Seeing is Believing: Non-invasive Imaging Technology Captures the Power of Compression Textiles

Suzie Ehmann PT DPT PhD(c) CWS CLWT CLT-LANA

Nova Southeastern University

Abstract

Introduction:
The increasing availability of non-invasive imaging technology has empowered clinicians with new practical tools capable of providing timely objective data for both an accurate initial assessment and comparative data for ongoing management of chronic non-healing wounds.[1] Utilizing specific properties of skin components, these devices capture biophysical changes otherwise invisible to the naked eye.[2] With these tools, cutaneous wound research is evolving from rudimentary wound measurements to a comprehensive dynamic picture of integument healing.

Objective was the utilization of non-invasive imaging technology for the assessment of effects of posture, activity, and compression textile on local tissue water content, tissue oxygenation and deoxygenated hemoglobin levels, and temperature with three different compression applications in healthy subjects.

Methods:
Tissue dielectric constant (TDC), near infra-red imaging spectroscopy (NIRS), and long wave infrared thermography (LWIT) were used to document cutaneous changes following the application of three different compression conditions: longitudinal elastic stockinette, 2-layer cohesive compression system, and combination of the two for 40 healthy subjects. Assessments were made at four time points, in areas of the limb covered by the compression applications and immediately adjacent. (Fig. 1-3) Statistical analysis was performed to analyze comparative changes between compression conditions.

Results:
Variation in biophysical parameters were observed spatially at baseline and remained after the intervention for TDC, NIRS and LWIT for all compression conditions assessed. There was a statistically significant change from baseline for all the compression conditions. However, no significant differences were observed between the compression applications.

Discussion:
Compression has an impact on both micro- and macro-vascular aspects of the integument.[3] Non-invasive imaging technology allows for the timely objective documentation of cutaneous dynamics following compression applications. Additional research is warranted in those patients with edema and chronic non-healing wounds. Focused compression science research utilizing non-invasive imaging technology offers the potential to individualize compression selection by further defining the specific biophysical impact of a specific compression textile application.

Methods

Baseline Measure → **Apply Compression, Measure IP** → **Exercise** → **Post Exercise Measure**

- Baseline Measure:
  - Circumference
  - TDC
- Apply Compression, Measure IP:
  - Apply sensor
  - Apply compression condition
  - Measure supine and standing IP
- Exercise:
  - Walk on TM
  - ≥2.0mph x10min
- Post Exercise Measure:
  - Standing IP
  - Supine IP
  - Circumference
  - TDC
  - LWIT
  - NIR

Figure 1 - Study Protocol (N=40)

IP

Interface pressure (IP, dosage = mmHg) created with the application of a compression textile was measured via TEKscan I-scan® piezoelectric sensor applied to the medial aspect of the right lower extremity. The sensor allowed visualization pressure distribution vertically and horizontally.

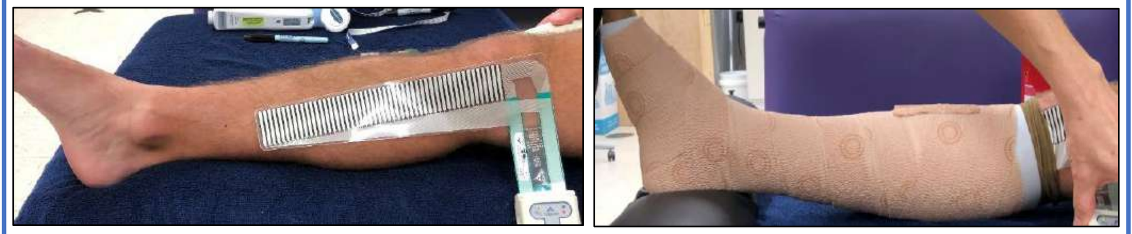


Figure 2 – Measurement of Interface Pressure

TDC

Tissue dielectric constant (TDC) is a non-invasive, convenient, reliable and accurate method to assess local tissue water content (LTWC). Using an open-ended coaxial probe, a low power 300MHz signal is transmitted into the skin. Based on the portion of the portion transmitted back, a TDC value is determined.

The TDC value contains both free and bound water in the tissue. It has been used to assess lower limb edema, lymphedema and both post-operative and post-treatment changes. The MoistureMeterD compact (MMDC) was utilized (Delfin Technologies Ltd, Finland).

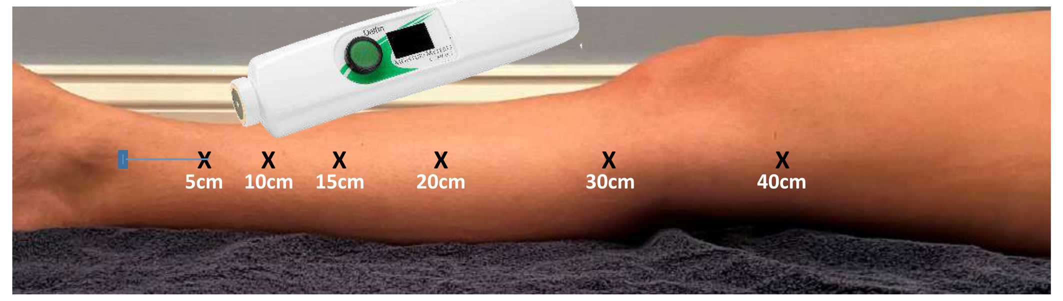


Figure 3 – Measurement of Local Tissue Water Content

NIRS

Near infrared spectroscopy (NIRS) uses light transmitting and absorption to calculate tissue composition including oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-HB) levels. By measuring the relative absorption of near infrared light, the ratio of oxygenated to oxygenated plus deoxygenated hemoglobin can be determined. This technology has been used in various experimental and clinical setting to investigate tissue perfusion and oxygenation non-invasively. The accuracy of this measurement technique has been correlated with transcutaneous oxygen perfusion (TCO2), correlation coefficient of .92.[4]

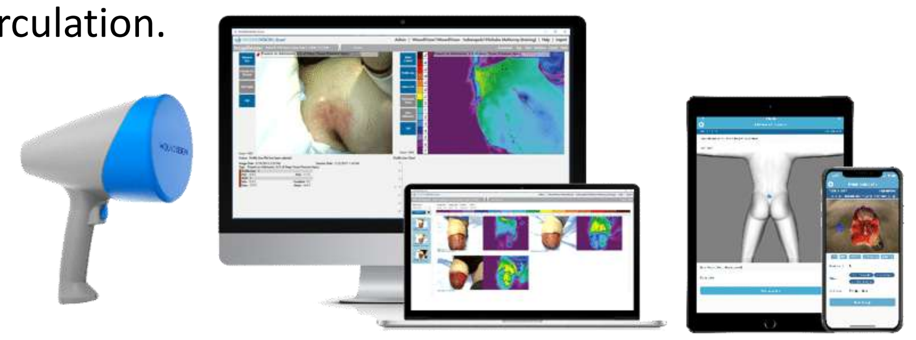
Cited clinical utilization of NIRS for the non-invasive assessment of tissue perfusion include determining potential of wound healing, assessment of skin flap or skin graft viability, early identification of post-surg complications to afford timely intervention.

The device used in this study is SnapShO$_2$t $_{NIRS}$ (Kent Imaging, Calgary, AB, Canada).

LWIT

Long wave (medical) infrared thermography (LWIT) is a non-invasive radiation-free imaging method that can be used to measure skin temperature, assess skin blood flow, wound healing, and potential tissue abnormalities beneath skin. Increased temperature in the skin or a joint, resulting from trauma, infection or other inciting process can be objectively measured as well as visually captured.

The Scout LWIT (WoundVision, Indianapolis, IN, USA) utilizes both a digital camera to capture visual images and long wave infrared camera to capture thermal images to measure relative thermal intensity data. Different colors in the images reflect degrees of heat obtained
Higher temperatures can be caused by increased metabolism and/or intensive blood supply. Lower temperatures are usually displayed by areas of poor local blood circulation.



Results

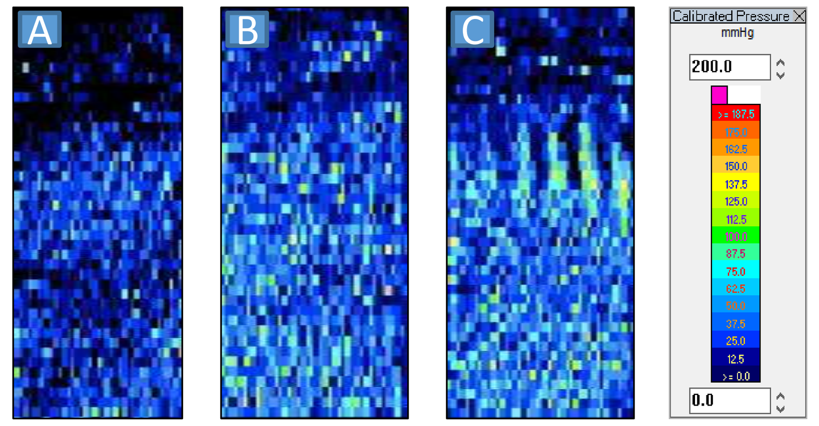


Figure 4 – TEKScan I-Scan® Pressure Distributions. (A) Longitudinal elastic stockinette application, (B) 2-Layer cohesive compression system, and (C) Combination (A) and (B)

Location	Longitudinal Elastic Stockinette		2-Layer Cohesive Compression System		Combination Application	
	Baseline	Post Exercise	Baseline	Post Exercise	Baseline	Post Exercise
10cm	44 ± 3.8 (39.2 - 51.9)	44.6 ± 4.1 p = 0.102	43.5 ± 3.1 (38.2 - 51.4)	42.9 ± 2.8 p = 0.408	43.5 ± 3.8 (34.3 - 52.1)	43.1 ± 4.2 p = 0.256
20cm	44.2 ± 4.0 (38.4 - 52.1)	44.1 ± 3.4 p= 0.811	44.1 ± 3.0 (39.3 - 51.4)	44.0 ± 2.4 p = 0.828	44.2 ± 4.5 (34.3 – 52.2)	43.8 ± 4.7 p = 0.538
30cm	42.4 ± 3.0 (34.3 - 45.9)	43.2 ± 3.0 p = 0.022	42.6 ± 2.5 (38.2 - 46.2)	43.5 ± 2.3 p = 0.026	42.7 ± 3.7 (34.3 – 51.3)	44.2 ± 4.2 p= 0.029
40cm	40.9 ± 3.1 (34.2 - 46.1)	40.5 ± 3.2 p = 0.223	41.4 ± 2.7 (38.1 - 46.0)	40.8 ± 2.5 p = 0.062	40.8 ± 3.6 (34.3 - 51.3)	40.3 ± 3.9 p = 0.049

Table 1 – Tissue Dielectric Constant in Healthy Female Volunteers

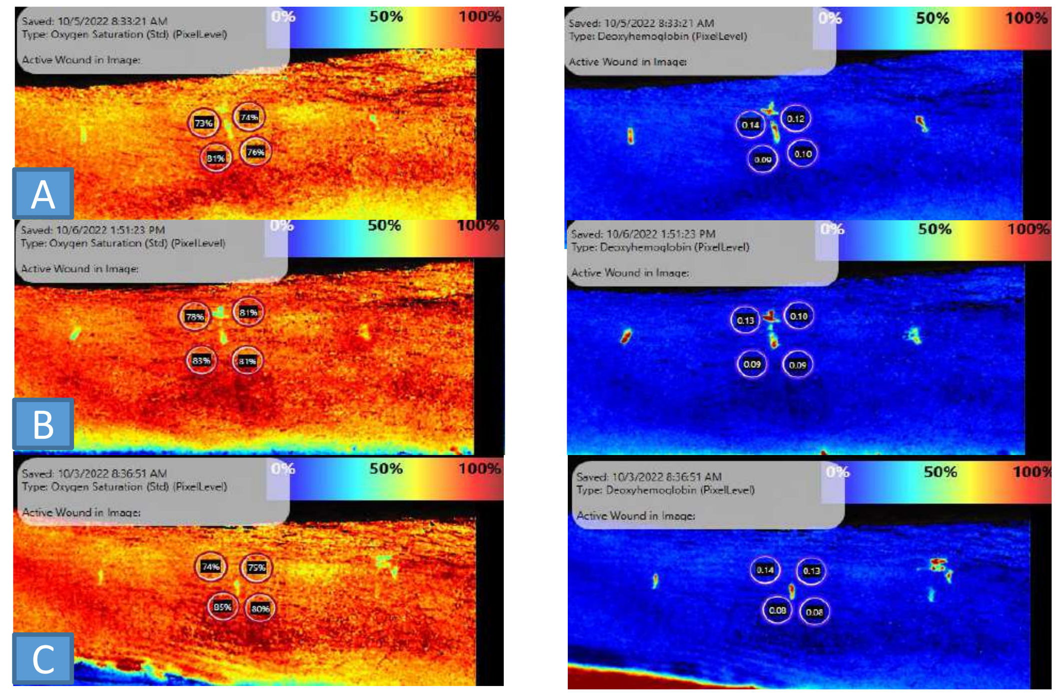


Figure 5 – Post Exercise NIRS Tissue Oxygenated and Relative Deoxyhemoglobin Healthy Volunteers. Immediately post removal compression application: (A) Longitudinal elastic stockinette application, (B) 2-Layer cohesive compression system, and (C) Combination (A) and (B)

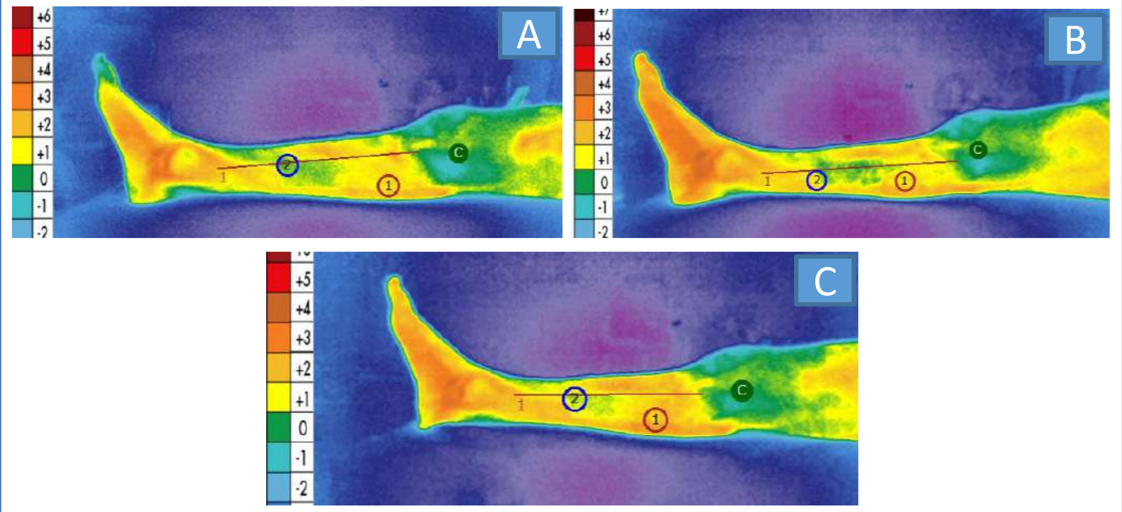


Figure 6 – Post Exercise LWIT Healthy Volunteers. Immediately post removal compression application: (A) Longitudinal elastic stockinette application, (B) 2-Layer cohesive compression system, and (C) Combination (A) and (B)

Discussion

TEKScan piezoelectric sensor captured point pressure averages and pressure distribution vertically and horizontally.

- Statistically significant difference IP observed between compression applications.
- In vivo visualized of alternating pressure profile with combination application.

TDC measured local tissue water content in the area of the limb covered, and just proximal to, the compression applications.

- Spatial and temporal variation in local tissue water content was observed at baseline and remained post activity.
- No significant difference between compression applications was observed.

NIRS objectively measured the amount of oxygenated and deoxygenated hemoglobin in the subcutaneous tissue of right lower limb of healthy volunteers at baseline and post activity.

- No Significant difference between compression application was observed.
- Visualization of textured compression textile was observed.

LWIT objectively documented change in temperature in the tissue of the right lower limb of healthy volunteers at baseline and post activity.

- No significant difference between compression application was observed.

Advanced imaging devices offer new insight into the pathophysiologic impact of compression applications beyond edema reduction and wound healing. Additional research extending to patients with lower extremity edema or lymphedema needs to be evaluated.

References

1. 1. Li S, Mohamedi AH, Senkowsky J, Nair A, Tang L. Imaging in Chronic Wound Diagnostics. Adv Wound Care (New Rochelle). May 2020;9(5):245-263. doi:10.1089/wound.2019.0967
2. 2. Paul DW, Ghassemi P, Ramella-Roman JC, et al. Noninvasive imaging technologies for cutaneous wound assessment: A review. Wound Repair Regen. Mar-Apr 2015;23(2):149-62. doi:10.1111/wrr.12262
3. 3. Bjork R, Ehmann S. S.T.R.I.D.E. Professional Guide to Compression Garment Selection for the Lower Extremity. J Wound Care. Jun 1 2019;28(Sup6a):1-44.doi:10.12968/jowc.2019.28.Sup6a.S1.
4. 4. Landsman AS, Barnhart D, and Sowa M. Near-Infrared Spectroscopy Imaging for Assessing Skin and Wound Oxygen Perfusion. Clinics in Podiatric Medicine and Surgery. 2018;35(3):343-355.

Acknowledgements

Research reported in this publication was supported in part by unrestricted educational grants from Milliken Healthcare Products and Compression Dynamics to Clemson University. The funders played no role in the design, conduct, or reporting of this study.

Advanced Imaging devices provided in kind by Kent Imaging Inc. (Calgary, AB Canada) and Wound Vision (Indianapolis, IN, USA)

2-Layer Cohesive Compression System assessed was CoFlex® TLC (Milliken Healthcare Products, Spartanburg, SC, USA)

Longitudinal Elastic Stockinette assessed was EdemaWear® (Compression Dynamics, Omaha, NE, USA)