edema, and 2 had pressure ulcers on the heel of the foot. 2 wounds were thought to be venous by staff but had atypical wound appearances; one with a suspicious dense granular surface and one with scattered bleeding superficial wounds over much of the anterior calf. All wounds were considered non-healing. The combined duration of the wounds was 13.7 years, the mean was 1.2 years per resident prior to starting the geko™ evaluation. The Ankle Brachial Pressure Index (ABPI), an indicator of peripheral arterial circulation was not available for most residents. The initial wound measurements and date of occurrence were available for 7 residents with 10 wounds, showing an average pre-geko™ weekly change in Surface Area (SA= Length x Width = cm²) of -7.35%, an increase in size. With use of the geko™ device, the average weekly percentage change in wound size for the wounds that were measured was a statistically significant 3.2% decrease in SA (p=0.004), and 11.5% (P = 0.00075) in residents who were adherent to geko™ and best practices. Nursing staff and cognitively intact residents can easily adjust the pulse of muscle pump activator, application and removal are simple. Most residents feel engaged with the therapy, “because they feel it working”. The LTC corporation feels that it’s a great adjunctive solution for many types of lower leg wounds (venous, mixed, diabetic, pressure) in addition to best practices in the LTC and Retirement home sectors.

Key Learning Points:

This is the first paper that illustrates use of the geko™ device enhancing healing in recalcitrant pressure injuries and diabetic foot ulcers in the Long-Term Care sector, and in residents with dementia. The four residents with six wounds who were adherent to available best practices and use of the MPA device showed an even higher significance of 11.5% weekly average decrease in SA, compared with their pre-MPA weekly average increase in size of -1.26% (P = 0.00075). These healed with an average time to healing of 10 weeks (range of 8-17 weeks).

7-2d. Poster: Sutor M. Adjunctive application of a muscle pump activator to improve blood flow in patients with lower limb ulcerations related to chronic venous insufficiency. Alberta Health Services. Moving Forward in Wound Management Conference: Engaging Learners, Motivating Change, and Inspiring Action. September 8, 2016. Poster available at: [https://www.gekodevices.com/wp-content/uploads/2018/04/adjunctive application of a muscle pump activator to improve blood flow in patients with lower limb ulcerations related to chronic venous insufficiency.pdf](https://www.gekodevices.com/wp-content/uploads/2018/04/adjunctive-application-of-a-muscle-pump-activator-to-improve-blood-flow-in-patients-with-lower-limb-ulcerations-related-to-chronic-venous-insufficiency.pdf)

Methods: The geko™ device was applied to three ambulatory wound clinic patients with mixed etiology lower extremity wounds and a history of chronic venous insufficiency. The device was applied to both legs over the common peroneal nerve for 6 hours per day; 5 days per week, during their daily period of greatest inactivity. This was done until wound closure was achieved and for up to one month following to help ensure a more robust healing after closure.

Results: All wounds attaining full closure and remained healed one month after the device trial was completed. Each patient demonstrated an individualized pattern of wound healing; however, healing times were expedited compared to baseline. Secondary findings included a reduced lower leg edema, improvement in subjective pain, a softening of woody fibrosis and an improvement in skin color.

Results: All wounds attaining full closure and remained healed one month after the device trial was completed. Each patient demonstrated an individualized pattern of wound healing; however, healing times were expedited compared to baseline. Secondary findings included a reduced lower leg edema, improvement in subjective pain, a softening of woody fibrosis and an improvement in skin color.

Key Learning Points: Lower extremity wounds are a challenge to the patients’ who live with them and to the health care teams developing a treatment plan. Use of NMES provides another opportunity to better address health concerns and promote positive patient outcomes.

7-2e.i. Poster: Ivins NM, Jones NJ, Hagelstein SM, Walkley NA, Harding KG. An evaluation of a neuromuscular electro-stimulation (NMES) device* on patients with differing lower limb wound etiologies. CBE Welsh Wound Innovation Centre. Presented at EWMA 2016. (Initial 10 patients).

7-2e.ii. Paper: Jones NJ, Ivins N, Ebdon V, Hagelstein S. Harding KG. A case series evaluating the geko™ neuromuscular electrostimulation device on lower limb wounds of differing etiology. British Journal of Nursing 2018, 27(20): S16-S21. TISSUE VIABILITY SUPPLEMENT.

Aims: *The purpose of this case series was to evaluate the therapeutic effect of the geko™ NMES device on wound healing outcomes over an 8-week period.*

Method: *Thirty patients with non-healing wounds (> 3-month duration) of either venous (VLU), mixed (MLU) or diabetic foot (DFU) etiology were recruited from a local Outpatient Wound Clinic in the South Wales area. All patients received standard of care plus geko™ (model not stipulated but thought to be R-2).*

Results: *During the eight-week period two participants (8%) achieved complete re-epithelialisation between baseline and endpoint. Mean wound surface area decreased over time (7.6 cm²) and an increase (21%) in the mean percentage of granulation tissue was observed in the wound bed. Pain levels reduced in 52% of patients who completed the study but the extent of edema reduction was difficult to establish given the fact that 76% of the cohort were treated with a form of compression as part of routine standard care.*

Conclusion: *These findings support the use of geko™ NMES therapy in patients with painful venous (VLU) and mixed leg ulceration (MLU) but further high-quality research needs to be conducted on the generalizability of these findings to the wider population of patients burdened with chronic wounds of differing aetiology in the lower limb.*

Key Learning Points: It was not stated how many hours per day the geko™ device was worn, or which device was used. The standard now is to use the geko™ Wound Therapy device 12 hours per day. Because there was not control group, there was no statistical significance to the 52% of patients reporting a reduction in their wound-related pain, but this encouraging result would mean a reduction in use of analgesia and quite likely perceived quality of life.

7-2f. Waterloo Wellington CCAC/ LHIN evaluation. Perfuse Medtec Inc. Stream 1 unpublished data 2018. Stream 2: Poster: Harris C. Thinking Outside of the Box: Examining the Use of an Adjunctive Therapy to Speed Healing and Shorten Length of Stay for Community Patients with New Venous Leg Ulcers. Wounds Canada Spring 2018 Winnipeg, MB.

https://www.gekodevices.com/wp-content/uploads/2018/07/Thinking-Outside-the-Box-April-25_18.pdf

Methods: Two streams of patients were used to evaluate the effect of the geko™ R-2 (54mA) device on lower leg wounds: Stream 1 for patients with wound which have not reduced in size by 30% with best practices within 30 days of admission (existing patients), and Stream 2 for newly admitted patients with VLUs < 3 months in duration since onset. The geko™ devices were to be applied to both legs for 6 hours per day 5 days per week, during a period where the patient could be sitting some of the time in order to get the largest therapeutic response to the stimulation.

Results:

Stream 1 (> 30 days on service) Demographics and Healing Rates prior to the geko™ device Evaluation:

- 9 Evaluation positions were used by 8 patients (# 2 and 4 same patient) for an approximate total of 62 weeks of therapy.
- The 10th position was not filled
- 5 wounds with measurements present at baseline in 5 patients; three more wound measurements not available and a ninth patient evaluated for lymphedema reduction had not actual open wounds, just dermatitis and scratches. An additional wound opened during the evaluation in one patient but closed in one week.
- The largest wound was 240 cm² (SA=L x W) at baseline, circumferential around leg. That patient has been on service since 2012; first wound measurement available from March 2013
- The average length of stay prior to geko™ implementation = 42.5 weeks (range 6 weeks to 208)
- The average weekly change in wound size pre-geko™ = -3.04%/ week (increase) with a range of -36% (increase in size) to 10% reduction in size

Stream 1 Results with the geko™ device:

- Three wounds in 2 patients closed during the evaluation with an average of 4 weeks per wound (range of 7 days to 6 weeks)
- The average weekly change in wound size with the geko™ device for 7 measured wounds in 5 patients was a 6.5% reduction per week (Image 1).

- The patient with lymphedema had a remarkable reduction in edema measurements within the first 10 days of treatment, where there were no other changes to his compression system that would account for this.

Stream 2 (< 30 days) Patient demographics and healing rates prior to the geko™ device:

- 10 patients with 16 wounds on admission; at baseline: 21 wounds.
- Largest wound 6.75cm² (SA=L x W) which was also the deepest wound was 0.5 cm deep at baseline
- Average length of stay prior to geko™ implementation = 22.6 days
- Average weekly change in wound size pre-geko™ = -79.29% (increase) with a range of -618% (increase in size) to 27.7% decrease.

Stream 2 Results with the geko™ device:

- 16 wounds in 9 patients closed –
- Average healing time of 3.03 weeks per patient (range of 5 days to 9 weeks);
- 20% healed in 1 week, 30% healed in 2 weeks, 70% healed in 4 weeks, 80% at 8 weeks, 90% at 9 weeks. One patient (10%) with recurrent infections (x 4) not healed at 17 weeks and device discontinued.
- Average weekly change in wound size with the geko™ device for all patients= 36.54% reduction SA or Volume per wound (range of 2.29 % to 100%).

Key Learning Points: The average pre-geko™ time on service of 23 days plus the average healing time of 21 days was less than half that provided for healing in Ontario’s Venous Leg Ulcer Outcomes Based Pathway (14 weeks). These results seem to support earlier use of the MPA device as a first-line adjunctive therapy treatment from both an efficacy and economic perspective, and may prevent new patients from developing chronic, non-healing wounds.

7-2g. Poster: Rabley-Koch C. A., Duong R, Cadavez R, Attard J, Entredicho A, Oshalla H, Orr A, Ramage D, Burrows C. Early Intervention with the geko™ device for Venous Leg Ulcers Predicted to Not Heal Within 24 Weeks. Presented at: Wounds Canada (Online) 2020. Available at: <https://www.gekodevices.com/wp-content/uploads/2020/11/Poster-0041-WC-Early-Intervention-with-the-geko-device-for-Venous-Leg-predicted-not-to-heal-within-24-wks-FINAL.pdf>

Aim: Quality Improvement Initiative aimed at enhancing policies and procedures so that patients can receive the most timely and effective practice to ensure or achieve better outcomes.

Procedure/ Method: Earlier use of the geko™ device was employed on patients whose venous leg ulcers (VLU) that had an elevated risk of failure to close within 24 weeks. Patients were admitted to community clinic settings at 2 Ontario nursing agencies. Eleven patients were assessed twice over two weeks using a Validated Leg Ulcer Risk Assessment tool (VLURA). Moderate to high risk scores had geko™ devices added to their standard of care for a maximum of 12 weeks. Low scores were reassessed in two weeks; those increasing to moderate were started on the geko™ device.

Findings: Frequent delays in the geko™ device initiation were related to a routine LHIN (Local Health Integration Network) policy need to access vascular studies • An average of 48.9 days elapsed between admission to device application • Ten out of eleven patients experienced increased risk scores within the two weeks between initial and follow-up visit • Preliminary results indicate a total of 12 wounds in 11 patients (80%) healed • 2 wounds (13%) remained open with an average decrease in size of 88% • One wound (6.7%) reopened • Without use of the geko™ device the average time for VLU closure in MH LHIN is 15 weeks • Healing time with the geko™ device is an average of 12 weeks.

Key Learning Points: Delays in access to timely care negatively impact wound healing • Implementing a VLURA tool on admission identifies wounds with the greatest risk of failure to close • Early intervention using the geko™ device improves healing outcomes and decreases nursing visits • Delay in the geko™ device initiation was related to clinician access to vascular studies/ABPI • More work will need to be conducted to explore this further, particularly with the geko™ device application immediately upon referral.

7-2h. Poster: Burrows C, Duong R, Evans R, Rabley-Koch CA. Time, Edema and Other Impediments to Healing . . . Why is This Important in Wound Care? Wounds Canada Presentation Digest. 2020. Available at: <https://www.woundscanada.ca/docman/public/wound-care-canada-magazine/2020-v19-n3/1849-wcc-fall-2020-v18n3-final-p-76-77-perfuse-medtec-geko-pd/file> Video of presentation is embedded in the document and on YouTube: https://www.youtube.com/watch?v=Ile_EbEUKuk, which outlines the challenges of managing edema and summarizes the quality improvement initiative documented in 7-2g. and the accompanying qualitative study in 8-1d.

7-2i. Poster: Burrows C, Ramage D, Rabley-Koch C, Evans R. Lower Leg Wounds and the Role of Edema: Managing Edema with the geko™ Wound Therapy Device. Wounds Canada Conference Fall 2021. Available at:

<https://d3ijrte8szaw67.cloudfront.net/wp-content/uploads/2020/11/Wounds-Canada-Fall-2020-Edema-poster-0035-FINAL1.pdf>

Background/Aim: To identify published literature exploring the role of neuromuscular electrical stimulation (NMES) in individuals with edema/calf muscle pump dysfunction/venous leg ulcers.

Method: A literature search included the Cochrane Library, Medscape, CINAHL, PubMed, Medline, Embase, Scopus and peer reviewed journals.

Results: Three papers were identified in which the geko™ device demonstrated improved edema reduction in comparison to the standard of care.

Key Learning Points: Intervention with the geko™ wound therapy device may reduce pain and congestion in the limb thereby affording improved adherence with compression therapy. Use of the geko™ wound therapy device can be taught and self-managed virtually by patients and care providers, offering an alternative for clinicians to treat lower leg edema.

7-2j. Poster: Murray H. How A Change in Practice in a Nurse-led Wound Clinic Improved Venous Leg Ulcer Healing Outcomes. Wounds Canada Fall 2021 And NSWOC Virtual Conference 2022. Available at:

https://www.nswocconference.com/files/ugd/9d080f_5a48237a3ee043e5b3a4bcb6d65642d6.pdf

Background: Prior to this evaluation clients with VLUs were provided with best practices and required 30 days of standard of care (SoC) before adding the geko™ device, although the average geko™ initiation time was 14.3 weeks. Prior to initiation of the geko™ device, the average time to close a wound was 15 weeks.

Methods: For this evaluation, patients with VLUs had the geko™ devices added to the treatment plan as soon as possible following admission.

Results: 18 patients were evaluated, using SoC plus the geko™ device. Linear advance of the wound margin (WPA) to ascertain the amount of wound healing. Although not stated in the poster, the geko™ W-2 devices were to be worn 6 hours per day. The average time to closure was 6.7 weeks with a geko™ initiation time of 3.8 weeks, a decrease of 55% in the time taken to add the geko™ device to the treatment plan. The results concurred with the patients also receiving optimal compression as well as the geko™ device added as soon as possible. Prior to adding the geko™ device, the rate of wound closure was 0.25 mm/ week. With the geko™ device it accelerated to 0.56 mm/week, an increase of 0.31 mm/ week.

Key Learning Points: The faster healing times allowed patients to be discharged from service sooner. A decision was made that allows the geko™ device is now initiated at baseline assessment in conjunction with SOC, with no delay in adding it to the treatment plan.

7-2k. Poster: Burrows, C. Case Study: An Evaluation of a Muscle Pump Activator (MPA) device. NSWOC Virtual Conference 2022. Available at:

https://www.nswocconference.com/files/ugd/9d080f_ff98614d017f45109ab2ec5feb92f94.pdf

Background: 77 year-old non-diabetic patient with 20 year history of recurrent venous leg ulcers with visible atrophie blanche, pain rated at 10/10 with ten being the worst pain imaginable. The patient was being treated with Gabapentin, suggesting that there was a neuropathic pain element involved as well as nociceptive. Over the course of 15 months did not respond to best practice and multiple treatment modalities. Noted that although ABPIs were normal, patient could only tolerate Tubular mesh stockinette but actual level of compression not stated. This compression usually provides approximately 10-15 mm depending on the size selected, single or double layer and size of the widest part of the patient's calf.

Method: At this point, the geko™ Wound Therapy Device was added to the usual care for this patient, device was and worn 12 hours/day for seven days/week.

Results: After 10 weeks of the geko™ therapy, the wound was closed. The patient no longer required Gabapentin for pain and self-described an improved quality of life. One year after the geko™ therapy was first introduced, the wound remained closed.

Key Learning Points: Using geko™ therapy 12 hours per day, 7 days per week in addition to local wound care and SOME but not optimal compression therapy, this recalcitrant VLU of 15 months duration achieved healing within 10 weeks.

7-2l. White Paper: Harris C, Shannon R. Using Propensity Score Matching Analysis to determine the benefit of Neuromuscular Electrical Stimulation as an adjunctive therapy to standard of care for venous leg ulcers.

September 2022. Declaration Potential Conflict of Interest: Both authors were contracted by Firstkind, High Wyckham, UK to prepare this paper. Author Information: CH was a site investigator for the CBT RCT, and a consultant for Perfuse Medtec Inc. regarding use of the NMES device for the NMES RWE evaluations, and as such has in-depth knowledge and experience of the two very different studies.

Objective: *To determine any benefit of Neuromuscular Electrical Stimulation (NMES) applied to the common peroneal nerve as an adjunctive therapy for venous leg ulcers in the real world by performing matching analysis.*

Methods: *Data was obtained from the Canadian Bandaging Trial (CBT) randomized, controlled trial (RCT) for venous leg ulcers (VLU) (424 patients / 1 VLU each) and Real-World Evidence (RWE) data from observational evaluations by Perfuse Medtec Inc. London, ON applying NMES to the common peroneal nerve plus standard care for VLU (49 NMES RWE patients with 91 VLU wounds). VLU healing trajectories were compared following Mahalanobis distance matching within propensity score caliper method. The following seven variables were selected as covariates for the matching procedure: ulcer area at baseline (cm²), ulcer duration at baseline (months), ulcer area category, ulcer duration category, Margolis score category, ulcer infection episodes and no presence of diabetes.*

Results: *The 1:1 matched sample included 49 CBT RCT ulcers and 49 NMES RWE ulcers. Healing trajectories were equivalent between the groups (Log rank test, χ^2 0.508, $P=$ 0.476). The disparity in the level of compression therapy and the history of non-healing with the current compression method (both in the NMES group) were the only significant differences in test variables. Even within the CBT RCT, where 100% of the 424 ulcers started in one of the two high compression systems, 57 (27%) had the allocated high compression therapy discontinued before healing. This included 15 of the 49 ulcers (31%) in the matched pairs, while 34 (69%) stayed in their allocated high compression system. Seven (14%) of these went into an alternate high compression system, 5 (10%) went to low compression, 2 (4%) went into stockings, and 1 (2%) had an unknown amount of compression. In contrast, 20 of the 49 (40%) of NMES ulcers in the matched pairs started and finished in high compression systems with an additional 12 ulcers (25%) moving to high compression, an increase of 25%.*

Key Learning Points: *In the CBT, the specialized bandaging skill of the trained RNs achieving adequate compression, the use of the evidence-informed protocol and the supervision and monitoring by the site investigators were believed to be significant factors in healing. The CBT study found that the type of compression therapy (4LB or SSB; 30-40 mm Hg.) did not materially affect healing times, recurrence rates, health-related Quality of Life (HRQoL), or pain. The key message was that when these variables are replicated or controlled, health care practitioners can be reasonably certain that both systems of bandaging were equally effective. In contrast, in the NMES "real world" uncontrolled evaluations, nursing competency for compression bandaging was unknown and it seems reasonable to assume that there were many variations in bandaging technique. Specially trained Registered Nurses were not the sole provider of wound care visits, there was no standardized evidence-based protocol for VLUs, and 50% of the ulcers were not treated with high compression bandages for the duration of the study. The NMES device as an adjunctive therapy, in addition to whatever level of compression is tolerated by the patients, may be an important option in the real world, and could be a valuable adjunct to improving tolerance to compression bandaging.*

7-2m. Bull RH, Clements D, Collarte AJ, Harding KG. The impact of a new intervention for venous leg ulcers: A within-patient controlled trial. *Int Wound J.* 2023 Aug;20(6):2260-2268. Paper available at:

<https://onlinelibrary.wiley.com/doi/10.1111/iwj.14107> Link confirmed June 10, 2025.

Background: *A major obstacle to the development of new treatments for venous leg ulcers is the difficulty in generating evidence for their effectiveness. Randomised controlled trials using complete healing as the endpoint are seldom powered to be successful, owing to the heterogeneity of cohorts.*

Methods: *A novel approach to the evaluation of treatments is presented, using a self-controlled trial model and two metrics of short-term healing rate as alternate endpoints: rate of wound margin advance, and percentage area reduction over 4 weeks (Day 0-28) with multi-layer compression as part of Standard of Care (SOC). At day 28 patients were randomized to either continuing with SOC alone or adding activation of the venous leg pump using neuromuscular stimulation (geko™) for 12 hours daily (Day 28-56). The results were then compared to the initial 28 day (run-in) results with the two endpoints.*

Results: *Sixty patients with chronic venous ulcers were enrolled: after exclusions 22 in SOC alone arm and 29 in SOC with geko™ device arm. Adding neuromuscular stimulation to multilayer compression resulted in a statistically significant two-fold increase in the rate of wound healing over a 4-week period, both in terms of wound margin advance ($p=$ 0.016) and percentage area reduction ($p=$ 0.011). The geko™ device was well tolerated with a 94% patient concordance, with*

patients reporting a greater reduction in pain VAS scores, greater improvement in Vascular Clinical Severity scores (VCSS) and a higher percentage of wounds healed at 3-month follow-up. There was no significant difference in results between the run-in and treatment phase in the SOC (compression only) arm.

Key Learning Points: This is the first controlled trial to show a statistically significant increase in the rate of healing of VLU treated with an advanced neuromuscular electrostimulation device (the geko™ device), adjunctive to standard of care. The WMA and PAR metrics allowed a self-controlled study model to distinguish between the relative efficacies of the treatment regimens more rapidly, with greater sensitivity and with fewer subjects than a conventional RCT cohort model. RCTs using complete healing as the endpoint are seldom powered to be successful, owing to patient clinical diversity under a study. This trial may be considered to be a landmark study with an unparalleled effect size for a medical device (Kieron Day, Sky Head of Clinical Studies) (<https://www.prnewswire.co.uk/news-releases/sky-medical-technology--new-study-demonstrates-double-the-rate-of-healing-of-venous-leg-ulcers-with-the-geko-device-301784552.html>).

7-2n. Poster: Murray H, Duong R. Healing rate and time to closure of VLUs: a real-world evaluation of a Muscle Pump Activator (MPA) device as an adjunct to compression therapy. 2024. Available at: https://www.gekodevices.com/clinical-studies/?fwp_cs_author=murray-h

Aim: A service evaluation of a muscle pump activator (geko™) as an adjunct to compression therapy.

Methods: Fifteen (15) patients with venous leg ulcers (VLU) were prescribed MPA, using the geko™ device (W-2) for 6 hours per day, 6 days per week. The geko™ device was applied for 56 days or wound closure (whichever was soonest), in addition to multi-layer compression. Wounds were selected for size, with an inclusion criterion of maximum 12cm. Wound progress was compared with 15 retrospective control patients, matched for ulcer size and age.

Results: The retrospective group had a healing rate of 0.31mm/week (95% CI 29-37 mm/week), whereas the prospective compression + geko™ group had a healing rate of 0.56 (95% CI 50-62 mm/week). $p=0.004$ (Student *t*-test). All wounds in both groups healed completely during the course of the trial. Mean time to closure for the retrospective group was 77 days (95%CI 66-88 days), whereas the geko™ group had a mean time to closure of 40 days (95% CI 37-43 days) $p=0.005$ (Student's *t*-test). The Kaplan Mier plot shows that the trajectory of the geko™ device group diverges from the compression-only group within 23 days, with all patients in the geko™ device group exhibiting complete healing by day 64, as opposed to day 195 for the compression-only group. The difference between the two lots is very highly significant (Log-rank test $p=0.0001$).

Key Learning Points: A regimen including MPA as an adjunct intervention to compression therapy for the acceleration of wound healing resulted in significantly faster wound margin advance, and significantly less time to heal, than retrospective matched controls.

7-2o. Paper: Tuson R, Metry A, Harding A. Cost-effectiveness analysis of the geko™ device (an NMES technology) in managing venous leg ulcers in UK healthcare setting. medRxiv preprint doi:

<https://doi.org/10.1101/2024.06.13.24308720> ; this version posted June 13, 2024.

Available at: <https://www.medrxiv.org/content/10.1101/2024.06.13.24308720v1.full.pdf> Accessed June 28, 2024.

Published Paper: Int Wound J. 2024 Oct; 21(10):e70048. Available at:

<https://pmc.ncbi.nlm.nih.gov/articles/PMC11471310/pdf/IWJ-21-e70048.pdf> Accessed Oct 28, 2024.

Objective: This study evaluates the cost-effectiveness of the geko™ device a neuromuscular electro-stimulator (NMES) technology which stimulates the common peroneal nerve, with standard of care versus standard of care alone (multilayer, multicomponent compression therapy) for venous leg ulcers treatment, from the UK National Health Service perspective over 12 months.

Setting: Research was conducted across NHS UK facilities, primarily within community services and outpatient leg ulcer clinics, encompassing a total of 51 patients.

Method: A partitioned survival model, based on a two-arm randomised controlled trial, assessed wound healing rates using Kaplan–Meier curves and parametric extrapolations over a 12-month time horizon. Costs were derived from UK reference costs, the British National Formulary, and the Personal Social Services Research Unit (2021/22). The primary outcome measured was the incremental cost per quality-adjusted life-year gained. The geko™ device provides additional benefits by stimulating the lateral popliteal nerve, augmenting venous, arterial and microvascular flow.

Results: The addition of the geko™ device to standard of care significantly enhanced outcomes, increasing healing probability by 68% compared to standard of care. This integration would result in a cost saving of £774.14 per patient

when compared to the standard of care alone across the NHS. Economic analyses indicate that integrating the geko™ device into standard of care protocols would reduce the overall NHS expenditure on venous leg ulcer wound management by as much as 15%. The approach also positively impacted health-related quality of life.

Conclusion: The geko™ device when used adjunctively with standard of care would be a cost-effective method for managing chronic venous leg ulcers within the NHS, improving healing rates and offering economic benefits.

Key Learning Points: The addition of the geko™ device to standard of care (multilayer, multicomponent compression therapy) significantly increases the probability of healing in patients with chronic venous leg ulcers and would lead to a reduction in the overall costs of wound management in the NHS, potentially up to 15%.

7-2p. Case Series: Collarte A. Evaluating a Neuromuscular Electrostimulation (NMES) device as part of the treatment pathway for patients with non-healing venous leg ulcers – A case series. April 2023. Available at: <https://www.gekodevices.com/wp-content/uploads/2024/05/Evaluating-a-Neuromuscular-Electrostimulation-NMES-device-as-part-of-the-treatment-pathway-for-patients-with-non-healing-venous-leg-ulcers-%E2%80%93-A-case-series.pdf> Accessed September 30, 2024.

Background: After participating in a successful recently published randomised self-controlled trial (RCT) (see 7-2m) comparing the rate of wound margin advance (WMA) for VLU receiving the geko™ NMES device as an adjunct to standard of care (multi-layered compression) to those receiving standard of care alone, the Tissue Viability team decided to evaluate the addition of the geko™ NMES device to standard of care, for patients with chronic non-healing venous leg ulcers in the real-world setting.

Methods: The trust pathway approach for venous leg ulcers is to ensure patients receive gold-standard management by having compression therapy for a minimum of 4 weeks. If a patient's wound is on a positive healing trajectory, then they would continue with this regimen alone. If, however, a patient's wound was showing no signs of improvement in the rate of healing, then an NMES device would be commenced as an adjunct therapy to standard care for a 4-week period, at the discretion of the Tissue Viability team.

Results: Five patients were deemed to have chronic non-healing venous leg ulcers. All 5 patients wore the NMES device for 12 hours per day, 7 days per week PLUS continuing with the standard of care during the evaluation period. The rate of wound healing was evaluated by a specialist nurse on day 28 and day 56 as part of the normal clinical review process (aligned to the patient pathway). Patients were asked to verbally report levels of wound related pain using a numerical rating scale of 0-10, both prior to, and during treatment with NMES. Patient acceptance of and ability to self-manage the device was also recorded. Patients' 1 and 2 wounds had fully healed at the end of 1 cycle (28 days) of treatment with the NMES device. Patients' 3, 4 and 5 wounds had all healed by the end of 2 cycles (56 days) of treatment with the device. All 5 patients were concordant with use of the NMES device and reported that they found it easy to apply and remove. No adverse events were reported during the evaluation period for any patients wearing the NMES device. 2 patients reported pain at baseline assessment. Both patients reported a reduction in pain with the use of the NMES device.

Conclusion: This reported case series demonstrates how the NMES device was used to promote healing in a group of patients with non-healing, chronic venous leg ulcers in a real-world clinical setting, thus emphasizing the advantage of integrating the NMES device into the leg ulcer treatment regimen for patient with VLUs that were not previously responding to standard of care protocols.

Key Learning Points: The results observed in this case series reflect those highlighted in the aforementioned RCT. In that RCT, the incorporation of the geko™ NMES device alongside standard care resulted in over a twofold increase in the healing rate for patients with venous leg ulcers when compared to those receiving standard care alone. These additional cases of non-healing ulcers demonstrate improved healing and health economic outcomes with the addition of the geko™ NMES device alongside standard care.

7-2q. Paper: Sibbald RG, Geng RSQ, Slomovic J, Stacey M. The muscle pump activator device: From evidence to lived experiences. *Int Wound J.* 2024; 21:e14949. Available at: <https://onlinelibrary.wiley.com/doi/epdf/10.1111/iwj.14949> Accessed September 30, 2024.

Background: Chronic wounds such as venous leg ulcers, diabetic foot ulcers, Ischaemic and mixed arterial/venous ulcer, place immense physical and psychosocial burden on patients and exact heavy costs for healthcare systems, with many patients continuing to live with chronic wounds even after all management options have been exhausted. The muscle pump activator (MPA) (geko™) device can be used to bridge this therapeutic gap. By stimulating the common peroneal nerve to activate venous muscle pump of the leg and foot, the MPA device increases blood flow to the lower leg

and foot to improve conditions for healing. Currently, evidence in the literature exist to show that the MPA device improves wound outcomes over standard compression therapy, decreases edema and increases wound healing rates, even in those recalcitrant to standard compression therapy due to pain, local edema or ischaemia. Also documented were reduced wound dressings resulting in a decreased need for nursing visits.

Methods:

Main outcomes from previously published articles are summarized within this paper. *In addition, the authors report on 127 chronic wound patients in multicentre clinics.* Types of wounds included Venous leg ulcer, DFU (neuropathic, ischaemic, mixed), Ischaemic and mixed ulcers, Traumatic and Surgical ulcers, Lymphedema and those with multiple aetiologies.

Results: This review of lived experiences *demonstrates the effectiveness of the MPA device to improve wound healing outcomes, reduce pain and edema and enhance patient quality of life. These in turn typically leads to decreased cost of wound dressings and reduced nursing visits.*

Conclusion: *There is evidence supporting the use of the MPA device in wound care with the above therapeutic benefits. The incorporation of the MPA device in wound therapy guidelines may provide large cost savings for healthcare systems.*

Key Learning Points: *Given the ability of the MPA device to improve outcomes for long-standing nonhealing wounds, the authors believe that the MPA device offers a potentially large cost-saving opportunity for healthcare systems. This cost-saving impact could be particularly pronounced if therapy with the MPA device is initiated early (≤ 4 weeks) in wound management.*

7-2r. Paper: Stacey M, Sibbald RG, Evans R. Continuous muscle pump activation by neuromuscular electrical stimulation of the common peroneal nerve in the treatment of patients with venous leg ulcers: A position paper. *Int Wound J.* 2024 Sep; 21(9): e70040. Available at:

<https://onlinelibrary.wiley.com/doi/epdf/10.1111/iwj.70040> Accessed September 30, 2024.

Background: *The standard treatment for patients with confirmed Venous Leg Ulcers (VLUs) is compression therapy to improve the function of the calf muscle pump. There is a significant cohort of patients who are unable to tolerate optimal (ie. High, 30-40 mmHg) compression therapy or indeed any level of compression therapy. In addition, there is a cohort of patients who can tolerate compression whose ulcers show little or no evidence of healing. There is a need for ways to further improve calf muscle pump function and to improve venous ulcer healing in these patients.*

Methods: *Published papers that had utilized Muscle Pump Activation (MPA) by means of neuromuscular electrical stimulation (NMES) (geko™ device) of the common peroneal nerve and that had assessed its impact on venous return or on the healing of venous ulcers. Book chapters, theses for higher degrees and conference presentations and posters were excluded.*

Results: *There is consistent physiological evidence that MPA can improve calf muscle pump function and venous return in both control subjects and in patients with venous disease. The use of MPA has also been shown to improve venous flow volume and venous flow velocity on ultrasound scanning in patients with venous disease, and to improve microcirculation in the skin using Laser Doppler and laser Doppler Speckle Contrast Imaging, in both normal subjects as well as in patients with venous disease and VLU. A recent randomized controlled trial of MPA plus compression therapy compared with compression therapy alone, found significantly faster rates of healing with the use of MPA in addition to compression therapy.*

Conclusion: *There are indications for the use of MPA as an adjunctive treatment to enhance calf muscle pump function in patients with VLU:*

- *who cannot tolerate compression therapy*
- *who can only tolerate suboptimal, low-level compression*

Key Learning Points: A key to the improvement in wound healing in patients with venous ulcers is that MPA provides continuous improvement in calf muscle pump function, whether the patient is walking or resting. The calf muscle function improvement with compression therapy occurs only when patients are exercising the calf muscle.

7-2s. Oral Presentations: Stacey M. Canadian consensus statement on the management of venous leg ulcers. Session 22, Canadian Society of Vascular Surgery Annual Meeting September 202, St. John's NFLD Canada; available at: <https://canadianvascular.ca/page-1700902> Also published in the *Journal of Vascular Surgery* 80(4) 2024;e111. Available at: [https://www.jvascsurg.org/article/S0741-5214\(24\)01554-4/fulltext](https://www.jvascsurg.org/article/S0741-5214(24)01554-4/fulltext) Both accessed October 23, 2024.

Paper: Stacey M, Evans R, Sibbald G. Canadian Consensus Statement: The management of venous leg ulcers. In Press; available at: <https://sites.google.com/view/VLUconsensus> Accessed October 22, 2023.

NEW: Wounds Canada Sponsored Learning Available at: <https://www.woundscanada.ca/docman/public/wound-care-canada-magazine/2024-vol-22-no-2/3445-wcc-winter-2024-v22-n2-pg68-73-perfuse-medtech-inc-sponsored-learning-1/file> Accessed May 23, 2025.

NEW: Endorsed by: Canadian Home Care Association Available at: <https://cdnhomecare.ca/wp-content/uploads/2024/11/Consensus-statement-of-the-treatment-of-venous-leg-ulcers-June-2024.pdf> Accessed May 23, 2025.

NEW: Endorsed by: Nurses Specialized in Wound, Ostomy and Continence Canada (NSWOCC) Nov 28, 2024. Available at: <https://www.nswoc.ca/post/announcing-the-canadian-consensus-statement-on-the-management-of-venous-leg-ulcers> Accessed May 23, 2025.

NEW: Published in: IWJ April 2025 Vol 22 (4). Available at: <https://onlinelibrary.wiley.com/doi/full/10.1111/iwj.70415> Accessed May 23, 2025.

Objective: *To develop a Consensus Statement on the Management of Venous Leg Ulcers (VLU) for Canadian clinicians that incorporates existing standards with recent data on technology for improving calf muscle pump function and an approach to the utilization of advanced wound therapies.*

Methods: *A panel of 19 clinicians from across Canada was formed and included physicians (vascular surgery, general surgery, dermatology, family medicine) and nurses (RNs and NSWOC [Nurses Specialized in Wound, Ostomy, Continence]), who are actively involved in treating patients with VLUs and who have experience with some of the new technologies. A draft document was circulated to the panel for initial feedback, and after revision was submitted to the panel for several rounds of consensus assessment of the key components. The goal was to have at least 80% consensus on the key components.*

Results: *The Consensus Statement has been completed and key elements of it are –*

- *Clinical assessment and investigations to determine the diagnosis of VLU*
- *Treatment that incorporates compression to improve calf muscle pump function, wound debridement and moisture control*
- *Use of adjunctive treatment with Neuromuscular Electrical Stimulation (NMES) of the common peroneal nerve to improve calf muscle pump function in patients who: 1. cannot tolerate any compression, 2. who can only tolerate reduced compression or 3. whose ulcers are not healing with optimal compression*
- *An algorithm for the use of advanced wound therapies for patients whose VLU are not healing in spite of optimal improvement of the calf muscle pump. That includes – antimicrobial and anti-biofilm dressings; anti-protease dressings; improvement of granulation tissue with Negative Pressure Wound Therapy or matrix substitute; topical growth factors; application of new cells to the wound*
- *The role of adjunctive wound therapies*
- *Prevention of VLU recurrence.*

Conclusion: The authors defines the NMES device's role as an adjunctive therapy for VLUs within specific parameters.

Key Learning Points: This consensus document clearly describes three situations where people with venous leg ulcers would benefit from use of the NMES device applied to the lower leg to stimulate the common peroneal nerve and improve calf muscle function as part of the treatment protocol: 1. *cannot tolerate any compression*, 2. *who can only tolerate reduced compression* or 3. *whose ulcers are not healing with optimal compression*.

7-2.t. NEW Paper: Bull BH, Clements D, Collarte AJ, Harding KG. A Novel Randomized Trial Protocol for Evaluating Wound Healing Interventions. *Adv Wound Care* 2023 Dec;12(12):671-679. Available at: <https://pmc.ncbi.nlm.nih.gov/articles/PMC10615036/pdf/wound.2023.0058.pdf> Accessed May 11, 2025.

Background: *Randomized controlled trials using complete healing as an endpoint suffer from poor statistical power, owing to the heterogeneity of wounds and their healing trajectories. The Food and Drug Administration (FDA) has recently consulted with expert groups to consider percentage area reduction (PAR) of the wound over a 4-week period as a valid intermediate endpoint, creating the opportunity for more powerful study designs.*

Methods: *A within-subject controlled study design comparing the PAR of venous leg ulcers (VLU) in patients over 4 weeks receiving different interventions. Twenty-nine patients received multilayer compression over 4 weeks, followed by*

neuromuscular electrostimulation (NMES) of the leg muscle pump (geko™) in addition to compression for a further 4 weeks. Paired comparison was then made of PAR between the two phases. A second cohort of 22 patients received only multilayer compression throughout both 4-week phases.

Results: Patients randomized to NMES saw a significant increase in healing rate compared with compression alone, whereas patients receiving compression only saw no significant change in healing rate throughout the course of the study.

Conclusions: Intermittent NMES of the common peroneal nerve significantly accelerates the healing of VLU. It is well tolerated by patients and deserves serious consideration as an adjuvant to compression therapy. PAR is a useful metric for comparing the performance of wound healing interventions, and the self-controlled trial design allows sensitive discrimination with a relatively small number of subjects over a reasonably short trial period. The study is reported according to the CONSORT reporting guidelines.

Key Learning Points: Use of the FDA recently-approved percentage area reduction (PAR) of the wound over a 4-week period as a valid intermediate endpoint allowed clear comparison of the two types of wound healing interventions in this short time period. This work supports the concept that use of the geko™ device stimulating the common peroneal nerve serves as a valuable adjunct to compression therapy versus compression therapy alone for the treatment of VLU, with significant increase in healing ($p=0.016$) during the four weeks of NMES therapy.

7-2.u. NEW Paper: Murray H, Duong R, Bain DS. Healing Rate and Time to Closure of Venous Leg Ulcers: A Real-World Service Evaluation of Neuromuscular Electrostimulation as an Adjunct to Compression Therapy. *Adv Skin Wound Care* 2025 Jun 1;38(5):246-250. Available at:

https://journals.lww.com/aswcjournal/fulltext/2025/06000/healing_rate_and_time_to_closure_of_venous_leg.5.aspx
Accessed: April 22, 2025.

Objective: To perform a service evaluation of neuromuscular electrostimulation (NMES) as an adjunct to compression therapy, comparing the rate of wound margin advance and time to closure with a matched retrospective control group.

Methods: Fifteen patients with venous leg ulcers were prescribed NMES for 6 hours per day for 56 days or until wound closure (whichever occurred first), in addition to multilayer compression. Wounds were selected for size, with an inclusion criterion of a maximum of 12 cm². Wound progress was compared with 15 retrospective control patients who were matched for ulcer size and duration.

Results: The retrospective group had a healing rate of 0.31mmper week (95%CI, 29-37mm/week), whereas the prospective compression plus NMESgroup had a healing rate of 0.56 mm per week (95% CI, 50-62 mm/week; $P = .004$). All wounds in both groups healed completely during the service evaluation. Mean time to closure for the retrospective group was 77 days (95% CI, 66-88 days), whereas the NMES group had a statistically significant mean time to closure of 40 days (95%CI, 37-43 days; $P= 0.005$).

Conclusions: Adding NMES of the common peroneal nerve to a care bundle including multicomponent compression resulted in significantly faster wound margin advance and significantly less time to heal in comparison with retrospective matched controls. Future randomized controlled trials or self-controlled studies of this approach would be of great interest to inform clinical practice.

Key Learning Points: The findings of this service evaluation are consistent with the results of earlier studies.

7-2v. NEW: Paper: Tezcan C. Use of a muscle pump activator to treat a left ankle wound. *Wound Care Canada*.

2025;23(1): 79-82. DOI: 10.56885/721671wlaoeq Available at: <https://www.woundscanada.ca/doclink/wcc-summer2025useofamusclepumpactivator/eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJzdWIiOiJ3Y2Mtc3VtbWVYmJyAyNS11c2VvZmFtdXNjbGVwdW1wYWNOaXZhdG9yIiwiaWF0IjoxNzQ4Mjc3OTI4LCJleHAiOiJlE3NDgzNjQzMjh9.gSEFqVXRk4SLayRUhwz4ArB554kLa-tLld-c1-Z7Vw#:~:text=The%20use%20of%20the%20MPA,day%20to%204.34mm2%2F%20day.>

Accessed June 5, 2025.

Background: This case study reports on a 68-year-old woman with a long-standing (> 4 years) recurring wound which was the result of a traumatic ankle injury requiring an open reduction and fixation, with many signs of concomitant venous disease, calf muscle pump failure due to ankle immobility and normal ABPI's.

Methods: The geko™ Wound Therapy device, a muscle pump activator (MPA) was added as part of the evidence-based wound management strategy, worn 12 hours per day, 7 days per week. The patient could manage self-application of both the compression therapy and the geko™ MPA device.

Outcomes: After 1,467 days (210 weeks) of living with a non-healing ulcer in spite of evidence-based interventions including compression therapy, the wound healed with the addition of the geko™ device in 112 days (16 weeks). *The patient reported high satisfaction and the nursing staff found the device easy to integrate into standard wound care.*

Key Learning Points: This case study adds to the existing published body of evidence regarding the efficacy of adding the geko™ device to evidence-based interventions for chronic non-healing leg ulcers, regarding in this case a post-traumatic injury compounded by chronic venous insufficiency.

7-3. The geko™ Device and Post-Operative Incisional Wound Healing: Kidney and Kidney-Pancreas Transplant

7-3a.i Poster: Aquil S, AlHarbi B, Sharma H, Pacoli K, Luke P, Sener A. The impact of a muscle pump activator on incisional wound healing compared to standard TED stockings and compression devices in kidney and kidney-pancreatic transplant recipients: A randomized controlled trial. Abstract submitted to Wounds Canada and CAET Conferences May 2017.

Background: *Wound infection is a serious complication in kidney and kidney pancreas (SPK) transplantation. Transplant patients are at higher risk of wound infections due to obligate immunosuppression in addition to concomitant poor wound healing risk factors including diabetes, obesity and vasculopathy. The use of muscle pump activators (MPA) has previously been shown to improve healing in patients with chronic lower leg diabetic ulcers. Its effect on wound healing in transplantation is unknown.*

Methods: *In a prospective, randomized, controlled, single-center, study we randomly assigned 60 patients (kidney, n=50; SPK, n=10) to wear either TED+ IPC (Group 1, n=33) or an MPA device geko™ R-2 (54mA) (Group 2, n=27) for the first 6 days following surgery. Patient demographics, postoperative outcomes and incisional wound images were taken using a HIPAA compliant application on post-operative day (POD) 3, 5 and 30 and blindly assessed using the validated Southampton wound care score. Patient satisfaction was assessed on POD 3 and 6.*

Results: *Recipients were 51 (24-72) years old and 66% were male with no differences in BMI or DM between groups. Although there was no difference in wound healing on POD 3 between the groups (p=0.175), the MPA group showed a significant improvement in wound healing by POD 5 (p=0.0008) which persisted till POD 30 (p=0.01). Bayesian inferential analysis revealed that the use of TED+IPC following transplantation had inferior outcomes compared to the use of a MPA with sequential moderate evidence. The rate of complex wound infections was significantly greater in the TED+IPC group compared to MPA (34% versus 22%, respectively, p<0.05). No complications were encountered in either group associated with the study.*

Key Learning Points: *The use of a MPA device in the immediate post-operative period leads to a significant improvement in early and late wound healing, and decreased number of complex wound infections following kidney and SPK transplantation compared to standard TED+IPC therapy.*

7-3a.ii. (same RCT as above but later in enrolment with larger sample size) Paper: Aquil S, Sharma H, Alharbi B, Pacoli K, Luke PP, Sener S. The impact of a muscle pump activator on incisional wound healing compared to standard stockings and compression devices in kidney and kidney-pancreas transplant recipients: A randomized controlled trial. Canadian Urological Association Journal. 2019; 13(11): E341-E349. Epub ahead of print. Available at:

<https://cuaj.ca/index.php/journal/article/download/5822/4226/>

Introduction: *The aim was to evaluate the impact of thrombo-embolic-deterrent + intermittent pneumatic compression (TED + IPC) vs. muscle pump activator (MPA) on incisional wound healing in kidney and simultaneous pancreas- kidney (SPK) transplant recipients.*

Methods: *We conducted a single-centre, randomized controlled trial in which 104 patients (kidney n=94; SPK n=10) were randomly assigned to wear TED + IPC (n= 52) or MPA (n=52) for the first six days following surgery. Patient demographics, postoperative outcomes, and incisional wound images were taken using a HIPAA-compliant application on postoperative days (POD) 3, 5, and 30, and assessed using the validated Southampton Wound Care Score.*

Results: *There were no demographic differences between the groups. The MPA group had a significant improvement in wound healing on POD 3 (p=0.04) that persisted until POD 5 (p=0.0003). At POD 30, both groups were similar in wound healing outcomes (p=0.51). Bayesian inferential analysis revealed that the use of TED + IPC following transplantation had inferior outcomes compared to the use of MPA with sequential moderate evidence. The rate of complex wound infections was significantly greater in the TED + IPC group compared to the MPA group (29% vs. 12%, respectively; p=0.03). Patients were more satisfied with the use of a MPA device than TED + IPC. No major complications were encountered in either group.*

Conclusions: *The use of a MPA device in the immediate postoperative period leads to a significant improvement in immediate and early wound healing, and decreased number of complex wound infections following kidney and SPK*

transplantation compared to standard TED + IPC therapy. Patients were more satisfied with the use of a MPA device than TED + IPC.

Key Learning Points: The use of a MPA device in the immediate post-operative period leads to a significant improvement in early and late wound healing, and decreased number of complex wound infections following kidney and SPK transplantation compared to standard TED+IPC therapy.

7-4. The geko™ Device and Diabetic Foot Ulcers

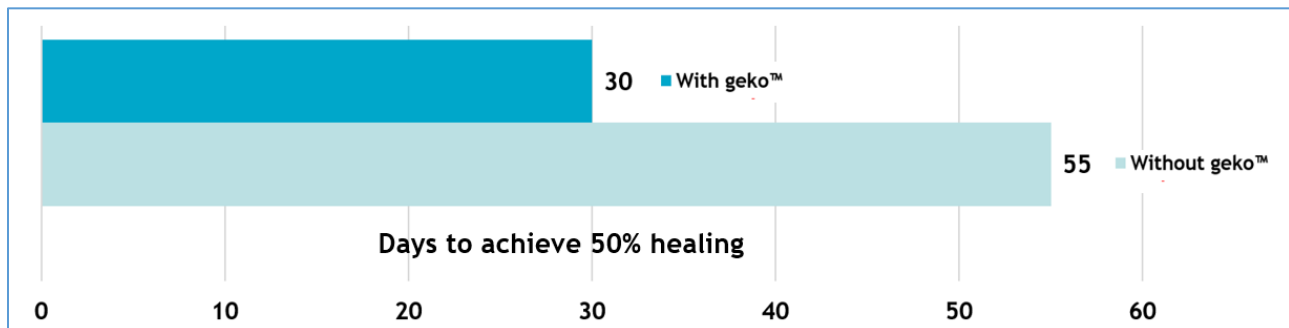
7-4a. Paper: Williams K. Section 7.3 NMES in the management of diabetic foot ulcers (ULCERS). Neuromuscular Stimulation of the Leg. PhD Thesis, Imperial College London for the degree of Doctor of Philosophy. April 2017. Pages 289-302. Available at: <https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf>

Purpose:

To investigate the effect of NMES on the rate of healing of diabetic foot ulcers, a randomised control trial was devised which would measure wound healing, pain, and quality of life.

Methods: The geko™ T-1 (27 mA) devices were worn on ulcerated limb only, 4-6 hours per day, 5 days per week set to minimum level to achieve distal twitch. The two cohorts were poorly matched with the subjects allocated to device tending to have a greater degree of ulceration, and more severe neuropathy scores. Any changes in these parameters must be interpreted with this in mind.

Results: The trial was suspended due to lack of staffing in September 2015. Eight patients were recruited. 4 patients with DFU on pressure-bearing surface and neuropathy secondary to diabetes +/- ischemic heart disease, stroke, nephropathy, retinopathy allocated to the geko™ device tended to have a greater degree of ulceration, more severe neuropathy scores and more smokers, yet achieved endpoint of 50% reduction in volume ($L \times W \times D = \text{cm}^3$) **25 days** sooner than the control group (without geko™). Kaplan-Meier analysis was not attempted due to the low number of subjects that achieved 50% healing in area and volume measurements. Generic quality of life scores increased much more in the device group than the control group, as measured by the VAS and SF-12, but Diabetes severity scores for both groups decreased by similar amounts.



Key Learning Points: Further research with larger number of patients is needed to demonstrate the role of the geko™ device in healing Diabetic Foot Ulcers, and to determine statistical significance.

7-4b. Poster: Parsons A. Muscle pump activator device: a case study in treating a diabetic foot ulcer (DFU). **Presented at: Wounds Canada Conference, Toronto ON, Canada October 14-16, 2022. Poster available at:**

<https://d3ijrte8szaw67.cloudfront.net/wp-content/uploads/2022/10/Parsons-Final-Muscle-Pump-Activator-Device-A-Case-Study-in-treating-a-Diabetic-Foot-Ulcer-DFU.pdf>

Aim: To evaluate the impact of the geko™ wound therapy device in treating a non-healing DFU.

Background: A 91-year-old lady, living in a Long-Term Care setting with Non-insulin Dependent Diabetes Mellitus and many co-morbidities. She developed a DFU secondary to wearing ill-fitting shoes resulting in a blister, then cellulitis/osteomyelitis and was treated with antibiotics. The resident was removed for 9 months in a wound care clinic. She was placed in an off-loading boot and the wound was managed with evidence-based treatment modalities such as iodine based products, silver dressings, and foam dressings, but the wound remained open.

Procedure/Method: After 9 months it was decided to initiate the geko™ wound therapy device. Vascular studies indicated vascular disease (ABPI Rt =0.61, Lt =0.46). The device was used for 6 hours/day for 6 days/week.

Findings/Results: The wound was closed in 53 days.

Implications/ Applications: The application of the geko™ wound therapy device as an adjunctive therapy improves wound healing outcomes in DFU's by increasing blood flow to the wound and peri-wound area, reducing edema, and significantly decreasing the healing time.

Key Learning Points: Earlier intervention with the geko™ device may be appropriate with diabetic foot ulcers, particularly in an aged population and/or with significant vascular disease.

7-4c. Poster: Burrows C, Duong R. The geko™ wound therapy device: a case study report on treating diabetic foot ulcers. Presented at: Wounds Canada Conference, Toronto ON, Canada October 14-16, 2022. Poster available at: <https://www.gekodevices.com/wp-content/uploads/2022/10/Burrows-Final-The-geko%E2%84%A2-Wound-Therapy-Device-A-Case-Study-Report-on-Treating-Diabetic-Foot-Ulcers-002.pdf>

Purpose/Aim: To evaluate the impact of the geko™ wound therapy device to treat a Diabetic Foot Ulcer (DFU).

Background: The left plantar foot ulcers over the 2nd, 4th, and 5th metatarsal heads started in August 2020. Right leg required below knee amputation (BKA) in November 2021 due to complications from osteomyelitis, at which time the left leg was revascularized. Both incisions became infected requiring 3 courses of antibiotics. Patient was non-weight bearing on left foot. By April 2022, the left foot DFUs, the right BKA stump wound and the left medial calf incision remained open.

Procedure/Method: In April 2022 the geko™ wound therapy device was placed over the fibular head to stimulate the calf and foot muscle pumps and worn for 12 hours per day, 7 days/week, on both legs. Information is not included as to the muscular response to the geko™ device on the BKA stump.

Findings/Results: The wound beds showed increased “pink tissue” within the first week of geko™ therapy and all three wounds closed following 8 weeks of therapy when added to standard care.

Implications/Applications: The outcome and potential application of the geko™ wound therapy device in practice is to increase blood flow, reduce edema, decrease time-to-heal, and is user-friendly as described by the primary caregiver.

Key Learning Points: Of particular interest is that use of the geko™ device on the right leg, with the below-knee amputation, appears to have been beneficial although the exact mechanism of the muscle response is not stated. Further research with larger number of patients is needed to demonstrate the role of the geko™ device in healing Diabetic Foot Ulcers, and to determine statistical significance.

7-4d. Paper: Goodall RJ, Langridge B, Lane T, Davies AH, Shalhoub J. A Narrative Review of the Use of Neuromuscular Electrical Stimulation in Individuals With Diabetic Foot Ulceration. *The International Journal of Lower Extremity Wounds*. 2020 Sep;19(3):242-250.

Aim: To summarize the evidence reported on the use of neuromuscular electrical stimulation (NMES) in individuals with diabetic foot ulceration (DFU).

Method: A systematic search of EMBASE and MEDLINE databases was performed, using search terms relating to the domains DFU and NMES.

Results: Of 344 references obtained from database searching, 7 met the inclusion criteria and included a total of 140 participants, 77 of whom had DFU. All seven studies used prospective design but were described by the authors as being generally low in methodological quality, size, and analysis. However, the studies reported a mean reduction in ulcer area rates ranging from 30.1% to 75% in 71 of the individuals with DFU treated with NMES.

Key Learning Points: *The present review has identified low quality and volume of evidence supporting a potential role for NMES in DFU healing. Given the significant morbidity and mortality that can arise from DFU, there is a pressing need for higher quality and better powered prospective studies in to the use, tolerability, and performance of NMES compared with current gold-standard treatment alone—and with other ES (Electrical Stimulation) devices—in the adjunctive management of diabetic foot disease.*

7-5. The geko™ Device and Venolymphedema

7-5a. Paper: Harris C, Rabley-Koch C, Ramage D, Cattrysse R. Debilitating Chronic Venolymphedema: Using a Muscle Pump Activator Medical Device to Heal Wounds and Improve Skin Integrity. *Journal of Lymphedema*. *Journal of Lymphoedema*, 2019; 14(1):50-53. Available at: <https://www.woundsinternational.com/journals/issue/580/article-details/debilitatingdebilitating-chronic-veno-lymphoedema-using-muscle-pump-activator-medical-device-heal-wounds-and-improve-skin-integrity>

Background: *This case study describes in detail the experience of one patient whose data was included in paper 3-6c. This 66-year old male with venolymphedema and chronic renal failure causing lower leg blistering resulting in wounds had received daily or twice daily dressing changes with frequent infections for five years. In the 12 months prior to the*

evaluation, he had three hospitalisations for cellulitis of the legs and sepsis with acute-on-chronic renal failure, including once with multiple maggots in the dressings and wound. The consulting surgeon anticipated eventual bilateral leg amputation, and the nephrologist was preparing him for hemodialysis intervention.

Aim: The aim was to evaluate and determine if the geko™ is effective in this population and if it should be added to the medical supply formulary.

Methods: As per paper 3-6c. Although the evaluation was completed at 20 weeks, this man’s response was so dramatic that devices were provided for a much longer period of time, concluding at 60 weeks.

Results: *His episodes of blistering with open wounds reduced, along with accelerated healing, a reduction in fibrotic edema and a return to more normal skin integrity. His mobility and ankle range of motion rapidly increased.*

Additionally, his renal function improved during the treatment, with a reduction in serum creatinine to the point that hemodialysis was no longer being considered. The improvements in his skin integrity and level of pain, reduction in the incidence and severity of infections, increase in mobility and activity and general quality of life were remarkable and unprecedented in our experience caring for patients with veno-lymphedema. The following table from the article shows the impact on his nursing visit frequency, rate of infection in his legs, and need for hospitalization for the legs.

| Parameter | 60 weeks pre-geko | 60 weeks with geko 5 days per week/10-12 hours/day on average | 52 weeks post-evaluation (geko used 24 hours/day ≈ twice weekly) |
|--|--|---|--|
| Infection in legs | Almost constant; 3 episodes cellulitis with sepsis; frequent IV Rx | 2 infections requiring oral antibiotics | 1 infection requiring oral antibiotics |
| Hospitalisations for leg infections | 3 | 0 | 0 |
| Nursing and Wound Care Specialist (WCS) Visits | 400 nursing 11 WCS | 319 nursing 16 WCS | 137 nursing 5 WCS |

Please note: The Journal of Lymphedema was not able to include the table of results due to page restrictions. The paper contains a link to the table at: https://www.gekodevices.com/wp-content/uploads/2019/06/1145-Chronic-veno-lymph-PDF_V2.pdf or they can be viewed as follows:

| Time Frame | Compression/ Pain/ Other Comments | Edema Point | Right (cm) | Left (cm) |
|------------|---|---|--------------------|--------------------|
| Baseline | Compression: Single Layer Tubular 5-10 mm Hg Pain: 8-10 /10 Other: MPA 6 hours per day/ 5 days per week. Setting 8 - no visible foot twitch. Could not dorsiflex foot or wiggle toes; walking less than 200 meters / day with walker; using urinal rather than going to the bathroom. | Mid-Foot Smallest Ankle Widest Calf | 30 30 48 | 27.8 29.8 47 |
| 4 weeks | Compression: Single Layer Tubular 5-10 mm Hg Pain: 2/10 Other: Using MPA 6 hours per day/ 5 days per week. Setting 8 but no visible foot twitch. At 2 weeks could dorsiflex and wiggle toes; new blisters occurring; legs less cumbersome; exudate pooling at feet. | Mid-Foot Smallest Ankle Widest Calf | 33.5 33 48.5 | 31.5 32 47.5 |
| 11 weeks | Compression: Single Layer Tubular 5-10 mm Hg. Pain: Increased pain posterior right leg where wound is deeper; not infected. Other: Initial areas on the left lateral leg healed; new blisters still occurring with exudate pooling distally in the dressings soaking his feet. He surprised himself by lifting his legs onto the stool independently | Mid-Foot Smallest Ankle Widest Calf | 33 32.3 49.1 | 31.5 31.5 48 |
| 21 Weeks | Compression: Higher compression tried but not tolerated Pain: Identified that neuropathic pain increased in weeks 11-12 when devices were stopped, then decreased again when resumed. Gabapentin stopped and Duloxetine (Cymbalta) 30 mg. daily added around 18 weeks Other: Using MPA 10-12 hours per day/ 5 days per week but skipped week 11-12 due to rash. Legs feel “lighter,” skin more normal appearance by week 16. Small blisters still occurring. | Mid-Foot Smallest Ankle Widest Calf | 33 33 50.5 | 31.2 32 48.3 |
| 42 weeks | Compression: Durable Velcro ReadyWrap (Solaris) compression system ordered Pain: only chronic old back pain- Cymbalta increased to 60 mg. daily @ 22 weeks, 90 mg. daily @ 31 weeks and Pregabalin 25 mg. 2x/day started | Mid-Foot Smallest Ankle Widest Calf | 29 29 47 | 29 28 46 |

| | | | | |
|----------|---|---|------------------|------------------|
| | MPA 10-12 hours per day/ 5 days per week. Skin smoother, tissue softer. New blisters still occurring but smaller; walking more for longer periods using just cane | | | |
| 46 weeks | <p>Compression: Durable short stretch compression system being worn during waking hours</p> <p>Pain: only chronic old back pain. Pregabalin increased to 50 mg. 2x/day at 44 weeks; continued Cymbalta 90 mg daily</p> <p>MPA 10-12 hours/ day/ 5 days per week Setting reduced to 6. Touch sensation has returned, could feel geko™ stimulation. Plan to wean off device with a referral to outpatient physio clinic pending; eager to gain independence.</p> | Mid-Foot Smallest Ankle Widest Calf | 26 27.3 44 | 26 27.5 44 |
| 55 weeks | <p>Compression: Durable short stretch compression system being worn during waking hours</p> <p>Pain: no pain other than chronic old back pain;</p> <p>MPA 10-12 hours per day/ 5 days per week. Setting 4 with foot twitch. Plan to wean off device over next 5 weeks, and to increase mobility including showering. Nursing visits decreased to 2 x weekly or less.</p> | Mid-Foot Smallest Ankle Widest Calf | 28 27 42 | 28 25 42 |

Key Learning Points: This single case study raises several questions about the benefit of using the geko™ device for an extended period of time (60 weeks) in a person with multiple chronic diseases and lower leg wounds. We can only state what he, his nurses and his physicians reported about improvement in his leg ulcers, his reduction in pain, fibrosis and edema of the legs, his increased tolerance for compression therapy, and the reduction in his serum creatinine levels during this time, preventing the need for hemodialysis.

7-5b. Poster: Reeves J, Gosse M, Sinclair H, Sindell J, Gates T. Muscle pump activator device: a case study in chronic leg lymphedema and papillomas. Presented at: Wounds Canada Conference, Toronto ON, Canada October 14-16, 2022. Poster available at: <https://www.gekodevices.com/wp-content/uploads/2022/10/Reeves-Final-Muscle-Pump-Activator-Device-A-Case-Study-in-Chronic-Leg-Lymphedema-and-Papillomas.pdf>

Aim: To evaluate the geko™ wound therapy device to reduce chronic lymphedema and papillomas prior to initiating compression therapy.

Background: A 60-year-old lady resided in a Long-Term Care (LTC) setting since 2017. She was confined to bed for 4 years, developed papillomas over the lateral aspect of the right thigh with recurring infections secondary to chronic lymphedema, in spite of treatment with best practices and evidence-based therapies (not listed). However, she was unable to tolerate high compression therapy due to pain.

Procedure/Method: The geko™ wound therapy device was implemented as an adjunctive therapy.

Findings/Results: Prior to initiating the geko™ wound therapy device average daily urinary output was 800- 1000cc's per day. During four weeks of geko™ wound therapy treatment the urinary output was 4-5L/day with a weight loss of 60lbs. There was no impact on the patients' serum potassium (pre geko™ -3.6mmol/L, post geko™ -4.8mmol/L). The resident tolerated the fluid shift well, the papillomas reduced in size and scaled off with light friction during cleaning. Following the reduction of edema, she was fitted with tubular elastic compression. Her caregivers reported that she experienced an improved quality of life and was able to sit in a chair for 2-hour intervals. Psychologically, the resident indicated that she "feels great," and was pleased to become more engaged in her care by moving independently in bed.

Implications/ Applications: The outcome and potential application of the geko™ wound therapy device used as an adjunctive therapy can significantly reduce edema and decrease pain to comfortably initiate compression therapy that wasn't previously tolerated. The staff expressed that the geko™ wound therapy device was easy to use, they were happy with the results.

Key Learning Points: Use of the geko™ device was instrumental in facilitating tolerance of compression therapy by the patient.

7-6. The geko™ Device and Radiation-Induced Wounds

7-6a. Poster: Lyver M. The geko™ wound therapy device: a case study of a radiation-induced lower leg ulcer. Presented at: Wounds Canada Conference, Toronto ON, Canada October 14-16, 2022. Poster available at: <https://www.gekodevices.com/wp-content/uploads/2022/10/Lyver-Final-The-geko%E2%84%A2-Wound-Therapy-Device-A-Case-Study-of-a-Radiation-Induced-Lower-Leg-Ulcer.pdf>

Aim: To evaluate the geko™ wound therapy device in the treatment of a non-healing lower leg ulcer secondary to radiation therapy.

Background: A 90-year-old lady who has been co-followed in Hyperbaric and Wound management clinics for a non-healing wound of the left lower leg, site of a previously treated squamous cell carcinoma (2019). Treatment modalities over the past three years included best practices, surgery, radiation therapy and a failed skin graft.

Procedure/Method: In 2022 it was approved to implement the geko™ wound therapy device as an adjunctive therapy to hyperbaric therapy and standard wound care.

Findings/Results: The wound responded positively to the geko™ wound therapy device following an 8 week course of treatment with improved granulation tissue, the tendon was no longer visible, and the wound size was reduced.

Implications/ Applications: The outcome and potential application of the geko™ wound therapy device as an adjunctive therapy in conjunction with Hyperbaric Oxygen therapy demonstrated that intervention with the geko™ wound therapy device offered this patient improved healing outcomes in treating her radiation-induced wounds.

Key Learning Points: The geko™ device may have a role in improving healing outcomes for wounds in irradiated fields and may be appropriate for early intervention. The poster describes this instance as an early intervention although it was three years after the initial treatment for the squamous cell cancer in a non-healing wound. Further case studies would be beneficial.

7-7. Reference Papers Regarding Measuring Wound Healing Outcomes

7-7a. Bull RH, Staines KL, Collarte AJ, Bain DS, Ivins NM, Harding KG. Measuring progress to healing: A challenge and an opportunity. *Int Wound J* 2021 Aug 10. doi: 10.1111/iwj.13669. Online ahead of print. Available at: <https://onlinelibrary.wiley.com/doi/epdf/10.1111/iwj.13669> Accessed December 17, 2021.

Background: Complete healing is problematic as an endpoint for evaluating interventions for wound healing. The great heterogeneity of wounds makes it difficult to match groups, and this is only possible with multivariate stratification and/or very large numbers of subjects. The substantial time taken for wounds to heal necessitates a very lengthy study. Consequently, high quality randomised controlled trials demonstrating an effect of an intervention to a satisfactory level of statistical significance and with a satisfactory level of generalisability are extremely rare.

Aims: to determine whether the healing of VLU receiving multilayer, multicomponent compression bandaging follows a linear trajectory over a 4-week period, as measured by gross area healed, percentage area healed, and advance of the wound margin.

Methods: Forty VLU patients (24M, 16F) were followed weekly for 4 weeks, with a total of 5 measurements per patient. All patients received standard of care continuously throughout the study, consisting of multilayer, multicomponent compression therapy. Compression systems used were deemed appropriate by the clinical team treating patients in this study. Measured wound area was plotted against time at weekly intervals to give a curve for Gross Area Reduction (GAR), Percentage Area Reduction (PAR) was calculated for each wound by dividing measured wound area at each time-point by its initial value at week 0, while Wound Margin Advance (WMA) was calculated at each of the five weekly wound measurements by dividing the perimeter into the area (A/P). These values were then regressed against time to generate a gradient to represent WMA, as well as a correlation coefficient R2.

Results: This study determines that the healing of venous leg ulcers receiving multi-component compression bandaging follows a linear trajectory over a 4-week period, as measured by gross area healed, percentage area healed, and advance of the wound margin. This makes it possible to identify an acceleration in healing resulting from an intervention, and allows self-controlled or crossover designs with attendant advantages of statistical power and speed. Of the metrics investigated, wound margin advance was the most linear, and was also independent of initial ulcer size.

Key Learning Points:

- randomised controlled trials using complete healing as an endpoint to evaluate interventions for wound healing are frequently under-powered
- statistical sensitivity can be improved by using a short-term surrogate or intermediate endpoint for healing, allowing self-controlled or crossover designs
- wound margin advance is close to linear over a 4-week term, and so is a suitable intermediate endpoint for identifying any changes in healing rate due to an intervention

8. The geko™ Device and Quality of Life

8-1a. Poster: Williams KJ, Ravikumar R, Babber A, Davies AH. Can neuromuscular stimulation relieve symptoms of chronic venous disease, and improve quality of life? Annual Meeting of the Society-of-Academic-and-Research-Surgery (SARS) 2015, Publisher: WILEY-BLACKWELL, Pages: 9-9, ISSN: 0007-1323.

Thesis: Williams KJ. Chapter 7.1. NMES in the management of chronic venous disease (VeINS). Neuromuscular Stimulation of the Leg. Thesis submitted to Imperial College London for the degree of Doctor of Philosophy April 2017. Pages 258- 269. Available at:

<https://spiral.imperial.ac.uk/bitstream/10044/1/49202/1/Williams-K-PhD-Thesis.pdf>

Accessed April 12, 2018. Please see Section 3-2i. for the Hemodynamic results of this study.

Aim: Examining the QoL with the geko™ T-1 (27mA) device over 8 weeks in patients with CVI

Methods: Quality of life (QoL) questionnaires were taken at week 0, 6 (end of treatment) and week 8 (2 weeks after geko™ treatment finished). Three disease-specific (Venous Clinical Severity Score [labelled as VCCS but should be VCSS], Venous Disability Score [VDS], Aberdeen Varicose Vein Questionnaire [AVVQ]) and four generic (EuroQoL [EQ5D], the Visual Analog Rating Scale [VAS] of health-related quality of life, the Center for Epidemiologic Studies Depression Scale [CES-D] and the Twelve Item Short Form [SF-12] for patients with chronic conditions) QoL questionnaires were used.

Results: The 30 patients with CVI (no mention of existing venous leg ulcers) had improvement in some of the disease specific and generic QoL questionnaires over the 6 weeks of treatment. Those with more severe disease (C4-6) had the biggest improvement in VDS, AVVQ, and SF-12. Only VDS was statistically significant ($p < 0.01$) between week 0 to 6 ($p = 0.03$, Mann-Whitney U test). Two weeks after the geko™ devices were stopped for this group, the improvement in venous clinical scores were sustained. The ten healthy individuals and those with mild clinical symptoms had no change in generic quality of life over 6 weeks.

Table of Results:

| QoL Surveys | | CEAP 0-3 disease | | | CEAP 4-6 disease | | | Significance for those with CEAP 4-6 |
|------------------|---------|------------------|--------|--------|------------------|-----------------------|-----------------------------|--|
| | | Week 0 | Week 6 | Week 8 | Week 0 | Week 6 (end of geko™) | Week 8 (no geko™ x 2 weeks) | |
| Disease-specific | VCCS* | 2.8 | 2.7 | 3.4 | 10.4 | 7.2 | 7.5 | Improved by Wk 6, Deteriorating by Wk 8 |
| | VDS* | 0.65 | 0.7 | 0.8 | 1.9 | 1.0*** | 1.1 | Improved Wk by 6, Deteriorating by Wk 8 |
| | AVVQ* | 9.0 | 7.5 | 9.2 | 26.4 | 20.8 | 19.3 | Improved Wk 6, Continued by Wk 8 |
| Generic | EQ5D** | 0.8 | 0.9 | 0.8 | 0.7 | 0.7 | 0.7 | No Change |
| | VAS* | 82.9 | 82.8 | 78.1 | 63.4 | 72.7 | 70.9 | Increased by Wk 6 then decreased by Wk 8 |
| | CES-D* | 8.8 | 7.9 | 10.6 | 13.8 | 11.8 | 13.4 | Improved by Wk 6 then worsened by Wk 8 |
| | SF-12** | 99.7 | 95.5 | 76.6 | 83.1 | 93.5 | 67.4 | Improved Wk by 6, Deteriorating by Wk 8 |

***- $p < 0.01$, independent t-test

Key Learning Points: Further evaluations may need to be done in order to determine what specifically improved in use of the geko™ for those individuals with deep CVI, and what it was about using the device that those with superficial disease objected to. None of the volunteers found that the devices interfered with their activities of daily living or their mobility. Some chose to activate the device overnight rather than in the waking hours. The trial was underpowered to fully evaluate quality of life changes from using the device, but the results when viewed as a pilot are encouraging.

8-1b. Harris C, Ramage D, Bolorchi A, Vaughan L, Kuilder G, Rakas S. Using a muscle pump activator device to stimulate healing for non-healing lower leg wounds in long term care residents. *IWJ* 2019;16(1):266-274.

Open access on-line <https://onlinelibrary.wiley.com/doi/epdf/10.1111/iwj.13027> (Please see wound results in paper 7-2.c.ii.)

In the Long-Term Care evaluation with Revera, the following feedback was received concerning use of the geko™ device:

- One resident was extremely thrilled with the wound healing progress and on numerous occasions sought the nurse out to let him know how much more enjoyable life was without the discomfort and knowledge of the wound.
- A resident with dementia whom nurses thought might not keep it on but did and healed quite quickly. The POA was happy that the resident was chosen for the pilot
- The son of another resident who healed was very pleased with outcome of pilot.
- Initial application of device was accepted well, throughout the process the resident was quite happy. He observed “marked improvement” in his wound healing and stated “I know it’s the machine”.
- Another resident was extremely happy that he does not have to have his “dressings” done. He liked how the device “feels” on his feet (he could feel it working)
- A final resident found the “strong beat” annoying and did not like to have the devices showing below her skirts.

Key Learning Points: There was positive feedback as well as the one negative; this woman was of a slight build and may have been more comfortable with a lower amplitude geko™ device (this was using R-2s).

8-1c. Paper: Jones NJ, Ivins N, Ebdon V, Hagelstein S. Harding KG, A case series evaluating the geko™ neuromuscular electrostimulation device on lower limb wounds of differing aetiology. *British Journal of Nursing* 2018, 27(20): S16-S21. TISSUE VIABILITY SUPPLEMENT.

Please also see the summary of this paper in 7-2e.ii. regarding the wound healing results.

Pain: 52% of patients reported a substantial reduction in wound pain during the evaluation. Two patients reported an increase in subjective pain during the 8 weeks, due to increasing bioburden within the wound bed which was treated. The remaining 40% of the cohort experienced either no pain (e.g. neuropathic DFU) or no change in pain levels between baseline and endpoint.

Patient satisfaction: *All patients who completed the evaluation reported 100% satisfaction with the device. They reported that it was easy to operate and provided minimal disruption to their daily living. These positive outcome measures enabled patients to self-manage manage the device and take control of their symptoms while undertaking normal daily activities.*

Key Learning Points: The results support the use of geko™ NMES therapy in patients with painful VLUs and Mixed venous etiology leg ulcers.

8-1d.i. Poster: Kuhnke JL, Maxwell S. Cape Breton University, Sydney, Nova Scotia, Canada. Venous Leg Ulcer Wound Healing with geko™: “I hope that my wound will heal faster”: A qualitative inquiry. Presented at: Wounds Canada (online) September 2020. Available at: <https://www.gekocodevices.com/wp-content/uploads/2020/11/2020-Sept-29-Neuromuscular-device-Kuhnke-Maxwell.pdf> Also see 7-2g. and 7-2j. for the wound healing results of the quality improvement initiative associated with this paper.

Aim: *Qualitative study focusing on exploring individual’s perspectives on using the muscle-pump activator - geko™ while living with a new or recurring venous leg ulcer.*

Methodology: *Using qualitative interviews, seven participants discuss their experiences with leg ulcers and use of the geko™. Research ethics and client consent were obtained. Using thematic analysis, themes emerged.*

Findings: *1) Participants describe use of pain medications and stress when living with leg ulcers; 2) They describe the concept of time, from the time the ulcer forms to wound healing; and 3) Participants describe feeling hopeful and were optimistic the device would help the wound become smaller and heal faster.*

Key Learning Points: Hope was described by participants as growing when offered the geko™ device to support wound healing. Participants describe feeling valued.

8-1d.ii. Paper: Kuhnke JL, Maxwell S. Patients’ Perspectives of Pain, Time, and Hope When Living with Venous Leg Ulcers and Using the geko™ Device: A Qualitative Descriptive Inquiry. *Spotlight on Research*. July 21. Available at:

<https://www.spotlightonresearch.com/exploratory-research-in-health/jksm> Accessed July 10, 2021.

Expanded information regarding the qualitative study described above.

Additional Key Findings: Participants in this study described ‘agency’ and a deep desire to want to feel hopeful while living with a new, or recurring ulcer. Agency is the “perceived capacity to use one’s pathways to reach desired goals”. Though they describe the emotional and physical burdens related to the venous disease process (pain, odour, fatigue, wound drainage), being offered the geko™ device drew forward deep, positive emotional responses. Words such as: “there is hope”, “finally, I feel optimistic”, “I educated myself”, and “I feel hopeful with this device” contribute to this understanding. In this study, participants yearned for wound healing or improvement in their ulcer. They identified this as possible, when offered the geko™ device to aid wound healing. Through offering the geko™ device, it generated in participants a sense of agency; in turn they described feeling valued. Hope was described by participants as growing when offered the geko™ device to support wound healing. We see this study as an important contribution to the role of adjunctive therapies in VLU.

9. The geko™ Device and Tolerability

9-1a.i. Paper: Williams KJ, Moore HM, Ellis M, and Davies AH. Comparing the venous haemodynamic effect of a neuromuscular stimulation device to intermittent pneumatic compression in healthy subjects. 14th Meeting of the European Venous Forum, Belgrade, Serbia, 27–30 June 2013. Paper 1.5. (The hemodynamic results for this paper appear in Section 3-2d-e.)

9-1a.ii. Paper: Williams KJ, Moore HM, M Ellis and Davies AH. Haemodynamic changes with the use of a neuromuscular stimulation device compared to intermittent pneumatic compression. Phlebology. Online 10 April 2014.

Results Tolerability of the device was rated by each user at the end of the protocol, using a verbal reported score (0–5; no pain, to that experienced by inflating a blood (pressure cuff to 200 mmHg). All patients tolerated both devices and completed the trial. On a verbal reported score, from 0 (painless) to 5 (as painful as a sphygmomanometer cuff inflated to 200 mmHg), IPC was rated a mean of 1.5, and NMES as 2.8 ($p=0.006$, paired Student’s t-test).

9-1b. Paper: Jawad H, Bain DS, Dawson H, Crawford K, Johnston A, Tucker AT. The effectiveness of a novel neuromuscular electrostimulation method versus intermittent pneumatic compression in enhancing lower limb blood flow. J Vasc Surg Venous Lymphat Disord. 2014;2(2):160-5. (The hemodynamic results for this paper appear in Section 3-2f).

Methods: At the end of each program, subjects were asked to evaluate their acceptance and tolerance to each device using a discomfort questionnaire. Maximum discomfort was compared to a blood pressure cuff inflated around the upper arm. Subjects rated their discomfort levels using a visual analogue scale (VAS) by marking the level of the perceived pain along a 100 mm line, marked at one end “no sensation” and at the other end “severe discomfort”. A discrete five category verbal rating scale (VRS) was used to select the appropriate category of the perceived discomfort, where “1 = no sensation (other than muscle tensing and relaxing)”, “2 = minimal sensation”, “3 = mild discomfort”, “4 = moderate discomfort”, or “5 = severe discomfort.”

Results: For the geko™ T-1 device: ~VAS: 35/100 geko™ set on low, 46.5/100 set on HIGH; VRS: ~2.4/5 set on LOW, 3.5/5 when set on HIGH. Analysis of the discomfort levels reported following the use of each device was not significant using the visual analogue score, $p > 0.05$, but showed a statistically significant difference using the verbal rating score, $p \leq 0.05$. The discomfort level following the use of the geko™ T-1 device at the Normal Clinical Use setting was rated as mild discomfort as compared to the other devices studied, which were rated at a minimal sensation.

9-1c. Paper: Warwick DJ, Shaikh A, Gadola S, Stokes M, Worsley P, Bain D, Tucker AT, Gadola SD. Use of the geko™ device in below knee cast patients. Neuromuscular electrostimulation via the common peroneal nerve promotes lower limb blood flow in a below-knee cast. Bone Joint Res 2013; 2:179–85. (The hemodynamic results for this paper appear in Section 3-2u.)

Methods: Participants were asked to evaluate acceptance and tolerability of the geko device using a verbal rating score (VRS): 1, no sensation; 2, minimal discomfort; 3, mild discomfort; 4, moderate discomfort; and 5, severe discomfort. Discomfort was related to normal measurement of blood pressure, measured on the upper arm using a standard sphygmomanometer cuff, which was standardized as rating 3. Participants also indicated the level of discomfort by marking a 10 cm visual analogue scale (VAS), with 0 denoting ‘no sensation’, and 10 indicating ‘severe discomfort’.

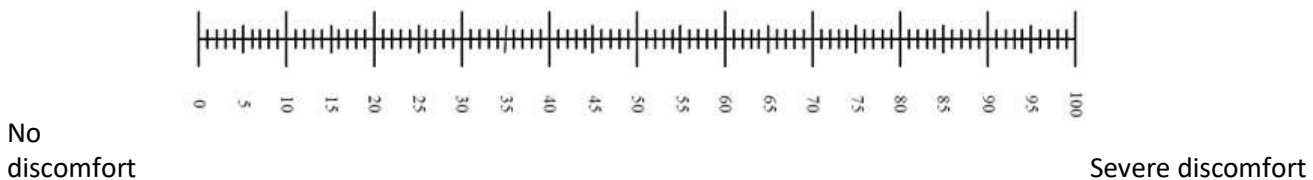
Results: The median level of discomfort measured on the VRS across all postural positions using the geko device was 2, denoting ‘minimal discomfort’. The median level of discomfort was slightly higher without casting compared with discomfort when casting was applied. The VRS showed that in the supine and leg-elevated positions participants were significantly less comfortable without casting compared with the same position with casting (median difference 1, $p =$

0.008 to 0.02). The median VAS across all positions was 2.5 (0.9 to 6.5) with the geko™ device. Again, a lower level of discomfort was reported in the supine and leg elevated positions with casting compared with no casting (median differences 1, $p = 0.002$ to 0.004).

Key Learning Points (all papers): there appears to be a trend with the VRS where individuals are aware of the sensation, with some feeling a mild discomfort. None of the participants in these papers had open wounds, which might impact their perception of the geko™ stimulation. Anecdotally, patients often say that they do not notice it after wearing for a short while, and it would be helpful to look at the results using these evaluations over a period of time, particularly when there is an open wound. It would be important to separate discomfort from the wound and discomfort from the device.

9-1d. Poster: Williams KJ, Ravikumar R, Babber A, Davies AH. Can neuromuscular stimulation relieve symptoms of chronic venous disease, and improve quality of life? Annual Meeting of the Society-of-Academic-and-Research-Surgery (SARS) 2015, Publisher: WILEY-BLACKWELL, Pages: 9-9, ISSN: 0007-1323. (Please see section 8-1a. for the QoL results)

Methods: The Visual Analogue Score (VAS) used asked: “If severe discomfort is comparative to that experienced when having your blood pressure taken, please mark the line where you place your discomfort level whilst wearing the neuromuscular device”.



Results: The device was well tolerated.

10. Consensus and Literature Reviews

10-1a. Paper: Williams KJ, Ravikumar R, Gaweesh AS, Moore HM, Lifszit AD, Lane TRA, Shalhoub J, Babber A, Davies AH. A Review of the Evidence to Support NMES in the Prevention and Management of Venous Disease. Chapter: Thrombosis and Embolism: from Research to Clinical Practice. Advances in Experimental Medicine and Biology. 2016. 906:377-386

Methods: A literature search of the EMBASE and Medline databases was performed, with articles up to August of 2014, and studies were included if they were full text articles, written in English, pertaining to venous disease and neuromuscular electrical stimulation (NMES).

Results: 46 articles met the inclusion criteria, although comparison between trials is hampered by variations in protocols and outcome measures, and the method of stimulation (direct muscle stimulation versus stimulation of the common peroneal nerve causing muscle innervation). NMES devices increase venous haemodynamic parameters such as peak velocity and volume flow with stimulation of the calf muscle pump compared to rest. Calf vascular resistance was significantly reduced after NMES, equivalent to that seen post-exercise, which may suggest that the benefit continues for some time after the device is stopped. Studies report them to be non-inferior to intermittent pneumatic compression (IPC), without the complications inherent to IPC. They are effective in the prevention of venous thromboembolism, though inferior to low molecular weight heparin. NMES can increase cardiac stroke volume (24%, cardiac output (26%) and reduce total peripheral resistance (21%) when compared to IPC of the calf and thigh. *NMES is an important tool in the prevention and management of venous disease, and avoids the significant risks associated with heparin administration. Data explored here is heterogenous in device, protocol, and reported end-points, therefore should be interpreted with care. Long term effects of treatment with NMES have not been explored. The lack of uniformity of nomenclature impedes comparison between devices. A consensus needs to be achieved on reporting of electrical parameters such as pulse width, frequency of stimulation, intensity and waveform. Research should also investigate the effects of dosing, duration of treatment and long-term effects of electrical stimulation in treating venous disease.*

Key Learning Points: NMES can reduce symptoms of chronic venous disease, causing reversal of fluid pooling in the legs (orthostatic edema) and is augmented by a factor of 2 with the addition of graduated compression stockings. NMES may also be able to positively impact the ability of the calf muscle pump to be trained over time. Many of the geko™ articles were published after the August 2014 search date and were not included in this review.

10-1b. Paper: Orsted HL, O’Sullivan-Drombolis D, Haley J, LeBlanc K, Parsons L. The effects of low frequency nerve stimulation to support the healing of venous leg ulcers. Canadian Association of Wound Care Consensus Paper - November 2016. <https://www.woundscanada.ca/docman/public/health-care-professional/bpr-workshop/70-bpr-lfns-final-110316/file>

Methods: A literature search was conducted (Spring 2016) to gain a better understanding of the evidence describing the physiological effects that LFNS may have on the body. Terms used included *electrical stimulation, leg ulcer, NMES* and *TENS*. The result is a narrative, not exhaustive review based on a selected sample of articles based on convenience from that initial search. Intended to provide an overview of this area of emerging research and clinical practice, using a small self-contained, portable, single-patient-use device that applies stimulation at 1 Hz over the common peroneal nerve in the lower leg (geko™).

Results: *LFNS appears to have positive effects on blood flow in healthy volunteers. As of yet there is limited research in patients with chronic venous insufficiency. More investigation on the physiological effects that occur when the machine is applied for longer periods is warranted. Low frequency nerve stimulation causes the release of endogenous opiates and hormones within the body, thereby activating the body’s own pain-relief mechanisms. This tends to have longer-lasting effects whole-body effect compared with other methods of electrical stimulation used for pain relief. This in turn encourages an increase in patient mobility. It is also effective in reducing the symptoms of neuropathy, which is experienced in CVI. It is not clear to date what benefit it will have on patients with CVI, and they recommend further study to assess the ejection fraction and direct comparison between use of LFNS over the common peroneal nerve and full-force contraction of the gastroc and soleus calf-muscle pump to help determine the actual physiological effects behind the demonstrated improvements in edema. The goal of LFNS is to optimize edema reduction pain control and improved blood flow for wound healing compare to direct electrical stimulation which stimulates the wound itself. The warnings and precautions listed in this document pertain to electrical stimulation and NOT the use of the geko™ device.*

Key Learning Points: *Although current literature is inconclusive, the evidence presented above does demonstrate that this modality does have benefit in addressing pain and neuropathy, venous stasis and blood flow. These impairments have important impact on a patient’s ability to heal, particularly in patients with venous leg ulcers. Clinicians should consider the use of LFNS:*

- with challenging and refractory wounds that are not responding to traditional treatments.
- to benefit patients who are at risk for developing DVT
- to manage lower leg edema that is contributing to reported pain
- to manage stalled, chronic lower leg wounds that are not progressing along the expected healing trajectory
- in conjunction with compression or when compression cannot be tolerated
- to benefit patients who have lower leg neuropathy
- for patients with fixed ankle joints, those who are bed ridden or those who have limited mobility.

Early expert opinion would suggest that an evaluation over a four-week period, and beginning cautiously, would be a good starting point to determine if LFNS has a patient-specific benefit. The cumulative effects of using LFNS — of improving circulation (arterial and venous) as well as reducing pain and associated improved mobility — have shown to have positive effects on wound healing.

10-1c. Paper: Harding, K. An Innovative Technology for Healing Venous Leg Ulcers: geko™. Expert opinion paper. Distributed at CAWC Conference 2016, Niagara Falls, ON.

Presented as a handout at an oral podium presentation that he was doing, Dr. Keith Harding used this opinion paper to discuss new evidence that has emerged since the LFNS Consensus paper by the CAWC group commenced their efforts and his own personal experience of using the technology. In his words: “geko™ should be considered as an adjunctive therapy in the following groups of patients until the larger trials are completed:

- *Fixed ankle joints or in those with limited mobility (i.e., < 200 metres per day). Blood flow is known to be compromised in these patients due to a lack of muscle pump activity.*
- *When wounds have become or are suspected to become (based on history/risk factors) difficult to heal. This is typically thought of as wounds that have not reduced in size by 30% at 30 days of best practice therapy.*
- *When compression cannot be tolerated. Without compression, blood flow is compromised. In some patients, compression could be tolerated after LFNS for a period of time.*
- *Where edema is present. Edema impedes healing progress and this, of course, is also tied to blood flow.*
- *For the management of peripheral neuropathic symptoms.*

- For patients that have pain associated with their wounds.

The main danger preventing wider adoption of this technology appears to be financial consideration. However, when one considers the guiding principle of “treating the root cause” of all wounds it would seem reasonable that many wound patients would benefit from improved blood flow. If the technology exists to deliver this, then it should be used where appropriate.”

10-1d. Paper: Richardson MC. In R. Mani et al. (eds.), Chapter 10. Alternative Technological Approaches to Achieving Improved Venous Return. *Compression and Chronic Wound Management* 2019. Pages 179-184.

Abstract *The role and importance of compression in achieving venous return is well understood and the use of multilayer compression remains the standard of care for the patient with a Venous Ulcer. However, a range of alternative technologies have emerged which aim to reduce or overcome some of the disadvantages of bandaging. This chapter explores methods of pressure assessment under bandages to facilitate application of bandages and also discusses alternatives to bandaging including adjustable systems, Intermittent Pneumatic Compression (IPC) Systems and finally powered muscle stimulators. All these approaches, as the evidence supporting them develops, could offer useful alternatives to compression for a number of patient groups.* Content regarding the geko™ device includes a summary of the method of increase to venous, arterial and microcirculation in people with chronic venous insufficiency, and the author offers it as a potential alternative to compression bandaging for patients allowing them to better achieve their treatment goals.

Key Learning Points: Since this was written, the Canadian Consensus Document for the Management of Venous Ulcers has been published (2024), recommending the Muscle Pump Activating Device (geko™) device as a viable option when patients cannot tolerate full or any compression therapy, thus supporting this statement.

10-1e. Paper: Aleksandrowicz H, Owczarczyk-Saczonek A, and Placek W. Venous Leg Ulcers: Advanced Therapies and New Technologies [Biomedicines](#). 2021 Nov; 9(11): 1569. Published online 2021 Oct 29. doi: [10.3390/biomedicines9111569](#)

Abstract:

*The prevalence of venous leg ulcers (VLUs) differs between 1.5% and 3% in the general population. The challenge in treating VLUs is common recurrence. Moreover, VLUs can be resistant to healing, despite appropriate treatment. In these cases, advanced wound therapies should be considered. The number of new technologies, applied in VLUs treatment, has increased in the last years. These therapies include biophysical interventions such as ultrasound therapy, electrical stimulations, electromagnetic therapy, or phototherapy. Furthermore, stem cell therapies, biologic skin equivalents, platelet-rich plasma therapy, oxygen therapies, anti-TNF therapy, or negative pressure wound therapy are advanced venous ulcer therapeutic methods that may support the standard of care. **Medical devices, such as a muscle pump activator, or intermittent pneumatic compression device, may be especially useful for specific subgroups of patients suffering from VLUs.** Some of the above-mentioned technologies require broader evidence of clinical efficacy and are still considered experimental therapies in dermatology.*

Key Learning Points:

The authors included reference to the geko™ case series paper Harris et al. Evaluation of a muscle pump-activating device for non-healing venous leg ulcers. *International Wound Journal*. 2017. 14;6: 1189-1198. They reviewed that the *Muscle pump activator (MPA) device works by neuromuscular electrostimulation (NMES) and stimulates the common peroneal nerve which causes calf muscles isometric activation. Consequently, a stimulated calf muscle pump induces venous return enhancement, and causes edema and venous stasis reduction, concluding that this therapy may be particularly advantageous in patients with limited mobility.*

10-1f. Paper: Bosanquet DC, Harding KG. Wound healing: potential therapeutic options. *Br J Dermatol*. 2021 Nov 2. doi: 10.1111/bjd.20772. Epub ahead of print. PMID: 34726774.

Background: *This review highlights the range of therapeutic options available to clinicians treating difficult-to-heal wounds. While certain treatments are established in daily clinical practice, most therapeutic interventions lack robust and rigorous data regarding their efficacy, which would help to determine when, and for whom, they should be used. The purpose of this review is to give a broad overview of the available interventions, with a brief summary of the evidence base for each intervention.*

Content concerning neuromuscular electrostimulation (NMES): *An alternative approach to improving lower limb circulation is to use a neuromuscular electrostimulation device. Devices are placed around the leg adjacent to the patella and cause isometric muscular contraction initiated by a transdermal stimulus to the common peroneal nerve. Other*

neuromuscular-stimulating devices are footplates, which initiate regular ankle dorsiflexion. Case series have described use of these devices for successful wound healing, although no randomized data currently exist for its efficacy.

Key Learning Points: The Canadian Consensus Document for the Management of Venous Ulcers has since been published (2024), recommending the Muscle Pump Activating Device (geko™) device as a viable option to improve calf muscle pump function when patients cannot tolerate full or any compression therapy, or when the wound is failing to heal, thus supporting this statement.

10-1g. Paper: Karanikolic V, and Karanikolic A. Diagnosis and Treatment of Venous Leg Ulcer. In: Maurício AC, Alvites RD, Gönül M. Wound Healing - Recent Advances and Future Opportunities [Working Title]. 2022. IntechOpen, London. 10.5772/intechopen.105676. Available at: <https://www.intechopen.com/online-first/82402>

Background: *If VLU do not heal despite the application of standard therapeutic modalities, there are opportunities to apply new treatment technologies. The modern approach to the treatment of VLUs is based on the application of various biophysical interventions and medical devices.*

Content concerning neuromuscular electrostimulation (NMES): *In addition to the application of standard methods of treating VLUs,..... the use of a muscle pump activator or device with occasional pneumatic compression in a number of patients with VLUs has been shown to be very successful.*

Key Learning Points: *The application of modern diagnostic and therapeutic modalities in the treatment of VLUs in combination with available evidence-based data will reduce the number of patients who will not heal and who will relapse. Therefore, the use of standard treatment methods and the use of expensive advanced therapeutic agents is of particular importance.* The Canadian Consensus Document for the Management of Venous Ulcers has since been published (2024), recommending the Muscle Pump Activating Device (geko™) device as a viable option to improve calf muscle pump function when patients cannot tolerate full or any compression therapy, or when the wound is failing to heal, thus supporting this statement.

11. Fecal and Urinary Incontinence: Use of the geko™ Device Stimulating the Tibial Nerve

11-1a. Paper: Rimmer CJ, Knowles CH, Lamparelli M, et al. Short-term Outcomes of a Randomized Pilot Trial of 2 Treatment Regimens of Transcutaneous Tibial Nerve Stimulation for Fecal Incontinence. *Dis Colon Rectum* 2015; 58:974-82.

Background: *Fecal incontinence is a socially disabling condition that affects ≤15% of adults. Neuromodulatory treatments for fecal incontinence are now well established. Less invasive, cheaper, and more ambulatory forms of neuromodulation are under exploration.*

Objective: *The purpose of this study was to assess the acceptability and safety of a new ambulatory tibial nerve stimulation device and to determine clinical effect size for 2 differing regimens of therapy.*

Design: *This was a randomized, investigator-blinded, parallel-arm, 6-week pilot trial.*

Settings: *The study was conducted at 7 United Kingdom trial centers. Patients were initially reviewed in the trial center, with subsequent applications of the device performed in the patients home setting.*

Patients: *A total of 43 eligible patients (38 women) who failed conservative management of fecal incontinence were included in the study.*

Intervention: *The study intervention involved twice weekly, 1- versus 4-hour transcutaneous tibial nerve stimulation for 6 weeks (total of 12 treatments). The geko™ T-1 device was utilized and the positioning over the tibial nerve is demonstrated in the article, using a vertical rather than horizontal orientation on the distal lower leg.*

Main outcome measures: *Standard fecal incontinence outcome tools (bowel diary, symptom severity score, and generic quality-of-life instruments) were used to collect data at baseline and at 2 weeks post treatment cessation.*

Results: *A total of 22 patients were randomly assigned to the 1-hour group and 21 to the 4-hour group. Improvements in fecal incontinence outcomes were observed for both groups, including median urge incontinence episodes per week at baseline and post treatment (1-hour group 2.0 to 0.5 versus 4-hour group 4.0 to 1.0) and deferment time (1-hour group 2.0 to 2.0 minutes versus 4-hour group 0.5 to 5.0 minutes). Accompanying changes were observed in physical functioning domains of quality-of-life instruments. There were no adverse events, and the treatment was highly acceptable to patients.*

Limitations: *Limitations included the pilot design and lack of control arm in the study. Future trials would need to address these limitations.*

Conclusions: *This pilot study provides evidence that transcutaneous tibial nerve stimulation with a new ambulatory device is safe and acceptable for the management of fecal incontinence. Additional study is warranted to investigate clinical effectiveness.*

Key Learning Points:

Transcutaneous posterior tibial nerve stimulation using the geko™ device is safe, non-invasive and allows the patients to be fully ambulatory during treatment without requiring visits to a clinic to have the treatment.

11-1b. Paper: Seth JH, Gonzales G, Haslam C, Pakzad M, Vashisht A, Sahai A, Knowles C, Tucker A, Panicker J. Feasibility of using a novel non-invasive ambulatory tibial nerve stimulation device for the home-based treatment of overactive bladder symptoms. *Transl Androl Urol.* 2018;7(6):912-919. doi: 10.21037/tau.2018.09.12.

Background: *To evaluate safety, acceptability and pilot efficacy of transcutaneous low-frequency tibial nerve stimulation (TNS) using a novel device as home-based neuromodulation.*

Methods: *In this single-centre pilot study, 48 patients with overactive bladder (OAB) (24 with neurogenic and 24 with idiopathic OAB) were randomized to use a self-applicating ambulatory skin-adhering device stimulating transcutaneously the tibial nerve at 1 Hz for 30 minutes, either once daily or once weekly, for 12 weeks. The geko™ T-1 device was utilized and the positioning over the tibial nerve is demonstrated in the article, using a vertical rather than horizontal orientation on the distal lower leg. Changes in OAB symptoms and QoL were measured at baseline, weeks 4, 8, and 12 using validated scoring instruments (ICIQ-OAB and ICIQ-LUTSqol), 3-day bladder diary and a Global Response Assessment (GRA) at week 12.*

Results: *Thirty-four patients completed the study (idiopathic n=15, neurogenic n=19). No significant adverse effects were noted. Patients found the device acceptable. Eighteen patients (53%) reported a moderate or marked improvement in symptoms from the GRA. Between baseline and week-12, ICIQ-OAB part A sub-scores improved from mean (SD) 9.3 (2.5) to 7.5 (3.1), and from 9.1 (1.9) to 5.9 (1.7) in the daily and the weekly arms, respectively. ICIQ-LUTSqol part A sub-scores improved from mean (SD) 51 (12.8) to 44.2 (13.1) and 44.9 (9.0) to 35.9 (8.8) in the daily and the weekly arms, respectively. Bladder diary mean 24-hour frequency episodes improved from 11.5 to 8.8 at week 12 for both arms.*

Conclusions: *This novel ambulatory transcutaneous TNS (TTNS) device is safe and acceptable for use in patients reporting OAB symptoms as a form of home-based neuromodulation. A larger study however is required to confirm clinical efficacy.*

Key Learning Points:

Transcutaneous posterior tibial nerve stimulation using the geko™ device is safe, non-invasive and allows the patients to be fully ambulatory during treatment without requiring visits to a clinic to have the treatment.

12. firefly™ Data for Elite Sport Recovery - OnPulse™ Technology

12-1a. Case Study: Dixon B. The Use of Neuromuscular Electro-stimulation during Rehabilitation Post Osteoarticular Transfer System Surgery in a Professional Football Player. 2013. Available at: <https://www.recoveryfirefly.com/pages/study-7> Accessed March 1, 2022.

Subject and medical history: 19-year-old male professional football player who reported chronic right ankle stiffness post training sessions believed to be due to a previous ankle inversion injury. A 1cm osteochondral defect of the talus with subchondral oedema and synovitis was observed on MRI. The subject underwent osteoarticular transfer system surgery and began a rehabilitation protocol.

Rehab Protocol: The player completed two standardized running sessions within seven days as part of his planned recovery, and on the second session the NMES (firefly™ On Pulse™) device was applied to both legs and worn for 6 hours following the second session.

Methods: The subjective measures were taken using a semi-structured interview where the player was asked their perception of general fatigue and muscle soreness, ankle swelling, ankle soreness, ankle range of motion (ROM), calf soreness, knee soreness (donor site), plantar/foot pain and any additional comments they considered relevant. Three objective markers were also used to measure the ankle swelling and ankle ROM. These were the figure of 8 measurement, malleolus girth and knee to wall (KTW).

Results: Following the NMES intervention, the athlete's perception of ankle swelling improved along with slight improvements in the perception of general soreness, specific ankle soreness and stiffness.

Figure of 8 measurements remained similar for both interventions. Malleolus girth increased 24 hours post in both. However, after the control intervention malleolus girth increased by 1.2cm on the injured side compared to an increase of 0.8cm in the NMES intervention.

Key Learning Points: The positive effect of the NMES device to reduce ankle swelling along with the improvements in perceived post exercise soreness, as shown by the general fatigue and soreness scores, are important to consider, and may contribute significantly to the athlete's confidence in their ability to perform and cope with the demands of their sport following a long-term injury.

12-1b. Poster: Pelech N, Morrissey D, Jawad H, Longbottom J, Tucker A. Comparing the effects of acupuncture with neuromuscular stimulation on short-term lower limb blood flow: an observational study. Unknown date. Available at: <https://www.recoveryfirefly.com/pages/study-5> Accessed March 1, 2022.

Background: Enhancing training or injury recovery is a fundamental aspect of achieving optimal athletic performance yet little evidence is available to support many of the popular recovery or treatment aids. Neuromuscular electrical stimulation (NMES) and acupuncture benefit some athletes possibly due to increased blood flow in the healing area.

Aim: The primary aim is to investigate the effect acupuncture (UB-40) asserts on short-term lower limb blood flow, in comparison to neuromuscular stimulation (firefly™ device), in healthy subjects.

Methods: 12 healthy volunteers randomly assigned by leg and intervention. Baseline thermography measurements to assess general perfusion of posterior knee, calf and ankle region were taken. Intervention applied, either 30 minutes of acupuncture to the popliteal fossa or 30 minutes NMES with firefly™ device with physiological measurements* taken throughout interventions. Intervention removed and discomfort questionnaire completed. Subjects rested for 30 minutes then second intervention repeated on opposing leg.

*Laser doppler fluxmetry (LDF), Photoplethysmography (PPG), blood pressure (BP), heart rate (HR), tissue oxygen (TcPO₂), oxygen saturation (SPO₂).

Results: Laser doppler fluxmetry (LDF) showed that the firefly™ device significantly increased microcirculatory velocity in the leg receiving the intervention (ipsilateral) by 30.0 flux units ($p \leq 0.001$) compared to the opposite (contralateral) leg which had no significant change ($p \geq 0.05$). LDF demonstrated that UB-40 acupuncture actually decreased microcirculatory velocity by 1.01 units (11%) in the ipsilateral leg and by 2.19 flux units (18%) in the contralateral leg, neither had significance ($p \geq 0.05$). PPG ipsilaterally showed a statistically significant difference in microcirculatory volume between firefly™ and acupuncture wherein the firefly™ NMES had no significant effect on volume and acupuncture significantly decreased volume by 0.75 normalize units (36%) ($p \leq 0.05$). The ipsilateral knee temperature increased (≤ 0.05) with firefly™ while the ipsilateral achilles and contralateral knee remained constant ($p \geq 0.05$) and both calves and contralateral ankle decreased ($p \leq 0.05$). With acupuncture, the temperature remained constant at all sites ($p \geq 0.05$). There was no difference in discomfort between the two interventions.

Conclusions: The firefly™ significantly increased peritendinous microcirculatory velocity, having the potential to benefit injury healing and training recovery without significantly increasing calf muscle metabolic activity. Future studies with the firefly™ should include patients with pathologies to investigate the effect of increased microcirculatory volume and velocity on healing injuries and improving training recovery.

Key Learning Points:

12-1c. Paper: Beaven CM, Cook C, Gray D, Downes P, Murphy I, Drawer S, Ingram JR, Kilduff LP, Gill N.

Electrostimulation's enhancement of recovery during a rugby pre-season. International Journal of Sports Physiology and Performance, 2013, 8, 92-98. Available at: <https://www.recoveryfirefly.com/pages/study-2> Accessed March 1, 2022.

Background: Rugby pre-season training involves high-volume strength and conditioning training, necessitating effective management of the recovery-stress state to avoid overtraining and maximize adaptive gains.

Purpose: Compression garments and an electrostimulation device have been proposed to improve recovery by increasing venous blood flow. These devices were assessed using salivary testosterone and cortisol, plasma creatine kinase, and player questionnaires to determine sleep quality, energy level, mood, and enthusiasm.

Method: Twenty-five professional rugby players were assigned to 1 of 2 treatments (compression garment or a concurrent combination of electrostimulation (OnPulse™ neuromuscular electrical stimulation device) and compression) in a crossover design over 2 × 2-wk training blocks. Each player self-selected a pulse width that was tolerable and produced visible ankle dorsiflexion and plantar flexion, which is considered to be a therapeutic response.

Results: On average, treatment duration was 11.3 ± 1.9 hours for compression and 8.4 ± 3.4 hours for the combined treatments. The combined treatment resulted in substantial benefits in self-assessed energy levels (effect size [ES] 0.86), and enthusiasm (ES 0.80) when compared with compression-garment use alone. No significant differences in salivary

hormones (testosterone and cortisol) were observed between the treatments. The electrostimulation device did tend to accelerate the return of creatine kinase (CK) to baseline levels after 2 preseason rugby games when compared with the compression-garment intervention but was not statistically significant (ES 0.61; P = .08).

Key Learning Points: The combined use of an electrical stimulation device with compression garments was more effective at eliciting positive responses in self-reported energy and enthusiasm, and reduced CK levels, than the use of a compression garment alone after rugby matches. Increased CK levels are considered markers of muscle damage, so an accelerated return to baseline suggests a faster muscle recovery period.

12-1d. Poster: Ferguson RA, Dodd MJ, Thompson EB, Taylor CW. Effect of neuromuscular electrostimulation via the peroneal nerve on one-legged peak oxygen uptake and peak power output following four weeks of high intensity intermittent training. 2014. Available at: <https://www.recoveryfirefly.com/pages/study-3> Accessed March 1, 2022.

Introduction: Numerous techniques have been suggested to enhance recovery following intense exercise; however, there is evidence that some of these practices, such as cold water immersion, may actually blunt the long term adaptive response to exercise (Yamane et al., 2006). We have previously demonstrated that the use of a novel technique of neuromuscular electrostimulation (NMES) enhances the recovery process following intense intermittent exercise (see 3-11e. which had been presented in Barcelona in 2013). However, the long-term effect of this technique and its impact on the adaptive response to training is not known. The aim of the present study was to examine the effects of NMES immediately following each training session during 4 weeks of high intensity intermittent training (HIIT).

Methods: Seven healthy males (age 23 ± 2 years, height 177 ± 8 cm, body mass 79 ± 17 kg, VO_{2max} 47 ± 7 ml.kg⁻¹.min⁻¹) completed 12 sessions of HIIT (3 sessions per week), which consisted of 3-7 repetitions of 30 second maximal sprints on a cycle ergometer, each separated by 4 minutes recovery. Immediately after each training session, using a within-subjects design, one leg underwent OnPulse™ NMES treatment set to at least level 3 with visible contractions for an 8-hour period and the contralateral leg did not undergo any treatment (CON). Pre- and post-training measurements were made in each leg of one-legged peak oxygen uptake (VO_{2peak}) and peak power output. A two-way (2 x 2) ANOVA with repeated measures was conducted to analyse the within-subject effect of treatment (NMES, CON) and time (pre, post). Significance was accepted at $P < 0.05$ and data are presented as mean \pm SD.

Results: Whole body VO_{2max} increased ($P < 0.05$) following 4 weeks of HIIT (47 ± 7 vs. 51 ± 7 ml.kg⁻¹.min⁻¹, pre and post-training, respectively). There was a main effect for time for one-legged VO_{2peak} ($P < 0.05$), which increased following training in CON from 37 ± 8 to 40 ± 8 ml.kg⁻¹.min⁻¹ and in NMES from 38 ± 6 to 42 ± 6 ml.kg⁻¹.min⁻¹. There was a main effect for time on one-legged peak power output ($P < 0.05$), which increased following training in CON from 138 ± 24 W to 157 ± 32 W and in NMES from 142 ± 36 W to 165 ± 30 W. There were, however, no differences between CON and NMES for either measure.

Key Learning Points: The use of a novel NMES technique immediately following each training session during 4 weeks of HIIT does not have a detrimental effect on the adaptive response.

12-1e. Paper: Ferguson RA, Dodd MJ, Paley VR. Neuromuscular electrical stimulation via the peroneal nerve is superior to graduated compression socks in reducing perceived muscle soreness following intense intermittent endurance exercise. Eur J Appl Physiol. Online 11 July 2014. Available at: <https://www.recoveryfirefly.com/pages/study-4> Accessed March 1, 2022

Purpose: A novel technique of neuromuscular electrical stimulation (NMES) device via the peroneal nerve has been shown to augment limb blood flow which could enhance recovery following exercise. The present study examined the effects of NMES OnPulse™ technology, compared to graduated compression socks on muscle soreness, strength, and markers of muscle damage and inflammation following intense intermittent exercise.

Methods: Twenty-one (age 21 ± 1 years, height 179 ± 7 cm, body mass 76 ± 9 kg,) healthy males performed a 90-min intermittent shuttle running test on three occasions. Following exercise, the following interventions were applied: passive recovery (CON), graduated compression socks (GCS) or NMES OnPulse™ technology positioned slightly above the posterior fold of the knee joint, using the biceps femoris tendon as a landmark, with setting no lower than 3 and achieving a consistent and clearly visible outward movement of the foot. Perceived muscle soreness (PMS) and muscle strength (isometric maximal voluntary contraction of knee extensors and flexors) were measured and a venous blood sample taken pre-exercise and 0, 1, 24, 48 and 72 h following exercise for measurement of creatine kinase (CK) and Lactate dehydrogenase (LDH) activity and IL-6 and CRP concentrations.

Results: PMS increased in all conditions immediately, 1 and 24 h post-exercise. At 24 h PMS was lower in NMES compared to GCS and CON (2.0 ± 1.6 , 3.2 ± 2.1 , 4.6 ± 2.0 , respectively). At 48 h PMS was lower in NMES compared to CON

(1.3 ± 1.5 and 3.1 ± 1.8 , respectively). This was statistically significant, favouring the NMES device ($p < 0.001$). There were no differences between treatments for muscle strength, CK and LDH activity, IL-6 and CRP concentrations.

Key Learning Points: 24 hours after exercise, those who had used the NMES device had a level of pain comparable to the control condition at 72 hours. The authors thought it probable that the NMES had an early phase analgesic effect due to stimulation of the afferent nerve fibers as well as contributing to a reduction in oedema due to the increased microvascular blood flow. There were no negative effects on recovery.

12-1f. Taylor T, West DJ, Howatson G, Jones C, Bracken RM, Love TD, Cook CJ, Swift E, Baker JS, Kilduff LP. The impact of neuromuscular electrical stimulation on recovery after intensive, muscle damaging, maximal speed training in professional team sports players. *Journal of Science and Medicine in Sport* 2015;18(3):328-32. Available at: <https://www.recoveryfirefly.com/pages/study-6> Accessed March 1, 2022.

Objectives: During congested fixture periods in team sports, limited recovery time and increased travel hinder the implementation of many recovery strategies; thus alternative methods are required. We examined the impact of a neuromuscular electrical stimulation (NMES) firefly™ OnPulse™ device on 24-h recovery from an intensive training session in professional players.

Methods: Randomised and counter-balanced study. After baseline perceived soreness, blood (lactate and creatine kinase) and saliva (testosterone and cortisol) samples were collected, players completed a standardised warm-up and baseline countermovement jumps (jump height). Players then completed 60 m × 50 m maximal sprints, with 5 min recovery between efforts. After completing the sprint session, players were randomised to wear a neuromuscular electrical stimulation (NMES) firefly™ OnPulse™ device or remained in normal attire (CON) for 8 hr. All measures were repeated immediately, 2- and 24-hr post-sprint.

Results: Twenty-eight professional rugby and football academy players completed this study, on 2 occasions, separated by 7 days. Player jump height was reduced from baseline at all time points under both conditions; however, at 24-hr NMES was significantly more recovered (mean ± SD; neuromuscular electrical stimulation -3.2 ± 3.2 vs. CON $-7.2 \pm 3.7\%$; $P < 0.001$). Creatine kinase concentrations increased at all time points under both conditions, but at 24-hr was lower under NMES ($P < 0.001$). At 24-hr, perceived soreness was significantly lower under NMES, when compared to CON ($P = 0.02$). There was no effect of condition on blood lactate, or saliva testosterone and cortisol responses ($P > 0.05$).

Conclusions: NMES improves recovery from intensive training in professional team sports players. This offers an easily applied recovery strategy which may have particular application during sleep and travel, when athletes are often in cramped conditions for hours at a time.

Key Learning Points: Neuromuscular function recovered to a greater extent with NMES when compared to control, and significantly improved recovery at 2- and 24-hours post-exercise, leading to significant improvements in physical performance at 24-hours post-exercise.

12-1g. Paper: Wainwright TW, Burgess LC, Middleton RG. Does Neuromuscular Electrical Stimulation Improve Recovery Following Acute Ankle Sprain? A Pilot Randomised Controlled Trial. *Clinical Medicine Insights: Arthritis and Musculoskeletal Disorders*. 2019; 12: 1–6. Available at:

<https://d3ijrte8szaw67.cloudfront.net/wp-content/uploads/2019/06/Paper-%E2%80%93-Wainwright-et-al-%E2%80%93-edema-reduction-acute-ankle-sprain-RCT.pdf>

Aim: Following soft tissue ankle injury, patients are often referred for out-patient physiotherapy and present symptoms including pain, reduced range of movement and function, and edema. In this study, we assess the use of a neuromuscular electrical stimulation (NMES) device as an adjunctive therapy to reduce edema in patients recovering from grade I and II ankle sprains.

Methods: This was a single-centre, pilot randomised controlled study, recruiting patients referred to physiotherapy following an ankle sprain. Participants presenting with edema were randomised to one of two treatment groups: (1) the current standard of care (patient education, manual therapy when indicated and personalized exercise prescription) and (2) the current standard of care plus NMES use (firefly™- Firstkind Ltd.) for a minimum of 8 to a maximum of 16 hours per day, while awake. Participants were identified in an emergency department and referred to a physiotherapy department for treatment 1 to 5 days following the injury and returned to clinic 7 days later.

Results: Twenty-two participants completed the study and had full data sets for analysis (11 in each group). Mean volumetric displacement was reduced in the intervention group in comparison to the standard care group ($P = 0.011$); however, there were no between-group differences in figure of eight measurements, function or pain scores. The device

was well tolerated, worn for 8 hours per day within waking hours, with no device-related adverse events recorded, including skin reactions.

Conclusions: *In this pilot, randomised controlled trial, NMES was well tolerated by patients following ankle sprain and demonstrated statistically significant improvements in edema reduction as measured by fluid displacement. No other changes were observed. Further work will need to confirm the clinical significance and effect on longer term recovery post-ankle sprain.*

Key Learning Points: The authors postulated that the short time frame of only 7 days, with some patients already five days post-ankle sprain when the device was fitted, and a small sample size could have limited the ability to detect any differences in pain and function for those using the firefly™ device. Further work is recommended.
