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 condi- tions. Thermography is noninvasive and does not involve the use of ionizing radiation. Thermog- raphy 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 inter- pretation of the significance of information ob- tained 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 mea- sures infrared energy emitted by the skin. These measurements, expressed in the form of thermal images, constitute the basis for suggestions that ther- mography is useful in the diagnosis of painful condi- tions such as herniated disc disease, myofascial pain syndrome, myositis, musculoligamentous injury,

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motor and sensory radiculopathy, reflex sympathetic dystrophy, carpal and tarsal tunnel syndromes, ath- letic injuries, neurovascular compression syndromes of the thoracic outlet and the inflammation of ar- thritis and bursitis, vascular thrombosis, and breast tumors.

In this report the Council on Scientific Affairs as- sesses 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.1 Subsequent studies suggested that variations of 0.5°C-0.7°C were indicative of dysfunction.[2,3]

The systematic application of such observed tem- perature differences measured by thermography to the detection of neuromuscular disorders was intro- duced in 1973 by Duensing.[4] In this study, tempera- ture changes were correlated with sensory distribu- tion of nerve in lumbosacral radiculopathy. Subse- quent studies have reported correlation between the existence of painful conditions and the occurrence of abnormal thermography patterns.[5,6,7]

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PHYSIOLOGICAL BASIS

Proposed Mechanisms of Skin Temperature Regulation

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 af- ferent pathways.[8]

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 local- ized muscular action, antidromic stimulation of sen-

and activation of sinuvertebral autonomic system include stimulation of the "spinal

sodilatory system,

mental regulation by the somatosympathetic re-

nisms 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 inhibi- tion of sympathetic neurons in the posterior hypo- thalamus 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, re- sulting 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 tem- perature difference was only 0.24°C.[45]

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 dys- function 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 func- tion, 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 differ- ence 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.[46] A s 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.[47] In studies of normal individuals, and patients with proven herniated intervertebral disc or mechan- ical back pain treated by intervertebral facet injection with local anesthetic, Mahoney and his co- workers[48,49] concluded that thermographic patterns of the lumbar area and extremities were of no diag- nostic value. These studies have been criticized on methodological grounds.

suggest that impartial controlled studies must be per- formed before thermography can be recognized as a reliable medical procedure.

Thermography in Radiculopathy

Nerve root dysfunction is accompanied by an ipsi- lateral thermal change in the corresponding dermatome. In lesions at lumbosacral levels, there may be an ipsilateral linear heat extension within the lumbosacral diamond in addition to the dermatomal tem- perature decrease.

As noted above, several pathophysiologic mecha- nisms 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 preganglionic cell bodies at all levels of the spinal cord. This work received direct support from Randall, Cox, and Alexander,[53] 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 sym- pathetic vasoconstrictors may result from release of a stance P, acetylcholine, bradykinin, and/or hista-

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 peripheral 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 crystal 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 interpretation 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 contouring 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
cially 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 insuffi- ciently. Second, the difficulty of contouring the flex- ible 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 dem- onstrated 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%, cer- vical-81 %); and EMG (lumbar-68%, cervical- 70%).[63] 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. [53,64,65] The correlation between ther- mography and EMG studies was about 10% less.[55,56] In a study comparing the results of lumbar examina- tion by thermography and magnetic resonance imaging (MRI) scanning, the overall correlation was 85%.[67]

Thermography and somatosensory cortical evoked potentials demonstrate equal sensitivity in diagnosis of clinical lumbosacral radiculopathy (77%). The re- sults 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.[68]

Evidence for Sensitivity and Specificity

In single-blind studies comparing lumbar ther- mography with myelography, CT scanning, and/or surgery, the sensitivity of thermography- was SO%- 100%.[68-71] The specificity ranged from 58% to 75% in these single-blind studies. A single-blinded study by Sherman, Barja and Bruno[72] 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%.[38,56,62,73]

Evidence on Reliability

In single-blind studies, the interobserver agree- ment ranged from 80% to 100%.[68,71,74] Persistence of results over time is another index of reliability. lndi- vidual thermographic patterns remain symmetric over time in normal controls and asymmetric (ab- normal) in patients upon repeat examination unless the underlying abnormality is corrected.[45,75]

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. Thermo- graphic imaging has a positive correlation with other diagnostic studies (EMG, CT scan, myelogram) in pa- tients with lumbar disc disease and associated spinal nerve root fiber abnormality.[56,76]

A study of 61 low back pain patients revealed an 84% correlation between thermography and myelography .[56] 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 ther- mographic examination correlated well

(80%-90%) with myelography, CT scan, and EMG.[56,70,77,78] Sim- ilar results were obtained for evaluation of cervical disc injury.[77,78] When compared to the physical findings, the accuracy of thermography and EMG

studies was 92% and 83%, respectively.[55] 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.[66]

Coldness in the involved limb is the typical thermo- graphic 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 pos-

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 re- lief of nerve fiber compression, the thermographic

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 pa- tients with bilateral disease particularly if the distri- bution 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, liga- ments, joint capsules, joints, skin and subcutaneous tissues. Pathological conditions involving these struc- tures that can be associated with thermographic ab- normality include inflammation and injuries in acute and chronic stages such as sprains, strains, tears, con- tusions and myofascial trigger points.

Thermography may aid the detection of muscular and/or fascial pathology in cases of subjective com- plaints, such as pain in the back and neck or extremi- ties that have a negative myelogram and CT scan. A thermogram may have abnormalities in association with the presence of anatomic changes that may indi- cate 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 cor- responds 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. raphic picture of a symptomatic trigger point consists of a localized area of thermal evaluation, usually 5- 10 mm in diameter and frequently disc-shaped and at least 1°C above the circumambient temperature.[83,84] 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 dys- trophy. Thermography appears to be a useful test in the differential diagnosis of reflex sympathetic dys- trophy. In the early stages of this distal peripheral nervous disorder, thermography may reveal the subtle temperature changes seen as initial signs of va- somotor

instability.[85] Early diagnosis of the disorder can avoid the need for unnecessary and more com- plicated therapeutic measures such as lumbar sym- pathectomy in patients with chronic injury.

Depending on the cause of the injury and the time elapsed since the injury, the affected area in a ther- mogram may be colder or warmer than the unin-

jured side. In most patients, the temperature of the symptomatic area is several degrees different from

that of the opposite side, but the severity of neuro- logical 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 vaso- constriction. With chronic injury, disuse atrophy occurs.

Uematsu and his co-workers[86] used thermography to evaluate 803 patients with chronic pain syn- dromes. The patients with abnormal thermography were divided into those with reflex sympathetic dys- trophy and those with evidence of nerve root injury. There were 42 cases with reflex sympathetic dys- trophy, of whom 67% had more than a 2 degree tem- perature 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 gener- ally 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[86] found that two-thirds of the patients with thermographic evidence of de- creased skin temperature in the injured limb bene- fited from sympathetic blocks. The effect of sympa- thetic blocks can be monitored by thermography.[85] After such therapy, thermography can be used to monitor the increase in skin temperature in the in-

jured extremity.

SUMMARY

The diagnosis of neurological and musculoskeletal abnormalities by thermography is based on asso- ciated thermal asymmetry between normal and ab- normal sites, a change in normal temperature gra- dients of limbs or between medial and lateral digits, or a disturbance of the normal physiological temper- ature distribution pattern. Thermography is an ad-

junctive procedure for the diagnosis of selected neu- rological and musculoskeletal conditions.

When the clinical history or physical findings are unclear, thermography may be of value in the diag- nostic evaluation of patients for the following reasons:

- When results of anatomic tests are unclear or con- tradictory, 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 ef-

fective screening method for spinal nerve root fiber

and distal peripheral nerve fiber pathology.
- Thermography is a physiological test that comple- ments anatomical and structural observations made with modern radiological techniques (x-ray , my- elography, CT scan) and magnetic resonance

imaging.

Thermography may be regarded as one piece of information that must be integrated with other avail- able information in the physician's decision-making process. Thermography cannot demonstrate the presence of pain and thus, cannot be used as a mea- surement 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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