Fast, non-invasive hyperspectral imaging tool for the diagnosis and management of complex foot and leg ulcers — part 1

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Article points

1. Images generated in 6.4 seconds
2. Measuring of tissue oxygenation, tissue haemoglobin index, perfusion in the deeper layer of the tissue and the tissue water index.
3. Control of the therapy and its influence on the wound and the tissue after 24 hours possible.

Key words

- Complex chronic wounds
- Hyperspectral imaging
- Fast, non-invasive improvement of patients' adherence

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This is the first of two articles examining a new hyperspectral imaging system (HSI). This non-invasive imaging system provides information about tissue oxygenation, tissue haemoglobin index, near-infrared and the tissue water index. The TIVITA® is a new compact camera that can be used in clinical practice by the patient's bedside. The data are generated within 6.4 seconds and the pictures can be shown to the patient directly at the bedside, enabling the clinician to discuss the findings with the patient, as well as possible treatment options. Part one shows how HSI can be used to increase the patient's adherence to treatment. Part two will provide a more extensive look at how HSI works and how it can be used to evaluate and monitor wound dressing, debridement and new technologies in the treatment of diabetic foot ulcers and other chronic wounds.

In 2019, the International Working Group on the Diabetic Foot (IWGDF) published new guidelines (Schaper et al, 2019). Every 20 seconds, somewhere in the world, a human with diabetes has an amputation (Schaper et al, 2019). That is a drastic increase in amputation rates compared to the previous guidelines, which highlighted that there were 30 seconds between amputations across the globe (Armstrong et al, 2007).

Patient-related factors can influence the outcomes, including comorbidities, severity of the underlying conditions and adherence (Atkin et al, 2019).

Poster and leaflet campaign to raise awareness about DFU-associated amputations

Fox and Smith-Burges (2018) reported a new educational approach for patients with diabetes and the possible improvement of their adherence. The Manchester Leg Circulation Service initiated a wide-ranging poster and leaflet campaign to increase the awareness of people with diabetic foot ulcers (DFUs) about their high mortality risks and support clinicians in discussing this issue with their patients. The posters should also help clinicians to focus on effective risk-reduction interventions, which is one option to consider when improving patient adherence.

Hyperspectral imaging for improving the treatment of patients with hard-to-heal wounds

Another option to improve patient adherence is the use of the TIVITA® Tissue hyperspectral imaging system (Diaspective Vision GmbH, Germany), (*Figure 1*; Wild et al, 2018). Hyperspectral imaging (HSI) is a non-invasive imaging technique in the visible and near-infrared spectral range. The TIVITA Tissue (Tissue Perfusion Imaging System) is a camera system used for wound documentation that can measure wound size, as well as tissue perfusion, e.g. in chronic wounds and flaps. The target fields for wound healing analyses are plastic surgery, wound diagnostics, dermatology, oral and head surgery, wound-healing centres and burns injury centres. Indications include DFUs, complex leg ulcers, oedema, flap diagnostics and monitoring, chronic wounds, postoperative wound-healing disorders, burn diagnostics, wounds caused by vascular disease and pressure ulcers. There are no known contraindications so far.

This system provides information about tissue oxygenation (StO2), the tissue haemoglobin index (THI), perfusion in the deeper layer of the tissue, near-infrared perfusion index (NIR) and the tissue water index (TWI).

How does this system work?

Tissue is a mixture of absorbers and stray particles. The main absorber is haemoglobin in the microcirculation and water of tissue cells. Light is reflected, remitted, transmitted or absorbed (Wild et al, 2018). Shortwave light in the structures and components of the wound or tissue can absorb and scatter irradiated light. These physical effects can be recorded with a camera, working like a push-broom imager (Tetschke et al, 2016). The TIVITA contains a spectrometer with a CMOS camera sensor, which is sensitive to a wavelength range of 500–1,000 nm, offering a spatial resolution of 640 x 480 and a spectral resolution of 5 nm. Rutkowski et al (2017) state: “Based on the spectral information, a three-dimensional (3D) data cube consisting of two spatial dimensions and one spectral dimension is generated which constitutes the basis for calculation of oxygen saturation at tissue surface (StO2 in [%]), as well as in deeper layers (NIR), 8 mm depth, calculated index (0–100) and haemoglobin contend (THI, calculated index (0-100)).” *Figure 2* shows the parameter images generated by the HSI data within 6.4 seconds.

Shortwave light is strongly absorbed, resulting in low penetration depth. This provides the user with information about the superficial part of the tissue. Long-wave light in the NIR range is slightly absorbed, resulting in higher penetration depth. This provides information on the deeper layer of the tissue (Wild et al, 2018).

For more detailed information about how the

Figure 1. The TIVITA® Tissue hyperspectral imaging system, Diaspective Vision GmbH

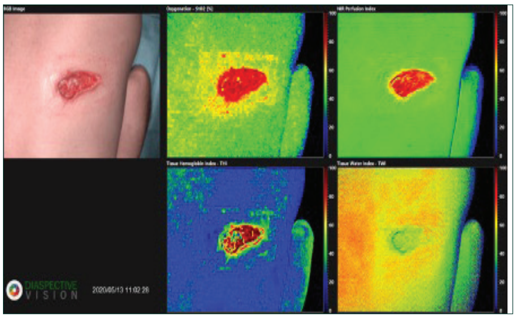


Figure 2. Presentation of the HSI data in the user interface.

Figure 3. Measurement of the wound.

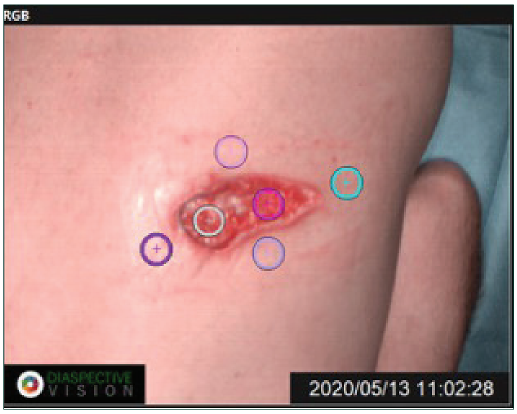


Figure 4. Marker can be set to measure different areas.

Figure 5 and Figure 6 showing the right leg of the patient. The leg is swollen, oedema and maceration are also present. The granulation tissue does not look healthy. Figure 7 shows the left leg, where oedema is also present.

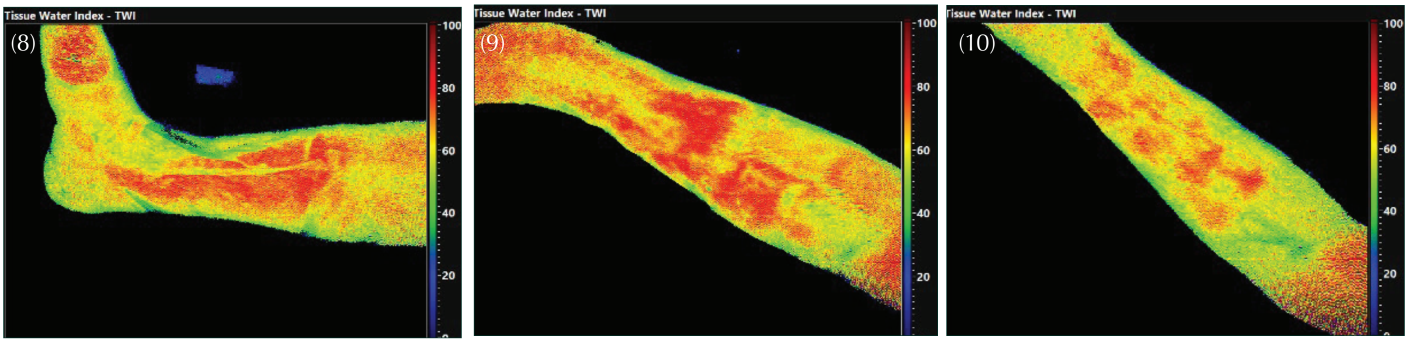


Figure 8. TWI: the red areas showing the presence of oedema in the right leg and in the wound. Figure 9. The patient started to use an adhesive compression bandage on the right leg with a visual indicator. Figure 10. The left leg after wearing the adhesive compression bandage for 4 days showing reduced oedema.

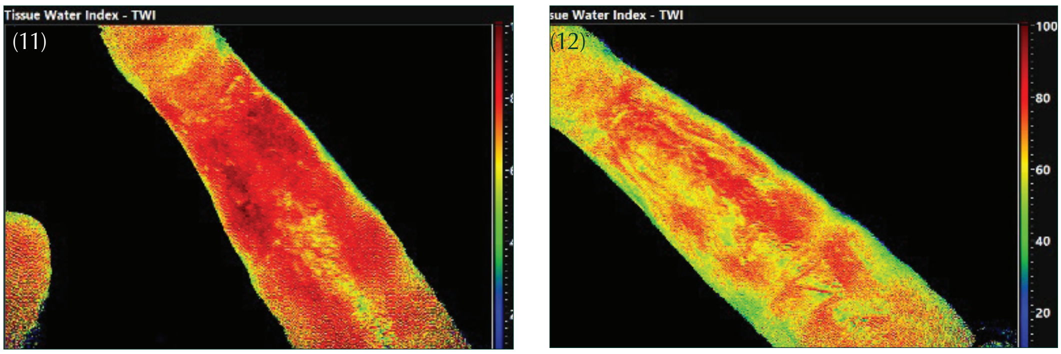


Figure 11. Extent of the oedema before the use of the velco wrap system on the right leg.
Figure 12. Reduced oedema seven days after using the velco wrap system on the right leg.

HSI system works, the author suggests reading the following papers: Rutkowski et al (2017), Tetschke et al (2016) and Wild et al (2018). Part 2 will provide a deeper look at how this system works and how it can help to monitor new dressings, to evaluate debridement methods and to monitor new treatment options, such as cold atmospheric plasma (CAP).

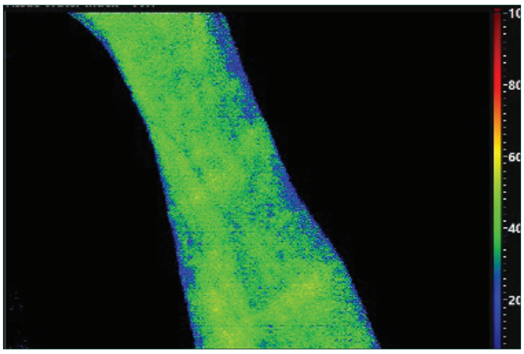
How can this hyperspectral imaging system contribute to the treatment of patients with DFU?

HSI is a new method for wounds and surgery (Köhler et al, 2019; Marotz et al, 2019). As it is contactless, HSI is ideal for conducting bedside diagnostics. Beside calculating the already mentioned parameters, the wound area can also be measured (*Figure 3*) and markers can be set for analysing different tissue areas (*Figure 4*).

Case report

The patient is male and was born in 1960. He presented with a DFU on the right forefoot (Wagner 3/Armstrong D). The ulcer was 11 cm

Figure 13 (left). Seven days after the use of the velco wrap systems.
Figure 14 (right). Two days after the skin graft.



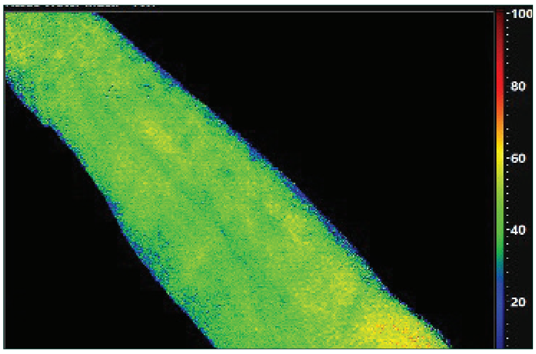


Figure 15 (left). No oedema present in the left leg.
Figure 16 (right). No oedema present in the right leg.

Figure 17 (left). Two weeks after the release from the hospital.
Figure 18 (right). One year later.

long and 7 cm wide. The big toe on the right foot was missing; it was amputated in November 2017 at another hospital. Since this time, the patient developed a DFU. In 2017, he underwent a thromboendarterectomy in the groin at the same hospital.

Peripheral arterial disease (PAD) was also present. He was admitted to the author's hospital through the outpatient diabetic foot clinic. The skin on the right leg was macerated due to chronic oedema. The leg was swollen, red and very painful (*Figures 5, 6 & 7*). Due to the pain, which was present when he lay in bed, he mostly sat on the bedside or in his wheelchair. He was a heavy smoker, thus he was outside with the wheelchair more than inside the room. The patient slept sitting on the bedside. He was very uncooperative to the treatment options and did not want compression therapy because of the pain. The patient did not trust the clinicians at Kreiskliniken Reutlingen, as the previous hospital had already taken into consideration a potential amputation of his right leg. The first picture taken with the HSI system (*Figure 8*) showed oedema in the wound bed and in the leg as a whole (*Figure 9*). He also had a swollen left leg (*Figure 10*).

A biopsy was taken of the wound. Five different bacteria species were found to be present in the wound (*serratia marcescens, citrobacter koseri, morganella morganii ssp. Morganii, comamonas testosterone* and *enterococcus faecium*). The patient was treated with intravenous antibiotics, and the wound was subjected to surgical debridement and larval therapy (maggots). The wound was then treated with a DACC dressing (Cutimed® Sorbact, Essity)

Conflict of interest

The author is a clinical adviser for Diaspective Vision GmbH, for Protex Healthcare Ltd. and for the Paul-Hartmann AG and received fees for lectures and travel/hotel compensation.

and a dressing with capillary action (Vacutex™, Protex healthcare) and a superabsorbent dressing (Zetuvit®, Paul Hartmann Ag).

The PAD was treated with a percutaneous transluminal angioplasty (PTA) of the arteria tibialis anterior and the arteria fibularis in the right leg in the author's hospital 7 days after admission.

The hospital's pain department was involved in the treatment of the patient's pain. After discussion with the patient, two nerve blocks were inserted in the right leg (DIC/saphenous). Additionally, continuous 24-hour medication was applied.

A picture was taken with the HSI (*Figure 9*) showing the presence of oedema in the right leg. Clinicians at the author's hospital discussed the different treatment options with the patient. Suggestions included manual lymphatic drainage, skin care and mild compression therapy (Todd, 2017). The patient was against this idea for two reasons: firstly, the pain; and secondly, his poor experience with his previous hospital. The images of the HSI were shown to the patient and the clinicians involved in his care continually explained to him the importance of compression therapy and manual lymphatic drainage (*Figure 10*). After 2 days, the patient was convinced to use a mild compression therapy on the left leg with adhesive compression bandages (UrgoK2 lite, Urgo Medical) (*Figure 11*).

After he recognised the positive impact of the compression therapy on the left leg, the patient was then convinced to try a velcro wrap system on his right leg (*Figure 12, 13 & 14*).

After a 75-day stay in the author's hospital, the patient was released and looked after through the diabetic foot outpatient centre. Four weeks later, the patient underwent a skin graft on the right forefoot (*Figure 15*). No oedema was present in the left leg (*Figure 16*) nor in the right leg (*Figure 17*). As the skin graft healed, he was discharged after 4 weeks. He visited the diabetic foot outpatient centre once a week until complete wound healing was achieved (*Figure 18*). In June 2019, he had an appointment in our diabetic foot outpatient centre. The wound was still healed.

Conclusion

HSI is a bedside diagnostic tool that is helpful in the monitoring of the treatment of patients with chronic wounds. As the images can be shown directly at the patient's bedside, it is also a useful tool to improve patient adherence to treatment.

HSI can be used to control the success of different therapeutic strategies, such as compression therapy. Another possible use is the evaluation of the mode of actions of different types of wound dressings directly on the wound bed/surface. This also applies for the different types of debridement. ■

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