Predicting Neuropathic Ulceration With Infrared Dermal Thermometry

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The authors' rationale for evaluating skin temperatures involves the search for a quantifiable, reproducible measurement of inflammation. Inflammation is one of the earliest signs of foot ulceration. It is characterized by five signs: redness, pain, swelling, loss of function, and heat. Many of these signs are difficult to assess objectively. In the neuropathic extremity, pain and disturbance of function may be absent because of neuropathy and thus are poor indicators of inflammation. In addition, swelling and redness are difficult to objectively grade from clinician to clinician or from visit to visit. For all practical purposes, this leaves heat as the most quantifiable means of monitoring inflammation.

The concept of infrared skin temperature monitoring is not new. Throughout the last three decades, several authors have suggested that skin temperature monitoring may be a valuable tool in detecting potentially at-risk sites.[1-5] However, the devices frequently used in these studies were bulky, expensive, and, in general, difficult to use or integrate into a normal clinical setting. Furthermore, there are not well established criteria or discrete temperature levels to determine pathology. Therefore, as a practical application of skin temperature assessment, the authors have used a simple hand-held dermal thermometer to measure skin temperatures at every clinical visit to the diabetic foot specialty clinic. For practical purposes, the authors have used the contralateral extremity to determine normal or baseline temperature levels. In a preliminary study, the authors hypothesized that local skin temperatures would be higher in extremities with pathology (neuropathic ulcers, acute Charcot's arthropathy) and the same in patients without pathology when compared with the corresponding site on the contralateral foot.[6] Further, it was expected that temperatures would return to normal once ulcer and fracture healing was complete. Lastly, the authors questioned whether dermal thermometry could be potentially predictive of neuropathic ulceration.

In this preliminary study, the authors reviewed 143 consecutive patients with diabetes presenting for treatment at a diabetic foot specialty clinic. These patients were divided into three groups: 78 patients with asymptomatic loss of protective threshold, 44 patients with neuropathic foot ulcerations, and 21 patients with neuropathic (Charcot) fractures. Temperatures were evaluated with a portable hand-held infrared skin temperature probe. Patients' skin temperatures were measured at the time pathology was initially identified and at subsequent clinical follow-up visits for an average of 22.1 ± 6.4 months. Temperatures on the contralateral foot were measured as a control.

In this population, there were significant differences in skin temperature at both the Charcot (8.30°F, $P < 0.0001$) and ulcer groups (5.60°F, $P < 0.0001$) compared with the region overlying the site of pathology on the contralateral side. No significant temperature difference was identified in the group with asymptomatic loss of protective threshold group and no acute pathology. Temperatures all normalized at the time of Charcot quiescence and ulcer healing. Eleven percent of patients in the ulcer group reulcerated a mean 12.2 ± 6.4 months after initial healing with a corresponding significant increase in skin temperature at the clinic visit immediately preceding reinjury ($P < 0.0001$). These data suggest that monitoring of the corresponding contralateral foot site may provide objective, clinical information before other clinical signs of injury can be identified and that infrared dermal thermometry may be predictive of neuropathic ulceration.[6]

Subsequent studies to the previously discussed work have indicated that elevated skin temperatures

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are directly correlated with location of acute neuropathic osteoarthropathy and that temperatures will equilibrate in a predictable manner as acute Charcot's arthropathy resolves into a postacute state.[7, 8] Furthermore, in neuropathic ulcerations, the difference in temperature on the wounded side compared with the corresponding contralateral site decreases as the surface area of the wound decreases.[9]

As a practical measure, the authors have used the opposite extremity as a control because it is exposed to the same duration and control of diabetes and systemic complications as the affected limb and should represent a built-in source of comparison. Because the disease processes of neuropathic fractures and ulceration involve multiple factors that affect lower extremity perfusion and temperature regulation, it would be difficult to identify an absolute skin temperature level that could be considered normal or one that could be used as a universal reference. For instance, the baseline temperatures for a patient with Charcot's fracture may be higher than those of diabetic patients without this complication or persons without diabetes.

Conclusion

Infrared dermal thermometry is an area with tremendous potential. It is, however, in need of further investigation. In subsequent investigations, the authors plan to examine the sensitivity and specificity of the human hand to repeatedly detect subtle differences in skin temperature. Additionally, other questions remain. In one study, in a group of fairly well vascularized patients with advanced degrees of sensory neuropathy, those with the highest degrees of neuropathy and most impaired peripheral vascular perfusion had larger skin temperature gradients than their counterparts with lesser degrees of peripheral neuropathy or greater peripheral vascular perfusion.[9] This clearly calls for further study and validation.

Lastly, the authors believe that the greatest utility and benefit of skin temperature-measuring devices may be realized through home use. Because this modality is simple, noninvasive, and relatively inexpensive, high-risk patients may be able to use a temperature probe on a daily basis to detect sites of inflammation much in the way that home glucometers are used to monitor blood glucose levels. In this manner, patients may be able to learn to dose their activity just as they do their insulin. If a given site is warm (≥ 4°F compared with the corresponding contralateral site), the patient should rest the site until temperatures equilibrate and notify the physician.

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