

# Using digital thermography to support patient engagement and behaviour change in the management of diabetes-related Charcot neuro-osteoarthropathy: a clinical case series

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## Key words

- Charcot neuro-osteoarthropathy
- Diabetic foot
- Digital thermography
- Pressure offloading
- Thermal imaging
- Ulceration

## Article points

1. Thermal imaging improved patient understanding and engagement by visually demonstrating inflammation in Charcot neuro-osteoarthropathy (CNO), helping overcome communication barriers due to sensory loss.
2. Patients responded positively to visual feedback, which enhanced their motivation, adherence to offloading strategies and glycaemic control through more meaningful, personalised clinician-patient conversations.
3. Thermographic imaging served both clinical and educational purposes, promoting shared decision-making and health literacy while supporting better self-care in managing CNO.

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**Introduction and importance:** Charcot neuro-osteoarthropathy (CNO) is a progressive, debilitating complication of diabetes that can severely impact mobility, independence and overall quality of life. Early recognition and ongoing management are critical, yet patient engagement is often challenged by the insensate nature of peripheral neuropathy, which can obscure the signs of inflammation. This case series explores the use of thermal imaging not only as a clinical tool to support early detection and monitoring of inflammation, but also as a means of enhancing patient education. By visualising thermal asymmetry, patients were better able to comprehend the underlying pathology of their condition. Importantly, these visual insights created opportunities for more meaningful, patient-centred conversations, enabling clinicians to develop individualised care plans that improved adherence to pressure-relieving strategies and supported better glycaemic control. **Methods:** A retrospective review of two patients with a confirmed CNO was undertaken in a multidisciplinary foot clinic. Digital thermographic imaging was used as part of the routine monitoring alongside standard care. Cases were selected to reflect a range of presentations and patient backgrounds. Clinical outcomes, patient interactions and behavioural changes were analysed to explore the educational impact of using thermal imaging during consultations. To explore patients' perspectives on the acceptability and perceived utility of the thermal imaging for monitoring Charcot neuroarthropathy, a 6-item Likert-scale questionnaire was administered to the participants at the end of their monitoring period. **Clinical discussion:** In all cases, the visual nature of the thermographic data helped to overcome communication barriers posed by sensory loss. Patients responded positively to visual feedback, leading to improved understanding of their condition, rationale for offloading devices and the importance of glycaemic control. These insights enabled clinicians to engage in more meaningful, personalised conversations that supported shared decision-making and improved adherence to treatment. The integration of visual technology into clinical consultations proved to be an effective method of enhancing motivation and promoting health literacy in individuals with complex needs. **Conclusion:** Digital thermographic imaging offers more than a diagnostic advantage — it acts as a visual language that bridges clinical knowledge and patient experience. This case series demonstrates its value in improving patient engagement, supporting self-care and reinforcing adherence to offloading and metabolic control strategies in the management of Charcot neuro-osteoarthropathy.

Foot and ankle complications in diabetes, including ulceration, amputation and Charcot neuro-osteoarthropathy (CNO), present a significant socioeconomic burden that negatively affects an individual's physical and psychological wellbeing, and the lives of their friends and families (Coffey et al, 2019, Gooday et al, 2022).

CNO is a destructive, inflammatory condition of the bones, joints and soft tissues of individuals with peripheral polyneuropathy. Although CNO can occur in anyone with peripheral neuropathy, it most commonly affects the foot and ankle of individuals with diabetes mellitus (International Working Group on the Diabetic Foot [IWGDF], 2023). In these cases, progressive and uncontrolled

inflammation causes osteolysis, leading to the weakening of the foot's structure, which can result in fractures, joint dislocations, severe lower limb deformities, ulceration and even amputation (Gooday et al, 2021).

For individuals with diabetes mellitus, the true incidence of CNO remains unknown, but reported prevalence ranges from as low as 0.04% in specialist foot care centres in England to 0.79% in Swedish national diabetes registries (Metcalf et al, 2018, Tsatsaris et al, 2023). With an estimated average prevalence of 0.3%, approximately 1.9 million people with diabetes worldwide are expected to develop CNO by 2030, increasing to 2.3 million by 2045 (International Diabetes Federation [IDF], 2021).

CNO is commonly associated with midfoot collapse and the distinctive 'rocker-bottom' deformity, but it can also affect other joints with varying life-limiting presentations. Despite being associated with sensory neuropathy, pain or discomfort may still be present during the early acute stage, however, is usually significantly reduced compared to individuals with intact sensation experiencing a similar injury (Rogers et al, 2011).

While it often presents with intact skin, the structural and functional changes in the limb can lead to the coexistence of active, infected foot ulcers. Studies have shown that individuals with foot ulcers resulting from CNO-related deformities have a 6 to 12 times higher risk of major amputation compared to those with ulcers unrelated to CNO (Sohn et al, 2010; Wukich et al, 2017).

The treatment goal is therefore to resolve the inflammatory process as soon as possible, alleviate pain and preserve foot architecture without advancement to ulceration. This is achieved by promptly initiating a knee-high offloading device, preferably a non-removable below-knee cast or walker boot (IWGDF 2023). The duration of offloading can vary significantly, with national and international studies reporting a median time to remission of between 3–12 months (Game et al, 2012; Chantelau et al, 2007), although frequent cases extending beyond 1–2 years have also been documented. Individuals who adhere to self-care practices such as consistent use of offloading

devices have been reported to have significantly better outcomes (Binning et al, 2019).

According to Sabate (2013), adherence is the extent to which a person's behaviour corresponds with agreed recommendations from a healthcare provider. In their systematic scoping review, Racaru et al (2022) identified various complex and multifactorial factors that can negatively affect adherence to foot offloading, and therefore poorer outcomes. These included biological factors, such as disrupted gait and postural instability, as well as psychosocial factors like stigma and lack of motivation.

Additionally, a qualitative study by Gooday et al (2022) exploring individuals' experiences of living with Charcot neuroarthropathy (CNO) highlighted impactful themes which extend beyond the burden of wearing an offloading device. These themes included feelings of frustration and social isolation, disruption or loss of roles and responsibilities, strain on relationships, additional pain caused by the offloading devices, and self-directed or externally perceived blame for developing CNO. The study emphasised that mitigating the negative consequences of CNO requires a deeper understanding of the physical and psychosocial experiences of individuals with diabetes and CNO.

Increasing knowledge through patient education remains a cornerstone of practice despite strong evidence showing it has a minimal effect on diabetes foot ulcer rates (Dorresteyn et al, 2014; Bus et al, 2016). This insight could assist healthcare professionals in developing interventions that extend beyond traditional patient education. Incorporating approaches such as motivational interviewing to enhance knowledge and foster motivation for behaviour change (Keukenkamp, 2018), alongside extrinsic prompts, such as digital watches, phone apps, activity diaries and infrared thermography, to support daily monitoring and understanding of the extent of a condition where lack of sensation limits understanding (Binning et al, 2019).

### **Infrared thermography**

Infrared thermography is a safe, non-invasive imaging technique used to measure skin temperature and plays a valuable role in the



Figure 1. Hand-held digital thermometer.



Figure 2. Infrared enabled tablet Thermidas IRT-384.

prevention, early detection, and monitoring of inflammatory complications in diabetic foot disease — including pressure related injury, infection, vascular compromise and Charcot neuroarthropathy (IWGDF, 2023). The technique works by detecting infrared radiation naturally emitted by the body and is commonly applied in clinical practice using two main methods. The first involves handheld digital thermometers, which provide quantifiable readings on a digital display [Figure 1]. The second method uses infrared-enabled tablets that capture thermal images — visual maps of temperature distribution across the skin using a graded colour scale (Harkin, 2023) [Figure 2]. This latter method, known as thermal imaging, offers a more detailed overview of the surface temperature variation and supports targeted assessment of the areas of concern.

Accurate site selection with handheld thermometers can be challenging, especially during the consolidating phase of CNO, when ‘hot spots’ are not always visibly apparent. To address this, the IWGDF recommends a standardised approach to temperature measurement to ensure consistent and reliable comparisons over time (IWGDF, 2023). In contrast, thermal imaging, offers a visual map of temperature distribution, allowing both clinicians and patients to easily identify areas of concern. Specific regions can then be precisely selected for targeted measurement and longitudinal comparison.

The following case studies demonstrate how the use of thermal imaging can serve as an effective clinical tool to educate and motivate patients towards positive behaviours — such as consistent use of offloading devices and activity modification. By visually revealing underlying inflammation or trauma, this approach enhances patient understanding and supports adherence to preventative strategies, ultimately contributing to improved clinical outcomes.

### Case study 1

A 70-year-old female with a 6-year history of type 2 diabetes, hypertension, hypercholesterolaemia, background retinopathy and peripheral neuropathy was referred to the acute multi-disciplinary diabetes foot clinic (MDFC) for assessment of an acute CNO. Prior to her first visit, plain X-Rays and magnetic resonance imaging (MRI) had already been performed. The X-Ray was unremarkable; however, the MRI revealed patchy marrow oedema involving the second to fourth tarsometatarsal joints, with minor involvement of the sustentaculum tali. The appearances were suggestive of early midfoot CNO with minor changes to the sustentaculum tali — consistent Stage 0 active CNO as defined by the IWGDF in 2023 (IWGDF, 2013).

At presentation, the patient reported an 8-week history of right foot swelling with a pain during mobilisation, which began after helping a neighbour paint their house. She expressed

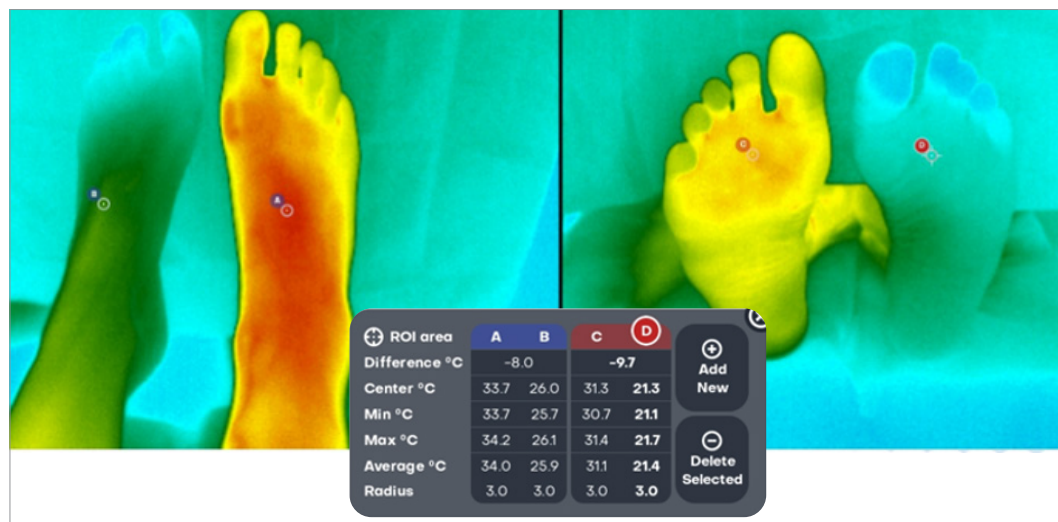


Figure 3. Case Study 1 – Quantitative and visual temperature mapping of both feet using the thermal imaging camera. Left image - dorsal view of both feet demonstrating a striking colour contrast between limbs, as well as showing an 8c temperature difference between points A and B (table on the left). Right image plantar views of both feet also demonstrating a clear colour contrast between limbs as well as a 9.7c temperature difference between points C and D (table below images).

frustration at the injury, as it significantly limited her ability to walk or exercise — an activity she relied on to support weight management and improve glycaemic control. Her HbA<sub>1c</sub> had recently improved, 99 mmol/mol to 66 mmol/mol over a 4-month period. She had no previous history of lower-limb ulceration or neuro-osteoarthropathy.

Clinical examination revealed palpable, bi-phasic pedal pulses and evidence of peripheral neuropathy. The right foot appeared more oedematous and erythematous, extending from the forefoot to the ankle, although the overall structure and arch profile remained intact. Using a standard hand-held digital thermometer [Figure 1], the temperature of the right midfoot was 10c higher dorsally and 11c plantarly compared to the same location on the contralateral foot.

## Treatment and intervention

A diagnosis of CNO was confirmed, and the patient was provided with a removable offloading walker boot, with plans to fit a custom insole the following week. Although she had been informed prior to the appointment that the diagnosis of CNO was likely, she appeared emotionally unprepared to accept it. She expressed disbelief — not only about the diagnosis but also about her diabetes itself — insisting her foot discomfort was merely a sprain and that her foot sensation was normal, despite clear clinical evidence of peripheral neuropathy. However she acknowledged the presence of inflammation and pain and agreed to wear the boot consistently

when mobilising. A follow-up review was scheduled 7 days later.

At the follow-up appointment in MDFC, the patient reported adherence to wearing the boot but remained sceptical about its necessity. To support consultation infrared thermal imaging was introduced [Figure 2], enabling both visual and quantitative comparison of foot temperatures [Figure 3]. The thermal image clearly illustrated the extent and distribution of inflammation, offering a compelling visual representation of the pathology. The asymmetry in temperature — both in numeric values and striking colour contrasts — had a significant impact on the patient. This visual evidence shifted the focus of the conversation from questioning the need for offloading to seeking clarity on treatment duration. This change in perspective opened space for a more meaningful patient-led discussion about her diagnosis and the implications of her diabetes management.

As part of her ongoing management, a custom total contact insole was fitted to the walker boot, with an ‘even-up’ shoe balancer to the contralateral limb to address leg length discrepancy and improve gait stability during offloading.

The patient was reviewed fortnightly in the joint podiatry-orthotics clinic over a 16-week period [Figure 4]. At each visit a progressive reduction in temperature differences and inflammatory signs was observed. By the end of this period, inter-limb temperature differences had fallen below 2c on two consecutive visits, using the thermal camera and all clinical signs of inflammation had resolved. The

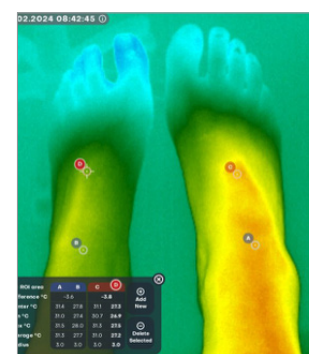


Figure 4. Case study 1 — 10 weeks later showing a reduction in quantitative and visual temperature mapping of both feet using the thermal imaging camera — Dorsal image of both feet using the thermal imaging camera. Temperature difference between points A and B – 3.6c and B and D 3.8c.



Charcot episode was deemed consolidated with no residual structural deformity or requirement for further imaging. She was subsequently discharged from specialist care with custom total contact insoles for use in her own trainers and referred to community podiatry foot protection services for continued preventative care and monitoring.

## Case study 2

A 56-year-old male with a 14-year history of type 2 diabetes ( $\text{HbA}_{1c}$  of 82mmol/mol, up from 65mmol/mol), hypercholesterolaemia, background retinopathy, a BMI of 34.8Kg/m<sup>2</sup>, established peripheral neuropathy, and a prior history of neuropathic foot ulceration was referred to the acute multidisciplinary diabetes foot clinic (MDFC) by the community podiatry foot protection team. The referral was prompted by multiple episodes of ankle inversion, which the patient associated with recently issued orthopaedic footwear and insoles. These episodes resulted in the development of a hot swollen left foot with a noticeable altered arch profile [Figure 5].

The patient reported a deep, throbbing pain in his left foot, accompanied by redness and swelling. He was concerned about the visible change in foot shape and expressed frustration, attributing the issue to the recently issued hospital footwear. On examination, peripheral neuropathy was confirmed, and pedal pulses were palpable and bi-phasic bilaterally. The left foot and lower leg showed increased oedema, and medial convexity deformity was noted, consistent with arch collapse. Using a standard handheld digital thermometer [Figure 1], his left midfoot was 9.5c warmer dorsally and 11c warmer plantarly than the

corresponding sites on the right foot — findings indicative of active CNO.

Differential considerations included ankle fracture, posterior tibial rupture, deep venous thrombosis. A plain X-Ray was performed and appeared normal despite clinical deformity [Figure 6]. However, weightbearing views were not obtained which may have demonstrated alignment abnormalities. Ideally, bilateral plain X-rays with anteroposterior (AP), medial oblique, and lateral projections should be taken for accurate comparison (IWGDF, 2023). Due to strong clinical suspicion of CNO, an MRI was arranged.

## Treatment and intervention

At initial presentation, immediate offloading of the affected limb was advised pending diagnostic confirmation. Removable and non-removable options were discussed, and the patient opted for a removable boot. He was fitted with the boot at the first visit, and a custom total contact insole was supplied and fitted the following week.

MRI findings confirmed active Charcot neuro-osteoarthropathy involving the ankle, hindfoot and midfoot, with a pes plano-valgus deformity, subluxation at the medial navicular, cuneiform joint, plantarflexion of the navicular, and a concurrent insufficiency fracture at the base of the second metatarsal [Figure 7]. According to the IWGDF (2023), the findings were consistent to Stage 1 active CNO.

During each clinical visit, the patient expressed frustration regarding the change in shape of his foot and the requirement to wear an offloading device, which he found cumbersome and awkward to walk with. He remained sceptical about the benefit



Figure 5. Case study 2 – left, dorsal view of both feet. Right, plantar view of both feet.



Figure 6. X-Ray - Dorso-plantar view L Foot

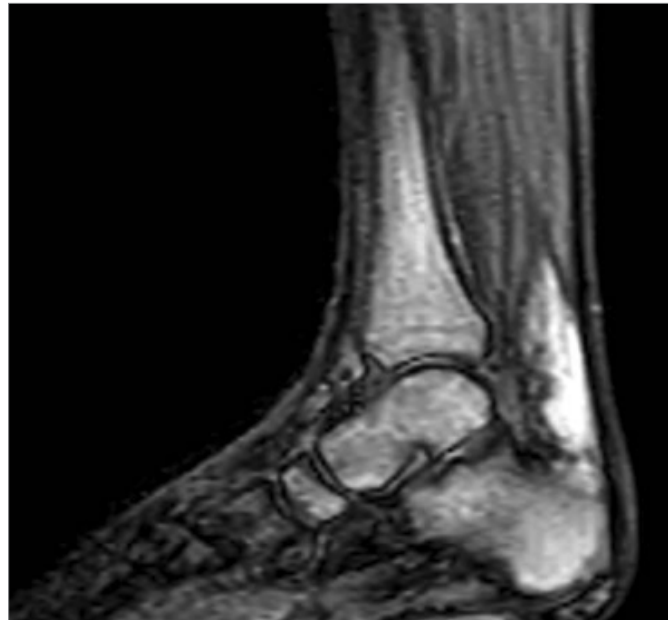


Figure 7. MRI – Sagittal plane view L foot..

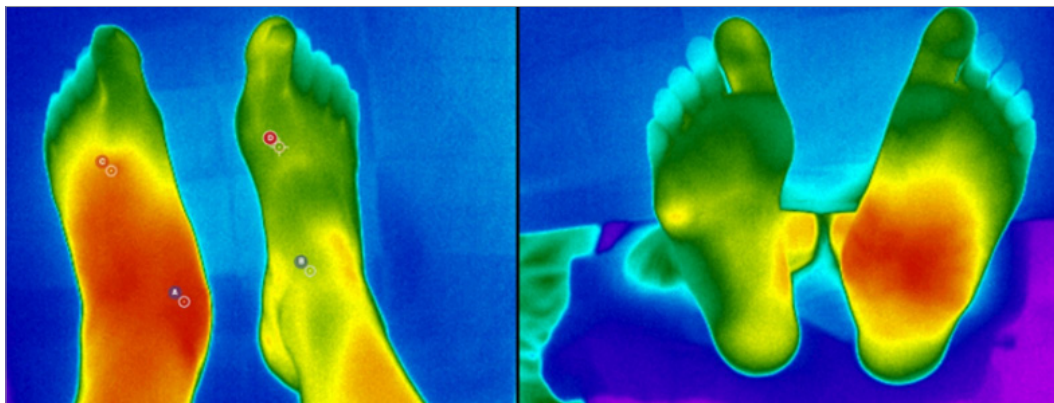


Figure 8. Images above: Case study 2: 8 weeks - Visual temperature mapping of both feet using the thermal imaging camera. Left image — dorsal view of both feet demonstrating a striking colour contrast between limbs, as well as showing an 10c temperature difference between points A and B and 9c temperature difference between points C and D. Right image plantar views of both feet also demonstrating a clear colour contrast between limbs at the plantar arch with an 8.6c temperature difference.

of the custom insole, particularly as he believed his previously issued footwear and insoles had contributed to the development of his condition.

In the early phase of management, foot temperatures were monitored using handheld digital thermometer [Figure 1]. This provided objective measure of inflammation and served as a useful tool to communicate the ongoing activity of CNO to the patient. At that stage, the information supported clinical rationale for continued offloading and improve adherence to the prescribed boot.

However, a notable shift in patient engagement

occurred at week 8, following the introduction of thermal imaging to monitor inflammation. Upon viewing the thermal images for the first time [Figure 8], the patient expressed surprise at being able to see the inflammation — particularly as he had no sensory perception of it. He remarked that, although he understood the importance of the boot, visualising the inflammation brought a new level of awareness and reinforced his motivation to adhere to treatment. Reviewing the thermal images and temperature readings each week also facilitated open discussions about the patients

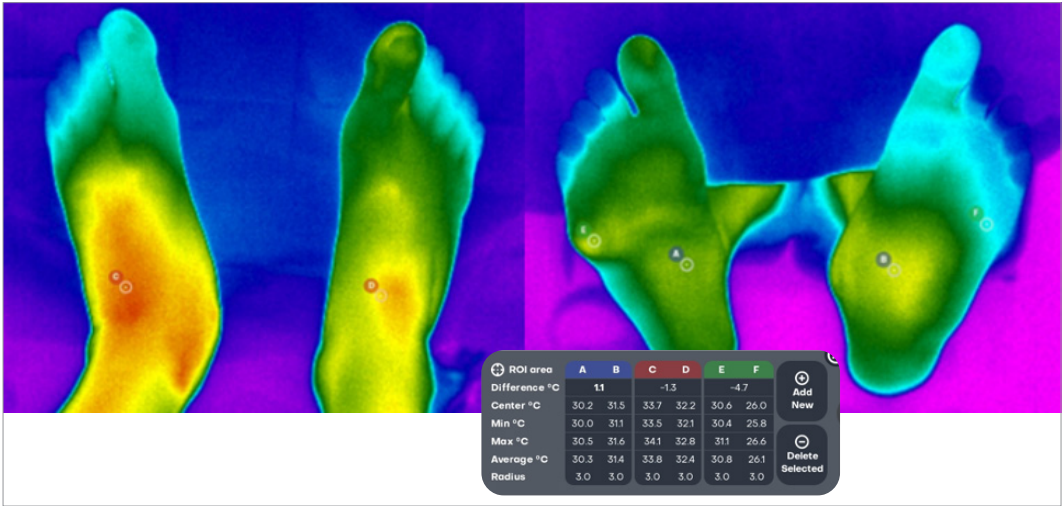


Figure 9. Images and quantitative table above: Case study 2: 16 weeks - Quantitative and visual temperature mapping of both feet using the thermal imaging camera. Left image - dorsal view of both feet demonstrating a reducing colour contrast between limbs and temperatures within normal limits (<2c) at points C and D. Right image — plantar view of both feet also demonstrating reduced colour contrast as well as temperatures within normal limits — A and B 1.3c (<2c).

understanding of his condition and empowered him to explore lifestyle changes that could help reduce his risk of future diabetes-related and limb complications. This was further reinforced through fortnightly reviews, during which serial images showed a gradual reduction in temperature and visible improvement in the pathology [Figure 9] — providing the patient with clear visual evidence of progress and strengthening his commitment to the treatment plan.

By 6 months, temperature differences between both limbs were within 2c across 3 consecutive visits, with all other clinical signs of active disease

resolved. His foot was deemed consolidated [Figure 10] and no further radiological investigations were required. Despite earlier concerns that similar footwear had contributed to his condition, he now understood their critical role in maintaining foot structure and function.

A brief questionnaire [Table 1] revealed highly positive patient-reported experiences, with both participants expressing confidence with the tool and recommending its broader use. Free text comments reflected perceived clarity and empowerment in understanding their condition.



Figure 10. Left image — dorsal view of both feet, initial visit. Right dorsal view of both feet at 6 months.

**Table 1. Summary of patient responses to thermal imaging experience questionnaire.**

Question	Patient 1 response	Patient 2 response
1. How clear was the explanation of the results provided by the healthcare professional?	Very clear	Very clear
2. Did you find thermal imaging helpful in understanding your condition?	Very helpful	Very helpful
3. How confident are you in the accuracy of the thermal imaging results?	Very confident	Very confident
4. Have you noticed any changes in your behaviour or management of your condition after using thermal imaging?	Significant positive changes	Significant positive changes
5. Would you recommend thermal imaging to others with similar health concerns?	Definitely yes	Definitely yes
6. Additional comments or suggestions	<p>‘Should be available for everyone.’</p> <p>‘I knew I needed to wear the boot, but the image really confirmed it</p>	<p>‘It really helped my understanding of what was happening to my foot.’</p> <p>‘It let me see what I couldn’t feel’</p>

## Discussion

The Thermidas IRT-384 thermal tablet [Figure 2] is a portable thermal imaging tablet designed for routine clinical use. It holds Class IIa CE certification as a medical device and is approved by the MHRA for use in the UK. This certification is more desirable to other models without approval as shows the device is validated, regulated and specifically designed for medical diagnostics. While lower-cost or industrial thermal cameras may look similar, they lack the clinical validation, legal assurance and safety standards required for use with patients, especially in high-risk scenarios like diabetes-related foot care.

The case series demonstrates the value of thermal imaging as a tool not only for clinical assessment but also for enhancing patient engagement in the management of CNO. In both cases presented, thermal imaging provided immediate, visual evidence of inflammation across both feet simultaneously that was not subjectively perceived by the patients due to peripheral neuropathy. The visibility of the thermal images facilitated more meaningful conversations around severity of the condition, underscoring the rationale for strict adherence to offloading regimens and the importance of glycaemic control. The thermal

tablet was easy for the clinicians to use, employing a simple point and shoot method that could be seen on the tablet screen during use for the best shot and required only basic operational instructions and guidance for initial image interpretation.

Patients responded positively to visual feedback, both reporting increased understanding of their condition and greater motivation to comply with treatment recommendations. This behavioural shift was associated with accelerated clinical improvements, including earlier than expected signs of resolution, reduced need for additional radiological imaging to confirm consolidation and avoidance of more severe structural foot changes. These outcomes suggest that thermal imaging may serve as a valuable adjunct in managing CNO, particularly when used to support patient support and engagement.

## Conclusion

Charcot neuro-osteoarthropathy is a serious, life-altering condition that can significantly compromise an individual’s quality of life and independence. This case series presents multiple examples where the use of digital thermal proved beneficial in clinical practice — not only as a diagnostic adjunct but also as a powerful connection tool. By visually



illustrating areas of inflammation, thermal imaging helped bridge the gap in patient understanding caused by peripheral neuropathy, which often masks symptoms. Furthermore, sharing these visual findings with patients created a valuable opportunity for open person-centred dialogue. This facilitated meaningful discussions about their condition and individual circumstances ultimately supporting the development of tailored management plans and motivating adherence to pressure-relieving strategies and improved glycaemic control. ■

### Patient consent

A written consent was gained from both patients at the time of manuscript submission.

### Declaration of conflicting interest

The author declares no conflicts of interest. The thermal imaging device used in this case series was selected independently. All thermal images presented were taken during routine clinical consultations as part of the case series. The author has no affiliations with the manufacturer of the device and has not received any financial support, funding, or benefits from them at any time

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