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REVIEW ARTICLE

Infrared thermography: a scoping review of its possible role in the diagnosis and follow-up of leprosy neuropathy

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Summary Neuropathy is a well-known complication of leprosy. Nerve palpation and assessment of motor and sensory nerves are routinely performed at diagnosis in leprosy, which helps establish the diagnosis and, during treatment, monitor the status of somatic nerve function. Assessment of peripheral autonomic nerve function is not commonly practiced for diagnosing leprosy or for diagnosing and monitoring neuropathy. Early impairments in autonomic function, however, may help to establish or confirm a diagnosis and predict the development of clinical leprosy and neuropathy. Several studies, including infrared thermography and electro-neurophysiological studies, have shown the presence of subclinical nerve impairments that may indicate a diagnosis of leprosy or lead to the development of neuropathy. Sudomotor and vasomotor impairments, in the presence of loss of protective sensation, also increase the risk for ulceration, often requiring chronic care. This article provides a brief discussion of the importance and assessment of peripheral autonomic nerve function in leprosy. Its focus is to review articles that have used infrared thermography to assess this function.

Keywords: Leprosy, Hansen's disease, neuropathy, assessment, infrared thermography, autonomic nerve function

Introduction

Leprosy is an infectious disease with low pathogenicity, primarily affecting the skin and superficial peripheral nerves. Approximately 180,000 patients are diagnosed with this condition annually, primarily in low-resource countries.[1–4]

The diagnosis of leprosy is typically made in the presence of one or more of the three so-called cardinal signs: a positive skin smear for *Mycobacterium leprae*, hypopigmented skin lesions accompanied by loss of light touch, and one or more enlarged peripheral nerves.[4,5]

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Patients without typical leprosy skin lesions may be diagnosed with "neural" leprosy, and skin smears are negative.[6–8]

Routine nerve function examinations used to establish a diagnosis are limited to somatic nerve function, including voluntary muscle testing (VMT) and sensory testing (ST).[9,10] The assessment of autonomic nerve function is hardly practiced (see Figure 1). Although some techniques have been developed, none have been routinely adopted.[11–14]

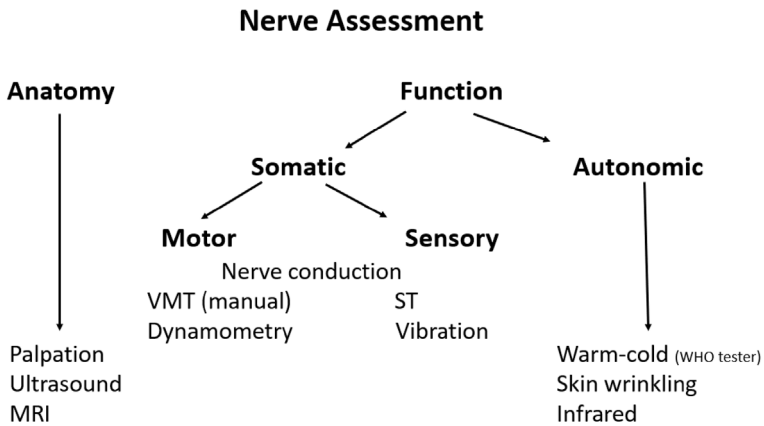

Figure 1. Nerve function assessment in neuropathies and nerve lesions. VMT: Voluntary muscle testing; ST = Sensory testing; Magnetic Resonance Imaging. WHO tester.[12] Autonomic: a distinction could be made between sudomotor and vasomotor function.

Some studies have used the inspiratory gasp to elicit a peripheral autonomic response, sometimes in conjunction with cold stress testing.[15–19] Again, these tests are not widely employed in everyday practice.

Many studies have suggested that subclinical impairment in nerve function can be one of the first indicators of leprosy or leprosy neuropathy, as evidenced by delayed sensory nerve conduction and vasomotor reflex testing.[13,15–17,20–22]

The consequences of loss of peripheral autonomic nerve function can be significant: loss of sweating resulting in skin dryness, a major predisposing cause of ulceration when superimposed on sensory loss, as it usually is.

In general practice, comparing two contralateral sites, feeling a raised skin temperature points to inflammation. Measuring skin temperature with a thermometer can quantify this, but infrared thermography can do this more accurately and visualize temperature changes. Raised skin temperatures or differences in skin temperature between similar body parts could play a crucial role in the early diagnosis of leprosy neuropathy, confirming or supplementing the diagnosis. This article focuses on studies that discuss the assessment of the Autonomic Nervous System (ANS) function and explores the potential applications of Infrared Thermography (IRT) in the diagnosis and management of leprosy and leprosy neuropathy.

Research on the use of IRT in leprosy needs to address some of the following questions:

To what extent does autonomic nerve impairment (ANI) occur independently of somatic nerve function loss as a possible early indicator for developing clinical leprosy or (subclinical) neuropathy? Can IRT confirm or supplement the early diagnosis of leprosy? What are the

potential differences in the presence and extent of Autonomic Nerve Impairment (ANI) in the leprosy classification spectrum?

These and other questions will not be answered in this overview of possible use. IRT will be presented as a relatively new assessment technique that could benefit the diagnosis and management of leprosy neuropathy and its consequences.

Method

The two main keywords used in the search for relevant articles are "leprosy" and "thermography." Article references were reviewed for potential additional documents pertinent to the assessment of leprosy autonomic dysfunction.

Infolep, (INFOrmation LEP) is a database developed explicitly for leprosy.[23] Searching this database with "thermography" yielded 20 articles, of which 12 were considered essential to extract information relevant to the diagnosis and possible follow-up of leprosy neuropathy.

The PubMed search yielded 18 articles with the same keywords. We read and checked the references for these articles to identify possible additional sources.

Google Scholar was hand-searched with an extended string adding the word "neuritis/neuropathy" (neur*), N 77. These articles were hand-searched, and reference checking was conducted for all relevant publications, particularly "review" articles, assuming that important articles that could be verified would be listed.

Finally, Science Direct showed 81 articles with the "Thermography AND Leprosy" string.

Due to the many similarities between diabetic and leprosy neuropathy, as well as their consequences, articles related to diabetes have been included in this paper when deemed relevant to illustrate the use of thermography in the diagnosis, assessment, and follow-up of nerve function impairment.

No attempt was made to conduct a comprehensive review of the use of thermography in diabetes or other diseases, nor was there an attempt to qualitatively grade the reviewed articles.

Infrared thermography in leprosy

IRT is a well-established imaging technique in general medicine and can be considered a proxy assessment for autonomic nerve function.[24,25] The indications for using infrared thermography in leprosy can be considered in two distinct groups. Applications related to the diagnosis and follow-up of the disease, including neuropathy, and indications that relate to the consequences of impaired neural function.

DIAGNOSIS OR CONFIRMATION OF THE DISEASE

The presence of one or more of the three cardinal signs determines the diagnosis.[4] Without clear cardinal signs, the findings of IRT research can increase the likelihood of a diagnosis, confirm it, and enhance the accuracy of the diagnosis.[26,27] Illarramendi reported a high prevalence of vasomotor reflex impairment in newly diagnosed patients with laser Doppler velocimetry.[18]

NERVES-NEUROPATHY

Balbinot (2012) and Zhou (2021) used thermography to diagnose early diabetic neuropathy.[28,29] Neuropathy is a critical component of leprosy, which is usually considered a dermatological disease. Neuropathy/neuritis may lead to loss of sensation and paralysis, often leading to well-known secondary, frequently preventable impairments and deformities.[30]

Monitoring leprosy neuropathy is crucial for assessing the effectiveness of treatment and taking prompt action when new nerve impairment is detected. Treatment results depend on factors such as age, classification, treatment efficacy, and duration of nerve function loss. IRT could be a functional adjunctive assessment in following neuropathy and its possible progression or resolution. No studies have been found that use IRT in follow-up assessments of nerve function impairment, either in its natural course or following medical or surgical interventions such as neurolysis.

SKIN LESIONS

Skin lesions are a typical cardinal sign of leprosy. They are usually described as anesthetic or insensitive; "hypo-aesthetic" is a better term. Is skin temperature impaired, maybe compared to the contralateral side? Does reduced touch sensation parallel *a reduction or an increase in temperature* when patients have leprosy reactions? Could IRT again be a valuable tool in monitoring and evaluating temperature recovery following treatment?[31,32] Rodrigues, using a thermal sensory analyzer—not infrared—showed temperature differences between skin lesions and the symmetrical contralateral skin.[33] Srinivasan and Stumpe developed a simple hand-held battery-operated pen-like instrument to detect temperature differences between normal and affected skin.[34]

NEUROPATHIC PAIN

Tiago *et al.* used IRT to assess neuropathic pain (2021). They concluded, "IRT confirmed the asymmetric pattern of leprosy neuropathy, indicating a change in the function of the autonomic nervous system, and proved to be a useful method in the approach of pain."[35]

ULCERATION AND "HOT" FEET

"The foot heats up before it breaks down"[36] (Paul Brand in Boulton)

The leading secondary, preventable complication following leprosy neuropathy is ulceration, especially plantar ulceration. In a well-functioning program, individuals with loss of protective sensation should be educated on how to care for their feet and be aware of signs such as swelling and *elevated temperature*.[35–37]

Boulton pointed out the many similarities between leprosy and diabetes-related neuropathy in plantar ulceration. Several studies have been conducted on diabetic neuropathy to evaluate skin temperature as a risk factor for plantar ulceration and to monitor its healing process.[36]

Armstrong *et al.* conducted a physician-blinded study comparing two groups of patients with neuropathic feet. Both received standard care. The experimental group monitored their feet with a skin thermometer. High temperature gradients between feet may predict the onset of neuropathic ulceration, and self-monitoring may reduce the risk of ulceration.[38] Of course, in diabetes, besides impaired vasomotor reflexes, impaired function is compromised by vascular pathology.[39–41]

CONTACT EXAMINATION

Studies indicate that social, environmental, and genetic factors may contribute to the development of leprosy.[42,43] As stated, multiple electro-neurophysiological studies also confirm that either subclinical somatic or autonomic nerve function impairments may be present in the contacts of leprosy-affected people.[44–46]

Using infrared thermography, Sabino and dos Santos showed changes in asymptomatic household contacts and concluded that IR thermography may detect temperature asymmetry in the hands of leprosy contacts, indicating peripheral autonomic dysfunction related to early neural impairment in these individuals.[45–48]

Discussion

This article emphasizes the importance of early diagnosis of leprosy neuropathy and the potential role of thermography in the diagnostic process (Table 1). This includes not only neuropathy but also possible assessment and follow-up of the consequences of nerve function impairment. Notably, thermography is not mentioned in two leading textbooks on leprosy.[49,50] It is essential to know that in leprosy, autonomic impairments are usually present when sensory and motor impairments are present. However, autonomic innervation can be unaffected with impaired sensation or motor function in other neurological diseases and can, therefore, be important in the differential diagnosis.[51]

Table 1. Selected quotes illustrating the importance of assessment of Autonomic Nerve Function (ANF) in the early diagnosis of leprosy neuropathy

Quote	Authors	Year
"...the detection of impaired VMRT distinguished newly registered leprosy patients from healthy controls"	*Abbot, Swanson Beck*[15]	*1991*
"Subclinical autonomic neuropathy is common among healthy contacts of leprosy patients…."	*Wilder-Smith*[40]	*1997*
"A high prevalence of peripheral autonomic dysfunction...was observed in newly diagnosed leprosy patients.....autonomic nerve lesion was more frequent than somatic lesions..."	*Illarramendi*[18]	*2005*
"Basic research (nerve conduction) has shown that nerve impairment is detectable long before it turns clinical"	*Wilder Smith, van Brakel*[65]	*2008*
"Thermography proved a potential tool... to assist in the early detection of neuropathies..." ...a significant interaction between clinical form of leprosy and the temperature..."	*Cavalheiro*[19]	*2016*
"Temperature diminished in leprosy patients compared to healthy controls" – "detect asymmetry to detect early autonomic dysfunction"	*Sabino, Dos Santos.*[47]	*2023*
"Detecting asymmetry in hands of leprosy contacts"	*Sabino, Dos Santos.*[46]	*2024*

VMRT – Vaso motor reflex testing.

Table 2 lists recent studies using thermography in leprosy. Interestingly, early research using thermography in leprosy confirmed the presence of *M. leprae* in the cooler parts of the body by thermography.[52,53] The mentor of preventative rehabilitation in leprosy, Paul Brand, used IRT a few decades ago to show that increased temperatures preceded skin breakdown.[52–55]

Notably, the study by Balagon *et al.* involved patients using a *self-assessment* tool. An essential part of this tool was asking patients to observe *inflamed* skin lesions. When located in the vicinity or overlying a nerve, these were considered to put the nerve at risk.[31]

In 2007, an internationally developed consensus workshop reviewed neuropathology, leprosy diagnosis, neurological assessment, and treatment. Given recent developments in evaluation and insights into prevention and treatment, an update to this important document is warranted.[56]

Table 2. Infrared thermography (IRT) studies in leprosy

Authors		Title	Ref.	Study subjects A Leprosy	B Non-leprosy	C Non-Leprosy	Temperature recorded by	Results	Comments
Cavalheiro	2016	Thermographic analysis of autonomic function following cold stress	[19]	Heterogeneous on treatment $N = 17$	$N = 15$		FLIR camera	See Table	Hands tested following cold spray
Tiago	2021	Assessment of neuropathic pain (NP)	[35]	$N = 55$ 29 with, 26 without NP	$N = 20$		Digital thermo-hygrometer	Compared to controls all patients showed temperature asymmetry	Neuropathic pain not defined Hands and Feet tested
Sabino	2023	Evaluation of skin temperature in hands	[47]	$N = 48$ on treatment	$N = 22$		FLIR	Increased asymmetry in leprosy MB > BT	Hands
Sabino	2024	Asymptomatic contacts	[46]	None	$N = 23$ Contacts	Seropos. = 66 Seroneg. = 55 No contact	FLIR	See Table	Hands
Vinay	2024	Use of cutaneous thermography	[66]	Newly diagnosed $N = 5$	None		FLIR	Sites of impaired sensation are cooler	Hands/feet

FLIR: Forward Looking Infrared.

Notice variability in the studies! See text for other than IRT studies of autonomic nerve function assessment in leprosy, none of which have been adopted in routine leprosy practice.

Many studies have been done in Diabetes (neuropathy) - See text

Little is known about the epidemiology of the diagnostic cardinal signs. Following further research, IRT could become a proper adjunctive technique in diagnosing or confirming the disease, for follow-up, and in the differential diagnosis. Some leprologists have been critical of relying solely on the three cardinal signs and suggested that two additional signs—ulnar nerve enlargement and sensory loss of the palms of the hands and soles of the feet—could be added to increase the validity of the diagnosis.[26,27]

Nerves may be palpable and found enlarged or tender. However, the lack of expertise in nerve palpation among primary healthcare workers in integrated health services and medical officers not trained in leprosy often renders the diagnosis inconclusive.

Potentially, IRT could be used to monitor the temperature of the nerves. When these are enlarged and inflamed, this may be reflected in the skin temperature overlying the nerve. This is particularly applicable to the commonly affected nerves, including the ulnar, median, common peroneal, and posterior tibial nerves.

Thermography can detect abnormal surface temperatures without the cardinal signs, especially in contact examinations of patients with lepromatous leprosy.[40–44] If found, prevailing policies should determine advice. Should subjects be reviewed after a given time? Should prophylactic treatment be given?[57]

Of course, age- and gender-specific normative and cut-off values should ideally be known, and more research is needed in this area. However, significant left-right differences could already be essential in decision-making and policy.

The reliability of somatic, sensory, and motor functions in leprosy has been assessed.[9,10] To date, no information exists regarding the reliability of IRT assessments in leprosy, unlike in diabetes, where several studies have been conducted.[28,29,58,59]

In leprosy, loss of autonomic nerve function is assumed when sensory loss is present. But if there is evidence that early sympathetic nerve function precedes sensory/motor loss, should there not be an inexpensive and practical way to determine autonomic nerve function loss? "*The advantage of infrared thermography is that it is a fast, non-contact, painless, side-effect-free, and non-observer-dependent diagnostic and evaluation tool.*"[59]

Our research group is currently investigating the use of IRT through a small infrared video camera attached to a mobile phone, where dynamic video recordings, following cold stress testing, can be analyzed to gain more insight and answers to some questions raised in this paper.[60]

Neuropathy in diabetes predominantly affects the lower extremities, whereas leprosy neuropathy may result in neuropathy affecting both upper and lower limbs. Studies in diabetes confirm that early impairments of autonomic nerve function may indicate the development of clinical diabetes and "manifest" sensory loss.[28,29]

Ultrasound examination could also be helpful in the differential diagnosis and in selected subjects where the diagnosis is doubtful, such as in cases of neural leprosy. Few studies have been conducted using ultrasound (US) in the treatment of leprosy.[61–64] Can IRT complement the diagnosis of neural leprosy to provide a better understanding of nerve pathology and assess treatment efficacy, whether medical or surgical? Ultrasound examinations would be potentially more informative about structure, whereas IRT could be more informative about function.

Besides ultrasound and electro-neurophysiological techniques, with further research, infrared thermography has the potential to become a valuable and affordable tool in the diagnosis of leprosy and the assessment and follow-up of its major complications, including neuropathy and its consequences.

Conclusions/recommendations

Several studies have shown that early loss of autonomic nerve function may precede impairments in somatic nerve function: sensation (touch) and muscle strength. Early impairments in autonomic function, preceding somatic nerve changes in leprosy, have been shown in electroneurophysiological and infrared thermography studies. These impairments may indicate early progression to clinical disease and neuropathy. Further studies are warranted to assess the clinical applicability and reliability of autonomic nerve function evaluation in leprosy.

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References

[1] Froes LAR, Sotto MN, Trindade MAB. Leprosy: clinical and immunopathological characteristics. *Ann Bras Derm*, 2021; **97**: 338–347. https://doi.org/10.1016/j.abd.2021.08.006.

[2] World Health Organization. *Weekly Epidemiological Record, vol.37*, Geneva: WHO, 2024. http://www.who.int/wer.

[3] Rodrigues LC, Lockwood DNJ. Leprosy now, epidemiology, progress, challenges, and research gaps. *Lancet Infect Dis*, 2011; **11**: 464–470. https://doi.org/10.1016/S1473-3099(11)70006-8.

[4] World Health Organization. *Guidelines for the Diagnosis and Prevention of Leprosy*. Geneva: WHO, 2018.

[5] Kumar DP, Uprety S, Dogra S. Clinical diagnosis of leprosy. In: *International Textbook of Leprosy*. 2017. https://doi.org/10.1489/itl.2.1.

[6] Wilder-Smith E. Diagnosis of pure neuritic leprosy. *Neurol J Southeast Asia*, 2002; **7**: 61–63.

[7] Brandsma JW, Post E, Wagenaar I *et al.* Pure neural leprosy. Mind the diagnosis. *Lepr Rev*, 2021; **92**: 38–46. https://doi.org/10.47276/lr.92.1.38.

[8] Tomaselli PJ, dos Santos DF, dos Santos ACJ. Primary neural leprosy: clinical, neurophysiological and pathological presentation and progression. *Brain*, 2022; **145**: 1499–1506. https://doi.org/10.1093/brain/awab396.

[9] Brandsma JW, Wagenaar I, Post E *et al.* Reliability of clinical nerve function assessment in peripheral neuropathies. *Lepr Rev*, 2014; **85**: 29–35. https://doi.org/10.47276/lr.85.1.29.

[10] Birke JA, Brandsma JW, Schreuders TAR, Piefer A. Sensory testing with monofilaments in Hansens' disease and control subjects. *Int J Lepr*, 2000; **68**: 291–298.

[11] Markendeya N, Srinivas CR. Ninhydrin sweat test in leprosy. *Ind J Lepr*, 2004; **76**: 299–304.

[12] Wagenaar I, Brandsma JW, Ziegler D *et al.* Early detection of neuropathy in leprosy: a comparison of five tests for field testing. *Infect Dis Poverty*, 2017; **6**: 115. https://doi.org/10.1186/s40249-017-0330-2.

[13] Wilder-Smith EP, Wilder-Smith AJ, Nirkko AC. Skin and muscle vasomotor reflexes in detecting autonomic dysfunction in leprosy. *Muscle Nerve*, 2000; **23**: 1105–1112.

[14] Wilder-Smith EP. Stimulated skin wrinkling as an indicator of limb sympathetic function. *Clin Neurophys*, 2015; **126**: 10–16.

[15] Abbot NC, Swanson Beck J, Samson PD, Butlin CR *et al.* Impairment of fingertip vasomotor reflexes in leprosy patients and apparently healthy controls. *Int J Lepr*, 1991; **59**: 537–547.

[16] Abbot NC, Swanson Beck J, Wilson SB, Khan F. Vasomotor reflexes in the fingertip skin of patients with type-1 diabetes mellitus and leprosy. *Clin Auton Res*, 1993; **3**: 189–193. https://doi.org/10.1007/BF01826232.

[17] Abbot NC, Swanson Beck J, Mostofi S, Weis F. Sympathetic vasomotor dysfunction in leprosy patients: comparison with electrophysiological measurement and qualitative sensation testing. *Neurosci Lett*, 1996; **206**: 57–60. https://doi.org/10.1016/0304-3940(96)12425-3.

[18] Illarremendi X, Buhrer-Sekula, Sales SMA *et al.* High prevalence of vasomotor reflex impairment in newly diagnosed leprosy patients. *Eur J Clin Invest*, 2005; **35**: 658–665. https://doi.org/10.1111/j.1365-2362.2005.01554.x.

[19] Cavalheiro AL, Costa DT, Menezes AL, Pereira JM, Carvalho EM. Thermographic analysis and autonomic response in the hands of patients with leprosy. *An Bras Dermat*, 2016; **91**: 274–283. https://doi.org/10.1590/abd1806-4841.20164612.

[20] Beck JS, Abbot NC, Samson PD, Butlin CR *et al.* Impairment of vasomotor reflexes in the fingertips of leprosy patients. *Int J Neur Neurosurg Psych*, 1991; **54**: 965–971. https://doi.org/10.1136/jnnp.54.11.965.

[21] Brakel WH, Nicholls PG, Das L *et al.* The INFIR cohort study: investigating prediction, detection and pathogenesis of neuropathy and reactions in leprosy. *Lepr Rev*, 2005; **76**: 14–34.

[22] Brakel WH, Nicholls PG, Wilder-Smith EP *et al.* Early diagnosis of neuropathy in leprosy – comparing diagnostic tests in a large prospective study (the INFIR cohort study). *PLoS Negl Trop Dis*, 2008; **2**: 1–12, e212. http://doi.org/10.1371/journal.pntd.0000212.

[23] Infolep: Leprosy Information Services. https://www.leprosy-information.org/.

[24] Kesztyus D, Bruchner S, Wilson C, Kesztyus T. Use of infrared thermography in medical diagnosis, screening, and disease monitoring: a scoping review. *Medicina*, 2023; **59**: 2139. https://doi.org/10.3390/medicina591221 39.

[25] Abdulkarim AF, Hashim AQ. Infrared medical thermography, medical applications, and its basic principles: a review. *Bio Web Conf*, 2024; **97**: 001140. https://doi.org/10.1051/bioconf/20249700140.

[26] Butlin CR. Diagnosis of leprosy. Letter to the Editor. *Lepr Rev*, 2018; **89**: 390–401.

[27] Saunderson P, Groenen G. Which physical signs help most in the diagnosis of leprosy? *Lepr Rev*, 2000; **71**: 34–42.

[28] Balbinot LF, Canani LH, Robinson CC *et al.* Plantar thermography is useful in the early diagnosis of diabetic neuropathy. *Clin Sci*, 2012; **67**: 1419–1425. https://doi.org/10.6061/clinics/2012(12)12.

[29] Zhou Q, Qian Z, Wu J *et al.* Early diagnosis of diabetic peripheral neuropathy based on infrared thermal imaging technology. *Diab Metab Res Rev*, 2021; **37**(7): e3429. https://doi.org/10.1002/dmrr.3429.

[30] Paul MSK, Kumar DP, Govindasamy K. Chapter 4.3. Physical rehabilitation in leprosy. In: Scollard DM, Gillis TP (eds), *International Textbook of Leprosy*. Greenville, SC, USA: American Leprosy Missions, 2019. https:// doi.org/10.1489/itl.4.3.

[31] Balagon MF, Maghanoy AM, Roferos FO, Saunderson PR. Inflamed skin lesions along the course of a nerve as patient self-help proxy indicator of nerve abnormalities in leprosy. *Lepr Rev*, 2021; **92**: 385–397. https://doi.or g/10.47276/lr.92.4.385.

[32] Hoeksma AF, Faber WR. Assessment of skin temperature: interobserver reliability and correlation with infrared. *Int J Lepr*, 2000; **68**: 65–67.

[33] Rodriques IA, Chaves AT, de Andrade LC *et al.* Detection of sensory deficits in fine nerve fibres in leprosy diagnosis. *Eur Trop Med Int Health*, 2025; **30**(3): 170–180. https://doi.org/10.1111/tmi.14079.

[34] Srinivasan H, Stumpe B. Leprosy diagnosis: a device for testing the thermal sensibility of skin lesions in the field. *Bull World Health Org*, 1989; **6**: 635–641.

[35] Tiago LM, dos Santos DF, Antunes DE, Tiago LMP, Goulart IMB. Assessment of neuropathic pain in leprosy patients with relapse or treatment failure by infrared thermography: a cross-sectional study. *PLOS Negl Trop Dis*, 2021; **15**(9): e009794. https://doi.org/10.1371/journal.pntd.0009794.

[36] Boulton AJM. Diabetic foot – what can we learn from leprosy? Legacy of Dr Paul W. Brand *Diab Metabol Res Rev*, 2012; **28**(suppl 1): 3–7. https://doi.org/10.1002/dmrr.2230.

[37] Ilozumba O, Lilford RJ. Self-care programmes for people with leprosy: a scoping review. *Lepr Rev*, 2021; **92**: 317–337. https://doi.org/10.47276/lr.92.4.317.

[38] Armstrong DG, Holtz-Neidereer K, Wendel C *et al.* Skin temperature monitoring reduces the risk for diabetic foot ulceration in high-risk patients. *Am J Med*, 2007; **120**: 1042–1046. https://doi.org/10.1016/j.amjmed.2007 .06.028.

[39] Aliahmed B, Tint AN, Arjunan SP *et al.* Is thermal imaging a useful predictor of the healing status of diabetes-related foot ulcers? A pilot study. *J Diab Sci Tech*, 2019; **13**: 561–567. https://doi.org/10.1177/1932296818803 115.

[40] Niri R, Lucas Y, Treuillet S, Douzi H. Smartphone thermal imaging system for diabetic foot ulcer assessment. *Hall Open Sci*, 2019. https://hal.science/hal-02161044.

[41] Van Netten JJ, Baal JG, Liu C, van der Heijden F, Bus SA. Infrared thermal imaging for automated detection of diabetic foot complications. *J Diabetes Sci Tech*, 2013; **7**: 1122–1129.

[42] Moet FJ, Meima A, Oskam L, Richardus JH. Risk factors for the development of clinical leprosy among contacts, and their relevance for targeted interventions. *Lepr Rev*, 2004; **75**: 310–326.

[43] Moet FJ, Pahan D, Schuring RP, Oskam L, Richardus JH. Physical distance, genetic relationship, age, and leprosy classification are independent risk factors for leprosy in contacts of patients with leprosy. *J Inf Dis*, 2006; **193**: 346–353.

[44] Wilder-Smith A, Wilder-Smith E. Electrophysiological evaluation of peripheral autonomic function in leprosy contacts and controls. *Int J Lepr*, 1995; **64**: 433–440.

[45] Wilder-Smith E, Wilder-Smith A, Egger M. Peripheral autonomic nerve dysfunction in asymptomatic leprosy contacts. *J Neur Sci*, 1997; **150**: 33–38.

[46] Sabino EFP, Dos Santos DF, Antunes DE *et al.* Asymptomatic leprosy contacts present asymmetrical skin temperature in hands by infrared thermography. *Lepr Rev*, 2024; **95**: 1–10. https://doi.org/10.47276/lr.95.2.2023071.

[47] Sabino EFP, dos Santos DF, Antues DE *et al.* Evaluation of skin temperature in the hands of leprosy patients to detect peripheral autonomic dysfunction by infrared thermography. *Lepr Rev*, 2023; **94**: 299–308. https://doi.org/10.47276/lr.94.4.299.

[48] Dos Santos DF, Garcia LP, Borges IS *et al.* Early diagnosis of neural impairment in seropositive leprosy household contacts – the experience of a reference center in Brazil. *Front Med*, 2023; **10**: 1143402. https://doi.org/10.3389/fmed.2023.1143402.

[49] Kar HK, Kumar B. *Indian Association of Leprologists (IAL) Textbook of Leprosy*. New Delhi: Jaypee Brothers Medical Publishers, 2010.

[50] Scollard DM, Gillis TP (eds) *International Textbook of Leprosy (Ebook)*. Greenville, SC: American Leprosy Missions, 2016. https://doi.org/10.1489/itl.

[51] Brandsma JW, Maharjan S, Sharma R, Das D, Visser L. Hirayama disease: the importance of the differential diagnosis in suspected neural leprosy. *Lepr Rev*, 2023; **94**: 1–7. https://doi.org/10.47276/lr.94.1.46.

[52] Sabin TD, Ebner JD. Patterns of sensory loss in lepromatous leprosy. *Int J Lepr*, 1969; **37**: 239–248.

[53] McDougall, Salter DC. Thermography of the nose and ear in relation to the skin lesions of lepromatous leprosy, tuberculosis, Leishmaniasis and Lupus Pernio. *J Invest Derm*, 1977; **68**: 16–22. https://doi.org/10.1111/1523-1747.ep12485135.

[54] Bergholdt HT, Brand PW. Thermography: an aid in the management of insensitive feet and stumps. *Arch Phys Med Rehab*, 1975; **56**: 205–209.

[55] Enna CD, Bergholdt HT. Temperature studies of the hand and its claw deformities due to peripheral nerve paralysis in leprosy. *The Hand*, 1973; **5**: 10–14.

[56] Van Brakel WH, Saunderson P, Shetty V, Brandsma JW *et al.* International workshop on neuropathology in leprosy – a consensus report. *Lepr Rev*, 2007; **78**: 416–453.

[57] Ellen F ter, Tielens K, Fenenga C, Mieras L *et al.* Implementation approaches for leprosy prevention with single dose rifampicin: a support tool for decision-making. *PLoS Negl Trop Dis*, 2022; **16**(10): e0010792. https://doi.org/10.1371/journal.pntd.0010792.

[58] Silva NCM, Castro HA, Carvalho LC *et al.* Reliability of infrared thermography images in the analysis of the plantar surface temperature in diabetes mellitus. *J Chiropract Med*, 2018; **17**: 30–35. https://doi.org/10.1016/j.jcm.2017.10.006.

[59] Salaris M, Marsocci A, Curti F *et al.* The use of infrared thermography in prevention and evaluation of diabetic foot ulceration and in detection of diabetic peripheral neuropathy: a systematic review. *Cureus*. https://doi.org/10.7759/cureus.

[60] Knulst AJ, van den Bogaert F, Kuipers AS, Roelofs L *et al.* Pre-clinical evaluation of a low-cost tool for skin temperature measurements as a proxy to assess autonomic nerve function in leprosy neuropathy. *PLoS One*. https://doi.org/10.1371/journal.pone.0327815.

[61] Pirola R, Visser LH, Nasr-Eldin YK *et al.* Neuromuscular ultrasound in leprosy. A scanning protocol. *J Clin Ultrasound*, 2023; **51**: 1529–1535. https://doi.org/10.1002/jcu.23591.

[62] Tjiamana MP, Zaidana MZ, Ausatha ZF *et al.* The role of high-resolution ultrasonography (HRUS) in detecting peripheral neuropathy in leprosy patients and household contacts: a systematic review. *Lepr Rev*, 2025; **96**: 1–13. https://doi.org/10.47276/lr.96.1.2024132.

[63] Wheat SW, Stryjewska B, Cartwright MS. A hand-held ultrasound device for the assessment of peripheral nerves in leprosy. *J Neuroimmun*, 2021; **31**: 76–78.

[64] Sreejith K, Sasiharanpillai S, Ajithkumar K *et al.* High-resolution ultrasound in the assessment of peripheral nerves in leprosy: a comparative cross-sectional study. *Ind J Derm Vener Derm*, 2021; **87**: 199–206. https://doi.org/10.25259/IJDVL_106_20.

[65] Wilder Smith E, van Brakel WH. Nerve damage and its management. *Nat Clin Pract Neur*, 2008; **4**: 656–666.

[66] Vinay K, Baskaran N, Narang T, Dogra S. Utility of cutaneous thermography in assessment of nerve function impairment in leprosy. *Int J Derm*, 2024; **63**: 1627–1629.