The Value of Thermography as a Clinical Imaging Diagnostic Test: A Review of and Response to the 1989 Office of Health Technology Assessment Report of Thermography for Indications Other than Breast Lesions

Rubem Pochaczevsky, M.D., F.A.C.R.

This paper is a comment on the statements and recommendations of the 1989 Office of Health Technology Assessment (OHTA), which reviewed thermography for indications other than breast lesions.'

Distinction Between Normals and Abnormals

The clinical usefulness of any diagnostic test, including an imaging modality, depends on its ability to distinguish normal from abnormal. Ample experimental and clinical documentation supports thermography in this regard.

Uematsu,[2–4] using sophisticated computerized infrared thermography, mapped 32 dermatome segments on the body's surface that approximated the areas of innervation of the major peripheral nerves. He studied 32 healthy subjects and 30 patients with peripheral nerve impairment. In normal persons, he found the skin temperature difference between sides of the body to be stable, varying only 0.24C + 0.073C. In contrast, patients with peripheral nerve injury had skin temperature deviations on an average of 1.55C ($p < 0.001$) in segments innervated by a damaged nerve.

Similar findings were obtained by Goodman et a1.[5] Feldman and Nickoloff, using liquid crystal thermography of the cervical spine and upper extremities of 100 asymptomatic subjects, concluded that an asymmetry of 0.6C was presumptive evidence of abnormality and that an asymmetry of greater than 1C was definitely abnormal.[6]

Other reports also noted symmetry in normals.[7,8] Even one study that was critical of thermography confirmed the presence of temperature symmetry in normals.[8] Other clinical studies further corroborated that temperature asymmetry between the sides of the body was closely associated with abnormalities.[7,8,10–18]

Although some of the above-noted studies were quoted in the OHTA report, however, the logical conclusion was not drawn-that, according to most papers, thermography can distinguish normal from abnormal and that the range of temperature differences between sides of the body in normals was clearly quantified. Instead, the report lumped the assessment of thermography together with another methodology, using thermocoupled thermometers,'" and did not base its conclusions on the individual merits of the two different techniques. Obviously, thermocoupled thermometers are not equivalent to a computerized thermographic imaging unit. The thermocoupled unit would include an impractical number of often haphazard spot temperatures in an attempt to obtain a composite imaging pattern. Thermocouples are also subject to other drawbacks, including stem effect, lead length, variable surface contact, and pressure effects."

Another paper, by Ash," claimed that thermography was unreliable in measuring heat emission patterns from curved living skin surfaces. However, the artifact noted by Ash was probably due to specular reflection in his equipment, as indicated by Anbar.[22]

Reliability in Neurological Studies-Nerve Root Compression

The OHTA report lists an overwhelming majority of reports that attest to the reliability of thermography as an indicator of spinal root compression syndromes.[20,23–36] Some studies compared thermography with clinical findings, electromyography, myelography,

From the Departments of Radiology al tk Albert Einstein College of Medicine, Long Island, New York, and the Lung Island Jewish Medical Center, New Hyie Park.

computerized tomography (CT), or a combination of these modalities.

Again, instead of concluding that most published papers support the role of thermography in the diagnosis of spinal root compression syndromes, the OHTA report gave undue prominence to the small number of papers criticizing thermography. Two of these papers[37,38] were subsequently reviewed by several experienced thermographers and found to have serious technical and design flaws.[39,40]

A critical report by Mills et al." evaluating liquid-crystal thermography in the investigation of lumbosacral lateral spinal stenosis stated that "the temperature required to cause a liquid crystal to change from one colour on to the next is not always the same for all colours" and therefore they concluded that it was unreliable. They did not mention that all liquid-crystal detectors have reliable color temperature scales and that all experienced thermographers rely on them for diagnostic interpretation. Their incorrect conclusion apparently led them to perform only quantitative evaluations. To establish such quantitative measurements, Mills et al. arbitrarily divided the extremities they examined into a number of boxes. They then measured the difference between the highest and lowest temperature in each box, which is an extremely crude estimation, and compared this figure with the opposite side. Not only do these differences represent crude averages, but the boxes illustrated do not coincide with known dermatomes. They also did not mention any qualitative or pattern recognition studies that they performed. These studies are prerequisites to conducting quantitative studies. Moreover, they obtained good symmetrical temperatures in normal subjects, as expected. Another paper, by Getty,[41] using the same clinical data as Mills et al., was published in another journal, and repeated the same criticisms based on flawed technique.

Peripheral Nerves

The OHTA report lists many papers reporting advantages of thermography in demonstrating sensory nerve irritation or damage.[18,42–46] By experimentally blocking the peripheral nerves of monkeys, one study[4]" provided clear laboratory evidence of the physiological basis of thermography.

Rejex Sympathetic Dystrophy

The OHTA report quotes numerous papers that establish thermography's important role in diagnosing reflex sympathetic dystrophy.[18,47,51] However, the OHTA report failed to draw the valid conclusion that thermography may be the only noninvasive imaging test that can detect the presence of sympathetically maintained pain before it progresses to full-blown reflex sympathetic dystrophy.[47–53]

Sympathetically maintained pain may not be recognized clinically as an early stage of reflex sympathetic dystrophy, as is evidenced by its incidental detection by thermography in 43 of 224 cases with chronic pain who received inappropriate psychiatric diagnoses[4]' as well as in another series of pediatric patients in whom this diagnosis was initially unsuspected.[53] If one waits until the disease progresses to its chronic stage, with resultant trophic changes and or Sudeck's atrophy, it is often irreversible and unresponsive to therapy. Therefore, failure to educate the medical profession about the value of thermography in the early diagnosis of sympathetic dystrophy may lead to unnecessary chronic disability and suffering. Moreover, the thermographic diagnosis of sympathetically maintained pain is not subtle; obvious, extensive unilateral limb heat asymmetry[47]-[52] is frequently associated with a classic "glove or stocking" pattern.'* Well-known experts on reflex sympathetic dystrophy have recognized the importance of thermography in this regard.[54]*[55]

Deep- Vein Thrombosis

The OHTA report lists an impressive number of papers with comments favoring thermography in the detection of deep-vein thrombosis,[56]-[67] with the exception of 2 reports.[68,69] However, even in the latter, the sensitivity of thermography was 77%[68] and 83%.[68] It is, therefore, disappointing that the OHTA report fails to conclude that an impressive weight of evidence favors thermography to diagnose deep-vein thrombosis.

One pitfall of thermography-the presence of varicose veins, which may cause confusion-can be avoided by decreasing the detector's sensitivity or decreasing the gain. This outlines the typical serpentine course of varicosities." Although other inflammatory conditions, trauma, and superficial thrombophlebitis can result in positive thermograms, these entities are often clinically appreciated, so that the final diagnosis can be highly specific." Many unnecessary venograms may be avoided by performing venography only when thermography is positive. Therefore, in the proper clinical setting, thermography can prove cost effective.'[7],[70],[71] Often neither ultrasound nor plethysmography can detect thrombi below the knee. (Although it is believed that pulmonary embolism is most frequently related to above-the-knee thrombi, a significant number are thought to originate in the legs, and subsequently move to the thighs.) Thermography can diagnose both above- and below-the-knee thrombi, thereby alerting clinicians to a potential pulmonary embolus even when it is less threatening.

Vascular-Head and Neck

The OHTA report quotes papers favorable to thermography in diagnosing extracranial carotid artery stenosis,"*'" migraine, and cluster headaches.[74,75]

Injlammatory-Trauma, New Growth, Other

The OHTA report quotes favorable reports on the use of thermography in evaluating melanomas[76~77] and other skin tumors," thyroid abnormalities,[78~7g] stress fractures,[80s1] patellofemoral arthralgia,** rheumatoid diseases,[s3s4] periodontal disease,[85] lacrimal tract inflammation,[s6] and varicoceles." Another recent paper not quoted in the OHTA report" noted good correlation between liquid-crystal thermography, spermatic venography, and embolization in the management of male infertility.

Anatomic Bases of Thermography in the Diagnosis of Spinal Column Pain

Ash et al.," quoted by the OHTA report, studied the sensory dermatomes of a number of patients with a thermocouple thermometer. The basic flaws of this methodology were noted above and discussed in a paper by Chang et al.""

In addition, Ash et al. stated in this paper that "irritation of spinal nerve roots C5, C6, C7, C8 and L4, L5, Sl, by herniated discs, spinal stenosis, arachnoiditis, etc., cannot produce temperature changes in the limb dermatomes since these roots contain no sympathetic fibers." They also stated that "sinovertebral (recurrent meningeal) stimulation cannot produce vasoconstriction of the corresponding sensory dermatome via antidromal simulation of sensory fibers." The paper they quote,"' however, states precisely the opposite. In fact, the recurrent meningeal nerve is joined by a major autonomic branch extending posteriorly from the sympathetic ganglion and gray ramus communicans.[8']-'[14] Thus, as stated by Jinkins et al.,"' "The entire disk periphery, and indeed the whole vertebral column, is supplied with afferent sympathetic fibers. This extensive network was initially fully detailed by Stilwell"" and is known as the paravertebral autonomic neural plexus."

Jinkins also stated that "Referred autonomic dysfunction of spinal column origin may be represented in the form of aberrant centrifugal, vasomotor, pilomotor, and sudomotor activity. "'l'.!" Since the skin microcirculation, which is controlled by the sympathetic system, is reflected in skin heat-emission patterns, thermography can readily detect changes resulting from such sympathetic system dysfunction.

Thermography as a Pertinent Test

The OHTA report states that thermography should be used as an "adjunct test," that it requires other supportive diagnostic tests. Of course, no single imaging test in the diagnostic armamentarium is or should be the only determinant, to the exclusion of other pertinent examinations or clinical findings.

The OHTA report further ignores the fact that thermography is the only imaging modality that can evaluate certain physiologic changes associated with pain, whereas plain radiographs, myelography, computerized tomography, and magnetic resonance imaging (MRI) only depict structural anatomic abnormalities that may not always coincide with or be responsible for patients' clinical complaints. As an example of this problem, Wiese1 et al." found spinal abnormalities in an average of 19.5% of asymptomatic volunteers under 40 years of age and in 50% of those over 40. In another paper, Teresi et al's found asymptomatic protrusions of the cervical disk in 20-57% of patients referred for MRI of the larynx. Wilmink[8]" also emphasized this problem when he observed that patients with atypical clinical findings may be subject to inappropriate management simply based on the detection of a herniated disc. Wilmink recommended meticulous clinical evaluation with other imaging procedures, such as myelography complemented by CT. Thermography could undoubtedly be added to these anatomic tests. If the thermogram is positive, the anatomic findings of other diagnostic imaging studies would be enhanced. However, if the thermogram is normal, a more conservative approach could be followed,[4~"'0] obviating excessive and costly imaging tests, many of which require contrast media injection, which has inherent small, but known, risks. Thus, thermography can aid in ensuring proper patient management.

Clinical Acceptability of Thermography

The OHTA report quoted a mail survey by Ash, an orthopaedic surgeon, and Foster,"" which claimed that only 2% of 405 orthopaedic surgeons use thermography and that the majority of those who use it do not find it helpful. Kalton"" found statistical flaws in this survey in view of the fact that 22% of the sample were nonrespondents. The results could vary significantly depending on the proportion of nonrespondents who used thermography. Kalton also pointed out that little weight should be placed on opinions of individuals who have no direct experience with thermography. Kalton also found fault with the fact that the questionnaire did not distinguish between those with and those without experience in thermography, both in terms of direct operation or degree of expertise of those conducting the study. In addition, Ash and Foster's sample of 18 users is too small and can be subject to large sampling errors.

Although thermography has been used for approximately 3 decades, it was not until the late 1970s and early 1980s that a revolutionary concept, the study of dermatomes':'-'",'" or "thermatomes""" of the extremities to evaluate spinal column pain, was introduced. In

the mean time, many physicians in diverse specialities have practiced thermography and two national thermology societies have been created. Perhaps if thermography, from its inception, had been under the aegis of a single specialty, its growth would have been better organized and more rapid.

Failure to appreciate that thermography does not compete with or is not outperformed by the new imaging modalities, such as CT or MRI, is also a factor. Educational efforts should emphasize that thermography offers a unique physiologic reflection of pathology that may confirm or enhance the anatomic findings of other diagnostic imaging modalities or render them more or less clinically significant.

Another major factor hampering the growth of thermography is the current difficulty in obtaining reimbursement for this test, which in turn is based on negative and often misinformed assessments.

Yet another factor retarding the acceptance of thermology is that it is, in legal contests, almost exclusively used for the benefit of the plaintiff. Thermography could be expanded more effectively if it were also used for the defense, for the benefit of all involved, and for the general population.

The slow growth and slow acceptance of thermography are not indicative of its inadequacy. Ultrasonography, for example, grew slowly, but its potential was finally appreciated.

Controlled Studies

The OHTA report repeatedly mentions the need for controlled or "blind" studies for evaluating the efficacy of thermography. However, Gelfand and Ottl° point out the fallacies of relying on blind studies to compare imaging procedures. First, if an imperfect study is selected as the gold standard, the compared study will always be found to be inferior to it. Even operative findings in the spine are often incomplete because of restricted fields of view for surgical access and restricted fields of view during surgery. Gelfand and Ott also warned about the pitfalls of comparing examinations performed by observers or investigators with different skills and equipment. Furthermore, retrospective studies may often be more desirable than prospective studies, since in the latter special conditions, such as heightened interest and extra effort and skills, play a role.

An additional problem related to the comparison of thermography of the spine with CT and MRI is that data with different meanings and scope are compared equally. Thermography essentially strives to demonstrate physiologic abnormalities. Their precise anatomic location, although diagnosed in most cases, may occasionally be said to be at a slightly higher or lower level than shown by other diagnostic imaging studies. Any imaging test that relies exclusively on physiologic data will yield such results. On the other hand, disagreements with other diagnostic imaging studies such as CT or MRI may occur, particularly since they depict purely structural anatomic abnormalities that may not be responsible for the patient's current symptomatology or may exist in asymptomatic patients.[g7-gg] Thermography's role is either to enhance or to decrease the significance of these findings. Therefore, conducting blind comparisons between thermography and other diagnostic imaging studies may be inappropriate, since comparisons are being made with qualitatively different sets of data. Furthermore, in view of the fact that standards for symmetrical heat emission in normals have already been developed,'-" blinded studies appear almost superfluous, since one of their most important objectives is to compare data from normal controls.

Some blinded comparisons have shown good correlation between thermography and other diagnostic imaging procedures.[‘‘5-‘0X] Nevertheless, a more appropriate evaluation of the efficacy of thermography would compare it with clinical syml!tomatology and the patient's outcome. Extensive favorable documentation correlating thermography with clinical findings existS,7-IX,20.22~:4ti.42-JT,

Contradictions of the OHTA Report

Most of the OHTA report contains impressive evidence of thermography's usefulness in a variety of conditions. Many favorable articles, along with some critical studies, were fairly discussed in the report's body. In view of this, the highly critical conclusions at its end come as a surprise. It is difficult to understand how the same author could arrive at conclusions in the summary that often contradict the body of the report. The author, after considering many arguments for and a few against thermography, appears to have arbitrarily chosen the latter. Moreover, his evaluation of the literature ended in 1987, thereby neglecting pertinent newer articles, some of which are listed in my review.[‘-~,‘0,“‘.‘“,4R,““-55.70.7,,xx.111.107-109] It is particularly important to appreciate that many of the articles reviewed in the OHTA report are outdated studies based on relatively old thermographic equipment. The last 5 years have seen significant progress in technology. The development of sophisticated digital computerized diagnostic thermographic equipment has resulted in markedly improved, high-quality studies.

One must also know whether the author has had any personal experience with clinical thermography-if he has performed it himself, observed examinations performed by others, or consulted with physicians who reg-

ularly perform such studies. Merely reading the literature or attending a few meetings or courses on thermography does not suffice. Lacking firsthand experience with a particular technology may hamper an assessor's ability to distinguish between good and bad data. A physician claiming knowledge of or competence in thermography should meet certain qualifications. LeRoyl[og] set forth some of the basic requirements:

> "An experienced clinical thermologist should have the following 5 qualifications a) physician-director of a thermography laboratory; b) teach in the field at postdoctoral seminars approved for continuing medical information credits; c) publish in refereed journals; d) have testified in court as an expert; e) conduct original research. It is important not to overinterpret the thermography test, overutilize it, or overcharge for services."

Only by fulfilling these minimal criteria can one claim sufficient expertise to evaluate thermography in a form that the medical community can confidently accept as a valid basis for discussion and study. The qualifications of reviewers who do not meet the above-noted standards are limited. Obviously, such reviewers may do the discipline reviewed, as well as physicians relying on such reviews, a disservice.

Conclusions

Analysis of the OHTA report reveals that many of its conclusions are sharply antithetical to its contents.

Extensive and carefully conducted quantitative studies have already established thermographic standards for normal symmetry between sides of the body. Therefore, thermography can distinguish normal from abnormal in most cases.

A considerable weight of evidence attests to the usefulness of thermography in the evaluation of a variety of neurologic conditions, including spinal nerve root compression and peripheral nerve injury and irritation, vascular conditions, deep-vein thrombosis, scrotal varicoceles, extracranial carotid artery stenosis, inflammatory and traumatic peripheral insults, and a variety of miscellaneous conditions.

The small number of papers critical of thermography, many of which have been refuted, were based on incomplete information and/or questionable technique or equipment.

An intensive effort should be made to disseminate information regarding thermography's ability to diagnose sympathetically maintained pain before it progresses to full-fledged reflex sympathetic dystrophy with irreversible damage and disability.

Thermography is a pertinent imaging modality that, like many other examinations, benefits from other supportive tests as well as clinical information. It is the only imaging modality that can evaluate autonomic system changes associated with pain, whereas plain radiography, myelography, computerized tomography, and magnetic resonance, by definition, document only structural abnormalities, which may not always be responsible for or coincide with patients' clinical complaints. Therefore, thermography can complement and substantiate the findings of even the newest diagnostic imaging techniques, which similarly cannot stand alone. Thermography therefore may serve as an initial screening method under proper clinical circumstances.

Since thermography and other diagnostic imaging studies offer data that are different in nature and have a different scope, they are not suitable for blinded studies. In view of the fact that standards for symmetrical heat emission in normals have already been developed, blinded studies appear almost superfluous, since one of their most important objectives is to compare data from normal controls. A more suitable evaluation would be the correlation of thermography with clinical data and patient outcome. However, many such studies exist that favorably correlate thermography with clinical findings.

Finally, an apparent and unexplained contradiction appears to exist between the favorable comments duly noted throughout the body of the OHTA report and its final conclusions. A judgment based on the entire OHTA report as well as a thorough reading of most of the articles on which is presumably based, as referenced by its author, can only lead to a radically different conclusion.

Address single-copy requests to Dr. Rubem Pochaczevsky, Long Island Jewish Medical Center, Department of Radiology, 270-05 76th Avenue, New Hyde Park, NY I1 042.

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