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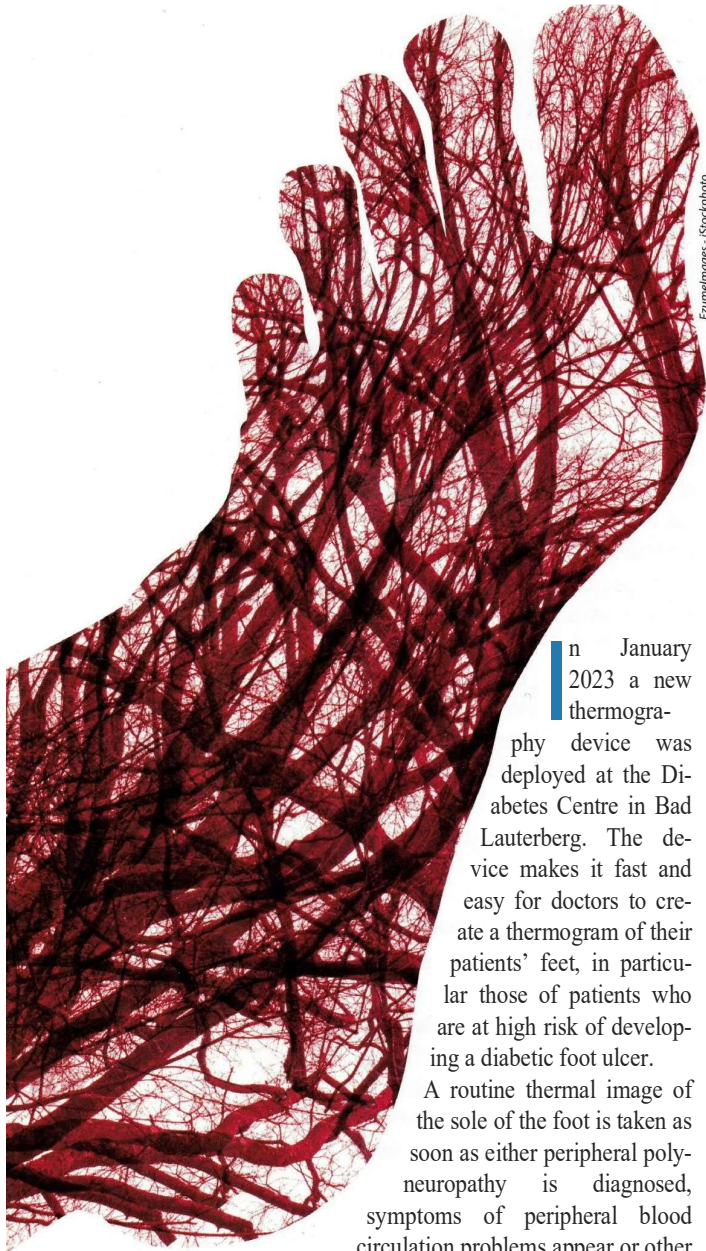
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## Thermography for risk detection

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*Translated from the original German text*

# Thermography for risk detection



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**DFS** Thermography, the visualisation of temperature distributions, can be a very powerful tool for the monitoring of foot health. In particular in the area of healthcare for patients with Diabetes mellitus with the risk of the developing Diabetic Foot Syndrome (DFS), research results suggest that frequent thermographic assessment has the potential to prevent serious complications.

In January 2023 a new thermography device was deployed at the Diabetes Centre in Bad Lauterberg. The device makes it fast and easy for doctors to create a thermogram of their patients' feet, in particular those of patients who are at high risk of developing a diabetic foot ulcer.

A routine thermal image of the sole of the foot is taken as soon as either peripheral polyneuropathy is diagnosed, symptoms of peripheral blood circulation problems appear or other risk factors are present. In this way pathological processes in the patients' feet can be identified at an early stage before serious damage occurs. Appropriately targeted

treatment or support measures can then be prescribed.

In the initial stages of developing diabetic foot problems early warning indicators can be easily overlooked during clinical investigations because of their low-grade nature. Amongst these indicators are inflammation, neuropathic condition changes and local perfusion disorders through micro- or macroangiopathy which may then not be recorded in the risk assessment scores. Additionally, both overloading and incorrect loading of the foot are easily recognised in the thermal foot image. In such cases characteristic indications and deviations from the healthy normal foot temperature distribution (see Figure 1) may be found in the thermal patterns. The main characteristic features are:

1. Contralateral Asymmetry. A healthy pair of feet shows mirror-symmetrical temperature distributions. Studies in healthy

subjects have shown that in 99% of cases the contralateral temperature difference (e.g. between the left and the right big toe) over the entire foot surface is consistently

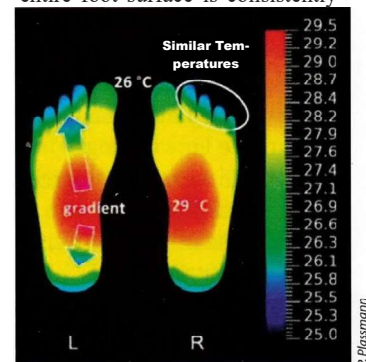



Figure 1. Temperature patterns in healthy feet

smaller than 1.8°C. Conversely this means that a difference of more than 1.8°C (some studies use a cut-off value of 2.2°C) can be used as an indicator for a possible pathological process.

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- Central-peripheral Temperature Gradient. In healthy feet the midfoot area is as a rule 7°C warmer than the peripheral plantar foot area. The heel and in particular the toes are physiologically colder. A difference missing larger or inverted temperature gradient amounts to a clinically relevant finding.
- So-called Hot Spots. These are small and localised areas on the sole of the foot which clearly differ by several degrees Celsius from the surrounding skin area. Local inflammation is a common cause of this difference.

If this inflammation is at the site of overloading it may indicate the start of subcutaneous tissue destruction and the beginning of a diabetic foot ulcer that is not yet visible on the surface of the foot. Typically, these areas are found under calluses.

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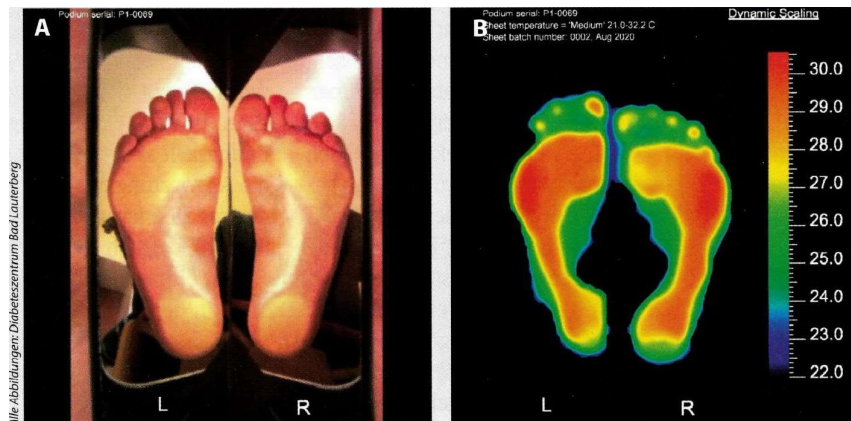
Ultimately, with all these indicators, it is the deviation from the normal foot temperature distribution in healthy feet that is important. However, it is important to include two fundamental limitations of thermography: Firstly, thermography alone is not a diagnostic tool and should not be used on its own to determine diagnoses or to make treatment decisions. The reason for this is that the temperature values and patterns

- Cold Areas. In contrast to Hot Spots, Cold Areas are often more extensive and they tend to be indicative of perfusion disorders. These can be caused by macro- or microangiopathy.

## i Typical examples for the use of Thermography

### Case 1:

The first case revolves around a patient with established peripheral polyneuropathy. Image (A) shows a good presentation of the feet on the measuring plate. In the thermographic image no significant temperature difference between the soles of the feet (B) is visible. However, there is no central-peripheral temperature gradient. This is consistent with the diagnosis of peripheral polyneuropathy.

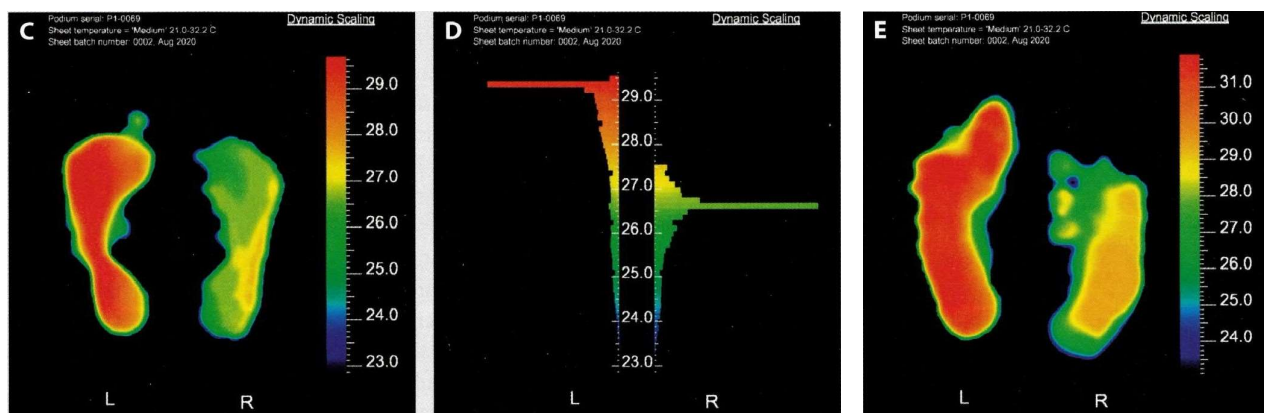


A: Feet on the measuring plate.

B: Patient with peripheral polyneuropathy.

### Case 2 & Case 3:

The second case study (C) shows a clear temperature difference of about 2°C (D) between left and right foot. The cause is an active left DNOAP (Diabetic Neuropathic OsteoArthroPathy) confirmed by MRT. Although in the third case (E) a similar thermography picture is observed the cause of the temperature difference in this case is a foot inflammation due to an abscessed foot ulcer.



C: Patient with active DNOAP

D: Temperature scale

E: Patient with foot inflammation.



are essentially a function of blood flow and therefore not specific to one illness or pathology. A hot spot on, for example, the big toe can be caused by an ingrown nail, a foreign body, or a fracture or through wearing inappropriate footwear. Thermography can only make invisible processes visible. It then requires the knowledge and the experience of the treating doctor/clinician, to set these indicators into the correct context and interpretation.

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Secondly, absolute temperature values are of limited meaning in thermography. This contrasts with a clinical thermometer, which indirectly measures the temperature of the body core. This temperature is known to be closely regulated by the body to a limited interval of between about 36°C and 37°C. Skin temperature however, and in particular in the peripheral areas such as the hands and feet, are highly variable and undergo an active regulation process to meet the requirements of the body as a whole. The normal temperature range in the body periphery can therefore be 25°C or more. During very cold weather it is possible that the extremities are limited to single-digit temperatures without developing structural damage. This normal active temperature regulation is influenced by a large number of internal and external parameters. These are, for example, ambient temperature, humidity, physical activity, nicotine, alcohol, caffeine and clothing. In a routine clinical setting it is impossible to keep all these factors constant and therefore reproducible.

On the contrary – it is often the striking absence of this active thermal regulation, for example in patients with more advanced foot neuropathy that is a strong

indicator of an underlying pathology. While the characteristic features of asymmetry, gradients, hot spots and cold areas outlined above are quantifiable this is, however, essentially only relative to other skin areas and thus not absolute. As such these characteristics, as opposed to the many other factors influencing skin temperature, are therefore far more reliable for supporting clinical diagnoses.

#### Assessment / Outlook

At the Diabetes Centre Bad Lautenberg around 200 high-risk patients were thermographically examined in the first quarter of 2023. This was carried out using the "Podium Professional" device made by Thermetrix Ltd. (Fig. 2). The procedure is easy to carry out and integrates well into the hospital workflow. The time expenditure for staff carrying out the investigations is, after a short practice time, acceptable. The evaluation of the generated images is also straightforward to learn. This makes thermography suitable for everyday use.

The main purpose of the procedure is to recognise high-risk patients. None of the patients examined thermographically in the Diabetes Centre were previously diagnosed with DFS. During the thermographic examination in particular those patients who previously had no symptoms recorded in their Neuropathy Symptoms Score (NSS) were often suspected of peripheral polyneuropathy. In these cases additional diagnostics were initiated through investigation by the recognised method of assessing the sudromotor function. With only few exceptions polyneuropathy could be confirmed. Through appropriate training patients received instructions on precautions to implement

in their daily lives in order to avoid future complications. Additionally, support aids (protective shoes) could be prescribed. These recommendations were documented and communicated to the patients' family doctor and/or diabetic specialist. Very useful assessments were possible for patients with active diabetic neuroosteoarthropathy where plantar temperature gradients are easy to detect and can replace other more complex methods. Through thermography patients with other specific foot problems could also be identified. Examples include fungal infections of the foot or incorrect orthopedic loading.



Figure 2. The device used for thermography: Podium Professional by Thermetrix Ltd.

In one individual case a specific perfusion disorder was detected that was not the result of a peripheral arterial disease (PAD) condition.

*"The admission examination includes an assessment of the foot"*

The high specialisation of the Bad Lautenberg Diabetes Centre means that all admission examinations include an assessment of the feet. As such any potentially dangerous "hot-spots" were already routinely identified during the admission examination and the appropriate therapies are started without thermographic examination. However, thermography could play a strong role in the outpatients department where it can facilitate more frequent screening scans of a large patient population. Currently, limitations in medical capacity mean that patients who have not yet been diagnosed with diabetic foot syndrome are subject to longer intervals between examinations and thermographic investigations could be of benefit to this cohort.



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