CHAPTER 28

CLINICAL USEFULNESS OF INFRARED THERMOGRAPHY

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Physicians monitor core body temperature as an indicator of basal metabolic rate which may vary due to age, exercise and activity. Body temperature may vary in the presence of disease as well as ambient temperatures. Generally, a patient is said to have a fever if the core body temperature is elevated. This paper will attempt to assess surface skin temperatures in the foot as an indicator of local inflammation and blood flow.

NORMAL SKIN TEMPERATURES

The skin is the body's radiator system and body temperature can be modified as a result of the blood flow through the venous plexus immediately beneath the skin. Most exposed areas of the body – the hands, feet and ears in particular are supplied by the inflow of blood through direct arteriovenous shunts. Blood flow through this venous plexus may vary significantly from barely zero to as much as 30% of the total cardiac output. The body increases blood flow to the extremities to dissipate heat from the internal organs and diminishes blood flow in an effort to maintain body core temperature. The sympathetic nervous system is responsible for control over this blood flow and ordinarily remains tonically active causing continual constriction of the arterioles supplying the skin. Stimulation of the sympathetic nervous system yields constriction and reduction of skin blood flow. Inhibition of the sympathetic impulses causes vasodilatation as demonstrated clinically with a peripheral nerve block.[1]

Regional skin temperatures of the body are non-uniform and vary considerably. Skin covering areas of high metabolic activity and high resting heat production have the highest skin temperatures, for example the trunk with the internal organs underneath, Figure 1. In the extremities, heat production is primarily dependent upon the underlying muscle mass. Areas with little muscle, joints such as the knee and wrist generally reveal cooler skin temperatures. The hands and feet are also cooler as a result of their limited muscle mass but as described are major dissipaters of body heat through the flow of warmer core arterial blood.

INFRARED THERMOGRAPHY

The basis of infrared thermography can be traced to Sir Isaac Newton's (1666) discovery of the color spectrum through passage of sunlight through a prism into visible colors from violet to red. This demonstrated the existence of light as radiated energy of differing wavelengths. Later, William Herschel (1820) measured the heat content of the colors of Newton's spectrum and found that the greatest heat was generated in an area of the spectrum beyond red which was not visible and he referred to as infrared.

Heat and energy transfer always occurs from the warmer object to the cooler. Heat energy transfer occurs by conduction (direct contact), convection (motion), radiation (electromagnetic) or evaporation (convection with phase change). In the case of a typical oral or rectal thermometer, heat is measured through conduction, energy from the body is transferred to the cooler glass thermometer by direct contact. The colored alcohol in the narrow tube expands and the volume change results in the fluid raising in the thermometer. A LCD thermometer registers as a result of color change from

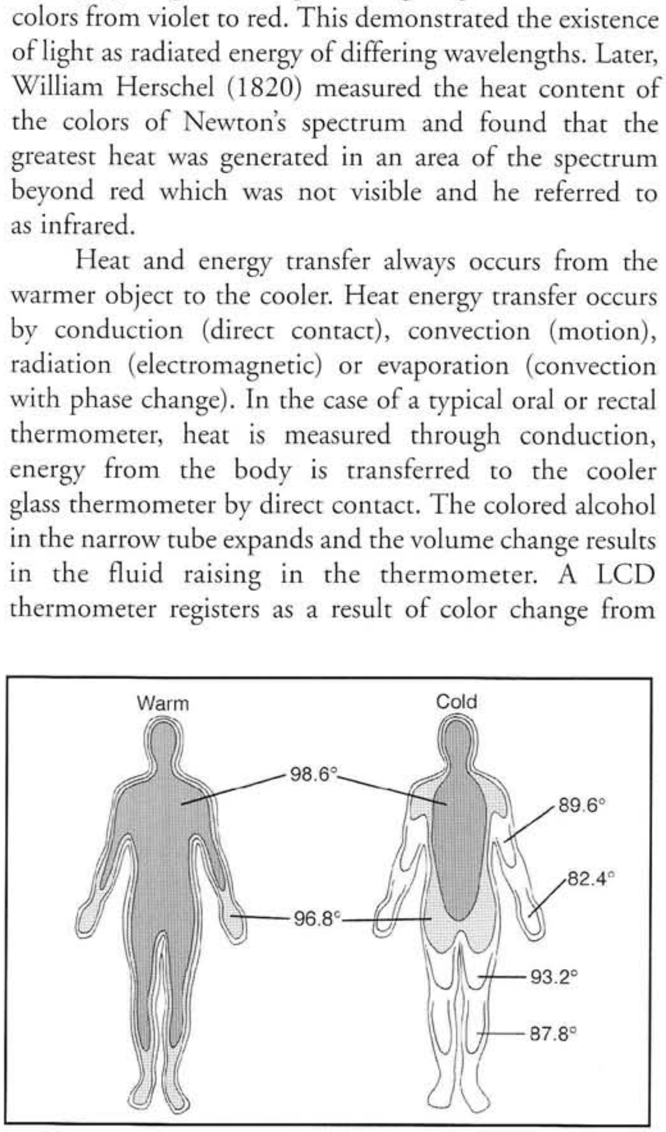

Figure 1. Body isotherms showing the temperature differences between the internal organs, skeletal muscle mass and the skin. At a comfortable room temperature, surfaces covering the large muscle masses of the arms and legs have a mean temperature of 87-90° and areas that cover little muscle, the hands and feet, have the lowest skin temperatures, 80-85°. At cold temperatures, the skin temperatures of the hands and feet drop further.

heat transfer by conduction and rearrange of the crystals. Even the electronic thermometer is nothing more than a more sophisticated conduction sensing instrument requiring thermal equilibration (time interval in contact with the warmer object) before a temperature measurement is recorded. In general, thermal contact thermometers require a long time to equilibrate, are sensitive to variations in contact pressures, and have significant variations from reading to reading.

The infrared thermometer measures heat through sensing only the heat radiation naturally emitted from a surface and thus does not require contact with the surface or object being measured. This is particularly significant in that infrared measurements are passive and can be made very fast with a high degree of reliability and reproduction.[2]

CLINICAL USE OF INFRARED THERMOGRAPHY

Surface temperatures may be recorded at instantaneous time intervals and without direct contact of the skin over a very small segment of surface area. Surface temperature measurements will vary due to local or regional blood flow. In the presence of injury or infection, inflammation occurs. Inflammation triggers local mediators to increase blood flow generating an increase in temperature proportional to the increase in blood flow. The maximal temperature however may be no higher than the body's core temperature.

Small, highly precise hand held infrared thermographic scanners are available and are able to detect subtle skin temperature variations that correlate with underlying skin/tissue perfusion. This author has been utilizing the Dermatemp unit (Figure 2) introduced by Exergen in 1987 as a fast and reliable method to determine surface skin temperatures in a clinical setting. The unit provides temperature measurement with pin-point like localization, 4mm spot, is a fast and clinical reproducible manner. The unit has been useful for assessment of localized inflammation useful for diagnosis and localization of gout, capsulitis, tenosynovitis and has been particularly helpful in the diagnosis of neuropathic arthropathy as well as its resolution. Almost any skin surface with sub-adjacent pathology may produce an increase in skin temperature.

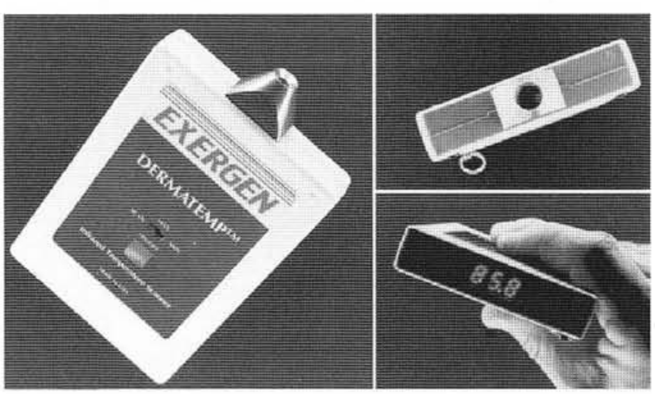

Figure 2. Exergen Dermatemp hand-held scanner – arrows point to sensing lens, 4 mm diameter. Momentary depression of scan button (red button) will provide instantaneous temperature readings in a tenth of a degree, Celsius or Fahrenheit.

TISSUE PERFUSION

Tissue perfusion is dependent upon local blood flow to the part, generally the further blood flows from the trunk the cooler the temperatures. Temperatures will also be lower in areas of low muscle mass, for example the foot or more specifically a toe or toes. Routine examination of patients with diabetes have shown that skin temperatures of the toes are generally in the high 70's to low 80's. Patients with poor tissue perfusion or arteriovascular disease will generally show digital skin temperatures in the low 70's or less. Conversely, patients with peripheral neuropathy, typically show vasodilatation and digital skin temperatures in the 90's (Figure 3).

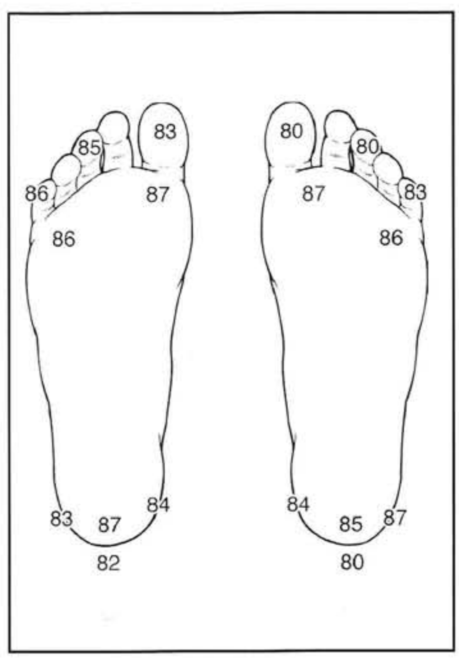

Figure 3. Resting skin temperatures in adult diabetic without any evidence of vascular disease showing lower skin temperatures in the toes and gradual increase proximal.

GOUT

Gout is generally characterized by an intense inflammatory capsulitis that is typically described in terms of the usual signs and symptoms of inflammation: calor, rubor, swelling, pain and loss of function. An acute gout attack is an intense inflammatory joint flare that characteristically provides for overlying skin temperatures in excess of 90° F. Generally, joint inflammation produced by sodium urate deposition and subsequent synovitis produces an intense clinical picture, acute in onset. Use of the infrared scanner to document joint inflammation is helpful particularly when compared to the contralateral foot or other joints of the involved foot, (Figure 4).[3]

NEUROPATHIC ARTHROPATHY

Neuropathic joint disease is characterized by an inflammatory reaction that may be localized or clinically manifest as more of a regional process. Neuropathic arthropathy begins as a detritic synovitis with an intense local inflammatory response that is exacerbated by weight-bearing. The joint pathology produces local inflammation that may be marked out by skin temperatures over the topographical skin surfaces. Skin temperature variations are helpful in localizing the exact joints involved as well as monitoring the gradual resolution of the neuropathic process.[4-6] (Figure 5).

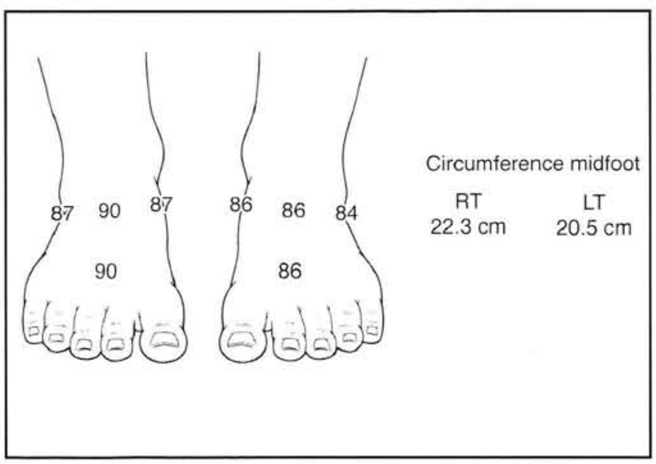

Figure 5. Diagnosis of neuropathic arthropathy requires a high index of clinical suspicion and evaluation of skin temperatures provides a useful clinical tool. Elevated skin temperatures correspond to specific joint(s) involved and may be compared to the contralateral limb to assess gradual resolution. Concomitantly, circumference is useful as a parameter of swelling.

TIBIALIS POSTERIOR DYSFUNCTION

Tibialis posterior dysfunction generally begins as a local inflammatory tenosynovitis of the tendon sheath of tibialis posterior from just proximal to the navicular tuberosity to above and posterior to the medial malleolus. The tenosynovitis may be mapped out and delineated by the localization of increases of local skin temperatures (Figure 6).

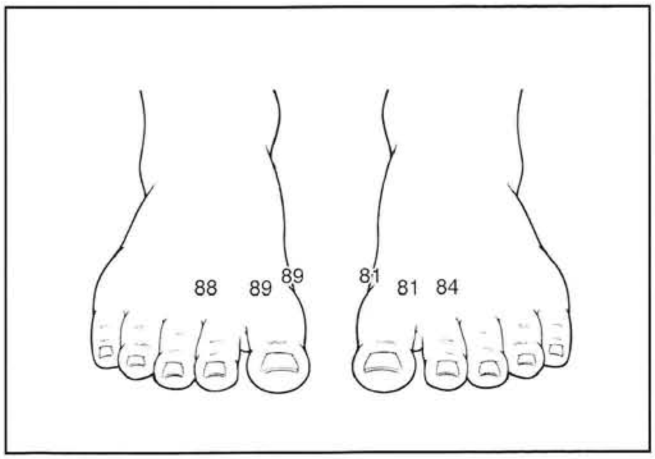

Figure 4. Skin temperatures measured dorsal, medial and plantar to the first MTP joint in a patient with acute gout of the right foot., show a variance of 89° on the involved foot to 81° on the unaffected side.

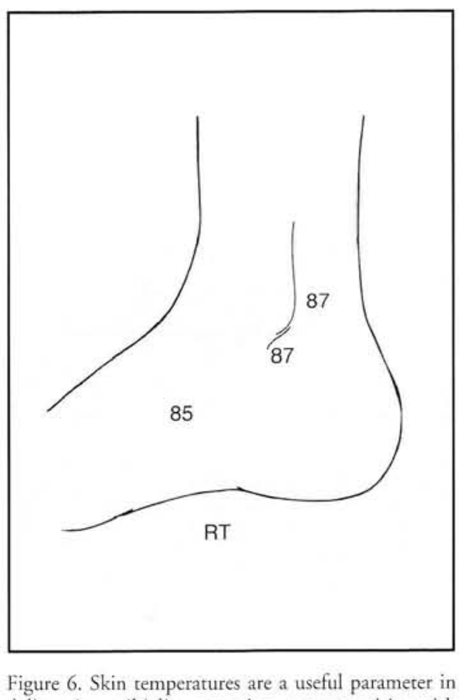

Figure 6. Skin temperatures are a useful parameter in delineating tibialis posterior tenosynovitis with increases in skin temperatures noted directly over the tendon of TP compared to adjacent areas as well as contralateral side.

METATARSAL STRESS FRACTURE

In the early stages prior to radiographic appearance of a fracture, the diagnosis of a metatarsal stress fracture may be aided by the use of digital thermography with the infrared scanner. An increase in the overlying skin temperatures may aid in the diagnosis prior to radiographic visualization of a fracture.[7]

INFECTION / ULCERATION

Infection may produce very intense local and regional inflammation depending upon the clinical process, such as abscess versus cellulitis. Infection also manifests itself with of the usual signs and symptoms of inflammation: calor, rubor, swelling, pain and loss of function. Even in patients with vascular compromise, local increases in skin temperatures may aid in the diagnosis of a pathologic process (Figure 7).

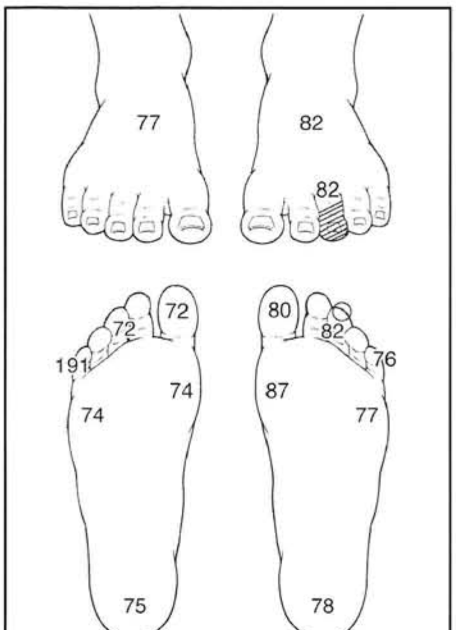

Figure 7. This example is from a patient with diabetes and vascular disease with a distal tip ulceration (circle) and erythema shaded area 3rd left toe showing local elevation of skin temperatures of 10° versus the contralateral 3rd toe.

REFLEX SYMPATHETIC DYSTROPHY

Variation of limb temperatures is just one parameter of evaluation and documentation of a patient with complex regional pain syndrome, type 2 (reflex sympathetic dystrophy). Testing such as the responses of the symptomatic and asymptomatic limbs to mild cold stress has been studied. Altered thermoregulation and hemodynamics were evident in RSD.[8,9]

SUMMARY

Measurement of skin temperatures have been utilized clinically to assess localized or regional inflammation of acute or chronic nature. Skin temperatures may be used much like the sedimentation rate as a non-specific indicator of inflammation. The inflammatory response of near damaged or damaged tissue presents as areas of increased heat on the surface that can be detected and documented. Infrared thermography has been found to be a valuable aid being both precise, small focal spot, and accurate to a tenth of a degree. The Dermatemp unit allows rapid clinical assessment of skin temperatures.

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