https://doi.org/10.46389/rjd-2020-1044
www.rjdnmd.org

Rom J Diabetes Nutr Metab Dis
2020; volume 27, issue 3, pages 298-302

Review

The Handheld Infrared Thermometry in the Diabetic Foot – Useful but Debatable Technique

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Received: 13 May 2020 / Accepted: 13 August 2020

Abstract

The non-contact (handheld) infrared thermometers are valuable instruments for evaluating diabetic foot pathology and foot ulcer prevention. Since there is no guideline to indicate the exact way they should be used, clinical judgment helps integrate the collected data in the case management process. Foot care providers must consider that some factors might interfere with the measurement correctness. It has been suggested that in some cases, other investigations besides thermometry have to be performed before making any decisions.

Keywords: Infrared thermometry, diabetes mellitus, Charcot neuroarthropathy, foot care, debatable technique.

Introduction

Diabetic foot problems are mainly the consequence of diabetic peripheral neuropathy, macro- and microvascular disease of the lower limbs, and any other musculoskeletal damage, including infections. Diabetic neuropathic osteoarthropathy is the consequence of damage to sensory, motor, and autonomic nerve fibers. This usually affects people with a long-standing unfavorable metabolic profile.

A redoubtable complication of the diabetic foot is the neuropathic ulceration.

It is thought that 15–20% of diabetics are likely to develop foot ulcerations throughout their long-running disease, becoming thus a public health issue. Once clinically manifested, it is believed to account for 85% of the lower limb amputations [1]. Charcot arthropathy is believed to have a prevalence of up to 1–7.5% in the diabetic population, being probably even higher (29–35%) in neuropathic diabetics [2–4]. Therefore, congruent efforts are continuously made for both prediction and accurate prevention of diabetic foot ulcerations.

Historically, Hippocrates was one of the first to mention about skin temperature changes, in 400 BC. He claimed that "in whatever part of the body excess of heat or cold is felt, the disease is here to be discovered" [5]. In the modern days (1971/1972), Goller and Sandrow have correlated dermal temperature with some specific areas which were subjected to inflammation and localized pressure and, ultimately, neuropathic osseous fractures [6].

In humans, the feet are not commonly displaying a difference higher than 1°C between corresponding anatomical areas, but the skin temperature on the trunk regularly fluctuates between 33.5–36.9°C, some anatomical regions exhibiting small physiological variations [7].

Many factors may influence skin temperature either diffusely (ambient, hypothalamus, damage of the internal organs) or localized (various conditions affecting either the skin itself or the underlying soft tissues).

Physiologically, there are certain anatomical areas known to display temperature inconsistencies such as body extremities, protruding body parts, close vicinity of the underlying large vessels, or whenever extreme ambient temperature impacts the skin surface. However, cutaneous vasculature does act efficiently [8, 9]. To note, the higher skin temperature related to the diabetic foot injuries has generated research activities which are increasingly numerous to the modern-day.

Various techniques can detect the skin surface temperature, either focusing on some specific anatomical areas as non-contact infrared thermometers do or providing values of the entire sole by using, among others, liquid crystal thermography, a temperature-sensing weighing scale or infrared (IR) camera systems [7, 9].

Although the thermal imaging systems have some important advantages, this paper's main subject will be the non-contact IR thermometer. It is cheaper, user-friendly, largely used by podiatrists, and also having a very good inter-instrument agreement in humans, despite being more time-consuming [1, 5, 6, 10].

The non-contact IR thermometers and scanning technique

Exergen DermaTemp 1001 and Temp Touch dermal thermometers have been considered for a long time, the only investigational and scientifically accepted thermometers for the foot skin measurements. Some observational studies, using four industrial thermometers, showed that these less-expensive devices are reliable tools for home monitoring. To be noted, they also avoid contamination by keeping a safer "distance-to-spot" [1, 5, 11]. Other thermometers may show similar results, but there is a lack of evidence regarding this aspect. However, in the podiatry departments, choosing an IR thermometer might be a challenge, and each practitioner has to deal with many aspects. The IR thermometers have a different range of temperature recording and functioning capabilities. Many of them are not explicitly designed for foot assessment, so we should remember that a damaged foot can display, compared with the presumed normal contralateral one, a more significant temperature domain. By looking at the ideal IR thermometer qualifications, we could name reliability and validity as an assessment tool, maneuverability, time-efficiency, and the comprehensiveness of its technical book. Without a standardized tool, other devices appeared as substitutes in our daily practice. Therefore, some practical obstacles could arise. Some differences between devices are the calibration frequency, well-timed pauses between measurements, or the number of measurements required at the same site. Besides these, patients have to accommodate at the workroom temperature (24–25ºC) by taking off their shoes at least 15 minutes before. However, the appropriate time frame could depend on the potentially asymmetric type of footwear/devices. Whenever certain dressings have previously covered the skin/wound's surface, they should be removed 10 minutes before to regain thermal rebalance [1].

Skin temperature measurements in Charcot's foot

Some researchers found that intense neuropathic foot exhibits higher skin temperature in its entirety but mainly on the dorsal aspect, probably as a consequence of increased blood flow via arteriovenous shunting [12, 13].

From the anatomical perspective, comparing with the sole, on the dorsal aspect, the skin and the subcutaneous tissue are thinner, and the muscle layers are not that complex. It should be mentioned that the thickness of the subcutis fatty layer (which is a real thermal barrier), modulates the transfer of the muscle (or deeper structures) heat to the skin. The lower the subcutis thickness, the higher the skin surface temperature [14]. These facts could also partly explain the findings of the above authors.

Charcot foot may involve one to a few joints/soft tissue areas, making up localized patterns or fully conjoining these in a diffuse picture [9, 15]. The dermal temperature fluctuates according to the stage; it is higher in the active (acute) inflammatory phase, gradually decreases in the subacute phase, and equalizes the unaffected symmetric areas at the end of the healing process after immobilization. As we might expect, this skin temperature dynamic mirrors the underlying damaged joints.

IR temperature measurements usually involve the plantar projections of the first, third, and fifth metatarsal heads, first metatarsal-cuneiform, talonavicular joints, cuboid, and heel. In fact, these joints are outlining the most vulnerable areas [1, 16]. However, any other region of interest (soft tissue/joint), could be assessed thermally.

As mentioned above, a non-ulcerated Charcot foot displaying a temperature difference >2°C vs. healthy contralateral foot, should be considered in its active stage. This cut-off point has generally been accepted as one of the offloading criteria [9, 17]. However, the practitioners should be aware that values <2°C, but higher than normal, could reflect either subclinical persistence of inflammatory activity (argued mainly on imaging), or its full relapse.

The practitioners have to cast the skin temperature criterion aside whenever the Charcot damage is bilateral and synchronously active. Also, whenever subclinical inflammation and soft tissue/osseous infections coexist, an accurate cutaneous temperature evaluation becomes more challenging [1, 9].

It is worth mentioning that a specific stress response (physical activity) of the plantar temperature might predict the conversion from a non-Charcot to Charcot's foot or that Charcot's foot is at-risk for ulcerations [18].

Dermal IR thermometry over at-risk areas, infectious wound, and during the self-monitoring process

Once some (localized) at-risk areas are suspected, it seems logical to focus on them. A diffusely high temperature could synchronously coexist with certain "hot spots", thus displaying >2.2°C when compared with the contralateral unaffected areas and also suggesting a deeper inflammatory event, probably anticipating clinical lesions.

Once diagnosed, physical activity and plantar pressure must be promptly reduced. Considerable research efforts were made in IR thermometry as an efficient warning methodology when applied regularly for at-risk areas [7, 16, 19-21].

Some particular entities, which are often encountered as a result of repeated exposure to minor trauma, are the foot's callosities. Becoming hemorrhagic entities, they are converted into pre-ulcerative "hot spots". The higher abnormal intrinsic vascularity there is, the higher their pre-ulcerative propensity.

A delayed wound healing could be the result of bacterial colonization either in the deeper layers or peri-wound. Among the clinical criteria (STONES: Size, Temperature, Osseous, New area of breakdown, Erythema/Edema, Exudate, Smell), a higher temperature gradient seems to reflect this fact up to 5 times. However, it is not a sine qua non-criterion concerning infectious events.

Because a neuropathic foot can display a higher skin temperature on its own and, as a result of repeatedly traumatic events, or even walking, another two STONES criteria must be added to prove infection [1, 18]. This specific situation has the benefit of therapeutic footwear, frequently, for months. Once the ulcer healing steadiness is achieved gradually, the temperature gradient (the affected vs. healthy contralateral matched area) is being replaced by thermal symmetry [11, 16, 21].

There are different examination protocols that frequently select some predefined plantar sites. Although these protocols are very didactic, they do not serve as an absolute rule because almost 52% of foot ulcers are located on the dorsal, lateral, medial, or interdigital surfaces. Moreover, a pre-existing localized plantar forefoot ulceration, which is under repeated pressure, could spread and fistulize to the dorsum of the foot, thus equalizing the temperature of hot spots, and the clinicians should always consider such a provocative sequential event [17, 22]. Thus, we could debate about the apparent rigidness vs. the versatility of the chosen measurement sites.

Home-monitoring for at-risk patients implies that they are specifically educated as well as in full physical abilities. They are greatly encouraged to embrace, regularly,

https://doi.org/10.46389/rjd-2020-1044

both self-inspection and dermal temperature scanning. Persistently focal measurement of the vulnerable anatomical sites (foot ulcer recurrence/propensity for new injuries) is an extremely useful self-care maneuver for predicting and further self-prevention practicing [1, 11, 19, 21, 23].

In order to avoid either false positive or negative results, whenever >2.2°C reflects the skin temperature difference between the corresponding locations, individualized thresholds (the baseline temperature difference between the left and the right foot) should be calculated [24].

Several pathologies and other factors that may induce distorted results

- Because of their declivity, the lower anatomical segments- ankle and foot- are the election place for the development of edema in several pathologies, which may also influence the skin temperature.
- The massive non-inflammatory lower limb edema (venous, cardio-renal, and others) could partially disguise more in-depth inflammatory activity, giving falsely lower temperature values.
- The hemiparesis (forearm, leg, and foot) of the contralateral limb after cerebral infarction evolves with lower cutaneous temperature related to its autonomic disfunction.
- Certain asymmetries of the vascular tree could be responsible for asymmetric skin temperature due to different vaso-reflex potency.
- It is known that blood flow influences the skin temperature; however, strict linearity is missing. Whenever the lower limb displays simultaneously venous and arterial disease, at rest, the cutaneous temperature gradient could be higher than normal because of the sluggish venous blood even when the foot pump normally acts during ambulation.
- In venous insufficiency, the higher skin temperature is strongly connected with lower limbs' inflammation, stasis, and edema [25, 26].
- Effective collaterals, revascularization, vasoactive medication, severe neuropathy, including autonomic disturbances, are factors that may offer unexpected results comparing with a pure severe arterial disease [27, 28].
- Speculating on the asymmetrical blood flow, the dermal temperatures, which are collected above and below the presumed atheromatous obstacle, could suggest an ischemic limb [1]. However, we should remember that the lower limb arterial disease, mainly in diabetics, is rarely fully asymmetric. Thus, the presumed healthy contralateral comparator is missing. Neither IR thermometry nor thermal imaging techniques can offer certainties about lower limb arterial disease complexity. Angiography and ultrasound images are needed.
- The dermal blood flow rate through microvasculature promotes skin temperature values accordingly. Some other factors, which we previously named, although not explicitly related to the device itself, are carrying the risk of distorting the final result [8].

Conclusions

The temperature measurement of the foot with a non-contact IR thermometer is considered an advantageous method for evaluating the diabetic foot, mainly its iconic (complicated or not) Charcot neuropathic osteoarthropathy. This probably unexpected context invites the dedicated caregivers never to exclude any potential influencing and limiting factors, and to ask for additional investigations for better decision making whenever needed.

Conflict of Interest

The authors declare no conflict of interest.

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