AMA Council Report

Thermography in Neurological and Musculoskeletal Conditions

Thermography is a safe adjunctive physiological procedure which may be useful in the diagnosis of selected neurological and musculoskeletal conditions. Thermography is noninvasive and does not involve the use of ionizing radiation. Thermography may facilitate the determination of spinal nerve root and distal peripheral nerve dysfunction. Thermography also contributes to the evaluation of possible autonomic nervous system dysfunction and of spinal disorders.

Thermography may be useful in documenting peripheral nerve and soft tissue injuries, such as muscle and ligament sprain, inflammation, muscle spasm, and myositis. Thermography is helpful in the diagnosis of reflex sympathetic dystrophy and can be used to follow the course of patients after spinal surgery. In those applications, thermography does not stand alone as a primary diagnostic tool. It is a test of physiological function that may aid in the interpretation of the significance of information obtained by other tests. In recent years, an increasing number of correlative studies have been published. Few of these studies can be characterized as well-controlled. This fact limits attempts at a definitive analysis of the overall value of thermography. More research will help to clarify the exact contribution of thermography to diagnostic problems.

INTRODUCTION

Thermography is a diagnostic procedure that measures infrared energy emitted by the skin. These measurements, expressed in the form of thermal images, constitute the basis for suggestions that thermography is useful in the diagnosis of painful conditions such as herniated disc disease, myofascial pain syndrome, myositis, musculoligamentous injury, and motor and sensory radiculopathy, reflex sympathetic dystrophy, carpal and tarsal tunnel syndromes, athletic injuries, neurovascular compression syndromes of the thoracic outlet and the inflammation of arthritis and bursitis, vascular thrombosis, and breast tumors.

In this report the Council on Scientific Affairs assesses the value of thermography in the diagnosis of selected neurological and musculoskeletal conditions.

OVERVIEW

Body temperature has been utilized as an index of dysfunction for thousands of years. In the twentieth century, contact thermometry showed that in normal persons temperature differences on opposite sides of the trunk and extremities do not exceed 0.3°C except on the forearms, where differences can be as great as 0.9°C. Subsequent studies suggested that variations of 0.5°C-0.7°C were indicative of dysfunction. The systematic application of such observed temperature differences measured by thermography to the detection of neuromuscular disorders was introduced in 1973 by Duensing. In this study, temperature changes were correlated with sensory distribution of nerve in lumbosacral radiculopathy. Subsequent studies have reported correlation between the existence of painful conditions and the occurrence of abnormal thermography patterns.
Skin temperature is a reflection of cutaneous blood flow under the control of the autonomic nervous system. A growing body of basic research supports clinical and experimental observations of interactions between sympathetic nerve fibers and afferent pathways. Various general and autonomic mechanisms have been proposed as the pathophysiologic basis for skin temperature changes in neuromuscular disorders. Among the proposed general mechanisms are localized muscular action, antidromic stimulation of sensory pathways, and activation of sinuvertebral autonomic system include stimulation of the “spinal nodulatory system,” mental regulation by the somatosympathetic reflexes has merit, it is probable that the ultimate pathophysiologic basis for thermographic changes in neuromuscular disorders will include portions of all of these theories. These proposed mechanisms are

Normal Physiology

**Thermal Symmetry of the Skin**

Core temperature homeostasis is maintained by feedback mechanisms that operate through a temperature-regulating center in the hypothalamus. Heat-sensitive neurons begin firing in response to an increase in the temperature of blood flowing through the preoptic nucleus. The resultant inhibition of sympathetic neurons in the posterior hypothalamus reduces the normal vasoconstrictor tone of blood vessels in the extensive subcutaneous venous plexus, causing vasodilatation and concomitant heat loss. Conversely, the flow of venous plexus blood is markedly reduced in response to constriction of sympathetically innervated arteriovenous anastomoses in the subcutaneous plexus. Central control of skin temperature affects both sides of the body uniformly and simultaneously, resulting in symmetry of thermal patterns. In a study of facial, trunk, and extremity temperatures in a series of healthy subjects, skin temperatures of 32 segments of the right and left sides of the body were remarkably symmetrical. The overall average temperature difference was only 0.24°C.

Abnormal Physiology

The spinal nerve roots and the peripheral nerves comprise the peripheral nervous system. In order to avoid confusion in this report, peripheral nerve dysfunction will be designated distal peripheral nerve (nonradicular) injury, to distinguish it from damage to the spinal nerve roots (radiculopathy). Abnormal thermograms occur in conjunction with vasomotor dysfunction. Such dysfunction cannot be demonstrated by conventional radiologic studies of the spine until structural changes develop. Thermographic change seems to parallel physiologic function, not morphology. Although thermography is somewhat analogous to nerve conduction studies, it reflects dysfunction of the small, sympathetic nerve fibers, while nerve conduction studies demonstrate the activity of large, myelinated A fibers. The presence of a significant temperature difference between corresponding areas of opposite sides of the body is suggestive of nerve impairment, since defective vasomotor mechanisms result in thermal asymmetry. In the acute stage of a peripheral nerve injury, the affected area is warmer. As the nerve regenerates the affected area becomes colder. A significant thermal asymmetry is the hallmark of abnormality in thermography, the patient serves as his own control. A study by infrared emission thermography of 24 consecutive patients with nerve injuries revealed an average temperature difference of 1.55°C between the affected side and the corresponding unaffected side. In studies of normal individuals, and patients with proven herniated intervertebral disc or mechanical back pain treated by intervertebral facet injection with local anesthetic, Mahoney and his co-workers concluded that thermographic patterns of the lumbar area and extremities were of no diagnostic value. These studies have been criticized on methodological grounds. Several pathophysiologic mechanisms have been proposed as explanations for these thermographic observations. Although traditional neuroanatomical tests indicate that sympathetic pre-
ganglionic cell bodies are confined to thoracic and upper lumbar levels, Mitchell** reported finding pre-ganglionic cell bodies at all levels of the spinal cord. This work received direct support from Randall, Cox, and Alexander,** who found both anatomic and physiologic evidence for the entry of preganglionic fibers at all lumbar levels of the sympathetic trunk.

Many workers have attributed thermal changes to pathologic antidromic activation of sensory root that a noxious stimulus excites the free nerve endings, sending an impulse toward the sensory cell body in the dorsal root ganglion. Inhibition of symp-pathetic vasoconstrictors may result from release of a substance P, acetylcholine, bradykinin, and/or histi-

Thermographic study of patients with spinal root compression nearly always reveals thermal asym-metry, with decreased temperatures in the involved dermatome. The literature reports a growing number of studies documenting a high correlation

**Thermography in Distal Peripheral Nerve Injury**

Although an acute nerve injury is accompanied by an increased infrared emission along the distribution of the injured sensory nerve, the area becomes colder findings have been supported further by Brelsford

that elicited clear-cut thermographic changes corre-sponding to the areas of distribution of the major pe-ripheral nerves of the extremities. These findings re-confirm Richter’s classic work on skin resistance and starch-sweat studies that demonstrate altered sensory impairment topographically superimposed on the area of altered sweat gland activity.

**Thermography in Spinal Cord Lesions**

One of thermography’s contributions is its ability to map previously obscure cutaneous temperature changes. Thermography’s ability to scan and detect the sometimes subtle skin temperature changes of vasomotor dysfunction makes it possible to demon-strate thermal changes associated with intramedul-

**IMAGING TECHNIQUES**

The two main techniques available for thermal imaging are infrared thermography and liquid crys-tal thermography. Infrared imaging antedates liquid crystal technology by many decades. Thermography measures heat distribution inte-grated over the body surface, as opposed to skin thermometry, which is limited to detection of point temperatures. In comparison to the human hand, which is not able to perceive a temperature change of less than 2°C to 4°C, infrared thermal imaging equip-ment detects temperature changes of 0.05% to 0.2°C and displays them as a thermal map.

**Electronic Infrared Telethermography**

Infrared telethermography is a noncontact method of determining skin temperature. It is the principal system used for thermal imaging. The infrared scan-ning device converts radiated thermal energy into electronic signals that are amplified and transmitted to a video display monitor. The infrared scanning unit is composed of an infrared detector, an electro-optical scanning mechanism, and control electronics. Oscillating mirrors and prisms image 30,000 to 64,000 discrete points in the field of view; thus, when the electronic signal is displaced on the cathode ray screen, the resultant scan contains from 30,000 to 64,000 points of thermal information. At a camera-to-object distance of 50 cm, each point represents a precise temperature measurement encompassing a

For lumbar examinations with infrared systems, thermal focusing using black and white imaging is used to reveal detailed thermographic changes and to obtain qualitative information. With such imaging, asymmetry in the lumbar area can be sufficient to es-tablish a positive thermogram. With color imaging, most clinicians suggest that at least two separate areas within a sensory distribution must be asymmetric for a thermogram to be considered positive in the pres-ence of a normal qualitative lumbar pattern. The possibility of observer bias is a valid criticism of any procedure dependent on subjective interpre-tation of results. Computerized thermography systems that record and analyze findings objectively have the potential to reduce this cause of bias.

**Liquid Crystal Thermography**

Liquid crystal thermography (LCT), uses plates of cholesterol esters embedded in flexible body con-touring sheets that are applied in direct contact to the back, neck, and extremities. Upon contact, the crystals absorb heat and change structurally; the plate then changes color in a pattern corresponding to the skin temperature pattern. This pattern is then recorded by photography to obtain a permanent record for each field examined.
The liquid crystal technique has been criticized for being critically dependent on the training and expertise of the person performing the study. Precise technique is necessary to provide an adequate study capable of being objectively evaluated and considered valid. Many users of this technology are trained insufficiently. Second, the difficulty of contouring the flexible sheets to the round and bony areas of the trunk and extremities leads to uneven pressure and false temperature readings. Both these problems affect the reliability and reproducibility of the liquid crystal method for a thermographic examination of the spine and extremities. Liquid crystal thermography at present is not considered as accurate a method of measuring thermographic change as is infrared emission thermography.

STUDIES THAT SUPPORT THE VALIDITY OF THERMOGRAPHY IN DIAGNOSIS OF UPPER OR LOWER BACK NERVE FIBER DYSFUNCTION

Evidence from Prospective Studies
Prospective studies with thermography have demonstrated high sensitivity and reasonable correlation with other imaging methods. In prospective studies comparing thermography and CT scanning in patients with low back pain and sciatica, the correlation high rates of sensitivity were observed in patients studies, the sensitivity of thermography was higher

Evidence from Retrospective Studies
Several retrospective studies have demonstrated the high sensitivity of thermography (above 90%) and have shown that this imaging method has good correlation with other imaging modalities. In one large study involving 805 patients with upper and lower back pain, thermographic evaluation revealed good correlation with myelography (lumbar-95%, cervical-79%), CT scanning (lumbar--80%, cervical-81%); and EMG (lumbar-68%, cervical-70%). Several other retrospective studies have shown that the correlation between thermography, myelography and CT scanning averaged 80%-85% for cervical examination and 85%-90% for lumbar examination. The correlation between thermography and EMG studies was about 10% less. In a study comparing the results of lumbar examination by thermography and magnetic resonance imaging (MRI) scanning, the overall correlation was 85%. Thermography and somatosensory cortical evoked potentials demonstrate equal sensitivity in diagnosis of clinical lumbosacral radiculopathy (77%). The results of both tests coincided in 70% of patients, with 62% positive findings. The tests are complementary: each added objective confirmation of clinical radiculopathy in 14% of patients when the other test was negative.

Evidence for Sensitivity and Specificity
In single-blind studies comparing lumbar thermography with myelography, CT scanning, and/or surgery, the sensitivity of thermography was 80%-100%. The specificity ranged from 58% to 75% in these single-blind studies. A single-blinded study by Sherman, Barja and Bruno demonstrated high sensitivity between thermographic findings and the presence of chronic pain in patients with a variety of conditions. Most prospective and retrospective studies with lumbar or cervical thermography show specificity values between 75% and 100%.

Evidence on Reliability
In single-blind studies, the interobserver agreement ranged from 80% to 100%. Persistence of results over time is another index of reliability. Individual thermographic patterns remain symmetric over time in normal controls and asymmetric (abnormal) in patients upon repeat examination unless the underlying abnormality is corrected.

USE OF THERMOGRAPHY FOR EVALUATION OF SELECTED NEUROLOGICAL AND MUSCULOSKELETAL CONDITIONS

Spinal Nerve Root Fiber Dysfunction
Several reports have appeared describing the high accuracy, sensitivity, and specificity of thermography in evaluation of lumbar disc disorders. Thermographic imaging has a positive correlation with other diagnostic studies (EMG, CT scan, myelogram) in patients with lumbar disc disease and associated spinal nerve root fiber abnormality.

A study of 61 low back pain patients revealed an 84% correlation between thermography and myelography. Furthermore, this study demonstrated that thermography correctly predicted the abnormality in 92% of patients who came to surgery, whereas the myelogram was predictive in 81%. In other studies evaluating lumbar disc function, the results of thermographic examination correlated well
(80%-90%) with myelography, CT scan, and EMG. Similar results were obtained for evaluation of cervical disc injury. When compared to the physical findings, the accuracy of thermography and EMG studies was 92% and 83%, respectively. In clinically proven lumbosacral radiculopathy with a positive thermogram, EMG was negative in 23%. On the other hand, thermograms were negative in only 10% of patients with positive EMGs and positive physical findings.

Coldness in the involved limb is the typical thermographic finding seen in over 80% of cases of chronic discogenic disease. At times, a focal area of increased skin temperature is noted in the lumbosacral area corresponding to the cutaneous branches of the posterior cutaneous nerve of the pelvis (L5, S1). Thermographic findings of abnormality can be confirmed during surgery. When spinal nerves are directly manipulated during surgery, the bilateral thermographic changes observed prior to surgery can be seen more clearly and extended through the affected dermatome. Upon successful surgery for relief of nerve fiber compression, the thermographic findings revert to normal in patients with severe nerve fiber damage. Therefore the value of thermography under these circumstances is questionable. Finally, thermography may be difficult to interpret in patients with bilateral disease particularly if the distribution is symmetric.

**Nonradicular (nonsegmental) Muscular and Fascial Disorders**

Thermography may play an adjunctive role in the diagnosis of nonsegmental, nonradicular muscular and/or fascial pathology. Structures that are involved include the muscles, tendons, tendon sheaths, ligaments, joint capsules, joints, skin and subcutaneous tissues. Pathological conditions involving these structures that can be associated with thermographic abnormality include inflammation and injuries in acute and chronic stages such as sprains, strains, tears, contusions and myofascial trigger points.

Thermography may aid the detection of muscular and/or fascial pathology in cases of subjective complaints, such as pain in the back and neck or extremities that have a negative myelogram and CT scan. A thermogram may have abnormalities in association with the presence of anatomic changes that may indicate radiculopathy. In the evaluation of muscular and/or fascial injury, an abnormal thermogram can lend credence to the fact that the pain is real and present. It may be of value not only in diagnosing the problem, but also in following the patient’s progress. Early diagnosis is valuable because successful therapy for muscular and/or fascial injuries of the upper and lower back depends on aggressive, prompt treatment of the acute injury. Delay in therapy and the development of additional problems such as the myofascial pain syndrome, decrease the chances for complete healing and prolong recovery.

**Muscle Spasm**

In the presence of muscle spasm or myositis, the increased thermographic temperature observed corresponds approximately to the shape of the muscle in spasm. Thermographic findings must correlate with the clinical findings to be considered significant.

**Evaluation of Injuries**

Thermography may be useful in the evaluation of nerve, muscle, and/or fascial injuries. Uncomplicated injuries in the form of muscle or ligament sprain and tear show thermographically detectable increases in temperature over the site of tissue damage, while cold limbs may signal sympathetic hyperactivity and Myofascial Pain Syndrome

The existence of the myofascial pain syndrome is controversial. Thermography has been suggested as a diagnostic tool useful to verify the existence of this syndrome. The graphic picture of a symptomatic trigger point consists of a localized area of thermal elevation, usually 5-10 mm in diameter and frequently disc-shaped and at least 1°C above the circumambient temperature. When symptomatic trigger points resolve clinically and pain subsides, the thermographic findings usually revert to normal. However, in cases of chronic pain sometimes they convert to cold zones. Thermographic imaging of this and other muscular and/or fascial disorders does not follow dermatomal distribution patterns.

**Reflex Sympathetic Dystrophy**

A distinct and clearcut diagnosis is essential for the successful treatment of the patient with chronic pain, particularly in the case of reflex sympathetic dystrophy. Thermography appears to be a useful test in the differential diagnosis of reflex sympathetic dystrophy. In the early stages of this distal peripheral nervous disorder, thermography may reveal the subtle temperature changes seen as initial signs of vasomotor changes.
Early diagnosis of the disorder can avoid the need for unnecessary and more complicated therapeutic measures such as lumbar sympathectomy in patients with chronic injury. Depending on the cause of the injury and the time elapsed since the injury, the affected area in a thermogram may be colder or warmer than the uninjured side. In most patients, the temperature of the symptomatic area is several degrees different from that of the opposite side, but the severity of neurological deficit has no correlation with the degree of temperature change. Usually, the affected extremity becomes warm after an acute injury; however, in most patients the temperature of the injured limb becomes cold after four or five months, due to vasoconstriction. With chronic injury, disuse atrophy occurs.

Uematsu and his co-workers used thermography to evaluate 803 patients with chronic pain syndromes. The patients with abnormal thermography were divided into those with reflex sympathetic dystrophy and those with evidence of nerve root injury. There were 42 cases with reflex sympathetic dystrophy, of whom 67% had more than a 2 degree temperature drop on the painful side. EMG's were not helpful in diagnosing the condition unless there was an associated nerve root injury.

Therapy for reflex sympathetic dystrophy generally consists of blockage of sympathetic activity through stellate ganglion or lumbar sympathetic blocks, or surgical sympathectomy in either the lumbar or cervical area. In the study discussed above, Uematsu and his co-workers found that two-thirds of the patients with thermographic evidence of decreased skin temperature in the injured limb benefited from sympathetic blocks. The effect of sympathetic blocks can be monitored by thermography. After such therapy, thermography can be used to monitor the increase in skin temperature in the injured extremity.

**SUMMARY**

The diagnosis of neurological and musculoskeletal abnormalities by thermography is based on associated thermal asymmetry between normal and abnormal sites, a change in normal temperature gradients of limbs or between medial and lateral digits, or a disturbance of the normal physiological temperature distribution pattern. Thermography is an adjunctive procedure for the diagnosis of selected neurological and musculoskeletal conditions. When the clinical history or physical findings are unclear, thermography may be of value in the diagnostic evaluation of patients for the following reasons:

- When results of anatomic tests are unclear or contradictory, the additional information provided by an abnormal thermogram may suggest a diagnosis that ultimately proves correct.
- Thermography can detect sensory/autonomic nerve dysfunction. In those cases where it is felt necessary to proceed beyond conservative therapy, thermal imaging has high sensitivity and is an effective screening method for spinal nerve root fiber and distal peripheral nerve fiber pathology.
- Thermography is a physiological test that complements anatomical and structural observations made with modern radiological techniques (x-ray, myelography, CT scan) and magnetic resonance imaging.

Thermography may be regarded as one piece of information that must be integrated with other available information in the physician's decision-making process. Thermography cannot demonstrate the presence of pain and thus, cannot be used as a measure of pain. Further, well-controlled, blinded studies are necessary to evaluate the full extent of the usefulness of thermography, especially in patients whose complaints suggest nonradicular muscular and fascial disorders.

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